Fire and Fuels Science Quarterly: Spring 2011

Carbon Management

Cathcart, Jim; Ager, Alan A.; McMahan, Andrew; Finney, Mark; Watt, Brian. 2010. Carbon Benefits from Fuel Treatments. In: Jain, Theresa B.; Graham, Russell T.; and Sandquist, Jonathan, tech. eds. Integrated management of carbon sequestration and biomass utilization opportunities in a changing climate: Proceedings of the 2009 National Silviculture Workshop. Proceedings RMRS-P-61. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station: 61-79. http://www.fs.fed.us/rm/pubs/rmrs_p061.html

Abstract: Landscape simulation modeling is used to examine whether fuel treatments result in a carbon offset from avoided wildfire emissions. The study landscape was a 169,200-acre watershed located in south-central Oregon. Burn probability modeling was employed under extreme weather and fuel moisture conditions. Expected carbon stocks post-treatment, post-wildfire were calculated for all stands on the treated landscape; post-wildfire on the untreated landscape. Results show a negative carbon offset initially—the known reduction of carbon stocks from treatment is greater than expected carbon benefit from reduced wildfire emissions. Treatment may break even as a carbon offset after 9 years.

Heath, Linda S.; Smith, James E.; Woodall, Christopher W.; Azuma, David L.; Waddell, Karen L. 2011. Carbon stocks on forestland of the United States, with emphasis on USDA Forest Service ownership. Ecosphere 2:art6. DOI:10.1890/ES10-00126.1.

Abstract. The U.S. Department of Agriculture Forest Service (USFS) manages one-fifth of the area of forestland in the United States. The Forest Service Roadmap for responding to climate change identified assessing and managing carbon stocks and change as a major element of its plan. This study presents methods and results of estimating current forest carbon stocks and change in the United States for public and private owners, consistent with the official 2010 U.S. greenhouse gas inventory, but with improved data sources for three states. Results are presented by National Forest System region, a major organizational management unit within the Forest Service, and by individual national forest. USFS forestland in the United States is estimated to contain an average of 192 Mg C/ha (megagrams carbon per hectare) on 60.4 million ha, for a total of 11,604 Tg C (teragrams C) in the year 2005. Privately-owned forestland averages 150 Mg C/ha on 173.8 million ha, with forestland of other public owners averaging 169 Mg C/ha on 43.1 million ha. In terms of change, private and USFS ownerships each sequester about a net 150 Tg CO_2/yr, but an additional 92 Tg CO_2/yr is stored in products from private harvests compared to about 3 Tg CO_2/yr from harvest on USFS land. Emissions from other disturbances such as fires, as well as corresponding area estimates of disturbance are also important, but the needed datasets are not yet available. Recommendations are given for improving the estimates.

Hurteau, Matthew D.; Stoddard, Michael T.; Fulé, Peter Z. 2011. The carbon costs of mitigating high-severity wildfire in southwestern ponderosa pine. Global Change Biology 17(4): 1516–1521. DOI: 10.1111/j.1365-2486.2010.02295.x.

Abstract. Forests provide climate change mitigation benefit by sequestering carbon during growth. This benefit can be reversed by both human and natural disturbances. While some disturbances such as hurricanes are beyond the control of humans, extensive research in dry, temperate forests indicates that wildfire severity can be altered as a function of forest fuels and stand structural manipulations. The purpose of this study was to determine if current aboveground forest carbon stocks in fire-excluded southwestern ponderosa pine forest are higher than prefire exclusion carbon stocks reconstructed from 1876, quantify the carbon costs of thinning treatments to reduce high-severity wildfire risk, and compare posttreatment (thinning and burning) carbon stocks with reconstructed 1876 carbon stocks. Our findings indicate that prefire exclusion forest carbon stocks ranged from 27.9 to 36.6 Mg C ha^{-1} and that the current fire-excluded forest structure contained on average 2.3 times as much live tree carbon. Posttreatment carbon stocks ranged from 37.9 to 50.6 Mg C ha^{-1} as a function of thinning intensity. Previous work found that these thinning and burning treatments substantially increased the 6.1 m wind speed necessary for fire to move from the forest floor to the canopy (torching index) and the wind speed necessary for sustained crown fire (crowning index), thereby reducing potential fire severity. Given the projected drying and increase in fire prevalence in this region as a function of changing climatic conditions, the higher carbon stock in the fire-excluded forest is unlikely to be sustainable. Treatments to reduce high-severity wildfire risk require trade-offs between carbon stock size and carbon stock stability.

Fire Behavior

Hyde, Joshua C.; Smith, Alistair M. S.; Ottmar, Roger D.; Alvarado, Ernesto C.; Morgan, Penelope. 2011. The combustion of sound and rotten coarse woody debris: a review. International Journal of Wildland Fire 20(2): 163-174. DOI:10.1071/WF09113.

Abstract. Coarse woody debris serves many functions in forest ecosystem processes and has important implications for fire management as it affects air quality, soil heating and carbon budgets when it combusts. There is relatively little research evaluating the physical properties relating to the combustion of this coarse woody debris with even less specifically addressing decomposition, a condition that eventually affects all debris. We review studies evaluating the combustion and consumption of coarse woody debris in the field and under controlled conditions. The thermal properties affected by decomposition are also reviewed, as are current modelling tools to represent their combustion. Management implications and suggestions for future research are then presented.

