JFSP Project Number: **04-1-2-01**

Principal Investigators: **Jon E. Keeley and Max A. Moritz**

Final Report

2003 Fires in Southern California: Impact of Fuel Age on Fire Behavior and Recovery

This project took advantage of the unique opportunities provided by the October 2003 fires in southern California which burned over 700,000 acres within a span of two weeks (Fig. 1). We addressed two questions important to prefire and postfire management: (1) What was the relative importance of fuel age vs weather in determining the size of these fires and their catastrophic impact, and (2) what role does fuel age play in determining fire severity and how does fire severity affect postfire recovery.

In many ecosystems both pre-fire fuel manipulations and post-fire rehabilitation projects are motivated by the perception that fire behavior and fire severity are affected by pre-fire fuel loads. It is increasingly evident that this generalization must be evaluated separately for different fire regimes and although we know a great deal about these relationships for western conifer forests with surface fire regimes, there is little agreement about the role that fuel loads play in determining fire behavior or fire severity in crown fire shrublands or how it affects postfire recovery. This project sought to clarify the relationship between pre-fire stand age, which is a surrogate for fuel load in these crown fire ecosystems, and fire behavior and parce out the relative importance of fuels vs weather in the 2003 southern California wildfires. In addition, the relationship between stand age and fire severity and the relationship between fire severity and ecosystem responses such as vegetative recovery and community vulnerability to alien plant invasion were investigated.

1. These fires burned through a variety of age classes, and Weibell fire interval analysis showed that across all fires, burning was not generally driven by age. Although these fires are commonly described as Santa Ana wind-driven fires, that only describes the first 2-3 days of the fire as all of these fires persisted for a week or longer under a more typical onshore wind flow. When considering all observations split into those that burned under Santa Ana conditions and those that burned under non Santa Ana conditions, results were mixed. In three instances (Cedar, Old, and Piru Fires, e.g. Fig. 2), Santa Ana burning days had approximately the same or lower age dependency along with lower median burn age than the non-Santa Ana observations for these fires. This is generally consistent with our hypothesis that fire would show less age preference during Santa Ana conditions, and would burn younger fuels as well as older. Santa Ana observations for the Paradise and Simi Fires (Fig. 3), however, while having the same or lower age dependency, were older than their corresponding non-Santa Ana observations. This demonstrates that the wind trajectory relative to the point of ignition dominates the fire path and fires do not randomly sample age classes from the landscape. Important from a management perspective, however, is the observation that these fires burn readily through young age classes, limiting the ability of age mosaics to control the path of fires burning under Santa Ana wind conditions. .

Reconstruction of historical fire danger during October Santa Ana events identified five major corridors or "hot spots" of high fire danger during these events (Fig. 1). Considering only areas with burnable fuel types (non desert, non urban etc), these spots were generally 1. the Tehachapi mountain area, 2. a NE-SW trending "corridor" north of the Santa Monica Mountains, and west of the San Gabriel Mountains, 3. a NW-SE trending corridor from the San Bernadino Mountain area to the coast, 4. the northern San Jacinto Mountain area, and 5. the Laguna Mountain area east of San Diego. Overlaying the 2003 fire perimeters on this surface, we see that the major complexes of the 2003 firestorm (Simi-Piru, Old-Grand Prix, and Cedar) were all in historical hot spots. The Paradise fire, Otay fire, and other smaller fires were in areas of lower fire historical fire danger than other areas.

2. Chaparral shrublands burn in large high intensity crown fires. Managers interested in how these wildfires affect ecosystem processes generally rely on surrogate measures of fire intensity known as fire severity metrics, which typically measure organic matter loss above- and belowground. In California shrublands burned in the autumn of 2003, a study of 250 sites distributed across five fires, investigated factors determining fire severity in these ecosystems and the extent to which fire severity affected ecosystem responses. Using structural equation modeling we showed that stand age, prefire shrub density and the shortest interval of the prior fire history had significant direct effects on fire severity, explaining over 50% of the variation in severity.

Fire severity *per se* is of interest to resource managers primarily because it is presumed to be an indicator of important ecosystem processes such as vegetative regeneration, community recovery and erosion. Our bivariate models as well as structural equation modeling showed that fire severity contributed relatively little to explaining patterns of vegetative regeneration after fire, measured as cover of all species or as resprouting success of shrubs (Fig. 4). Where fire severity did affect recovery, two generalizations can be drawn: fire severity effects are mostly short-lived, i.e., by the second year they are greatly diminished, and fire severity may have opposite effects on different functional types.

