

## Annotated Bibliography of Mechanical Mastication Research

**Amacher, A. J., R. H. Barrett, J. J. Moghaddas, and S. L. Stephens. 2008.** Preliminary effects of fire and mechanical fuel treatments on the abundance of small mammals in the mixed-conifer forest of the Sierra Nevada. *Forest Ecology and Management* 255:3193-3202.

Keywords: California; Fire and Fire Surrogate Study; restoration; mixed-conifer forests; Sierra Nevada; small mammals; thinning; timber harvest.

Study Detail and Findings: A study of small mammal response to mastication and other fuels treatments. Of studied species, only one (deer mouse; *Peromyscus maniculatus*) were affected by the treatments (positive from fire only or mechanical plus fire; negative from mechanical only).

**Battaglia, M. A., M. E. Rocca, C. C. Rhoades, and M. G. Ryan. 2010.** Surface fuel loadings within mulching treatments in Colorado coniferous forests. *Forest Ecology and Management* 260:1557-1566.

Keywords: Colorado; crown fire risk; fuel loading; mulching; stand structure; pine; pinyon-juniper.

Study Detail and Findings: A study of the consequences of mastication (mulching) on stand structure and fuel loading in ponderosa pine and pinyon-juniper ecosystems. Fuel loads were substantial, increasing loading but providing changes to the overstory that may enable resilience to future crown fires. Fuel loads, size class determination, and bulk densities were measured intensively.

**Bennett, M. and S. A. Fitzgerald. 2008.** Reducing hazardous fuels on woodland property: mechanical treatments. [Corvallis, Or.]: Oregon State University, Extension Service.

Keywords: Oregon; slashbusting; mowing; crushing.

Study Detail and Findings: A review of common mechanical methods to fuels reduction on woodland properties in Oregon including various types of mechanical masticators. The study evaluates slashbusting, mowing/mastication, or crushing with respect to costs, site impacts, and needs for treatment maintenance.

**Bolding, M. C., L. D. Kellogg, and C. T. Davis. 2006a.** An integrated study of mechanical forest fuel reduction: quantifying multiple factors at the stand level. Dissertation, Oregon State University, Corvallis.

Keywords: Oregon; ladder fuels; mechanical mastication, mulching, commercial harvesting; fuels treatment economics.

Study Detail and Findings: A study investigating various silvicultural options and machine configurations for fuels treatments including mechanical mastication. This research highlights important factors affecting treatment costs as well as the potential needs for follow-up treatments.

**Bolding, M. C., L. D. Kellogg, and C. T. Davis. 2006b.** A productivity and cost comparison of two non-commercial forest fuel reduction machines. *in* Coeur d'Alene, ID: Proceedings of the 29th Annual Council on Forest Engineering Meeting.

Keywords: Oregon; mechanical mastication; swing-boom excavator; flexible tracked machine; fuels treatment economics.

Study Detail and Findings: This study investigated the productivity, costs, and treatment effectiveness of two types of masticators; a swing-boom excavator with rotary disc mulching head and a flexible tracked machine with a rotating drum mulching head. The flexible tracked machine with a rotating drum type mulching head was 61% more productive (2 acres more per day), however due to differences in operating cost the two options were nearly equivalent in cost per acre.

**Bradley, T., J. Gibson, and W. Bunn. 2006.** Fire severity and intensity during spring burning in natural and masticated mixed shrub woodlands. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006. Fuels Management—How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Keywords: California; fire effects; fire behavior; overstory mortality.

Study Detail and Findings: This study investigated the influence of mastication on fire behavior and fire effects in a shrub woodland of northern California. Woody fuel loading was 200-300% higher after mastication and flame lengths and flaming zone depths were three times greater in

the masticated treatments, leading to overstory mortality rates in conflict with management objectives.

**Brennan, T. J. and J. E. Keeley. 2015.** Effect of mastication and other mechanical treatments on fuel structure in chaparral. *International Journal of Wildland Fire* 24:949-963.

Keywords: California; crushing; re-mastication; fuel recovery; time since treatment.

Study Detail and Findings: This research investigated changes in shrub-dominated chaparral following crushing, mastication, re-mastication, and mastication plus burning, and to assess treatment longevity. Height, cover, and mass of live woody fuels were positively associated with time since treatment, and downed woody fuels were negatively associated with time since treatment, however, all mechanical treatments were compromised by woody recovery in the short-term.

**Brewer, N. W., A. Smith, J. A. Hatten, P. E. Higuera, A. T. Hudak, R. D. Ottmar, and W. T. Tinkham. 2013.** Fuel moisture influences on fire-altered carbon in masticated fuels: An experimental study. *Journal of Geophysical Research: Biogeosciences* 118:30-40.

Keywords: Idaho; black carbon, pyrogenic carbon; fuels treatment; charred residues.

Study Detail and Findings: This study investigated the conversion of biomass to black carbon following mastication and fire under three levels of fuel moisture and found that black carbon production rates were greatest within the highest fuel moisture group (13-16%). Results of this study demonstrate the importance of fuel moisture for soil carbon storage following mastication and fire.

**Brockway, D. G., K. W. Outcalt, B. L. Estes, and R. B. Rummer. 2009.** Vegetation response to midstorey mulching and prescribed burning for wildfire hazard reduction and longleaf pine (*Pinus palustris* Mill.) ecosystem restoration. *Forestry* 82:299-314.

Keywords: Georgia; mastication; pine forest; prescribed fire; vegetation response.

Study Detail and Findings: Vegetation response to mastication and burning of masticated sites in different seasons in longleaf pine sandhills were examined in Georgia. Mastication reduced midstorey tree density, but shrubs, vines, and herbaceous plants increased. Burning in masticated sites increased plant cover in general, but while shrubs and vines increased the most following

winter and spring burns, grasses increased more following winter burns, and forbs following summer burns. Understory species richness increased following all treatments.

**Burnett, R. D., N. E. Seavy, L. Salas, and D. L. Humple. 1912.** Avian community response to mechanical fuel treatment in the Sierra Nevada, USA. Petaluma, CA: PRBO Conservation Science.

Keywords: California; shaded fuel break; group selection; pre-commercial thin; mastication; songbird; focal species; forest heterogeneity; fire surrogates.

Study Detail and Findings: This study investigated the abundance of focal bird species in response to three fuels reduction techniques (shaded fuel breaks, group selection, and pre-commercial understory thinning) in the northern Sierra Nevada. Treatments significantly affected vegetation characteristics, but had only modest impacts to bird community composition and abundance (with mature canopy associated species negatively affected and edge and open forest species enhanced by fuels treatments).

**Busby, L. and D. Southworth. 2014.** Minimal persistence of native bunchgrasses seven years after seeding, following mastication and prescribed fire in southwestern Oregon, USA. *Fire Ecology* 10:63-71.

Keywords: Oregon; *Achnatherum lemmonii*; *Bromus carinatus*; *Elymus glaucus*; *Festuca roemerii* var. *klamathensis*; long-term monitoring; restoration ecology; chaparral.

Study Detail and Findings: This study investigated the effectiveness of native seeding following mastication and prescribed fire in southwestern Oregon shrublands. The study found a successful increase in bunchgrass cover after two years post-fire, however, after seven years post-fire composition and abundance of native species unchanged demonstrating that native seeding was not successful over the long-term.

**Busse, M. D., K. R. Hubbert, G. O. Fiddler, C. J. Shestak, and R. F. Powers. 2005.** Lethal soil temperatures during burning of masticated forest residues. *International Journal of Wildland Fire* 14:267-276.

Keywords: California; fuel reduction; prescribed fire; soil heating; soil moisture; soil water repellency; wildfire; wildland-urban-interface; wood mulch.

Study Detail and Findings: This study investigated whether burning of masticated shrub residues leads to lethal soil heating under different levels of mulch depth and soil moisture. Results indicated there were no effects of burning on water repellency for regardless of soil moisture and that a potential for lethal soil heating exists following mastication and burning when soils are dry and mulch depth exceeds 7.5 cm.

