Final Report Joint Fire Science Program AFP2-2004

Project Title: Learning from the past: Retrospective analyses of fire behavior in Yosemite and Sequoia-Kings Canyon National Parks.

JFSP Project Number: 04-2-1-110

Project Location: South Fork Merced watershed in Yosemite National Park and upper Kaweah watershed in Sequoia-Kings Canyon National Park, California.

Principal Investigators: Carol Miller[1*] (PI), Anne Black[1], Mike Beasley[2], Tony Caprio[3]

Titles and Affiliations: [1]Research Ecologist/Ecologist, USDA Forest Service Rocky Mountain Research Station, Aldo Leopold Wilderness Research Institute, [2]Fire Use Manager, Yosemite National Park, [3]Fire Ecologist, Sequoia-Kings Canyon National Park

[*]**Primary Contact:** 790 East Beckwith Ave., Missoula, MT, 59801, (406) 542-4198, cmiller04@fs.fed.us

This final report summarizes findings to date and proposed and accomplished deliverables. Details on the background, objectives, methods, and detailed results can be found in the forthcoming General Technical Report: 'Retrospective fire modeling to quantify the cumulative effects of fire suppression' and on the project website: http://leopold.wilderness.net/research/fprojects/F006.htm.

PROJECT OVERVIEW AND OBJECTIVES

Excluding fire has untold effects on the landscape. Yosemite and Sequoia-Kings Canyon National Parks have expressed the need to understand and track these effects and thereby the consequences of fire suppression decisions. This project developed and used methods to quantify the impacts of suppressing lightning-caused ignitions. We retrospectively modeled those ignitions that that might have been considered for Wildland Fire Use (WFU) designation and compared the landscape conditions that would have resulted from these fires to the conditions that actually developed as a consequence of their suppression. Ignitions were limited to those caused by lightning that occurred between 1994 and 2004. Their spread and effects were chronologically modeled using the weather and fuel conditions that would have been present at the time of ignition. Fuels were updated between each fire season using a fuel succession model. Through the comparison of the resultant landscape with the current observed landscape, we measured the impacts of suppression. This project focused on two study areas within the parks: the South Fork Merced (SFM) 31,400 ha watershed in Yosemite National Park and the 90,696 ha Kaweah watershed in Sequoia-Kings Canyon National Park. Three project objectives were:

1) Cumulative Effects: Evaluate the cumulative effects of past fire suppression decisions on Fire Return Interval Departure (FRID), a measure used by the Parks to describe departure from natural conditions. The FRID that would have resulted had these ignitions been allowed to burn was calculated and compared to what actually resulted as a consequence of their suppression. While the cumulative impact on FRID was our main focus, other risks and benefits were measured and are described below. These quantitative estimates of the impacts of past decisions will be used to inform future suppression decisions.

2) Map Library: Develop a GIS data library of risks, benefits and costs of potential ignitions within each study area. This map library is to be used as an easy and readily available source of information when deciding whether or not to suppress future ignitions, when preparing Stage III Wildland Fire Implementation Plans (WFIP) analyses and when developing appropriate management response (AMR) on suppression incidents. Data sets were created by modeling the spread and effects of hypothetical ignitions using current fuel conditions and a range of weather and wind conditions.

3) Guidebook: Document step-by-step procedures used to conduct retrospective fire analyses in a user-friendly guidebook. The guidebook will facilitate continued analysis in subsequent years in the two Parks and enable the use of these methods elsewhere. Documentation will take the form of a General Technical Report.

SUMMARY OF PRODUCTS AND FINDINGS

Chronological retrospective fire modeling can be used to estimate the cumulative impacts of fire suppression.