Kreye, Jesse K.; Varner, J. Morgan; Knapp, Eric E. 2011. Effects of particle fracturing and moisture content on fire behaviour in masticated fuelbeds burned in a laboratory. International Journal of Wildland Fire 20(2): 308-317. DOI:10.1071/WF09126.

Abstract. Mechanical mastication is a fuels treatment that converts shrubs and small trees into dense fuelbeds composed of fractured woody particles. Although compaction is thought to reduce fireline intensity, the added particle surface area due to fracturing could also influence fire behaviour. We evaluated effects of particle fracturing and moisture content (ranging from 2.5 to 13%) on fire behaviour in fuelbeds composed of masticated *Arctostaphylos manzanita* Parry and *Ceanothus velutinus* Dougl. shrubs in the laboratory. Fuelbeds composed of fractured particles did not burn with greater intensity than fuelbeds composed of intact particles, as hypothesised. Flame heights ranged from 54 to 95 cm and fireline intensity from 50 to 140 kJ s^{-1} m^{-1}, approximating values observed in field experiments. Masticated fuelbeds burned with shorter flame heights and longer flaming duration under higher fuel moistures, but duration of lethal heating (>60°C) above fuelbeds did not differ across the range of fuel moistures, averaging 12 min over a 0.1-m^2 area. Our results suggest that expected fire behaviour increases due to particle fracturing may be overwhelmed by fuelbed bulk density. The long-duration heating of burning masticated fuels may require managers to mitigate effects to trees and soils when fuel loads are high.

Forests

Briles, Christy E., Whitlock, Cathy; Skinner, Carl N.; Mohr, Jerry. 2011. Holocene forest development and maintenance on different substrates in the Klamath Mountains, northern California, USA. Ecology 92(3):590–601. DOI:10.1890/09-1772.1.

Abstract. The influence of substrate on long-term vegetation dynamics has received little attention, and yet nutrient-limited ecosystems have some of the highest levels of endemism in the world. The diverse geology of the Klamath Mountains of northern California (USA) allows examination of the long-term influence of edaphic constraints in subalpine forests through a comparison of vegetation histories between nutrient-limited ultramafic substrates and terrain that is more fertile. Pollen and charcoal records spanning up to 15000 years from ultramafic settings reveal a distinctly different vegetation history compared to other soil types. In non-ultramafic settings, the dominant trees and shrubs shifted in elevation in response to Holocene climate variations resulting in compositional and structural changes, whereas on ultramafic substrates changes were primarily structural, not compositional. Fire activity was similar through most of the Holocene with the exception of declines over the last 4000 years on ultramafic substrates, likely due to the reduction of understory fuels and cooler wetter conditions than in the middle Holocene. These results suggest that the tree and shrub distributions were more responsive to past climate changes on non-ultramafic substrates compared to those on ultramafic substrates. The combination of these dynamics may help explain high levels of plant diversity in the Klamath Mountains and provide insights for managing these complex ecosystems.

Busse, Matt. 2010. Site Quality Changes in Response to Slash Retention and Prescribed Fire in Thinned Ponderosa Pine Forests. In: Jain, Theresa B.; Graham, Russell T.; and Sandquist, Jonathan, tech. eds. Integrated management of carbon sequestration and biomass utilization opportunities in a changing climate: Proceedings of the 2009 National Silviculture Workshop. Proceedings RMRS-P-61. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 239-250. http://www.fs.fed.us/rm/pubs/rmrs_p061.html.

Abstract. The ecological effects of post-thinning slash retention on vegetation, wildlife browse, and soil were evaluated in sixty-year-old stands of second-growth pine in central Oregon. Three slash-retention treatments were compared: whole-tree removal, bole-only removal, and thin no removal (boles and slash scattered on site). The study intent was to create a wide gradient of surface organic matter mass among treatments and assess any ensuing changes in site quality. No differences in site or soil productivity indices were found among the slash-retention treatments after 20 years. Tree growth, understory plant production and diversity, wildlife browse cover, litter decay, soil nutrients, and soil biological activity were similar among the treatments, suggesting that the retention of thinning slash is trivial to the health of these forests. In general, thinning alone, regardless of slash treatment, and thinning with subsequent burning were sound options for reducing wildfire hazard and maintaining site quality in these pine ecosystems.

Collins, Brandon M., Everett, Richard G.; Stephens; Scott L. 2011. Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests. Ecosphere 2:art51. DOI:10.1890/ES11-00026.1.

Abstract. We re-sampled areas included in an unbiased 1911 timber inventory conducted by the U.S. Forest Service over a 4000 ha study area. Over half of the re-sampled area burned in relatively recent management- and lightning-ignited fires. This allowed for comparisons of both areas that have experienced recent fire and areas with no recent fire, to the same areas historically based on early forest inventories. Our results indicate substantially altered present forest conditions, relative to the 1911 data, and can largely be attributed to the disruption of the key ecosystem process for these forests, fire. For areas that burned recently there was a noticeable difference in forest structure based on fire severity. Current tree density and canopy cover in areas burned recently with moderate severity did not differ from 1911 estimates, while areas that burned recently with low severity or were unburned had higher tree density and canopy cover relative to the 1911 estimates. This emphasizes an important distinction with regard to using fire to restore forests, resting primarily on whether fires kill trees in the lower and intermediate canopy strata. Our results also demonstrate nearly a doubling of live tree carbon stocks in the present forest compared to the historical forest. The findings presented here can be used by managers and ecologists interested in restoring Sierra Nevada mixed conifer systems.

Fonda, Richard W.; Binney, Elizabeth P. 2011. Vegetation Response to Prescribed Fire in Douglas-Fir Forests, Olympic National Park. Northwest Science 85(1): 30-40.