Species richness exhibited a highly significant negative relationship to fire severity in the first year but fire severity impacts were substantially less in the second postfire year and varied by functional type. Much of this relationship was due to alien plants that are sensitive to high fire severity; at all scales from 1 – 1000 m^2, the percentage of alien species in the postfire flora declined with increased fire severity. Other aspects of disturbance history are also important determinants of alien cover and richness as both increased with the number of times the site had burned and decreased with time since last fire.

A substantial number of studies have shown that remote-sensing indices are correlated with field measurements of fire severity. Across our sites, absolute dNBR (Fig. 5) was strongly correlated with field measures of fire severity and with fire history at a site but relative dNBR was not. Despite being correlated with fire severity, absolute dNBR showed little or no relationship with important ecosystem responses to wildfire such as shrub resprouting or total vegetative regeneration (Fig. 6). These findings point to a critical need for further research on interpreting remote sensing indices as applied to postfire management of these shrublands.

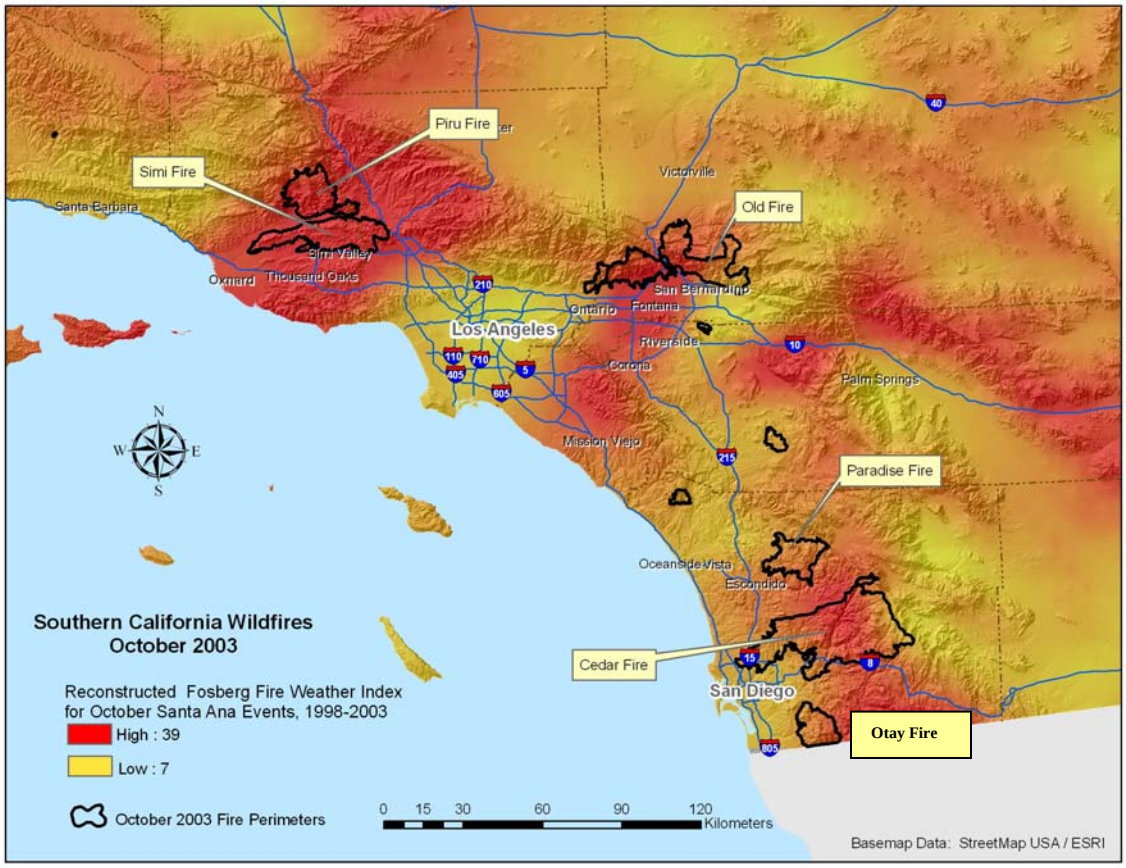

Figure 1. October 2003 fire perimeters, and reconstructed Fosberg Fire Weather Index (FFWI) for 18 October Santa Ana events over the period 1998-2003. FFWI calculated from MM5 weather reconstructions at~3400 points over Southern California.