**Busse, M. D., C. J. Shestak, K. R. Hubbert, and E. E. Knapp. 2010.** Soil physical properties regulate lethal heating during burning of woody residues. *Soil Science Society of America Journal* 74:947-955.

Keywords: California; soil heating; soil moisture; soil texture; fuel load; mechanical mastication; fuels treatment.

Study Detail and Findings: Soil heating profiles were measured for 60 experimental burns of masticated fuelbeds as part of a factorial design with four groups of soil texture and four levels of soil moisture. Soil moisture was the most important factor for heat transfer with a 20% volumetric moisture content threshold for regulating lethal heating at depths of 2.5 cm and greater.

**Bybee, J., B. A. Roundy, K. R. Young, A. Hulet, D. B. Roundy, L. Crook, Z. Aanderud, D. L. Eggett, and N. L. Cline. 2016.** Vegetation response to piñon and juniper tree shredding. *Rangeland Ecology & Management* 69:224-234.

Keywords: Utah; encroachment; expansion; fuels treatments; mastication; resilience; resistance; sagebrush.

Study Detail and Findings: This study investigated vegetation response to mastication or seeding followed by mastication of encroaching piñon and juniper in sagebrush steppe communities on 44 sites in Utah. In general, understory cover was negatively related to tree cover, perennial herbaceous cover was higher with tree shredding than no treatment, and cheatgrass cover was reduced when mastication was followed by seeding and tree cover exceeded 50% and also when perennial herbaceous cover exceeded 42%. These results suggest mastication or mastication and native seeding should increase resistance to weed dominance and increase perennial herbaceous cover.

**Carvajal-Acosta, A. N., S. R. Abella, and D. B. Thompson. 2015.** Initial vegetation response to fuel mastication treatments in rare butterfly habitat of the Spring Mountains, Nevada. *Journal of the Arizona-Nevada Academy of Science* 46:6-17.

Keywords: Nevada; *Plebejus shasta charlestonensis*; slash deposition; seed germination; *Astragalus calycosus* var. *calycosus*; understory response

Study Detail and Findings: This study investigated the effects of thinning and slash mastication on the host plant of the Mount Charleston blue butterfly (*Plebejus shasta charlestonensis*), a rare endemic of the Spring Mountains of Nevada. By experimentally manipulating fuel bed depth of masticated slash and conducting germination studies on the host plant *Astragalus calycosus* var. *calycosus*, the results of this study suggest that activity fuels less than 5 cm in depth are unlikely to have an effect on the availability of host plants for the Mount Charleston blue butterfly.

**Cline, N. L., B. A. Roundy, F. B. Pierson, P. Kormos, and C. J. Williams. 2010.** Hydrologic response to mechanical shredding in a juniper woodland. *Rangeland Ecology & Management* 63:467-477.

Keywords: Utah; soil compaction; infiltration; mechanical mastication; soil penetration resistance; *Juniperus oostesperma*, *Artemesia tridentata*; *Artemesia nova*; sagebrush.

Study Detail and Findings: This study investigated the potential effects of mastication on soil compaction and hydrologic responses in Juniper encroached sagebrush/bunchgrass plant community. Mastication led to reduced cover of bare ground, rates of infiltration were reduced only where tire tracks were present since they increased penetration resistance, and higher infiltration rates and lower sediment yields were observed in bare intertree spaces where masticated fuels were present.

**Collins, B. M., A. J. Das, J. J. Battles, D. L. Fry, K. D. Krasnow, and S. L. Stephens. 2014.** Beyond reducing fire hazard: fuel treatment impacts on overstory tree survival. *Ecological Applications* 24:1879-1886.

Keywords: California; forest resilience; frequent-fire forests; large trees; mixed-conifer forest; restoration; Sierra Nevada.

Study Detail and Findings: This study investigated the impact of commonly used fuels treatments on the overstory growth response of five common conifers with growth as an

indicator of future vulnerability to wildfire. Observed mortality and projected vulnerability were lowest for mechanical only treatments which included slash mastication, however, fire only and mechanical plus fire treatments resulted in higher projected vulnerability and observed mortality.

**Collins, B. M., J. J. Moghaddas, and S. L. Stephens. 2007.** Initial changes in forest structure and understory plant communities following fuel reduction activities in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management* 239:102-111.

Keywords: California; fuel treatments; alien species; prescribed fire; National Fire and Fire Surrogate study.

Study Detail and Findings: This study compared the effects of fuels treatments mechanical thinning (low thinning and mastication), mechanical thinning and prescribed fire, prescribed fire, and no treatment on vegetation response. Across fuels treatments, forb and graminoid abundance did not differ from untreated controls and mechanical thinning and prescribed fire treatments significantly reduced shrub cover compared to untreated control, but also increased the richness and cover of exotic species. The small magnitude of the observed treatment differences suggests a high degree of resilience within Sierran mixed-conifer understories.

**Coulter, C. T. 2008.** Vegetation Response to Seasonality of Prescribed Fire and Postfire Seeding Following Mechanical Fuel-reduction Treatments in Oak-chaparral Communities of Southwestern Oregon. Thesis, Southern Oregon University.

Keywords: Oregon; mechanical mastication; *Achnatherum lemmonii*; *Bromus carinatus*; *Elymus glaucus*; *Festuca idahoensis*; exotic invasion.

Study Detail and Findings: This study investigated the effects of post-fire seeding and prescribed fire season (fall or spring) on vegetation response following mastication of oak-chaparral communities in southwestern Oregon. Seasonality of prescribed burning largely influenced fire severity, germination rates of seeded bunchgrasses, and the abundance of non-native annual grasses.

**Coulter, C. T., D. Southworth, and P. E. Hosten. 2010.** Prescribed fire and post-fire seeding in brush masticated oak-chaparral: consequences for native and non-native plants. *Fire Ecology* 6:60-75.

Keywords: Oregon; bunchgrasses; fire, fuels reduction; mechanical mastication; native plants; oak-chaparral; post-fire seeding; weeds.

Study Detail and Findings: This study compared vegetation response following mastication and either fall or spring prescribed burning in addition to the effect of post-fire seeding of native bunchgrasses at two oak-chaparral communities in southwestern Oregon. Prescribed fire led to an decrease in native abundance, an increase in non-native abundance, an increase in both and native and non-native richness, whereas seeded bunchgrasses successfully germinated and established only after fall prescribed burning.

**Fernández, C. and J. A. Vega. 2016.** Shrub recovery after fuel reduction treatments in a gorse shrubland in northern Spain. *Journal of Environmental Management* 166:211-216.

Keywords: Spain; prescribed burning; mastication; clearing; resprouting; gorse.

Study Detail and Findings: This study investigated shrub recovery up to four years following prescribed burning, clearing, or mastication in a gorse shrubland of northern Spain. Fuels treatments did not differ with respect to observed total shrub cover and all treatments doubled the cover of Ericaceae shrubs and total grasses, whereas prescribed burning resulted in higher species richness over the study period.

**Fernández, C., J. A. Vega, and T. Fonturbel. 2013a.** Fuel reduction at a Spanish heathland by prescribed fire and mechanical shredding: Effects on seedling emergence. *Journal of Environmental Management* 129:621-627.

Keywords: Spain; seed bank; prescribed burning; soil heating; mastication; mulching; *Erica*, *Halimium*; *Pterospartum*.

Study Detail and Findings: This study compared mastication and prescribed fire on seedling emergence within a fire-prone heathland of northern Spain. Seedling emergence was enhanced by prescribed fire, but not mastication in a greenhouse study. Seedling emergence was very low for both treatments in a field study.

**Fernández, C., J. A. Vega, and T. Fonturbel. 2013b.** Shrub resprouting response after fuel reduction treatments: comparison of prescribed burning, clearing and mastication. *Journal of Environmental Management* 117:235-241.

Keywords: Spain; prescribed burning; mastication; clearing; resprouting; heathland

Study Detail and Findings: This study compared resprouting of five common shrub species among fuels treatments clearing, mastication, and prescribed fire at two shrubland areas in northern Spain. Both plant mortality and the number and length of resprouts was largely unaffected by initial plant size or treatment type, although the number of shoots for one shrub species was reduced by prescribed burning.