- Available fire modeling tools and data from suppressed ignitions can be used to chronologically model the spread of fires and estimate the cumulative fire effects that would have occurred.
- We used the model FARSITE in a new research application, running it for longer periods and over larger areas than is customary. In doing so, we discovered new limitations and errors in the software of which developers were previously unaware.
- From the set of all suppressed lightning ignitions that occurred between 1994 and 2004, *ten* ignitions in the SFM watershed and *thirty-two* ignitions in the Kaweah watershed were selected as being viable for significant spread. We did not model every suppressed ignition because we recognize that some ignitions may merely smolder in a snag or log and extinguish on their own. We selected the ignitions for retrospective modeling from information on the fuel type and the weather conditions present.
- Of the ten selected ignitions in the SFM watershed, *five* were subsequently eliminated from our modeling analysis because of the effects from previously modeled fires. Of the thirty-two ignitions in the Kaweah, *nine* were subsequently

eliminated from our analysis. In all, we simulated the spread and effects of 5 ignitions in the SFM watershed and 23 ignitions in the Kaweah watershed.

- Actual landscape conditions can be compared with the landscape conditions that would have resulted had suppressed ignitions been allowed to burn to quantify the effect of suppression on the landscape. These effects include, but are not limited to, effects on Fire Return Interval Departure, expected flame length, and total potential smoke emissions from the landscape.
- Comparison of retrospective modeling results with observed landscape conditions cannot be done without recognizing several key assumptions we made in our methodology, as well as all the assumptions and limitations of the individual models used. Key assumptions and limitations are outlined in the guidebook, to be published as a General Technical Report.
- Modeling results should not be interpreted to mean that the ignitions we retrospectively modeled should have been allowed to burn, or that we are second-guessing suppression decisions. Decisions to suppress were based on a complex suite of factors present at the time of the ignitions. A number of risks and limitations would have been associated with allowing these ignitions to burn, such as escape from Park boundaries, smoke impacts on neighboring communities, and risks to valuable resources. This project merely demonstrates an approach to quantify the ecological and managerial impacts of suppression, and thus, some of the potential benefits of fire.
- We believe ***these methods are unique in that they allow managers to quantify the impacts of removing fire from the landscape***. These quantitative estimates of impacts provide valuable information to managers when faced with future suppression decisions or prioritization of restoration strategies such as prescribed fire. In particular, the results of our analyses will be extremely valuable to managers when communicating tradeoffs about smoke with the public and air quality regulatory agencies.
- We did not simulate confinement strategies, and some of the modeled fires were much larger than what would ever be acceptable to managers or the public. We believe ***a fruitful next step would be to apply a more realistic "best management practice" scenario*** that employed confinement strategies, such as those used in Appropriate Management Response.

FRID values would have been reduced substantially.

- The sequential modeling of the 5 ignitions in the SFM watershed and 23 ignitions in the Kaweah watershed resulted in substantially lower values for FRID in 2004 when compared to the FRID that resulted in their absence.
- For the SFM watershed, the average FRID would have decreased from 4.5 to 1.8 and average FRID in the Kaweah watershed would have decreased by from 4.3 to 0.3.
- Moreover, the percentage of the Kaweah watershed in the extreme departure category (FRID ≥ 5) would have decreased from 40% to 2% if the twenty ignitions had not been suppressed. In the SFM watershed there is a drop from 49% to 18%.

- Differences in FRID demonstrate lost opportunities that could have improved the ecological health of the study areas.
- Managers use FRID to help prioritize areas for prescribed fire. Our estimates will further assist them in prioritizing efforts.

The behavior of subsequent fires would have been affected.

- Results from our sequential modeling suggest that the potential fire behavior of the landscape would have been substantially different if our modeled ignitions had been allowed to burn. We quantified potential fire behavior under extreme weather conditions with the point-in-time fire behavior model FlamMap.
- Under extreme weather conditions ($\geq 98^{th}$ percentile ERC), flame lengths in the SFM watershed would have been lower by 0.8 feet when averaged across the landscape (2.1 feet vs. 1.3 feet). In the Kaweah watershed, flame lengths would have been reduced by an average of 4.5 feet (5.7 feet vs. 1.2 feet).
- Lower flame lengths have implications for firefighter safety and the Parks' ability to use direct attack strategies when suppressing undesirable ignitions.

The number of subsequent ignitions and the need for initial attack resources would have been reduced.