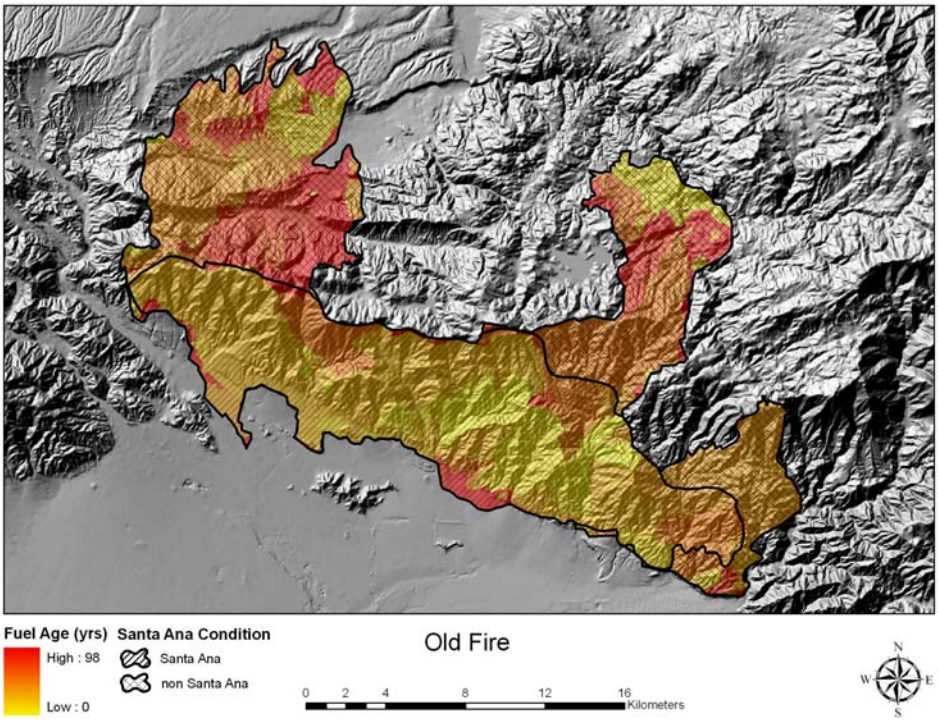

Figure 2. Old Fire age surface and Santa Ana condition

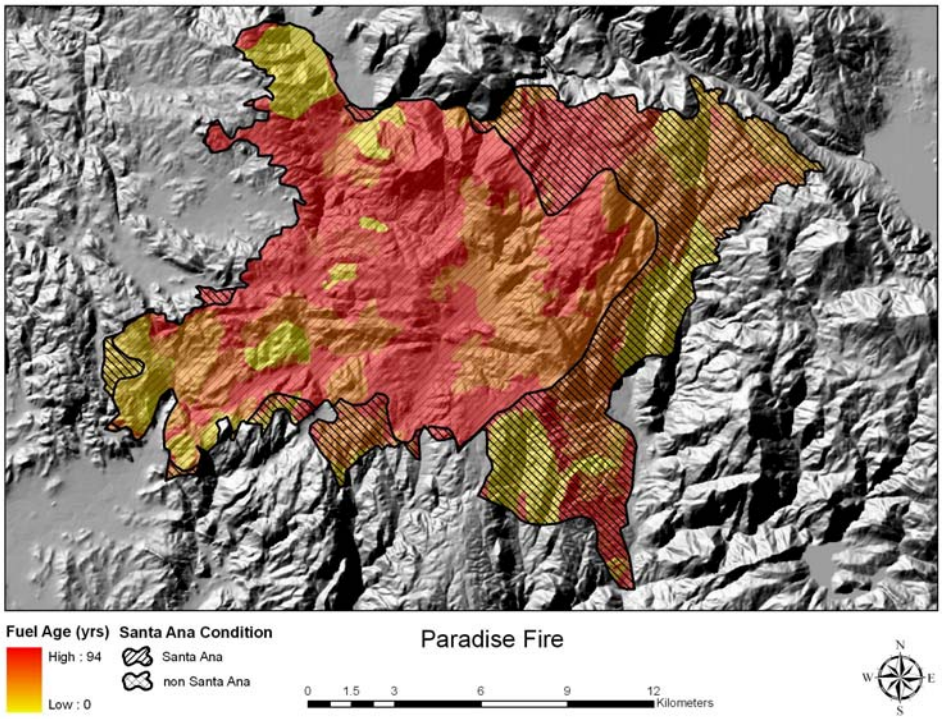

Figure 3. Paradise Fire age surface and Santa Ana condition

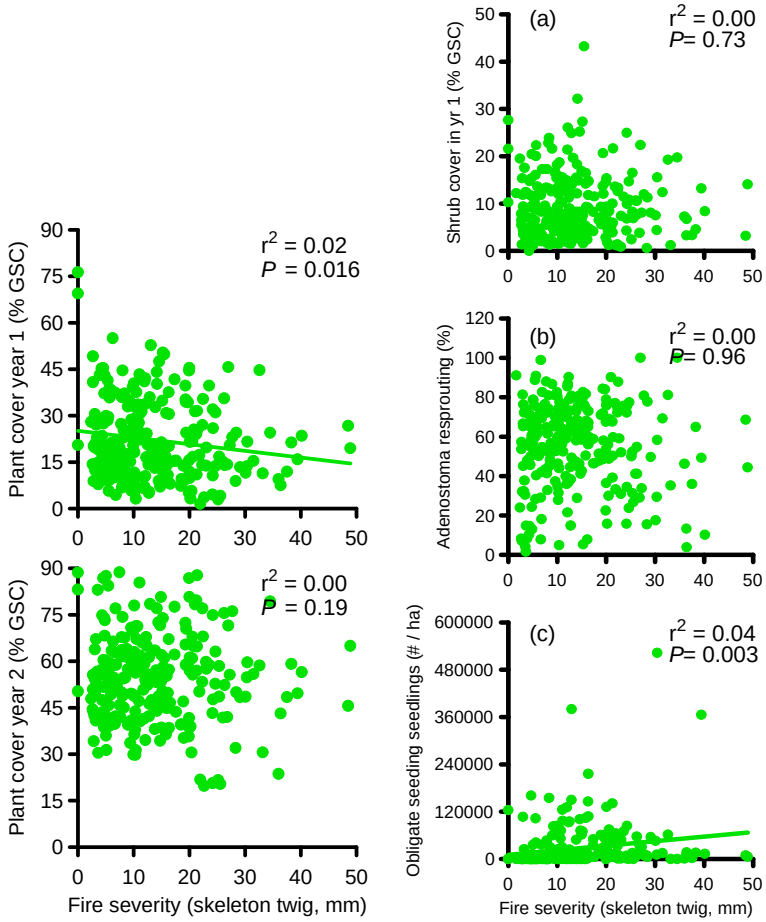

Figure 4. Relationship of fire severity to ecosystem responses.