**Fernández, C., J. A. Vega, and T. Fonturbel. 2015.** Does shrub recovery differ after prescribed burning, clearing and mastication in a Spanish heathland? *Plant Ecology* 216:429-437.

Keywords: Spain; prescribed burning; mastication; clearing; resprouting; heathland.

Study Detail and Findings: This study investigated shrub recovery up to four years following prescribed burning, clearing, or mastication in a heathland of northwestern Spain. Fuels treatments did not differ with respect to shrub cover or height, nor did treatments differ with respect to species richness, evenness, or alpha diversity.

**Glitzenstein, J. S., D. R. Streng, G. L. Achtemeier, L. P. Naeher, and D. D. Wade. 2006.** Fuels and fire behavior in chipped and unchipped plots: Implications for land management near the wildland/urban interface. *Forest Ecology and Management* 236:18-29.

Keywords: South Carolina; Fuels; Fire behavior; Mechanical chipping; Wildland/urban interface; Flatwoods; Southeastern coastal plain.

Study Detail and Findings: Fuels and fire behavior were measured in chipped and unchipped sites in loblolly pine flatwoods in South Carolina. Total surface fuels were substantial in treated sites with large downed woody material dominating, likely a result of post-hurricane fuels not fully masticated, and fine woody fuel loads were greater than in untreated sites. Fire behavior was mild in both treated and untreated sites burned under the mild burning conditions.

**Godwin, D. R. 2012.** The influence of prescribed fire and mechanical fuels mastication on soil CO<sub>2</sub> efflux rates in two southeastern US pine ecosystems. Dissertation, University of Florida.

Keywords: Florida; mastication; pine flatwoods; prescribed fire; soil carbon respiration.

Study Detail and Findings: Study evaluated soil carbon efflux in fuels treatments (mastication, mastication plus prescribed fire) in pine flatwoods. Soil CO<sub>2</sub> efflux did not differ across treatments, but were instead driven by environmental and site variation.

**Halbrook, J., H.-S. Han, R. Graham, T. Jain, and R. Denner. 2006.** Mastication: A fuel reduction and site preparation alternative. *in Proc. July, 2006 Council On Forest Engineering (COFE) meeting, Coeur d'Alene, ID.*

Keywords: cost analysis; equipment combinations; fuel loading; Idaho; treatment limitations.

Study Detail and Findings: Study evaluated costs of mastication machinery and equipment productivity. Costs were driven by stand conditions (residual tree density, basal area), slope (the more steep, the slower and more expensive), and the area treated.

**Hamma, C. C. 2011.** Effects of wildland-urban interface fuel treatments on potential fire behavior and ecosystem services in the central Sierra Nevada mountains of California. Thesis, California Polytechnic and State University.

Keywords: California; erosion; fuel loading; potential fire behavior; Sierra Nevada.

Study Detail and Findings: Study evaluated fuel loading and potential fire behavior in a variety of fuels treatments in the Sierra Nevada. Mastication increased fuel loading substantially, but caused no increases in potential fire behavior.

**Harrison, N.M., A.P. Stubblefield, J. M. Varner, and E.E. Knapp. 2016.** Finding balance between fire hazard reduction and erosion control in the Lake Tahoe Basin, California-Nevada. *Forest Ecology and Management* 360: 40-51.

Keywords: California; erosion; fuel loading; Nevada; sediment yield.

Study Detail and Findings: Study evaluated potential erosion and sediment yield in masticated fuels using snowmelt simulator in field settings. Small residual loads and strips of retained masticated woody fuels limited erosion substantially; results varied based on soil parent material and slope.

**Hatchett, B., M. Hogan, and M. Grismer. 2006.** Mechanical mastication thins Lake Tahoe forest with few adverse impacts. *California Agriculture* 60:77-82.

Keywords: California; erosion; mixed-conifer forest; sediment yield; soil compaction.

Study Detail and Findings: Study evaluated sediment yield and soil compaction from mastication in mixed-conifer forests in western Lake Tahoe. Sediment yields and soil compaction were minimal in masticated sites.

**Jain, T. B., R. T. Graham, J. Sandquist, M. Butler, K. Brockus, D. Frigard, D. Cobb, H. Sup-Han, J. Halbrook, and R. Denner. 2008.** Restoration of northern Rocky Mountain moist forests: Integrating fuel treatments from the site to the landscape. Proceedings of the 2007 National Silviculture Workshop. Gen. Tech. Rep. PNW-GTR-733. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Keywords: fuels treatments; Idaho; mastication; prescribed fire; silviculture; wildfire simulation.

Study Detail and Findings: Study evaluated costs and benefits of several thinning and fuels treatments (including mastication) in the Selkirk Mountains of northern Idaho. Mastication modified stand structure, altering potential fire behavior, with costs equivalent to other mechanical treatments.

**Johnson, D. W., R. F. Walker, D. W. Glass, C. M. Stein, J. B. Murphy, R. R. Blank, and W. W. Miller. 2014.** Effects of thinning, residue mastication, and prescribed fire on soil and nutrient budgets in a Sierra Nevada mixed-conifer forest. *Forest Science* 60:170-179.

Keywords: California; fuels treatments; nitrogen; potassium; prescribed fire; Sierra Nevada; soil nutrients.

Study Detail and Findings: Study evaluated soil nutrient responses to mastication and other fuels treatments (including mastication plus prescribed fire) in the Lake Tahoe Basin. Most soil nutrients were changed minimally (except potassium, which increased) in mastication alone treatments; when combined with prescribed fires, substantial changes in nitrogen, sulfur, phosphorus, and calcium resulted.

**Kane, J. M., J. M. Varner, and E. E. Knapp. 2009.** Novel fuelbed characteristics associated with mechanical mastication treatments in northern California and south-western Oregon, USA. *International Journal of Wildland Fire* 18:686-697.

Keywords: bulk density; California; fuel loading; Oregon; particle specific gravity; shrubs; woody fuel.

Study Detail and Findings: Study evaluated fuel loading and characteristics of fuels and fuelbeds of 10 sites in northern California and southern Oregon. Fuel loads, particles, and bulk densities were highly variable across sites, but similar patterns were found in loading: depth relationships and proportion of loading by size classes.

**Kane, J. M., J. M. Varner, E. E. Knapp, and R. F. Powers. 2010.** Understory vegetation response to mechanical mastication and other fuels treatments in a ponderosa pine forest. *Applied Vegetation Science* 13:207-220.

Keywords: fuels treatments; California; prescribed fire; resprouting; shrubs.

Study Detail and Findings: Study of vegetation responses to mastication and other fuels treatments. Short-term responses were treatment-specific, with mastication alone reducing vegetation response and mastication followed by prescribed fire stimulating substantial shrub germination and sprouting.

**Knapp, E. E., S. L. Stephens, J. D. McIver, J. J. Moghaddas, and J. E. Keeley. 2004.** Fire and Fire Surrogate Study in the Sierra Nevada: Evaluating Restoration Treatments at Blodgett Forest and Sequoia National Park1. USDA Forest Service Gen. Tech. Rep. PSW-GTR-193:79-85.

Keywords: California

Study Detail and Findings: The early effects of thinning + mechanical treatments and prescribed burning were examined at a mixed-conifer forest in California as part of a larger nation-wide fire and fire surrogate study. Thinning + mechanical treatments reduced total fuel loading, presumably from removal of thinned trees, but mastication increased fine surface fuel loads, which could influence surface fire behavior.

**Knapp, E. E., J. M. Varner, M. D. Busse, C. N. Skinner, and C. J. Shestak. 2012.** Behaviour and effects of prescribed fire in masticated fuelbeds. *International Journal of Wildland Fire* 20:932-945.

Keywords: California; crown scorch; fuels treatments; mastication; ponderosa pine; prescribed fire; tree mortality.