- If the ignitions modeled in this study had been allowed to burn, numerous suppression ignitions would not have occurred due to the consumption of flammable fuels in burned areas. We estimate there were 18 suppression ignitions in the SFM watershed between 1994-2006 that would not have occurred had the selected ignitions been allowed to burn. In the Kaweah, we estimate that 21 suppression ignitions would not have occurred between 1994-2006.
- This would have reduced the subsequent need for initial attack resources. At least 101 firefighters were assigned to initial attack and at least 14 helicopter and airtanker flights were used on the 18 wildfires in the SFM watershed. At least 212 firefighters and 60 flights were used on the 21 fires in the Kaweah watershed.

Potential smoke emissions of the landscape would have been reduced.

- Of the all the atmospheric emissions from wildfires, PM 2.5 (Particulate Matter < 2.5 microns in diameter) and PM 10 (<10 microns) are of the most concern to the local air quality districts and the Parks.
- The sequential modeling suggests that the total smoke "loading" of the landscape as a whole would decrease if the modeled ignitions had been allowed to burn. The smoke "load" represents the amount of smoke that would be produced if the entire study area burned at once. This reduction is a direct result of the decrease in the amount and type of fuels available on the landscape.
- We used the 'Emission Estimation System' (EES) to compute the total potential PM 2.5 and PM 10 "load" for the two landscapes in 2004. If the modeled ignitions had been allowed to burn, we estimate that potential PM 2.5 and PM 10

laods in 2004 would have been 25% lower in the SFM watershed and 45% lower in the Kaweah watershed.

- Such reductions must be evaluated in light of emissions from the modeled fires—these fires may reduce fuels and future smoke loads on the landscape, but they do so by creating smoke when they occur. However, it is very possible that the discontinuity of fuels created by the modeled fires would have reduced the likelihood of large scale wildfires in the two watersheds. Smoke emissions spread over an eleven year period may be more desirable than emissions from a single catastrophic wildfire.

The project created a new fuel succession model.

- Our methods required that we update surface fuel loadings to reflect consumption by both modeled and real fires and to reflect the natural accumulation of fuel over time. We developed a fuel succession model in cooperation with staff and scientists at Yosemite and Sequoia-Kings Canyon National Parks and the United States Geological Survey (USGS). The rule-based model updates fuels based on fire severity or lack of fire. While many vegetation succession models are in existence, we believe ***this is the first time a succession model has been developed specifically for fuels***.
- The fuel succession model was integral to this study and will be a valuable tool that the Parks can use to keep their surface fuel information updated. Vegetation data were cross-walked to derive the surface fuel model data we used. Vegetation data is generally developed via the interpretation of aerial or satellite imagery and is therefore a snapshot in time based on the imagery capture date. As time moves further and further away from the capture date, the original classifications become less accurate due to vegetation growth and disturbances such as fire. The dynamic fuel succession model allows managers keep their fuel model data updated with respect to fuel consumption and accumulation.

Map libraries of fire behavior and effects can be used to expedite go/no go decisions.

- We built an extensive GIS data library of the risks, benefits and costs of hypothetical fires in each study area (objective 2). Hypothetical ignition locations (20 in the SFM watershed and 25 in the Kaweah watershed) were distributed based on past ignition patterns and particular locations requested by Park staff. Their spread and effects were modeled using current fuel conditions under various weather conditions.
- For each ignition, we generated data on expected progression, crown fire activity, flame length, emissions and estimated costs. We also quantified the potential benefits of the fire in terms of reduction in Fire Return Interval Departure. The results of these analyses were delivered to the Parks as interactive CDs.
- The GIS map libraries of potential fire behavior and effects provide a ready source of information to managers during the fire season when making the decision whether or not to suppress an ignition, when preparing Stage III

Wildland Fire Implementation Plan (WFIP) analyses, when developing appropriate management response on suppression decisions and when communicating tradeoffs with the public and air quality regulatory agencies.

