MECHANICAL MASTICATION AS A FUELS TREATMENT IN SOUTHEASTERN FORESTS

Jesse K. Kreye, J. Morgan Varner, and Leda N. Kobziar[1]

Abstract—Mastication is an increasingly common fuels treatment that redistributes ''ladder'' fuels to the forest floor to reduce vertical fuel continuity, crown fire potential, and fireline intensity. Despite its widespread adoption, it remains unclear how mastication impacts fuels, fire behavior, or plant communities across Southeastern forest ecosystems. We evaluated these effects by reviewing studies conducted across Southeastern pine forests. Mastication is typically applied to reduce fire hazard prior to reintroducing fire to long-unburned sites and to promote desired herbaceous groundcover where woody species have become dominant. Pretreatment fuel conditions varied across the different studies, ultimately leading to variation in post-treatment fuels. Only a few studies have examined fire behavior in masticated fuels and its potential effects. Field-scale burns conducted under mild conditions have resulted in variable fuel consumption and minimal overstory tree mortality. Substantial surface fuel loads in sites with prior stand damage, however, suggests that fire hazard may not be alleviated if sites burned under wildfire conditions. Modeled fire behavior indicates the effectiveness of treatments at reducing potential fire hazard, but verifying predictions under wildfire conditions has not been done. Initial herbaceous response has been positive in some sites, but rapid recovery of woody species indicates the importance of frequent burning to sufficiently restore plant communities and vegetation structure indicative of fire dependent pine forests in the Southeastern US.

INTRODUCTION

Mechanical mastication (“mowing”, “chipping”, “mulching”) has become a widely used fuels treatment option in forests and shrublands across the US (Kreye and others 2014a). Mastication primarily targets under- and mid-story vegetation either alone or in conjunction with other treatments (e.g., overstory thinning or prescribed fire). Treatments are aimed at reducing fire hazard by altering fuel structure through disconnecting surface and canopy fuels. Mastication is also used as a restoration tool where undesired species composition or structure has developed over long periods of fire exclusion. The widespread use of mastication as a management tool has outpaced research efforts aimed at understanding their treatment efficacy or unexpected consequences.

Much of the research evaluating the initial effects of mastication on over- and understory vegetation, post-treatment fuel characteristics, and subsequent fire behavior has been conducted in the western US (Collins and others 2007, Kane and others 2010, Kreye and others 2014a, Moghaddas and others 2008, Ostaja and others 2014, Perchlemlides and others 2008, Potts and Stephens 2009, Ross and others 2012, Young and others 2013). Studies across a variety of ecosystems have highlighted the variability of these effects.

Reductions in stand density are common in forests where under- and midstory trees were present, but as a stand-alone treatment, the impacts of mastication on basal area are less prominent, as small-diameter trees are usually targeted. Surface fuels resulting from mastication vary in loading, but are often dominated by small-diameter (<7.62 cm) fractured woody debris compacted into shallow (<10 cm) fuel depths. Surface fuel loading can be substantial, however, particularly where dense pre-treatment vegetation existed (Kreye and others 2014a). Early vegetation response varies greatly across the ecosystems in which mastication is used. Surface debris may inhibit woody and herbaceous recruitment unless bare ground is exposed from post-treatment burning.

Given the compactness of post-mastication surface fuels and their fine woody composition, early lab-scale fire behavior studies revealed their propensity for long-duration combustion and potential surface and belowground heating (Busse and others 2005, Kreye and others 2011). Field-scale studies have highlighted substantial overstory mortality following prescribed burns in masticated stands (Bradley and others 2006), even where flame lengths were minimal (Knapp and others 2011). Given the trade-off between potential crown ignition and surface fire behavior it is important

[1]Jesse K. Kreye, Postdoctoral Research Associate, Mississippi State University, Starkville, MS, 39762; J. Morgan Varner, Assistant Professor, Virginia Tech, Blacksburg, VA, 24061; Leda N. Kobziar, Associate Professor, University of Florida, Gainesville, FL, 32611

Citation for proceedings: Schweitzer, Callie J.; Clatterbuck, Wayne K.; Oswalt, Christopher M., eds. 2016. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

to fully understand the fuel dynamics associated with these treatments and their links to subsequent fire effects.