Study Detail and Findings: Study of fire behavior (measured prescribed fires) and tree mortality in masticated sites in the Sierra Nevada and southern Cascade Range. Tree mortality varied by

site, but was consistently related to crown scorch. Fire behavior was characterized by short flame heights (but long flame lengths, causing substantial scorch) and slow rates of spread.

**Kobziar, L., D. Godwin, M. Camp, D. McKinstry, M. Steifel, A. Kattan, and D. Godwin. 2011.** The Influence of Prescribed Fire and Understory Fuels Mastication on Soil Carbon Respiration Rates in Flatwoods Forests. JFSP Final Report 11-3-1-21.

Keywords: Florida; mastication; pine flatwoods; soil respiration.

Study Detail and Findings: The influence of prescribed burning, mastication, and mastication followed by prescribed burning on soil C respiration was investigated in pine flatwoods in north Florida. Neither burning, mastication, nor mastication followed by burning altered C respiration rates within one year of treatment, but all increased soil temperatures.

**Kobziar, L., A. J. Long, W. C. Zipperer, and J. K. Kreye. 2013.** Characterization of Masticated Fuelbeds and Fuel Treatment Effectiveness in Southeastern US Pine Ecosystems. JFSP Final Report 10-1-01-16.

Keywords: Florida, fuels treatment; mastication; prescribed fire.

Study Detail and Findings: Vegetation response, fuel dynamics, fire behavior, and fire effects were all examined in masticated palmetto/gallberry shrub dominated pine flatwoods sites in north Florida. Mastication converted live shrubs into a compact layer of surface debris, but shrubs recover quickly following treatments, with little increase in herbaceous cover. Masticated sites burned with less fire intensity compared to controls, overstory mortality was minimal in both treated and untreated sites burned in the winter, but tree mortality was observed after summer burning in masticated sites.

**Kobziar, L. N., J. R. McBride, and S. L. Stephens. 2009.** The efficacy of fire and fuels reduction treatments in a Sierra Nevada pine plantation. *International Journal of Wildland Fire* 18:791-801.

Keywords: California; fire behavior; fire modeling; mastication; *Pinus jeffreyi*; *Pinus ponderosa*; prescribed fire; thinning.

Study Detail and Findings: Fire behavior was predicted in masticated only, burned only, masticated + burned, and controls in ponderosa pine plantations and predictions were

compared to observations in the burned sites. Modeling suggests that mastication is detrimental while prescribed burning is effective at reducing potential fire behavior under moderate to extreme conditions. Fire behavior predictions were similar to observations in homogeneous stands, but were very different when evaluated in masticated sites with heterogeneous fuel distributions.

**Kobziar, L. N. and S. L. Stephens. 2006.** The effects of fuels treatments on soil carbon respiration in a Sierra Nevada pine plantation. *Agricultural and Forest Meteorology* 141:161-178.

Keywords: California; fire; soil temperature; soil moisture; gas exchange; soil CO<sub>2</sub>.

Study Detail and Findings: Changes in soil temperature, moisture and respiration were examined following mastication and mastication followed by burning in Sierra Nevada ponderosa/Jeffrey pine plantations. Mastication alone reduced soil respiration and soil moisture while mitigating soil temperature variability, while burning in masticated sites also lowered soil respiration, but increased soil moisture.

**Kreye, J. K., J. M. Varner, and E. E. Knapp. 2012.** Moisture desorption in mechanically masticated fuels: effects of particle fracturing and fuelbed compaction. *International Journal of Wildland Fire* 21:894-904.

Keywords: California; bulk density; fuel moisture; masticated fuels; laboratory study; moisture loss; shrubs.

Study Detail and Findings: A laboratory study of the effects of mastication (particle fracturing) on moisture loss and a comparison of fuel particle and fuelbed responses. Fractured particles did not dry faster than unfractured particles at the fuelbed level, but fuelbeds dried much slower than the particles at their surface, indicating their propensity for moisture retention.

**Kreye, J. K., N. W. Brewer, P. Morgan, J. M. Varner, A. M. Smith, C. M. Hoffman, and R. D. Ottmar. 2014a.** Fire behavior in masticated fuels: A review. *Forest Ecology and Management* 314:193-207.

Keywords: Combustion; Fire hazard; Fuels heterogeneity; Fuels management; Fuels treatments; Silviculture.

Study Detail and Findings: A review of the literature was conducted to describe the current state of scientific knowledge on fuel characteristics and fire behavior in masticated fuels. Fuel characteristics vary across sites, but fuelbeds are commonly shallow, compact and primarily composed of small-diameter shredded wood and litter. Fire behavior was also quite variable across laboratory and field-scale studies, but masticated fuels had a propensity to burn for long-durations.

**Kreye, J. K. and L. N. Kobziar. 2015.** The effect of mastication on surface fire behaviour, fuels consumption and tree mortality in pine flatwoods of Florida, USA. *International Journal of Wildland Fire* 24:573-579.

Keywords: Florida; crown scorch; fire behaviour; fire effects; fuels treatments; prescribed fire.

Study Detail and Findings: The effects of mastication on fire behavior and fire effects were examined in a field-scale experiment in a pine flatwoods site in Florida. Flame heights, bole char, and tree crown scorch were all reduced in masticated sites, but recovering shrubs influenced fire behavior just six months after mastication and tree mortality was minimal in both masticated and unmasticated sites that were burned.

**Kreye, J. K., L. N. Kobziar, and J. M. Camp. 2014b.** Immediate and short-term response of understory fuels following mechanical mastication in a pine flatwoods site of Florida, USA. *Forest Ecology and Management* 313:340-354.

Keywords: Florida, fire management; Forest management; Fuel models; Fuels treatments

Study Detail and Findings: Fuel dynamics were examined in mastication treatments in three types of pine flatwoods sites in Florida: mature stands that were burned 5 years prior to mastication, mature stands not burned for > 10 years, and a younger unburned plantation. Palmetto and gallberry shrub dominated understories were converted to shallow, dense and shredded-litter-dominated fuelbeds that become compacted over time, but shrubs began to rapidly recover following treatments.

**Kreye, J.K., L.N. Kobziar, W.C. Zipperer. 2013.** Effects of fuel load and moisture content on fire behaviour and heating in masticated litter-dominated fuels. *International Journal of Wildland Fire* 22:440-445.

Keywords: Florida; fire hazard reduction; flammability; mechanical fuel treatment; pine flatwoods; saw palmetto.

Study Detail and Findings: Fuelbeds were created from masticated palmetto/gallberry, collected from pine flatwoods, and experimentally burned. Both flame length and fireline intensity increased with fuel load and decreased with moisture content, rate of spread decreased under wetter conditions, and soil heating was influenced by both fuel load and moisture content, but soil temperatures did not exceed 60 °C.

**Kreye, J. K., J. M. Varner, J. M. Kane, E. E. Knapp, and W. P. Reed. 2016a.** The impact of aging on laboratory fire behaviour in masticated shrub fuelbeds of California and Oregon, USA. *International Journal of Wildland Fire* 25:1002-1008.

Keywords: California, Oregon, fireline intensity, fuel decomposition, fuels treatments, mechanical mastication, smouldering combustion.

Study Detail and Findings: Masticated woody debris was collected from four sites across a chronosequence (2 to 16 years since treatment), where the treated understory vegetation was dominated by *Arctostaphylos* spp. and *Ceanothus* spp. shrubs, and burned in a laboratory experiment to examine how fuel age influenced fire behavior. Older fuelbeds, that were less dense and composed of less smaller diameter 1 hr fuels, burned less intensity across three different fuel loads, but also smoldered for longer durations.

**Kreye, J. K., J. M. Varner, and E. E. Knapp. 2011.** Effects of particle fracturing and moisture content on fire behaviour in masticated fuelbeds burned in a laboratory. *International Journal of Wildland Fire* 20:308-317.

Keywords: California, *Arctostaphylos*, *Ceanothus*, fire intensity, fuels management, mechanical fuels treatment.