Abstract. Fire exclusion for more than a century in Olympic National Park changed old-growth Douglas-fir forest stand structure and species composition from an open structure of fire-adapted species to a more crowded, complex structure formed by fire-avoiding species. A previous study identified an historical mean fire return interval of 21 yr for these forests in the eastern Olympics prior to fire exclusion, with frequent, small surface fires maintaining an open forest. We tested whether Douglas-fir/salal forests would support low intensity prescribed fires, and monitored community responses for 3 yr post-fire in a randomized complete block ANOVA. Compared to pre-fire values, total fuels, 1000-hr fuels, 1-hr fuels, duff depth, total tree density, tree species density, sapling density, understory cover, and understory frequency of five prominent species were significantly lower one month post-fire. Differences in tree basal area, Douglas-fir sapling density, and western redcedar tree density were not significant after the fire. Lower sapling density was an important result. Salal, a known resprouter, was the only understory species to return to at least 50% of pre-fire cover within 3 yr. This first use of prescribed fire in Olympic National Park demonstrated that Douglas-fir/salal forests would support low intensity surface fire. Although community structure changed significantly immediately after fire, the tree canopy was little affected, and the understory will eventually recover to pre-fire values. The data from this study will contribute to a fire management plan that will incorporate prescribed fire with fire suppression, non-suppressed fires, and other active management to maintain forest health in the eastern Olympic Mountains.

Halofsky, J. E., Donato, D. C.; Hibbs, D. E.; Campbell, J. L.; Cannon, M. Donaghy; Fontaine, J. B.; Thompson, J. R.; Anthony, R. G.; Bormann, B. T.; Kayes, L. J.; Law, B. E.; Peterson, D. L.; Spies, T. A.. 2011. Mixed-severity fire regimes: lessons and hypotheses from the Klamath-Siskiyou Ecoregion. Ecosphere 2:art40. DOI:10.1890/ES10-00184.1.

Abstract. Although mixed-severity fires are among the most widespread disturbances influencing western North American forests, they remain the least understood. A major question is the degree to which mixed-severity fire regimes are simply an ecological intermediate between low- and high-severity fire regimes, versus a unique disturbance regime with distinct properties. The Klamath-Siskiyou Mountains of southwestern Oregon and northwestern California provide an excellent laboratory for studies of mixed-severity fire effects, as structurally diverse vegetation types in the region foster, and partly arise from, fires of variable severity. In addition, many mixed-severity fires have occurred in the region in the last several decades, including the nationally significant 200,000-ha Biscuit Fire. Since 2002, we have engaged in studies of early ecosystem response to 15 of these fires, ranging from determinants of fire effects to responses of vegetation, wildlife, and biogeochemistry. We present here some of our important early findings regarding mixed-severity fire, thereby updating the state of the science on mixed-severity fire regimes and highlighting questions and hypotheses to be tested in future studies on mixed-severity fire regimes. Our studies in the Klamath-Siskiyou Ecoregion suggest that forests with mixed-severity fire regimes are characterized primarily by their intimately mixed patches of vegetation of varied age, resulting from complex variations in both fire frequency and severity and species responses to this variation. Based on our findings, we hypothesize that the proximity of living and dead forest

after mixed-severity fire, and the close mingling of early- and late-seral communities, results in unique vegetation and wildlife responses compared to predominantly low- or high-severity fires. These factors also appear to contribute to high resilience of plant and wildlife species to mixed-severity fire in the Klamath-Siskiyou Ecoregion. More informed management of ecosystems with mixed-severity regimes requires understanding of their wide variability in space and time, and the particular ecological responses that this variability elicits.

Hudak, Andrew T.; Rickert, Ian; Morgan, Penelope; Strand, Eva; Lewis, Sarah A.; Robichaud, Peter R.; Hoffman, Chad; Holden, Zachary A. 2011. Review of fuel treatment effectiveness in forests and rangelands and a case study from the 2007 megafires in central, Idaho, USA. Gen. Tech. Rep. RMRS-GTR-252. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 60 p.

Abstract. This report provides managers with the current state of knowledge regarding the effectiveness of fuel treatments for mitigating severe wildfire effects. A literature review examines the effectiveness of fuel treatments that had been previously applied and were subsequently burned through by wildfire in forests and rangelands. A case study focuses on WUI fuel treatments that were burned in the 2007 East Zone and Cascade megafires in central Idaho. Both the literature review and case study results support a manager consensus that forest thinning followed by some form of slash removal is most effective for reducing subsequent wildfire severity. **http://www.fs.fed.us/rm/pubs/rmrs_gtr252.pdf**

Johnson, Morris C.; Kennedy, Maureen C.; Peterson, David L. 2011. Simulating fuel treatment effects in dry forests of the western United States: testing the principles of a fire-safe forest. Canadian Journal of Forest Research 41:1018-1030. DOI: 10.1139/x11-032.