While studies examining the role of mastication in western forests and shrublands have gained some momentum over the last ten years, much less research has been focused on the recent widespread mastication in the Southeast. Here we review recent research in Southeastern forest ecosystems examining the use of mastication employed as a restoration or fire hazard mitigation tool. We compile findings evaluating impacts of mastication on fuel structure and characteristics, subsequent fire behavior during lab- or field-scale burns, and vegetation response following stand-alone mastication treatments or prescribed burns conducted following these treatments. We concurrently compare and contrast treatments in the Southeast with those applied in the western US in order to put these treatments into a broader context of their impacts and effectiveness. While the breadth of mastication research in the Southeast remains modest, we prioritize research needs that will inform our understanding of these treatments in the region to better evaluate their efficacy as a land management tool.

MASTICATION TREATMENTS IN SOUTHEASTERN FORESTS

Mastication is the grinding, shredding, chipping, mulching, or mowing of understory shrubs or small trees (Kreye and others 2014a). Front- or boom-mounted rotary heads are attached to ground-based equipment, wheeled or tracked, where the operator has hydraulic control of the mastication head. Rotary mastication heads may be cylindrical, with fixed or flailing cutters (fig. 1a), or consist of rotating blades, similar to a lawnmower. In either case, masticators can target specific vegetation unlike roller-chopping or bush hogging that treat sites more bluntly.

Mastication is used in Southeastern pine forests to mitigate fire hazard in the wildland-urban-interface where burning is difficult, to restore stand structure in fire excluded sites, and as a pre-treatment to reintroducing fire into long-unburned sites. Restoration objectives often include promoting herbaceous plants where woody vegetation has become dominant with fire exclusion. Historically, frequent fire regimes maintained open canopy structure and high herbaceous diversity in the understory (e.g., longleaf pine (*Pinus palustris*) sandhills and flatwoods). Other targeted ecosystems, such as sand pine (*P. clausa*) scrub, oak-saw palmetto scrub, and coastal scrub are typified by a less frequent stand replacing fire regime; mastication is used in these ecosystems to alter vegetation structure where prescribed burning is a challenge.

Few studies have evaluated mechanical mastication treatments in Southeastern forests. Glitzenstein and others (2006), Kreye and others (2013a, 2104b, 2015), and Ottmar and Prichard (2012) characterized post-treatment fuels and assessed their burning behavior, while others have focused on treatment effects to various plant community attributes (Brockway and others 2009, Kreye 2012, Schmalzer and others 2003, Weekley and others 2008). Treatments have occurred in sites that have been unburned for as little as five years (Kreye and others 2014a) or up to several decades (Brockway and others 2009). In some sites, mastication took place following other disturbances that have resulted in significant stand damage and in high quantities of snags and large woody debris (Glitzenstein and others 2006, Stottlemyer and others 2015).

FUELS AND FIRE BEHAVIOR

Fuels have been characterized in masticated treatments in coastal plain forests in South Carolina (Glitzenstein and others 2006, Ottmar and Prichard 2012, Stottlemyer and others 2015) and northern Florida (Kreye and others 2014b) (table 1). Glitzenstein and others (2006) characterized fuels following mastication in loblolly pine (*Pinus taeda*) flatwoods on the Francis Marion National Forest in stands with dense mid- and under-story regeneration and large downed woody material following hurricane damage. Total surface fuels were substantial (195 Mg ha^{-1}) in treated sites, dominated by large fuels (>7.62 cm) that were likely post-hurricane debris not fully masticated. Finer wood (<7.62 cm) comprised a smaller proportion of surface fuels (32 percent) but were much greater than fine fuel loads in untreated sites. Glitzenstein and others (2006) modeled fire behavior in these sites and compared their predictions with fire behavior during prescribed burns. Observed fire behavior was mild, with flame lengths <50 cm and rate of spread varying between 0.5 to 3.0 m min^{-1}, similar to burns conducted at the same time in untreated sites. Mastication resulted in lower scorch heights than unmasticated sites.