The project created previously unavailable spatial datasets

- Management staff and future research will benefit from previously unavailable spatial datasets we created during the course of this project.
- We developed surface fuel model datasets using the new expanded set of fire behavior fuel models. These expanded fuel models provide a more detailed depiction of surface fuels vs. the standard 13 NFFL fuel models. This should result in more accurate fire modeling in any model capable of using them.
- Other new datasets created include spatial interpolations of duff and coarse woody debris point data gathered in and around the two parks.

DELIVERABLES CROSSWALK TABLE

Proposed Deliverable (Type and ID)	**Delivered**	**Status**
Dataset 5224 (GIS Data Library)	Electronic (interactive GIS Map Library CD) and hardcopy formats. Modeled fire progression, flame length and crown fire potential for 20 ignitions under 2 weather conditions in the South Fork Merced watershed, Yosemite NP. Includes daily estimates of smoke emissions and final effect on Fire Return Interval Departure (FRID) index and more. Delivered June, 2006	Complete
Dataset 5225 (GIS Data Library)	Electronic (interactive GIS Map Library CD) and hardcopy formats. Modeled fire progression, flame length and crown fire potential for 25 ignitions under 3 weather conditions in the Kaweah watershed, Sequoia-Kings Canyon NP. Includes daily estimates of smoke emissions and final effect on Fire Return Interval Departure (FRID) index and more. Delivered June, 2006	Complete
NonRefereed Publication (Guidebook)	Davis, B. and C. Miller. *In review*. Retrospective fire behavior modeling: methods and uses. Gen. Tech. Rep. RMRS-GTR-???. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. *Draft to be revised based on feedback from second training session (Jan 17, 2008). To be sent out for technical review Feb 2008 and submitted for publication April 2008.*	Draft complete; Final in progress
NonRefereed	Miller, C. and B. Davis. Quantifying the	Draft

Publication (Journal Article)	consequences of fire suppression for two national parks. *To be submitted to the George Wright Forum, January 2008.*	complete; in internal review before submission
Progress Reports for JFSP	Two progress reports for JFSP. Delivered in 2005 and 2006.	Complete
Final Report 1820	Final report outlining findings and deliverables.	Complete
------------------------------**Additional Products**------------------------------		
Invited presentation	Davis, B. and C. Miller. 2006. Research to Support Wildland Fire Use Decisions in Yosemite National Park. Yosemite Fire Science Symposium, May 9-10, 2006, Yosemite National Park, CA.	Complete
Poster	Davis, B. 2006. Retrospective fire modeling to quantify the cumulative effects of suppression. Joint Fire Science Program Governing Board visit, Lubrecht Experimental Forest, Montana, September 14, 2006.	Complete
Poster (2 presentations)	Davis, B. 2007. Retrospective fire modeling to quantify the cumulative effects of suppression. Presented at 2nd Fire Behavior and Fuels Conference, Destin, FL, March 26-30, 2007; and Geospatial 2007: Building Bridges to Information Sharing, Portland, OR, May 7-11, 2007.	Complete
Model/software/ algorithm	22 fuel succession model diagrams were created for grass, shrub, grass-shrub, timber litter, and timber understory fuel types.	Complete
Field Demonstration	Presentation of results to managers and scientists at Yosemite (December 18, 2007)	Complete
Training Session	Training for fire management staff on the procedures described in the draft GTR (Refereed publication, above) to conduct cumulative effects analysis at Yosemite (December 18, 2007)	Complete
Field Demonstration	Presentation of results to managers and scientists at Sequoia-Kings Canyon National Parks (January 17, 2008).	To be completed January 17, 2008
Training Session	Training for fire management staff on the procedures described in the draft GTR (Refereed publication, above) to conduct cumulative effects analysis at Sequoia-Kings Canyon National Parks (January 17, 2008).	To be completed January 17, 2008
NonRefereed Publication	The Cumulative Effects of Fire Suppression; research highlight for Rocky Mountain Research Station Annual Accomplishment Report	To appear 2008
Refereed	Miller, C. and Davis, B. A retrospective approach to	In progress

Publication	quantifying and evaluating the consequences of fire suppression in two national parks. *In preparation. To be submitted to Ecological Applications May 2008.*	