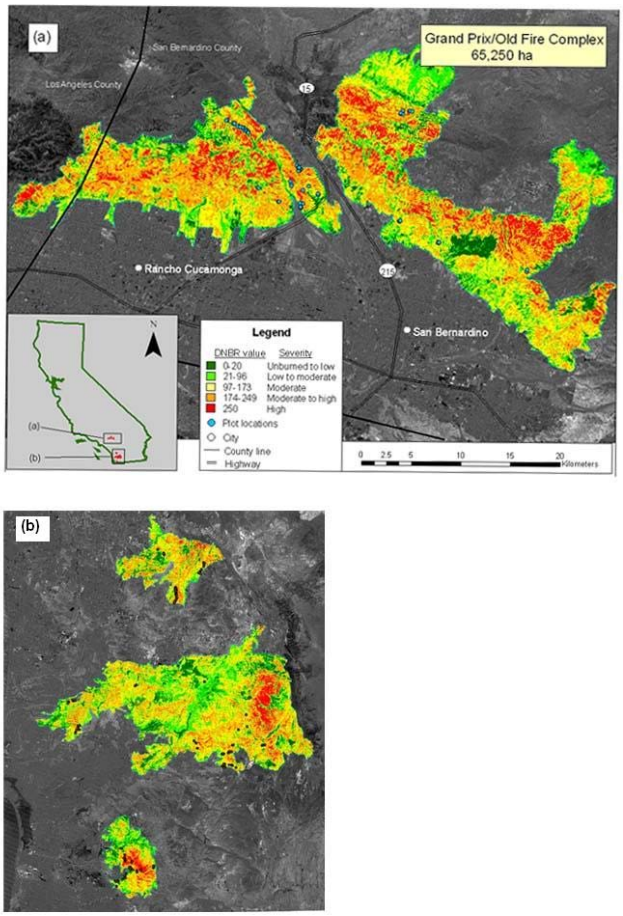

Figure 5. Fires in (a) Los Angeles and San Bernardino and (b) San Diego counties studied in this investigation shown in colors reflecting the Landsat differenced Normalized Burn Ratio (dNBR). Plot locations indicated with closed circles.