Abstract. We used the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) to simulate fuel treatment effects on 45 162 stands in low- to midelevation dry forests (e.g., ponderosa pine (*Pinus ponderosa* Dougl. ex. P. & C. Laws.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) of the western United States. We evaluated treatment effects on predicted post-treatment fire behavior (fire type) and fire hazard (torching index). FFE-FVS predicts that thinning and surface fuel treatments reduced crown fire behavior relative to no treatment; a large proportion of stands were predicted to transition from active crown fire pre-treatment to surface fire post-treatment. Intense thinning treatments (125 and 250 residual trees·ha^{-1}) were predicted to be more effective than light thinning treatments (500 and 750 residual trees·ha^{-1}). Prescribed fire was predicted to be the most effective surface fuel treatment, whereas FFE-FVS predicted no difference between no surface fuel treatment and extraction of fuels. This inability to discriminate the effects of certain fuel treatments illuminates the consequence of a documented limitation in how FFE-FVS incorporates fuel models and we suggest improvements. The concurrence of results from modeling and empirical studies provides quantitative support for "fire-safe" principles of forest fuel reduction (sensu Agee and Skinner 2005. For. Ecol. Manag. **211**: 83–96).

Metz, Margaret R.; Frangioso, Kerri M.; Meentemeyer, Ross K.; Rizzo, David M. 2011. Interacting disturbances: wildfire severity affected by stage of forest disease invasion. Ecological Applications 21(2):313–320. DOI:10.1890/10-0419.1.

Abstract. Sudden oak death (SOD) is an emerging forest disease causing extensive tree mortality in coastal California forests. Recent California wildfires provided an opportunity to test a major assumption underlying discussions of SOD and land management: SOD mortality will increase fire severity. We examined prefire fuels from host species in a forest monitoring plot network in Big Sur, California (USA), to understand the interactions between disease-caused mortality and wildfire severity during the 2008 Basin Complex wildfire. Detailed measurements of standing dead woody stems and downed woody debris 1–2 years prior to the Basin fire provided a rare picture of the increased fuels attributable to SOD mortality. Despite great differences in host fuel abundance, we found no significant difference in burn severity between infested and uninfested plots. Instead, the relationship between SOD and fire reflected the changing nature of the disease impacts over time. Increased SOD mortality contributed to overstory burn severity only in areas where the pathogen had recently invaded. Where longer-term disease establishment allowed dead material to fall and accumulate, increasing log volumes led to increased substrate burn severity. These patterns help inform forest management decisions regarding fire, both in Big Sur and in other areas of California as the pathogen continues to expand throughout coastal forests.

Grasslands and Rangelands

Beckstead, Julie; Street, Laura E.; Meyer, Susan E.; Allen, Phil S. 2011. Fire Effects on the Cheatgrass Seed Bank Pathogen *Pyrenophora semeniperda*. Rangeland Ecology & Management 64(2): 148-157.

Abstract. The generalist fungal pathogen *Pyrenophora semeniperda* occurs primarily in cheatgrass (*Bromus tectorum*) seed banks, where it causes high mortality. We investigated the relationship between this pathogen and its cheatgrass host in the context of fire, asking whether burning would facilitate host escape from the pathogen or increase host vulnerability. We used a series of laboratory and field experiments to address the ability of host seeds and pathogen life stages to survive fire. First, we determined the thermal death point (TDP_{50}; temperature causing 50% mortality) of seeds and pathogen propagules at two time intervals using a muffle furnace. We then measured peak fire temperatures in prescribed burns at sites in Utah and Washington and quantified seed and fungal propagule survival using pre- and postburn seed bank sampling and inoculum bioassays. Finally, we investigated the survival of both seeds and pathogen after wildfires. We found that radiant heat generated by both prescribed and wild cheatgrass monoculture fires was generally not sufficient to kill either host seeds or pathogen propagules; most mortality was apparently due to direct consumption by flames. The 5-min mean TDP_{50} was 164°C for pathogen propagules and 148°C for host seeds, indicating that the pathogen is more likely to survive fire than the seeds. Peak fire temperature at the surface in the prescribed burns averaged 130°C. Fire directly consumed 85–98% of the viable seed bank, but prescribed burns and wildfires generally did not lead to dramatic reductions in pathogen inoculum loads. We conclude that the net effect of fire on this pathosystem is not large. Rapid postburn recovery of both host and associated pathogen populations is the predicted

outcome. Postfire management of residual cheatgrass seed banks should be facilitated by the persistent presence of this seed bank pathogen.

Gucker, Corey L.; Bunting, Stephen C. 2011. Canyon grassland vegetation changes following fire in northern Idaho. Western North American Naturalist 71(1): 97-105.

Abstract. Native and nonnative vegetation mosaics are common in western rangelands. If land managers could better predict changes in the abundance of native and nonnative species following disturbances, maintenance of native plant cover and diversity may be improved. In August 2000, during suppression of a wildfire near Lewiston, Idaho, a backing fire burned canyon grassland plots. A previous study had recorded species composition and cover prior to the fire, so we were able to evaluate changes in species composition and abundance on established plots before and after the fire. Overall, summer burning had little effect on the grassland communities. *Pseudoroegneria spicata* recovered to prefire coverage by the third postfire year. In the third postfire year, cover of native and nonnative annual species was significantly greater on burned than unburned sites ($P < 0.03$). *Bromus tectorum* cover increased, as expected, on burned plots. Prefire and postfire cover values for *Centaurea solstitialis* were nearly equal, and there were no significant cover differences between burned and unburned plots in any year. As part of this study, we also evaluated changes in the cover of dominant native and nonnative species with respect to their prefire seral stage on burned and unburned plots. Because our sample sizes were small, we only report community-level trends but suggest that this type of community analysis could make for an interesting future study.

Postfire Recovery

Leirfallom, Signe B.; Keane, Robert E. 2011. Six-year post-fire mortality and health of relict ponderosa pines in the Bob Marshall Wilderness Area, Montana. Res. Note RMRS-RN-42. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 5 p. **http://www.fs.fed.us/rm/pubs/rmrs_rn042.pdf**.