Stottlemyer and others (2015) also evaluated surface fuels following mastication in sites with previous stand damage. They reported substantial surface fuel loads in masticated loblolly pine plantations (18-33 years old) in the South Carolina Piedmont that had substantial overstory mortality (79 dead pines ha^{-1}) from bark beetle attack that occurred 4 to 6 years prior to fuels treatment. Total surface fuel loading increased from 27 to 192 Mg ha^{-1} following treatment, with post-treatment biomass ranging from 126 to 258 Mg ha^{-1}. Although surface fuel loads were substantial, fuel depth averaged only 15 cm across stands, ranging from 12 to 17 cm, highlighting the significant fuelbed bulk density often observed in other sites (Kreye and others 2014b). Although woody fuel biomass was not separated by size

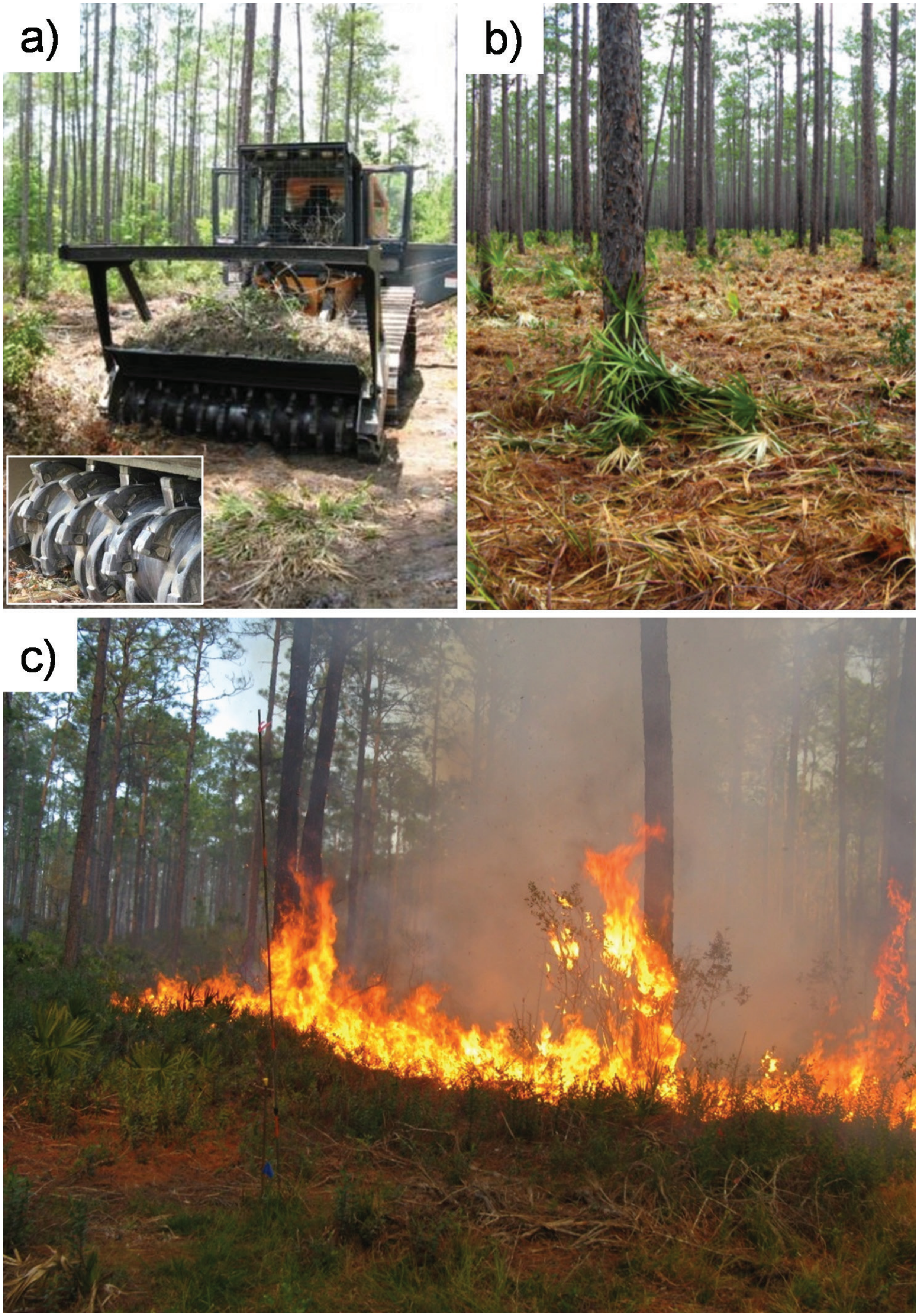

Figure 1—A front-mounted masticator (a), a post-masticated pine flatwoods site in northern Florida (b), and a prescribed burn conducted in a pine flatwoods site in north Florida six months following treatment (c).