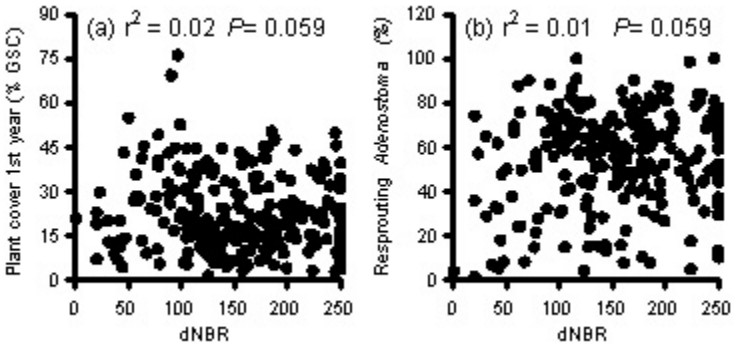

Figure 6. dNBR (absolute spring assessment) as a predictor of (a) total plant cover, expressed as percentage ground surface covered, and (b) resprouting success of Adenostoma fasciculatum in the first postfire year.

Appendix 1. Deliverables for JFSP Project Number: 04-1-2-01

Proposed	Delivered	Status
Publications:		
	Keeley, J.E. Fire intensity, fire severity and burn severity terminology: A brief review and suggested usage. ***International Journal of Wildland Fire***. *In review.*	**In review**
	Keeley, J.E., T. Brennan, and A.H. Pfaff. Fire severity and ecosystem responses following crown fires in California shrublands. ***Ecological Applications.*** *In press.*	**In press**
	Dennison, P.E., Moritz, M.A., and Taylor, R.S. in press. Evaluating predictive models of critical live fuel moisture in the Santa Monica Mountains, California. ***International Journal of Wildland Fire.*** *In press.*	**In press**
	Keeley, J.E. 2007. Appropriate postfire management for the 2007 Griffith Park Fire. ***Newsletter of the Los Angeles & San Gabriel Rivers Watershed Council*** 11(1):3-5.	**Published**
	Schoenberg, F.P., C.-H. Chang, J.E. Keeley, J. Pompa, J. Woods, and H. Xu. 2007. A critical assessment of the burning index in Los Angeles County, California. ***International Journal of Wildland Fire*** 16:473-483.	**Published**
	Dennison, P.E., Cova, T.J., Moritz, M.A. 2007. WUIVAC: a wildland-urban interface evacuation trigger model applied in strategic wildfire scenarios. ***Natural Hazards*** 41:181-199.	**Published**
	Fried, J.S., K. Gilless, W.J. Riley, T.J. Moody, C.S. de Blas, K. Hayhoe, M.A. Moritz, S.L. Stephens, and M. Torn. 2006. Predicting the effect of climate change on wildfire severity and outcomes in California: A preliminary analysis. Appendix report for ***Scenarios of Climate Change in California: An Overview***, California Energy Commission, Public Interest Energy Research Program, California	

Climate Change Center. **Published**

Syphard, A.D., V.C. Radeloff, J.E. Keeley, T.J. Hawbaker, M.K. Clayton, S.I. Stewart, and R.B. Hammer. 2007. Human influence on California fire regimes. ***Ecological Applications*** 17:1388-1402. **Published**

Keeley, J.E. and C.J. Fotheringham. 2006. Wildfire management on a human dominated landscape: California chaparral wildfires, pp. 69-75. *In* G. Wuerthner, Editor***, Wildfire ---A Century of Failed Forest Policy.*** Island Press, Covelo, CA. **Published**

Cova, T.J., Dennison, P.E., Kim, T.H., and Moritz, M.A. 2005. Setting wildfire evacuation trigger points using fire spread modeling and GIS. ***Transactions in GIS*** 9:603-617. **Published**

Moritz, M.A. 2004. Rethinking how we live with fire. Pp. 103-105 in R. Halsey, ***Fire, chaparral, and survival in southern California***, Sunbelt **Published**