Abstract. In 2003, lightning-caused fires burned through relict ponderosa pine (*Pinus ponderosa*) stands in the Bob Marshall Wilderness, Montana, after decades of fire exclusion. Since many trees in these stands had Native American bark-peeling scars, concern arose about the adverse fire effects on this cultural and ecological resource. In 2004, Keane and others (2006) began a post-fire monitoring study of the relict pine stands. In 2009, we completed a six year re-measurement of those stands. We found that many of the pines with major fire injury had recovered, and tree mortality was not as high as initially estimated. A low-intensity surface fire, prescribed or lightning-caused, within the next 10 years will help preserve the health of these stands in the future.

Lewis, Sarah A.; Robichaud, Peter R. 2011. Using QuickBird imagery to detect cover and spread of post-fire straw mulch after the 2006 Tripod Fire, Washington, USA. Res. Note RMRS-RN-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 9 p. **http://www.fs.fed.us/rm/pubs/rmrs_rn043.pdf**

Abstract. Agricultural straw mulch is a commonly applied treatment for protecting resources at risk from runoff and erosion events after wildfires. High-resolution QuickBird satellite imagery was acquired after straw mulch was applied on the 2006 Tripod Fire in Washington. We tested whether the imagery was suitable for remotely assessing the areal coverage of the straw mulch treatment. Straw mulch was easily identified in the imagery because of the distinct spectral signature of the mulch against the burned background. The measured straw cover on the ground was correlated to the modeled cover in the imagery with a correlation coefficient of r = 0.47, and a rank analysis indicated the ability to predict relative straw cover amounts on the plots with a rank correlation of ? = 0.40. Better correlations may be possible if the time between the image acquisition and field validation was shorter. Our results encourage further exploration of the use of high-resolution imagery for research applications and postfire management.

Mahlum, Shad K.; Eby, Lisa A.; Young, Michael K.; Clancy, Chris G.; Jakober, Mike. 2011. Effects of wildfire on stream temperatures in the Bitterroot River Basin, Montana. International Journal of Wildland Fire 20(2): 240-247. DOI:10.1071/WF09132.

Abstract. Wildfire is a common natural disturbance that can influence stream ecosystems. Of particular concern are increases in water temperature during and following fires, but studies of these phenomena are uncommon. We examined effects of wildfires in 2000 on maximum water temperature for a suite of second- to fourth-order streams with a range of burn severities in the Bitterroot River basin, Montana. Despite many sites burning at high severity, there were no apparent increases in maximum water temperature during the fires. One month after fire and in the subsequent year, increases in maximum water temperatures at sites within burns were 1.4–2.2°C greater than those at reference sites, with the greatest differences in July and August. Maximum temperature changes at sites >1.7 km downstream from burns did not differ from those at reference sites. Seven years after the fires, there was no evidence that maximum stream temperatures were returning to pre-fire norms. Temperature increases in these relatively large streams are likely to be long-lasting and exacerbated by climate change. These combined effects may alter the distribution of thermally sensitive aquatic species.

Rhoades, Charles C.; Entwistle, Deborah; Butler,Dana. 2011. The influence of wildfire extent and severity on streamwater chemistry, sediment and temperature following the Hayman Fire, Colorado. International Journal of Wildland Fire 20(3): 430-442. DOI:10.1071/WF09086.

Abstract. The 2002 Hayman Fire was the largest fire in recent Colorado history (558 km^2). The extent of high severity combustion and possible effects on Denver's water supply focussed public attention on the effects of wildfire on water quality. We monitored stream chemistry, temperature and sediment before the fire and at monthly intervals for 5 years after the fire. The proportional extent of a basin that was burned or that burned at high severity was closely related to post-fire

streamwater nitrate and turbidity. Basins that burned at high severity on >45% of their area had twice the streamwater nitrate and four times the turbidity as basins burned to a lower extent; these analytes remained elevated through 5 years post-fire. In those basins, the highest post-fire streamwater nitrate concentrations (23% of USA drinking water standards) were measured during spring, the peak discharge period. Summer streamwater was 4.0°C higher in burned streams on average compared with unburned streams; these persistent post-fire stream temperature increases are probably sufficient to alter aquatic habitat suitability. Owing to the slow pace of tree colonisation and forest regrowth, recovery of the watersheds burned by the Hayman Fire will continue for decades.

Rosenberger, Amanda E.; Dunham, Jason B.; Buffington, John M.; Wipfli, Mark S. 2011. Persistent Effects of Wildfire and Debris Flows on the Invertebrate Prey Base of Rainbow Trout in Idaho Streams. Northwest Science 85(1): 55-63.

Abstract. Wildfire and debris flows are important physical and ecological drivers in headwater streams of western North America. Past research has primarily examined short-term effects of these disturbances; less is known about longer-term impacts. We investigated wildfire effects on the invertebrate prey base for drift-feeding rainbow trout (*Oncorhynchus mykiss*, Walbaum) in Idaho headwater streams a decade after wildfire. Three stream types with different disturbance histories were examined: 1) unburned, 2) burned, and 3) burned followed by debris flows that reset channel morphology and riparian vegetation. The quantity of macroinvertebrate drift (biomass density) was more variable within than among disturbance categories. Average body weight and taxonomic richness of drift were significantly related to water temperature and influenced by disturbance history. During the autumn sampling period, the amount of terrestrial insects in rainbow trout diets varied with disturbance history and the amount of overhead canopy along the stream banks. Results indicate that there are detectable changes to macroinvertebrate drift and trout diet a decade after wildfire, and that these responses are better correlated with specific characteristics of the stream (water temperature, canopy cover) than with broad disturbance classes.