Table 1—Studies characterizing surface fuels and fire behavior in mastication fuels treatments in Southeastern US forests

Forest Type (State)	1h	10h	100h	1000h	Litter	Shrubs	Grass	Total	Flame Length	Rate of Spread	Fire Intensity[g]
	------------------Mg ha^{-1}------------------								m	m min^{-1}	
Loblolly Pine Flatwoods (SC)[a] (hurricane damage)	2.82	24.10	35.15	127.30	5.31	0.95	0.18	195.81	0.35	1.36	
Variable, Coastal Plain (SC)[b]											
Unthinned											
masticated only	----------4.86[‡]---------				9.57	0	0	14.43	1.70	0.90	396 $kW\ m^{-2}$
masticated only	----------4.37[‡]----------				7.25	0	0	11.63	1.50	0.70	362 $kW\ m^{-2}$
masticated / burned	----------5.15[‡]----------				11.31	3.24	0.02	19.72	2.10	0.90	402 $kW\ m^{-2}$
Thinned											
masticated only	----------6.48[‡]----------				7.83	0	0	14.31	0.80	1.40	384 $kW\ m^{-2}$
masticated only	----------4.98[‡]-----------				6.09	0	0	11.07	0.70	1.40	375 $kW\ m^{-2}$
masticated/herbicide/burned	----------7.04[‡]----------				8.70	0	0.02	15.73	0.80	1.90	366 $kW\ m^{-2}$
Longleaf Pine Flatwoods (FL)[c]											
low load				na		na	na	10.0[‡‡]	0.49	0.75	183 $kW\ m^{-1}$
moderate load				na		na	na	20.0[‡‡]	0.91	0.98	487 $kW\ m^{-1}$
high load				na		na	na	30.0[‡‡]	1.40	1.00	773 $kW\ m^{-1}$
Longleaf Pine Flatwoods (FL)[d]											
10+ yr rough	3.1	2.1	0.4	na	12.6	0	0	18.2			
10+ yr rough	3.2	5.3	2.8	1.9	9.5	0	0	22.7			
5 yr rough	2.3	2.6	0.4	0.6	11.8	0	0	17.7			
27 yr old plantation	2.7	5.4	1.3	5.1	13.6	0	0	28.1			
Longleaf Pine Flatwoods (FL)[e]	1.1	2.1	1.1		13.4	cover 33% height 58cm			1.1	3.4	
Loblolly Pine Plantation (SC)[f] (bark beetle damage)								192.4[‡‡‡]			

[a]Glitzenstein et al. 2006
[b]Ottmar & Prichard 2012 ([‡]1,10,100 h fuels combined; fire behavior modeled in FCCS)
[c]Kreye et al. 2013 ([‡‡]lab scale burns conducted with masticated surface fuels collected immediately following treatment)
[d]Kreye et al. 2014
[e]Kreye et al. 2015
[f]Stottlemyer et al. 2015([‡‡‡]Included all surface fuels)
[g]Reported as either reaction intensity ($kW\ m^{-2}$) or fireline intensity ($kW\ m^{-1}$)

class, they indicate that all standing live and dead fuel, except for the few remaining live pines, and all surface fuels were masticated. Operators masticated surface debris so that litter, duff, and mineral soil were mixed during treatment. Glitzenstein and others (2006) and Stottlemyer and others (2015) both highlight substantial increases in surface fuels that occur when mastication is used to treat sites with significant large dead woody material that can result from other natural disturbances.

Kreye and others (2014b) quantified surface fuels following mastication in longleaf/slash pine (*Pinus elliottii*) flatwoods in northern Florida. In contrast to previous findings (Glitzenstein and others 2006, Stottlemyer and others 2015), surface fuels in masticated sites were dominated by shredded foliar litter (from saw palmetto (*Serenoa repens*) and gallberry (*Ilex glabra*) shrubs) with a smaller proportion of fine woody debris (primarily < 2.54 cm) and few large fuels (fig. 1b). Even though a dense shrub stratum was treated, post-treatment surface fuels were lighter than in many other masticated sites (Kreye and others 2014a), averaging only 17 to 23 Mg ha^{-1} across different stand types. Kreye and others (2013a) examined fire behavior in surface fuels collected from these sites during controlled lab-scale (4 m diameter) burns. They revealed the strong role of fuel load and moisture content on fire intensity and showed the potential for long-duration surface heating, but residence times were shorter than those observed in other laboratory studies that burned woody-dominated fuels (Busse and others 2005, Kreye and others 2011). Soil temperatures failed to reach lethal levels (60 °C) as shallow as 2 cm, in contrast to western studies (Busse and others 2005). Kreye and others (2014b) subsequently examined fuel response for up to two years following treatments in their sites and examined fire behavior at the stand-scale during prescribed burning. Rapid shrub recovery was evident following treatments (Kreye and others 2014b) and shrub cover, rather than surface fuel loading, was strongly correlated with observed flame lengths during dormant-season prescribed burns (fig. 1c; Kreye and others 2015). Mastication did result in lower flame lengths and subsequently lower bole char and crown scorch compared to burning of untreated controls. Overstory mortality was minimal following burns in both treated and untreated sites. Most of the masticated debris was consumed in treated sites (>80 percent), but almost no duff was consumed in any sites.