Keeley, J.E. and C.J. Fotheringham. 2004. Lessons learned from the wildfires, pp. 112-122. *In* R.W. Halsey, editor. ***Fire, Chaparral and Survival in Southern California***. Sunbelt Publications, El Cajon, California. **Published**

Keeley, J.E. 2005. Lessons from the 2003 fire siege in California. ***Fire Management Today*** 65(4):9-10. **Published**

Keeley, J.E. 2005. Chaparral fuel modification: what do we know --- and need to know? ***Fire Management Today I***65(4):11-12. **Published**

Moritz, M.A., J.E. Keeley, E.A. Johnson, and A.A. Schaffner. 2004. Testing a basic assumption of shrubland fire management: Does the hazard of burning increase with the age of fuels? ***Frontiers in Ecology and the Environment*** 2:67-72. **Published**

Keeley, J.E., C.J. Fotheringham, and M.A. Moritz. 2004. Lessons from the 2003 wildfires in southern California. ***Journal of Forestry*** 102(7):26-31. **Published**

Keeley, J.E. et C.J. Fotheringham. 2004. La prévention des resques et la lutte contre les incednies dans un paysage fortement marqué par la presence humaine: les incedies de chaparral californien. In ***Les Feux de Forests dans les Regions a Climat Mediterraneen***, Domaine du Rayol, Le Royol-Canadel, République Française. **Published**

Annual progress reports:	**2005 JFSP Principal Investigator Project Progress Report**	**Submitted**
	2006 JFSP Principal Investigator Project Progress Report	**Submitted**
Workshop:	**All day special session on lessons learned from the 2003 fires held at the 3rd International Fire Ecology and Management Congress, November 2006, San Diego (Appendix 2).**	
Presentations:	**Keeley, J.E. *Lessons Learned From the 2003 California Fires* (powerpoint)**	
	Conservatoire du Littoral, La Royal, France, Oct 2004	**Presented**
	Whittier College, Nov 2004	**Presented**
	Union of Concerned Scientists, Berkeley, Jan 2005	**Presented**
	UCLA, Dept of Atmospheric Sciences, Jan 2005	**Presented**
	Between the Fires Conference, Lk Arrowhead, February 2004	**Presented**
	Spirit of the Land Conference, San Diego State University, February 2004	**Presented**
	San Diego Fire Recovery Network Symposium, San Diego, CA, April 2004	**Presented**
	American Society of Landscape Architects, Lk Arrowhead, June 2004	**Presented**
	Central Coast Botanists meeting, Ventura, CA June 2005	**Presented**
	Keeley, J.E. *Impact of Fuel Age on Fire Severity & Vegetative Recovery*	
	University of California, Irvine, Oct 2005	**Presented**
	4th USGS Fire Workshop, Tucson, AZ, December 2005	**Presented**
	California Botanical Society, annual banquet speaker, Feb 2006	**Presented**
	Fire Behavior and Fuels Conference, International Association of Wildland Fire, Portland, OR, March 2006 (panel)	**Presented**
	Tulsa University, Tulsa, OK, March 2006	**Presented**
	Texas A&M University, College Station, TX, April 2006	**Presented**
	Northern Arizona University, Flagstaff, AZ, May 2006	**Presented**
	Los Angeles Watershed Symposium on Postfire Management, Griffith Park, L.A., June 2006	**Presented**
	Forest Disturbance, Biodiversity, and Management Symposium, National Commission on Sustainable Forestry, Denver, April 2006	**Presented**
	EROS Data Center, Sioux Falls, SD, Aug 2006	**Presented**