Restoration

Fulé, Peter Z.; Ramos-Gómez, Mauro; Cortés-Montaño, Citlali; Miller, Andrew M. 2011. Fire regime in a Mexican forest under indigenous resource management. Ecological Applications 21(3):764–775. DOI:10.1890/10-0523.1.

Abstract. The Rarámuri (Tarahumara) people live in the mountains and canyons of the Sierra Madre Occidental of Chihuahua, Mexico. They base their subsistence on multiple-use strategies of their natural resources, including agriculture, pastoralism, and harvesting of native plants and wildlife. Pino Gordo is a Rarámuri settlement in a remote location where the forest has not been commercially logged. We reconstructed the forest fire regime from fire-scarred trees, measured the structure of the never-logged forest, and interviewed community members about fire use. Fire occurrence was consistent throughout the 19th and 20th centuries up to our fire scar collection in 2004. This is the least interrupted surface-fire regime reported to date in North America. Studies from other relict sites such as nature reserves in Mexico

or the USA have all shown some recent alterations associated with industrialized society. At Pino Gordo, fires recurred frequently at the three study sites, with a composite mean fire interval of 1.9 years (all fires) to 7.6 years (fires scarring 25% or more of samples). Per-sample fire intervals averaged 10–14 years at the three sites. Approximately two-thirds of fires burned in the season of cambial dormancy, probably during the pre-monsoonal drought. Forests were dominated by pines and contained many large living trees and snags, in contrast to two nearby similar forests that have been logged. Community residents reported using fire for many purposes, consistent with previous literature on fire use by indigenous people. Pino Gordo is a valuable example of a continuing frequent-fire regime in a never-harvested forest. The Rarámuri people have actively conserved this forest through their traditional livelihood and management techniques, as opposed to logging the forest, and have also facilitated the fire regime by burning. The data contribute to a better understanding of the interactions of humans who live in pine forests and the fire regimes of these ecosystems, a topic that has been controversial and difficult to assess from historical or paleoecological evidence.

Nesmith, Jonathan C.B.; Caprio, Anthony C.; Pfaff, Anne H.; McGinnis, Thomas W.; Keeley, Jon E. 2011. A comparison of effects from prescribed fires and wildfires managed for resource objectives in Sequoia and Kings Canyon National Parks. Forest Ecology and Management 261(7): 1275-1282.

Abstract. Current goals for prescription burning are focused on measures of fuel consumption and changes in forest density. These benchmarks, however, do not address the extent to which prescription burning meets perceived ecosystem needs of heterogeneity in burning, both for overstory trees and understory herbs and shrubs. There are still questions about how closely prescribed fires mimic these patterns compared to natural wildfires. This study compared burn patterns of prescribed fires and managed unplanned wildfires to understand how the differing burning regimes affect ecosystem properties. Measures of forest structure and fire severity were sampled in three recent prescribed fires and three wildfires managed for resource objectives in Sequoia and Kings Canyon National Parks. Fine scale patterns of fire severity and heterogeneity were compared between fire types using ground-based measures of fire effects on fuels and overstory and understory vegetation. Prescribed fires and wildfires managed for resource objectives displayed similar patterns of overstory and understory fire severity, heterogeneity, and seedling and sapling survival. Variation among plots within the same fire was always greater than between fire types. Prescribed fires can provide burned landscapes that approximate natural fires in many ways. It is recognized that constraints placed on when wildfires managed for resource objectives are allowed to burn freely may bias the range of conditions that might have been experienced under more natural conditions. Therefore they may not exactly mimic natural wildfires. Overall, the similarity in fire effects that we observed between prescribed fires and managed wildfires indicate that despite the restrictions that are often placed on prescribed fires, they appear to be creating post-fire conditions that approximate natural fires when assessed on a fine spatial scale.

Syphard, Alexandra D.; Scheller, Robert M.; Ward, Brendan C.; Spencer, Wayne D.; Strittholt, James R. 2011. Simulating landscape-scale effects of fuels treatments in the Sierra Nevada, California, USA. International Journal of Wildland Fire 20(3): 364-383. DOI:10.1071/WF09125.

Abstract. In many coniferous forests of the western United States, wildland fuel accumulation and projected climate conditions increase the likelihood that fires will become larger and more intense. Fuels treatments and prescribed fire are widely recommended, but there is uncertainty regarding their ability to reduce the severity of subsequent fires at a landscape scale. Our objective was to investigate the interactions among landscape-scale fire regimes, fuels treatments and fire weather in the southern Sierra Nevada, California. We used a spatially dynamic model of wildfire, succession and fuels management to simulate long-term (50 years), broad-scale (across 2.2×10^6 ha) effects of fuels treatments. We simulated thin-from-below treatments followed by prescribed fire under current weather conditions and under more severe weather. Simulated fuels management minimised the mortality of large, old trees, maintained total landscape plant biomass and extended fire rotation, but effects varied based on elevation, type of treatment and fire regime. The simulated area treated had a greater effect than treatment intensity, and effects were strongest where more fires intersected treatments and when simulated weather conditions were more severe. In conclusion, fuels treatments in conifer forests potentially minimise the ecological effects of high-severity fire at a landscape scale provided that 8% of the landscape is treated every 5 years, especially if future fire weather conditions are more severe than those in recent years.