Study Detail and Findings: Fuelbeds were created from masticated and unmasticated *Arctostaphylos manzanita* and *Ceanothus velutinus* shrubs and burned in a laboratory experiment to examine the effects of fuel moisture and particle fracturing on fire behavior and surface heating. Fuelbeds composed of fractured particles did not burn with greater flame heights or fireline intensities than unfractured particles, as was hypothesized, and while wetter

masticated fuels burned with lower intensities, lethal heating was observed for long durations under all conditions.

**Kreye, J.K., Varner, J.M., and L.N. Kobziar. 2016b.** Mechanical mastication as a fuels treatment in southeastern forests. Pages 198-205 in Proceedings of the 18th Biennial Southern Silvicultural Research Conference. eGTR-SRS-212. USDA Forest Service, Southern Res. Sta., Asheville, NC.

Keywords: fire behavior; fuel loading; fuels treatments; pine flatwoods; synthesis; vegetation response.

Study Detail and Findings: A synthesis of literature on the effects of mastication in southeastern US wildlands. Report on fuel loading, fuelbed dynamics, vegetation responses, and fire behavior in a diversity of masticated sites in the region.

**McIver, J., M. Brunson, S. Bunting, J. Chambers, P. Doescher, J. Grace, A. Hulet, D. Johnson, S. Knick, R. Miller, M. Pellant, F. Pierson, D. Pyke, B. Rau, K. Rollins, B. Roundy, E. Schupp, R. Tausch, and J. Williams. 2014.** A Synopsis of Short-Term Response to Alternative Restoration Treatments in Sagebrush-Steppe: The SageSTEP Project. *Rangeland Ecology & Management* 67:584-598.

Keywords: western USA; cheatgrass invasion; ecological resilience; ecosystem management; environmental gradients; sagebrush restoration; woodland expansion.

Study Detail and Findings: A synopsis of results from an integrated long-term study evaluating the ecological effects of alternative treatments aimed to reduce woody fuels and increase herbaceous understories in sagebrush steppe communities. Results are summarized through 3 years post-treatment.

**Moghaddas, E. E. and S. L. Stephens. 2007.** Thinning, burning, and thin-burn fuel treatment effects on soil properties in a Sierra Nevada mixed-conifer forest. *Forest Ecology and Management* 250:156-166.

Keywords: California; Fuel treatment; Soil; Sierra Nevada; Skid trail; Forest restoration.

Study Detail and Findings: Effects of burning on soil properties were investigated in stands that were thinned and subsequently masticated in a field experiment in California. Burning in treated sites increased mineral soil concentrations of nitrate, ammonium and exchangeable calcium;

increased inorganic pools of N and pH; and while burning reduced C and N in soil organic horizons, total soil C and N in the mineral soil did not differ from controls.

**Moghaddas, E. E. and S. L. Stephens. 2008.** Mechanized fuel treatment effects on soil compaction in Sierra Nevada mixed-conifer stands. *Forest Ecology and Management* 255:3098-3106.

Keywords: California; Fuel treatment; Mastication; Soil compaction.

Study Detail and Findings: Soil compaction was examined in thinned stands that were masticated and thinned/masticated stands that were subsequently burned in California. Soil bulk density did not differ between treated stands and controls and while soil strength was found to be higher in thinned/masticated/burned stands, but was only detected along skid trails and not within the remainder of the units.

**Moghaddas, J. J., R. A. York, and S. L. Stephens. 2008.** Initial response of conifer and California black oak seedlings following fuel reduction activities in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management* 255:3141-3150.

Keywords: California; Fuel treatments; Prescribed fire; Fire surrogates; Fire hazards; Regeneration; Wildfire.

Study Detail and Findings: The response of mixed-conifer and California black oak seedling regeneration to burning in stands that were thinned and subsequently masticated as well as burning in stands that were not mechanically treated was examined in field-scale experiments in California. Douglas-fir seedling density increased as a result of burning in both treated and untreated sites, ponderosa pine seedling density increased only following burning in the mechanically treated stands, while burning in untreated stands reduced California black oak seedlings.

**Moody, T. J., S. L. Stephens, and M. A. Moritz. 2009.** Effects of fuels management on future wildfires in the Lake Tahoe Basin. *Effects of Fuel Management in the Tahoe Basin: A Scientific Literature Review*. Final Report: 83-114.

Keywords: California; fuels treatment; Sierra Nevada; synthesis.

Study Detail and Findings: A literature review was conducted to summarize study results of fuels treatments and their potential impacts on fire and fire effects in the Lake Tahoe Basin in

California. A review of relevant mastication research suggests that masticated fuels may be difficult to quantify using current methods and adequate fuel models do not exist, increased fire severity effects may occur when masticated sites burn given their heavy fuel loading, but that following mastication with prescribed burning may alleviate potential overstory mortality from a subsequent wildfire.

**Murphy, K., P. Duncan, and C. Dillingham. 2010.** A summary of fuel treatment effectiveness in the Herger-Feinstein Quincy Library Group Pilot Project Area. United States Forest Service: R5-TP-031. Sacramento, CA.

Keywords: California; fuels treatments; Sierra Nevada.

Study Detail and Findings: Pilot project directed by the Forest Recovery Act of 1988 to evaluate the effectiveness of various hazard fuel reduction treatments at meeting ecological, economic, and fire management objectives in the northern Sierra Nevada mountain range in California. By evaluating fire behavior and suppression activities for 20 wildfires that started within or entered fuels treatments within the project study, findings suggest that fuel treatments were effective at modifying fire behavior, fire size, suppression costs, and fire-induced tree mortality with thinning and prescribed fire used in combination being the most effective of treatments.

**Ottmar, R. D., and S. J. Prichard. 2012.** Fuel treatment effectiveness in forest of the upper Atlantic Coastal Plain – An evaluation at two spatial scales. *Forest Ecology and Management* 273:17-28.

Keywords: South Carolina; Fuel treatment effectiveness; Fire behavior; Fire hazard; Fuel Characteristic Classification System; Southeastern US.

Study Detail and Findings: Fuels were inventoried across several stands in South Carolina, six of which were masticated, and data were used to construct fuelbeds within the Fuel Characteristic Classification System (FCCS) and predict fire behavior. Surface fuels were heavy following mastication, but were dominated by litter. Predicted fire behavior suggested reduced fire behavior in treated sites, but that litter and shrub accumulation may reduce treatment efficacy.

**Owen, S. M., C. H. Sieg, C. A. Gehring, and M. A. Bowker. 2009.** Above-and belowground responses to tree thinning depend on the treatment of tree debris. *Forest Ecology and Management* 259:71-80.

Keywords: Colorado; Arbuscular mycorrhizal fungi (AMF); Exotic plants; Mechanical mastication; Pinyon–juniper woodlands; Soil nutrients and stability; Slash pile burning.

Study Detail and Findings: Effects of mastication and slash-pile burning on soil properties, mycorrhizal fungi, and understory plant communities were examined in pinyon-juniper woodlands in Colorado. Mastication increased soil moisture and reduced soil temperature, resulted in greater post-treatment plant cover and richness than controls, but non-native cover of *Bromus tectorum* was also increased. Pile burning, however, had significantly greater negative impacts to soils and myco-flora than mastication.

**Perchemlides, K. A. 2006.** Impacts of fuel reduction thinning treatments on oak and chaparral communities of southwestern Masters Thesis. Oregon State University 48 pp.

Keywords: chaparral; Oregon; Oregon white oak; vegetation response.

Study Detail and Findings: Vegetation and abiotic characteristics were compared between thinned and unthinned chaparral and oak communities in southwestern Oregon. Thinning increased herbaceous cover and altered herbaceous community composition, but species richness and diversity were not affected. While overall proportions of natives and exotics did not change, changes at the functional group level were observed.

**Perchemlides, K. A., P. S. Muir, and P. E. Hosten. 2008.** Responses of chaparral and oak woodland plant communities to fuel-reduction thinning in southwestern Oregon. *Rangeland Ecology & Management* 61:98-109.

Keywords: *Arctostaphylos*; Oregon; *Ceanothus*; exotic grasses; mastication.