	13th International Boreal Forest Research Association Conference, Umea, Sweden, August 2006	**Presented**
	University of Nevada, Reno, Oct 2006	**Presented**
	University of California Reserve Annual Meeting, Nov 2006	**Presented**
	3rd International Fire Ecology and Management Congress, Nov 2006	**Presented**
	USFS Region 5 Annual Meeting, Reno, NV, Jan 2007	**Presented**
	Wildlife Society Annual Meeting Symposium, Reno, NV, Jan 2007	**Presented**
	Adelaide Botanical Garden, Adelaide, Australia, Aug 2007	**Presented**
	USGS Menlo Park Campus, Public Lecture, Oct 2007	**Presented**
	University of California, Santa Barbara, Oct 2007	**Presented**
	Claremont Conservancy Annual Banquet Speaker, Nov 2007	**Presented**
	American Geophysical Union Fall Meeting, San Francisco, Dec 2007	**Presented**
	The Nature Conservancy Annual Banquet Speaker, Jan 2008	**Presented**
	University of California, Davis, Feb 2008	**Presented**
	Moritz, M.A. 2005. Fire regimes: Controls at different scales of space and time, presented at Annual Meeting of International Biometric Society, Eastern North American Region (ENAR); March 21, 2005.	**Presented**
	Moritz, M.A. 2004. Historical and contemporary contrasts between forest and chaparral fires, presented at "The Cedar Fire and Cuyamaca Rancho State Park One Year Later: Recovery Expectations and Realities" Anza-Borrego Institute Fire Recovery Symposium; Cuyamaca Rancho State Park, CA; October 16, 2004.	**Presented**
	Moritz, M.A. 2004. Spatial variation and age dependency in burning patterns of California shrublands, presented at Annual Meeting of Ecological Society of America, Portland, OR; August 4, 2004.	**Presented**
Mailing list:	**Creation of mailing list of managers for sending publications and publication briefs (Appendix 3)**	
Publication Briefs for Resource Managers:	**A Critical Assessment of the Burning Index Used in Fighting Wildland Fires**	**Posted**

	http://www.werc.usgs.gov/pubbriefs/keeleypbaug2007.html	
	Human Influence on California Fire Regimes http://www.werc.usgs.gov/pubbriefs/keeleypbjul2007.html	**Posted**
	Fire in California's Ecosystems http://www.werc.usgs.gov/pubbriefs/vanwagtendonkpbfeb2007.html	**Posted**
	Wildfire Management on a Human-Dominated Landscape http://www.werc.usgs.gov/pubbriefs/keeleypbnov2006b.html	**Posted**
	A Different Perspective on Global Fire http://www.werc.usgs.gov/pubbriefs/keeleypbjun2005.html	**Posted**
	Lessons From the October 2003 Wildfires in Southern California http://www.werc.usgs.gov/pubbriefs/keeleypbnov2004.html	**Posted**
	Testing a Basic Assumption of Shrubland Fire Management: How Important is Fuel Age? http://www.werc.usgs.gov/pubbriefs/keeleypbmar2004.html	**Posted**
Website:	**Decided against this because of limited use to managers.**	**Dropped**

Appendix 2. Outline from all day special session at the 3rd International Fire Ecology and Management Congress, November 2006, San Diego.

The 2003 Southern California Fires: Science Insights Into the Fire Event and Recovery

Introduction Organizers: **Jon Keeley and Max Moritz** **8:00**

Richard Hawkins, FMO, U.S. Forest Service, Clevland National Forest
"On the Ground at the Cedar Fire" 8:30
Philip Riggan, U.S. Forest Service, Riverside Fire Lab
"Remote Imaging *Before and After the Cedar Fire"* 9:00
Richard Halsey, California Chaparral Field Institute
"Fuels and Fire Behavior on the Cedar Fire" 9:30

Break **10:00**

Max Moritz, University of California, Berkeley
"*Parsing Out Fuels and Weather in Fire Behavior for the 2003 Fires*" 10:30
Jan Beyers, US Forest Service, Riverside Fire Lab
"BAER Team Approach to Massive Wildfires [or other?]" 11:00
Pete Wohlgemuth, U.S. Forest Service, Riverside Fire Lab
"Evaluating the Effectiveness of Postfire Mulching" 11:30

Lunch **12:00 – 1:30 pm**

Janet Franklin, San Diego State University
"Fire Impacts on Forest Tree Mortality" 1:30
Jon Keeley and **Teresa Brennan**, U.S. Geological Survey,
Sequoia and San Diego field stations 2:00
"Fire Severity Impacts on Postfire Vegetation Recovery"
Rob Fisher, U.S. Geological Survey, San Diego Field Station 2:30
"Amphibian and Other Animal Responses to the 2003 Wildfires"

Break **3:00**

Phil Unitt and Jenny Rechel, San Diego Natural History Museum &USFS 3:30
"Bird Responses to 2002 and 2003 Wildfires"
Jeff Lincer, Wildlife Research Institute
"Raptor Responss to 2003 Wildfires" 4:00
Wayne Spencer, Conservation Biology Institute
"Small Mammal Response to Fire and Habitat Fragmentation" 4:30
Hugh Safford, U.S. Forest Service, Region 5
"The 2003 Fires: Lessons Learned and Unlearned" 5:00