Terrestrial Wildlife

Gaines, William L.; Lyons, Andrea L.; Weaver, Kathleen; Sprague, Ann. 2011. Monitoring the short-term effects of prescribed fire on an endemic mollusk in the dry forests of the eastern Cascades, Washington, USA. Forest Ecology and Management 261(8): 1460-1465.

Abstract. The restoration of natural fire regimes has emerged as a primary management objective within fire-prone forests in the interior western US. However, this objective becomes contentious when perceived to be in conflict with the conservation of rare or endemic species. We monitored the effects of two forest restoration treatments, spring- vs fall-prescribed burning, on the density of the endemic Tiny Canyon mountainsnail (*Oreohelix sp.*). We used a randomized block design with three replicates of each of the treatments and controls, and analyzed our data using multivariate repeated measures analysis of variance. We conducted pre-treatment surveys for mountainsnails and post-treatment surveys at three time periods: within two weeks of the treatment, the next snail season following the treatment (next spring or fall), and one year following the treatments. We did not detect any statistically significant differences in mountainsnail densities as a result of the spring-burn or fall-burn treatments, time of survey, or treatment × time interaction. The burns resulted in a fine-scale mosaic that included un-burned and lightly burned areas that acted as refuge for mountainsnails. We recommend that the application of prescribed burning as a restoration treatment within mountainsnail habitat be conducted under prescriptions that create a mosaic of burn conditions, including small unburned areas, and that prescribed fire return intervals mimic natural fire intervals (10–40 years).

Nappi, Antoine; Drapeau, Pierre. 2011. Pre-fire forest conditions and fire severity as determinants of the quality of burned forests for deadwood-dependent species: the case of the black-backed woodpecker. Canadian Journal of Forest Research 41:994-1003. DOI: 10.1139/x11-028.

Abstract. Burned forests represent high-quality habitats for many deadwood-dependent species. Yet, post-fire conditions may vary greatly within and among burns and thereby may affect habitat suitability for these species. We studied habitat selection of nesting black-backed woodpeckers (*Picoides arcticus* Swainson) in recently burned spruce-dominated boreal forests. Our objectives were to (*i*) identify factors involved in snag selection for both nesting and foraging and (*ii*) examine selection of nest sites within the burned landscape. A total of 92 nests and 1612 foraging observations were used to investigate snag selection. Our results show that both pre-fire forest conditions and fire severity are important in determining the quality of burned forests for black-backed woodpeckers. This species selected large snags for both nesting (>20 cm DBH) and foraging (>15 cm DBH). Woodpeckers selected deciduous and degraded "pre-fire" snags for nesting whereas black spruce snags that had been created by fire and that were moderately burned were preferred for foraging. Nest sites were concentrated in burned mature stands and supported higher densities of large snags (e.g., >15 cm DBH). Our results suggest that burned forest patches of at least 20 ha and composed mainly of burned mature and old-growth forests should be maintained during post-fire harvesting. The decrease in the amount of late seral stands in managed forest landscapes raises concerns about the future availability of high-quality burned forests for this species.

Saracco, James F., Siegel, Rodney B.; Wilkerson, Robert L. 2011. Occupancy modeling of Black-backed Woodpeckers on burned Sierra Nevada forests. Ecosphere 2:art31. DOI:10.1890/ES10-00132.1.

Abstract. The Black-backed Woodpecker (*Picoides arcticus*) has been designated by the USDA Forest Service as a management indicator species for snags in burned conifer forests of the Sierra Nevada of California, USA. However, little is known about the characteristics that affect between-fire and within-fire habitat selection by the species in the region. Here we report on the first broad-scale survey of Black-backed Woodpeckers on wildfire-affected forests of the Sierra Nevada. We implemented a Bayesian hierarchical model to: 1) estimate Black-backed Woodpecker occupancy probability in fire areas burned within a time window of 1–10 years; 2) identify relationships between occupancy probability and habitat covariates (fire age, change in canopy cover pre-to-post fire, and snag basal area), elevation, and latitude; and 3) estimate detection probability and relate it to survey interval length and survey type (passive v. broadcast). We included random fire-area effects in our model of occupancy probability to accommodate clusters of non-independent points surveyed within the larger set of fire areas. Mean occupancy probability was estimated to be 0.097. Elevation (after controlling for latitude) had the strongest effect on occupancy probability (higher occupancy at higher elevation) followed by latitude (higher occupancy at northerly sites). Fire age was also important; occupancy probability was about 4× higher on the youngest compared to oldest fires. Although the direction of regression coefficients were in the expected direction (positive), snag basal area and canopy cover change were of minor importance in affecting occupancy probability. There was some indication, however, that the importance of snag basal area increased with fire age. Weak links between occupancy and canopy cover change suggested the species uses a range of burn

severities, and such heterogeneity may promote habitat longevity. Our estimate of overall detection probability (across all survey intervals) was 0.772. We found strong effects of survey interval length (higher for longer interval) and, especially survey type (higher for broadcast survey) on detection probability. Our modeling framework and implementation illustrates the flexibility of the Bayesian hierarchical approach for handling complexities such as estimating derived parameters (and variances) and modeling random effects, and should prove generally useful for occupancy studies.

Wilson, Tammy L.; Howe, Frank P.; Edwards, Thomas C. Jr. 2011. Effects of Sagebrush Treatments on Multi-Scale Resource Selection by Pygmy Rabbits. Journal of Wildlife Management 75(2): 393-398.