Study Detail and Findings: Vegetation and abiotic responses to fuel treatments in chaparral and oak woodlands were examined in southwestern Oregon. Mastication resulted in greater cover of woody debris and herbaceous plants, but a mixed response was observed when looking at more more specific plant types (e.g., natives/exotics, annuals/perennials, forbs/grasses, woody shrubs).

**Phillips, R. J., T. A. Waldrop, and A. D. Stottlemeyer. 2013.** Occurrence and spread of nonnative invasive plants in stands treated with fire and/or mechanical treatments in the Upper Piedmont of South Carolina. In: Guldin, J.M., ed. 2013. Proceedings of the 15th biennial southern silvicultural

research conference. e-Gen. Tech. Rep. SRS-GTR-175. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 525-531.

Keywords: South Carolina, mastication, southern pine beetle, prescribed burning.

Study Detail and Findings: The effects of fuel-reduction treatments were examined on nonnative invasive plants in mixed *Pinus taeda*/*P. echinata* stands in western South Carolina, USA.

Mastication followed by burning resulted in the largest increases in invasive plants in stands previously unaffected by southern pine beetle infestation, while mastication alone resulted in the greatest invasive abundance in stands that had previously succumb to beetle attack.

**Potts, J. B., E. Marino, and S. L. Stephens. 2010.** Chaparral shrub recovery after fuel reduction: a comparison of prescribed fire and mastication techniques. *Plant Ecology* 210:303-315.

Keywords: California; Prescribed burning; Mastication; Resprouting; Fire hazard; Herbivory; Chamise; *Adenostoma fasciculatum*; *Ceanothus cuneatus*.

Study Detail and Findings: The effects of mastication and prescribed burning on shrub response were compared in an oak chaparral ecosystem in California. Vegetation mortality was 90-10% following both treatments, but in masticated sites shrub cover was less than burned sites 3 years after treatments, but there were no differences between shrub height, species richness, or composition.

**Potts, J. B. and S. L. Stephens. 2009.** Invasive and native plant responses to shrubland fuel reduction: comparing prescribed fire, mastication, and treatment season. *Biological Conservation* 142:1657-1664.

Keywords: California; Annual grasses; Chaparral; Invasive species; Species diversity; Fire hazards; Urban–wildland interface.

Study Detail and Findings: Native and non-native plant response to mastication treatments and prescribed burning were examined in California chaparral ecosystems. Response differed more between treatment type rather than treatment season, with non-native plant invasion being the greatest in masticated sites and winter and spring burning were most resistant to invasion by exotic species.

**Redmond, M. D., T. J. Zelikova, and N. N. Barger. 2014.** Limits to understory plant restoration following fuel-reduction treatments in a piñon–juniper woodland. *Environmental management* 54:1139-1152.

Keywords: Utah; Mastication; Prescribed fire; Seeding; Invasive species; Herbivory; Pinyon–juniper.

Study Detail and Findings: Vegetation response to fuels treatments (mastication, broadcast burning, and pile burning) and native grass seeding was examined in a piñon–juniper woodland in southeast Utah. Herbaceous cover increased following broadcast burns, but only increased in the other treatments where native grasses were seeded; all treatments resulted in increased relative density of invasive species.

**Reemts, C. M. and D. A. Cimprich. 2014.** Restoring early-successional shrubland habitat for black-capped vireos using mechanical mastication. *Natural Areas Journal* 34:400-407.

Keywords: Texas; fire-surrogate; shrubland restoration; songbird habitat; *Vireo atricapilla*.

Study Detail and Findings: Black-capped vireo habit structure and nesting activity was examined in masticated oak shrublands in Texas. Vegetation height remained low for 4 growing seasons following treatment, breeding pairs started to nest in these sites 3 years after treatment, their abundance was twice that of untreated areas by the 4<sup>th</sup> season, but the probability of nest survival did not differ between masticated and unmasticated sites over the period from egg-laying to fledging.

**Reiner, A. and S. Decker. 2009.** Fuel loadings in masticated areas on the San Jacinto District of the San Bernardino National Forest. Final Report. USDA Forest Service, Adaptive Management Services Enterprise Team. (Sparks, NV).

Keywords: California; fuel loading; mastication.

Study Detail and Findings: Surface fuel characteristics were examined in mastication treatment sites on the San Jacinto District of the San Bernardino National Forest in California. Masticated surface fuels, ranging from 17-34 tons ac<sup>-1</sup> with shallow fuel depths (3-5 cm), were composed primarily of 10-h and 1-h timelag fuels and relationships between fuel depth and fuel load were developed for sites treated 1 and 2 years prior to sampling.

**Reiner, A. L., N. M. Vaillant, and S. N. Dailey. 2012.** Mastication and prescribed fire influences on tree mortality and predicted fire behavior in ponderosa pine. *Western Journal of Applied Forestry* 27:36-41.

Keywords: California; fire behavior; fuel treatment; ponderosa pine; southern Sierra Nevada.

Study Detail and Findings: Tree mortality was examined following burning in a masticated ponderosa pine plantation in California and wildfire behavior was modeled for 90<sup>th</sup> to 97<sup>th</sup> percentile fire weather conditions in treated and untreated sites. Almost half of the trees had died 2 yrs following burning in masticated sites, and 27% mortality was observed even where fuels were pulled away from tree bases prior to burning. Wildfire predictions indicated flame lengths and rates of fire spread being greatest in masticated sites versus those either untreated or masticated with follow-up prescribed burning.

**Reiner, A. L., N. M. Vaillant, J. Fites-Kaufman, and S. N. Dailey. 2009.** Mastication and prescribed fire impacts on fuels in a 25-year old ponderosa pine plantation, southern Sierra Nevada. *Forest Ecology and Management* 258:2365-2372.

Keywords: California; Fuel treatment; Mastication; Prescribed burn; Ponderosa pine; Southern Sierra Nevada.

Study Detail and Findings: Pre- and post-treatment fuel loadings were examined in ponderosa pine plantations either masticated or masticated followed by prescribed burning in California. Mastication increased surface fuel loads and decreased canopy fuels, but follow-up burning reduced both of these fuel strata. Relationships between surface fuel depths and fuel loads were also developed.

**Rhoades, C., M. Battaglia, M. Rocca, and M. Ryan. 2012.** Short-and medium-term effects of fuel reduction mulch treatments on soil nitrogen availability in Colorado conifer forests. *Forest Ecology and Management* 276:231-238.

Keywords: Colorado; Mastication; Chipping; Nitrogen cycling; Soil productivity.

Study Detail and Findings: The effects of mastication on soil properties were examined in piñon-juniper woodlands in Colorado. Mastication reduced summer soil temperatures and increased soil moisture, reduced N concentrations (while increasing C:N), and although available N decreased in the 1<sup>st</sup> year, it increased 3-5 years following treatments.

**Rocca, M. 2013.** Joint Fire Science Final Report: Mastication effects on fuels, plants, and soils in four western US ecosystems: Trends with time-since-treatment. JFSP Final Report: Project 10-1-01-10.

Keywords: Colorado; mastication; mixed-conifer forests; soil moisture; soil nutrients; vegetation responses.

Study Detail and Findings: Masticated and unmasticated sites in dry forests across Colorado were examined to evaluate treatment effects on forest regeneration, understory plant communities, fuel loads, and ecosystem N dynamics and forest productivity. Tree seedlings grew better in treated sites, with increased foliar N. Herbaceous cover and species diversity were greater in masticated sites, but exotics were also more prevalent. Woody surface fuels remained high in masticated areas up to the 9 years post-treatment evaluated. Increased soil moisture was observed in ponderosa and lodgepole pine/mixed conifer forests during parts of the growing season, and while available soil N was not generally reduced by treatments, short-term effects were observed in piñon–juniper woodlands.

**Ross, M., S. Castle, and N. Barger. 2012.** Effects of fuels reductions on plant communities and soils in a Piñon-juniper woodland. *Journal of Arid Environments* 79:84-92.

Keywords: Utah; Piñon-juniper woodlands; Mechanical mastication; Biological soil crusts (BSCs); Pile burning; *Bromus tectorum*; Soil nutrients.

Study Detail and Findings: Short-term effects of mastication and hand thinning treatments on plant communities and soil resources were examined in piñon–juniper woodlands in southeast Utah. Understory plant cover was much greater in masticated sites 2 growing seasons following treatment, invasive *Bromus tectorum* was present in all treatments, and while soil quality was lower in pile burn and masticated sites, N fixation potential was lowest in lop & scatter and masticated sites.

**Roundy, B. A., R. F. Miller, R. J. Tausch, K. Young, A. Hulet, B. Rau, B. Jessop, J. C. Chambers, and D. Eggett. 2014.** Understory cover responses to pinon–juniper treatments across tree dominance gradients in the Great Basin. *Rangeland Ecology & Management* 67:482-494.

Keywords: California; Oregon; brush control; mastication; mechanical treatments; prescribed fire; resilience; state and transition; thresholds.

Study Detail and Findings: Vegetation response was examined in prescribed fire, tree felling, and mastication treatments. Shrub cover was reduced by mechanical treatments and increased herbaceous cover, but also increased the non-native cheatgrass (*Bromus tectorum*) at high tree dominance indices (>0.45).

**Schiks, T., D. K. Thompson, and B. M. Wotton. 2015.** Short-term effects of mastication on fuel moisture and thermal regime of boreal fuel beds. *Canadian Journal of Forest Research* 45:867-876.

Keywords: Alberta; black spruce; fuels management; fuel treatments; lodgepole pine; mulching; chipping; moisture modelling.

Study Detail and Findings: Temperature and moisture profiles were monitored in masticated surface fuels in a lodgepole pine-black spruce forest. Depth to surface moisture movement was very low, promoting highly variable surface moisture, and surface temperatures were observed that were far in excess of air temperatures during full sun. Thermal properties of masticated debris indicate that these fuelbeds have a thermal and moisture regime more similar to soil than to fuel cribs, with a diffusion-dominated regime enhanced by minor advection.

**Schiks, T. and B. Wotton. 2014.** Assessing the probability of sustained flaming in masticated fuel beds. *Canadian Journal of Forest Research* 45:68-77.

Keywords: Alberta; ignition probability; fire behaviour; fuel management; moisture content; mulch.

Study Detail and Findings: Fuel moisture content, wind speed, and firebrand size were evaluated for their influence on the probability of sustained flaming in masticated fuels, through firebrand ignition, in lab and field studies. Probability of ignition increased with decreasing moisture and increasing wind in both lab and field studies, but firebrands were only influential in lab experiments. Field models were also developed using estimated moisture contents from the Canadian Fine Fuel Moisture Code, the US National Fire Danger Rating System, and the new masticated surface fuel moisture model (MAST). Disparities between lab-based and field-based modeling were discussed.

**Schiks, T. and B. Wotton. 2015.** Modifying the Canadian Fine Fuel Moisture Code for masticated surface fuels. *International Journal of Wildland Fire* 24:79-91.

Keywords: Alberta; chipping; mechanical fuel treatment; moisture dynamics.

Study Detail and Findings: The applicability of the Canadian Fine Fuel Moisture Code (FFMC) for tracking diurnal and day-to-day surface moisture changes was examined. A calibration of the standard conversion between moisture content and FFMC was developed and several modifications to the FFMC model were proposed, including solar radiation driven fuel temperature.

**Schiks, T. J. 2014.** Fuel moisture and sustained flaming in masticated fuelbeds. Masters Thesis, University of Toronto.

Keywords: Alberta; fuels management; mechanical fuels treatment; chipping.

Study Detail and Findings: Micrometeorology and surface fuel moisture dynamics were examined in masticated forest fuels in Alberta, Canada and a fuel moisture model was created for masticated surface debris and shown to improve upon existing models. Ignition tests were conducted to better predict sustained flaming in masticated surface fuels and findings were compared with existing models developed for other fuels.

**Schmalzer, P. A. 2003.** Growth and recovery of oak-saw palmetto scrub through ten years after fire. *Natural Areas Journal* 23:5-13.

Keywords: Florida; mastication; prescribed fire; scrub ecosystem.

Study Detail and Findings: Vegetation response was examined in masticated scrub ecosystems in Florida. Saw palmetto cover and height were reduced in the long-term in masticated stands in both oak-saw palmetto scrub and coastal scrub, while oak recovery was rapid following both mastication and burning.

**Schwilk, D. W., J. E. Keeley, E. E. Knapp, J. McIver, J. D. Bailey, C. J. Fettig, C. E. Fiedler, R. J. Harrod, J. J. Moghaddas, and K. W. Outcalt. 2009.** The National Fire and Fire Surrogate study: effects of fuel reduction methods on forest vegetation structure and fuels. *Ecological Applications* 19:285-304.

Keywords: fuel loading; fuels treatments; prescribed fire; snags; vegetation responses.

Study Detail and Findings: Effects of different fuel reduction treatments (prescribed burning, mechanical treatments, combination of both) on vegetation and fuels were examined across several study locations across the United States. Short-term results indicate mechanical treatments were most effective at reducing overstory tree density and basal area, but treatments that included prescribed burning were better at creating snags, inducing seedling mortality, increasing height:live crown ratios, and reducing surface woody fuels. The combination of mechanical and burning treatments also maximized the ecological response to treatments.

**Seavy, N. E., J. D. Alexander, and P. E. Hosten. 2008.** Bird community composition after mechanical mastication fuel treatments in southwest Oregon oak woodland and chaparral. *Forest Ecology and Management* 256:774-778.

Keywords: Avian response; Oregon; Chaparral; Fire management; Fuels reduction; Mechanical mastication; Monitoring; Oak woodlands.

Study Detail and Findings: Vegetation structure and bird abundance were compared between masticated and untreated chaparral sites in southwest Oregon. Shrub cover was less in treated sites. Bird abundance varied by species in their response to treatment, with shrub-associated species being more abundant in untreated sites and species associated with open areas more abundant in masticated sites.

**Shakespear, A. W. 2014.** Fuel response to mechanical mastication of pinyon-juniper woodlands in Utah. Thesis, Brigham Young University.

Keywords: Utah; mechanical mastication; pinyon-juniper woodlands; fuel loading; fire; decomposition.

Study Detail and Findings: Fuel loading and fuel cover were examined in untreated, masticated, and masticated + burned sites in pinyon-juniper woodlands in Utah. Surface fuel loads were greatest in masticated sites and dominated by 10-h fuels, but were reduced to pre-masticated levels in the mastication + burned sites. Shrub loading was not affected by mastication, but was reduced in mastication + burned treatments, and both mastication and mastication + burning increased herbaceous fuels.

**Sikes, K. G. and P. S. Muir. 2009.** A comparison of the short-term effects of two fuel treatments on chaparral communities in southwest Oregon. *Madroño* 56:8-22.

Keywords: Oregon; burn piles; *Ceanothus cuneatus*; chaparral; fire management; fuel reduction; mastication.

Study Detail and Findings: The effects of mastication and hand cut, pile, and burn (HPB) on chaparral communities were examined in southwestern Oregon. Treatment effects on species composition and herbaceous abundance were minimal. Mastication reduced species diversity, and HPB treatments had the greater affect on plant communities by increasing annuals and introduced weeds in the areas where hand piles were burned.

**Southworth, D., J. Donohue, J. L. Frank, and J. Gibson. 2011.** Mechanical mastication and prescribed fire in conifer–hardwood chaparral: differing responses of ectomycorrhizae and truffles. *International Journal of Wildland Fire* 20:888-896.

Keywords: California; brush mastication; fuels reduction; hypogeous fungi; oak–chaparral.

Study Detail and Findings: The effects of mastication, burning, and mastication followed by burning on ectomycorrhizae and truffle communities were examined in *Pinus attenuata* - *Quercus kelloggii* oak woodlands in northern California. Ectomycorrhizae communities did not differ among treatments, or controls, but burning reduced the abundance and species richness of truffles in both controls and masticated sites.