Abstract. The effects of widespread sagebrush removal treatments on pygmy rabbits (*Brachylagus idahoensis*) are not well understood. Due to reliance on sagebrush, pygmy rabbits are among the species for which these treatments may be detrimental. Our objectives were to evaluate the effects of experimental sagebrush treatment on 8 radio-collared pygmy rabbits between and within home range habitat selection using Monte Carlo simulation from null models. Pygmy rabbits were not extirpated from plots containing habitat treatments, and we found no evidence that treatments affected home range placement. The mean treatment distance of observed home range centers did not differ from repeated trials of random points. However, we found evidence of within home range selection against treatments from 2 of 8 rabbits located close to the treatments. The mean treatment distance of all observed locations for these 2 rabbits was greater than expected based on a null model. We also used snow tracking to show that pygmy rabbits entered treatments in 4 out of 21 trials, which was less often than expected by chance ($G^2 = 8.662$, $P = 0.003$). Conservatively, sagebrush removal treatments should not be conducted on active or recently active pygmy rabbit burrows. Elsewhere near known pygmy rabbit sites, treated patches should be small and connected by untreated corridors to prevent potentially limiting movement of rabbits among the untreated habitat.

Wildland-Urban Interface

Absher, James D.; Vaske, Jerry J. 2011. The role of trust in residents' fire wise actions. International Journal of Wildland Fire 20(2): 318-325. DOI:10.1071/WF09049.

Abstract. Residents' trust in the managing agency has been heralded as a necessary precursor to success in preventing wildland fire losses in the wildland–urban interface. Trust, however, is a complex concept. Homeowners' specific fire wise actions may not be easily linked to general measures of trust. This article uses two distinct trust indices to predict residents' intention to do fire wise actions to their house and adjacent site. Results of structural equation models using a survey of Colorado Front Range residents ($n = 456$) revealed strong explanatory power: 85% (house behaviours) and 72% (site behaviours) of the variation in intentions were accounted for by trust, previous fire wise behaviours and the perceived effectiveness of the actions. The trust measures, however, were not major influences. 'Trust in agency competence' weakly predicted perceived effectiveness for site behaviours; 'trust in agency information' weakly predicted past house behaviours. Neither trust variable directly affected intentions to perform these actions. We conclude that trust is best viewed as a broad precursor whose influence on behavioural intentions is

mediated by other constructs (e.g. past behaviour, perceived effectiveness). The implications for further work to understand the role of trust and the possible social mechanisms involved are discussed.

Jakes, Pamela J.; Nelson, Kristen C.; Enzler, Sherry A.; Burns, Sam; Cheng, Antony S.; Sturtevant, Victoria; Williams, Daniel R.; Bujak, Alexander; Brummel, Rachel F.; Grayzeck-Souter, Stephanie; Staychock, Emily. 2011. Community wildfire protection planning: is the Healthy Forests Restoration Act's vagueness genius? International Journal of Wildland Fire 20(3): 350-363. DOI:10.1071/WF10038.

Abstract. The Healthy Forests Restoration Act of 2003 (HFRA) encourages communities to develop community wildfire protection plans (CWPPs) to reduce their wildland fire risk and promote healthier forested ecosystems. Communities who have developed CWPPs have done so using many different processes, resulting in plans with varied form and content. We analysed data from 13 case-study communities to illustrate how the characteristics of HFRA have encouraged communities to develop CWPPs that reflect their local social and ecological contexts. A framework for analysing policy implementation suggests that some elements of HFRA could have made CWPP development and implementation problematic, but these potential shortcomings in the statute have provided communities the freedom to develop CWPPs that are relevant to their conditions and allowed for the development of capacities that communities are using to move forward in several areas.

Toman, Eric; Stidham, Melanie; Shindler, Bruce; McCaffrey, Sarah. 2011. Reducing fuels in the wildland–urban interface: community perceptions of agency fuels treatments. International Journal of Wildland Fire 20(3): 340-349. DOI:10.1071/WF10042.

Abstract. Wildland fires and resulting effects have increased in recent years. Efforts are under way nationwide to proactively manage vegetative conditions to reduce the threat of wildland fires. Public support is critical to the successful implementation of fuels reduction programs, particularly at the wildland–urban interface. This study examines public acceptance of fuels treatments and influencing factors in five neighbourhoods in Oregon and Utah located adjacent to public lands. Support for treatment use was high across locations. Findings suggest citizen trust in agency managers to successfully implement treatment activities is particularly influential on treatment acceptance. Thus, building and maintaining trust with local citizens is an essential element in the successful implementation of fuel management programs.

Woodlands and Shrublands

Breshears, David D.; López-Hoffman, Laura; Graumlich, Lisa J. 2011. When Ecosystem Services Crash: Preparing for Big, Fast, Patchy Climate Change. Ambio 40(3): 256–263.

Assessments of adaptation options generally focus on incremental, homogeneous ecosystem responses to climate even though climate change impacts can be big, fast, and patchy across a region. Regional drought-induced tree die-off in semiarid woodlands highlights how an ecosystem crash fundamentally alters most ecosystem services and poses management challenges. Building on previous research showing how choice of location is linked to adaptive capacity and vulnerability, we developed a framework showing how the options for retaining desired ecosystem services in the face of sudden crashes depend on how portable the service is and whether the stakeholder is flexible with regard to the location where they receive their services. Stakeholders using portable services, or stakeholders who can move to other locations to obtain services, may be more resilient to ecosystem crashes. Our framework suggests that entering into cooperative networks with regionally distributed stakeholders is key to building resilience to big, fast, patchy crashes.