**Stephens, S. L., B. M. Collins, and G. Roller. 2012.** Fuel treatment longevity in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management* 285:204-212.

Keywords: California; Fire ecology; Fire management; Forest ecology; Restoration; Fire hazards; predicted fire behavior.

Study Detail and Findings: Changes to fuels, forest structure, and predicted fire behavior were examined 7 years following mechanical only, mechanical plus fire and prescribed fire only treatments as well as untreated controls. Predicted fire hazard initially associated with the mechanical only treatment had decreased after 7 years and had become no different than either fire treatment, which were low in fire hazard throughout the duration following treatments. Tree density declined over 7 years following fire only treatments, but basal area in both fire treatments was unchanged compared to immediate post-treatment conditions.

**Stephens, S. L. and J. J. Moghaddas. 2005a.** Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. *Forest Ecology and Management* 215:21-36.

Keywords: California; Fire hazard; Fire surrogates; Forest restoration; Fuels management; Sierra Nevada.

Study Detail and Findings: Effects of thinning, mastication, and prescribed burning on fuels, forest structure, as well as potential fire behavior and tree mortality were examined from field experiments in mixed-conifer forests in California. Thinning and mastication both reduced crown bulk density, but prescribed burning reduced surface fuel loads, resulting in lower predicted fire intensity, rate of fire spread, and tree mortality in burned sites. The control resulted in the most severe predicted fire behavior and tree mortality and while mechanical treatments were an improvement over controls, they still resulted in predicted tree mortality under severe fire weather conditions compared to the burned treatments.

**Stephens, S. L. and J. J. Moghaddas. 2005b.** Fuel treatment effects on snags and coarse woody debris in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management* 214:53-64.

Keywords: California; Prescribed fire; Fuels; Forest restoration; Downed logs; Fire hazard; Coarse wood.

Study Detail and Findings: Effects of mastication, mastication + burning, and burning on coarse woody debris were evaluated. Both burning treatments increased new snag density and reduced rotten coarse woody debris.

**Stephens, S. L., J. J. Moghaddas, B. R. Hartsough, E. E. Moghaddas, and N. E. Clinton. 2009.** Fuel treatment effects on stand-level carbon pools, treatment-related emissions, and fire risk in a Sierra Nevada mixed-conifer forest. *Canadian Journal of Forest Research* 39:1538-1547.

Keywords: California; fuels treatments; forest carbon; potential fire behavior; Sierra Nevada.

Study Detail and Findings: Carbon pools were examined in mechanical, burned, mechanical + burned, and controls sites in California. Above-ground live tree C was reduced in both mechanical treatments, but dead tree C did not differ. Both burn treatments emitted more CO<sub>2</sub> than unburned treatments.

**Stottlemeyer, A. D., T. A. Waldrop, and G. G. Wang. 2015.** Prescribed burning and mastication effects on surface fuels in southern pine beetle-killed loblolly pine plantations. *Ecological Engineering* 81:514-524.

Keywords: South Carolina; Forest disturbance; Site preparation; Hazard reduction; Fire behavior; Masticated debris.

Study Detail and Findings: Surface fuels and predicted fire behavior were examined in loblolly pine plantations that were killed by southern pine beetle then treated by either prescribed burning or mastication. Mastication resulted in a dense continuous layer of heavy surface woody fuels, while surface fuel continuity was reduced by burning. Standard slash models SB2 and SB3 produced similar predicted fire behavior as custom low, moderate, and high load fuel models using BehavePlus.

**Stottlemeyer, A. D., G. G. Wang, T. A. Waldrop, C. E. Wells, and M. A. Callaham. 2013.** Short-term effects of fuel reduction treatments on soil mycorrhizal inoculum potential in beetle-killed stands. In: Guldin, James M., ed. 2013. Proceedings of the 15th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-GTR-175. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 357-360.

Keywords: bark beetles; mastication; mycorrhizae; southern pine forest.

Study Detail and Findings: Soil ectomycorrhizal (ECM) and vesicular-arbuscular mycorrhizal (VAM) fungi inoculum potential was examined across prescribed burned and masticated loblolly pine plantations, previously killed by southern pine beetle in South Carolina, using greenhouse bioassays. ECM and VAM inoculum potential were highly variable within treated stands and were no different between either treatment and controls.

**Thompson, D., T. Schiks, and B. Wotton. 2016.** Fuel size impacts on carbon residuals and combustion dynamics in masticated woody debris. *Forest Ecology and Management* 369:59-65.

Keywords: Canada; Fuel management; Mastication; Mulch; Smouldering; Black carbon; Pyrogenic carbon.

Study Detail and Findings: Combustion dynamics and pyrogenic C production were examined during laboratory experimental burning of masticated woody debris from boreal coniferous forests. Mass loss rates during flaming and smoldering combustion were influenced by fuel

moisture content, but not particle size, however pyrogenic C production > 1 mm in size and its C content increased with the inclusion of coarse fuels. Production of pyrogenic C < 1mm in size was not influenced by moisture or particle size, but was related to conductive heat flux and combustion duration.

**Vitorelo, B., H.-S. Han, and J.M. Varner. 2009.** Masticators for fuel reduction treatment: equipment options, effectiveness, costs, and environmental impacts. Page 11 *in* Proceedings of the 2006 Council on Forest Engineering (COFE) meeting, Lake Tahoe, CA.

Keywords: fuels treatments; equipment selection and limitations; fuels; slope; vegetation.

Study Detail and Findings: A study of costs, limitations, and ecological consequences of mastication. Mastication costs were highly variable, driven by travel distance, slope, machinery, and treatment intensity.

**Weekley, C. W., E. S. Menges, M. A. Rickey, G. L. Clarke, and S. Smith. 2008.** Effects of mechanical treatments and fire on Florida scrub vegetation. Final Report to U.S. Fish and Wildlife Service. Vero Beach, FL. 37 pp.

Keywords: Florida; mastication; scrub ecosystems; vegetation response.

Study Detail and Findings: Scrub response to mastication and burning treatments were examined at two sites in Florida. Woody cover was reduced by mastication, but not as successfully as in sites that were burned, either with or without prior mastication. Plant composition was changed in masticated sites and in masticated and unmasticated sites that were burned, but composition in the mastication only sites became more similar to controls over time.

**Young, K. R., B. A. Roundy, S. C. Bunting, and D. L. Eggett. 2015.** Utah juniper and two-needle piñon reduction alters fuel loads. *International Journal of Wildland Fire* 24:236-248.

Keywords: Utah; fire; mulch; resilience; resistance; resource availability; weed invasion.

Study Detail and Findings: The effects of burning, tree cutting, and mastication on fuel load characteristics were examined in piñon-juniper woodlands in Utah. Cut and mastication treatments increased fine woody fuel loading, with masticated-tree depth as a good estimator of fuel load, and herbaceous fuel loads were increased in all treatments after 2 years.

**Young, K. R., B. A. Roundy, and D. L. Eggett. 2013a.** Plant establishment in masticated Utah juniper woodlands. *Rangeland Ecology & Management* 66:597-607.

Keywords: Utah; grass emergence; invasive weeds; mulch; resilience; resistance; resource availability.

Study Detail and Findings: The effects of mastication on the establishment of an invasive annual grass and a native perennial grass was examined in masticated juniper woodlands in Utah.

Seedling emergence of both species was reduced in masticated sites, but seedling growth was increased for both species as a result of increased inorganic N and soil water.

**Young, K. R., B. A. Roundy, and D. L. Eggett. 2013b.** Tree reduction and debris from mastication of Utah juniper alter the soil climate in sagebrush steppe. *Forest Ecology and Management* 310:777-785.

Keywords: Utah; Mulch; Resistance to invasion; Resource availability; Soil temperature; Soil water; Weeds.

Study Detail and Findings: The effects of tree reduction and surface masticated debris on soil water potential and soil temperature was examined in mechanically treated juniper woodlands in Utah. Masticated sites had more wet days, degree days, and wet degree days than untreated areas, but soil cover was less influential than tree reduction, which increased wet days by 45 days during the spring and summer growing seasons.