Ottmar and Prichard (2012) inventoried fuels across several stands on the Francis Marion National Forest in South Carolina, six of which had been masticated, and used their data to construct fuelbeds and predict fire behavior within the Fuel Characteristic Classification System (FCCS) (Ottmar and others 2007). Surface fuels six to eight months following mastication were 11.6 to 14.4 Mg ha^{-1} in unthinned stands with litter comprising >60 percent of mass. One year following prescribed burning in an unthinned masticated stand, surface fuels were 16.5 Mg ha^{-1} (>60 percent litter), but shrubs and grasses were also present, unlike stands that had not been burned. In thinned stands, masticated sites were comprised of 11.1 to 14.3 Mg ha^{-1} (>50 percent litter) six years following treatment. In one thinned and herbicided stand followed by mastication and subsequent burning, surface fuels were 15.7 Mg ha^{-1} (>50 percent litter) eight months after treatment. Although treatments occurred over different stand types, surface fuel characteristics were generally similar, with low fuel loading compared to other studied sites (Kreye et al. 2014a) and composed of over half to two-thirds litter by mass, similar to Kreye and others (2014b). Ottmar and Prichard (2012) subsequently used FCCS to predicted fire behavior across their fuelbeds. Their findings predict reduced fire behavior (reaction intensity, rate of spread, flame length) in treated sites, but suggest that litter and shrub accumulation following treatments may reduce treatment efficacy.

Studies characterizing surface fuels following mastication treatments in the Southeast are limited, yet fuels information is critical for evaluating the efficacy of treatments in altering fire behavior and effects. Kreye and others (2014b) and Ottmar and Prichard (2012) both indicated low to moderate surface fuel loads compared to many masticated sites studied in the west (Kreye and others 2014a) and to other Southeastern sites where substantial large woody debris resulted from previous wind (Glitzenstein and others 2006) or bark beetle (Stottlemyer and others 2015) damage. Mitigating potential wildfire hazard using mastication may be effective where masticated fuels are light or where a mulching effect retains moisture (Kreye and others 2012), thereby limiting forest floor consumption and potential deleterious effects. Moisture regimes of the Southeast may be more conducive to treatment efficacy compared to western climates where prolonged summer drying occurs (Schroeder and Buck 1970) and where fire behavior in masticated sites has resulted in overstory mortality (Bradley and others 2006, Knapp and others 2011). Using prescribed fire to consume masticated debris, however, may be challenging in the Southeast given the complexities of fuel and moisture dynamics in these treatments. Balancing surface fuel consumption with the potential for duff ignition (Kreye and others 2013b) may be critical. These few studies highlight the variability of surface fuels created from mastication treatments.

PLANT COMMUNITIES

Two studies have examined vegetation response in masticated sites in scrub ecosystems in Florida (table 2). Schmalzer and others (2003) showed that saw palmetto cover was reduced in the long-term in masticated stands in both oak (*Quercus chapmanii,*

Table 2—Vegetation response to mastication fuels treatments in Southeastern US Forests. Increase (+), decrease (-), change (Δ), no change (=), or not studied (blank). Diversity included species richness (rich), species evenness (even), or abundance of rare species (rare). Treatment differences are indicated where a treatment increased (++) or decreased (--) more than the other treatments

	Masticated			**Burned**			**Masticated and Burned**		
Forest Type (State)	Herbs	Composition	Diversity	Herbs	Composition	Diversity	Herbs	Composition	Diversity
Oak-Saw Palmetto Scrub (FL)[a]					=			Δ‡	
Coastal Scrub (FL)[a]					=			Δ‡	
Lake Apthorpe Scrub (FL)[b]		=	= rare		Δ	++ rare		Δ	+ rare
Lake Placid Scrub (FL)[b]		Δ	= rare		=	+ rare		Δ	= rare
Longleaf Pine Sandhill (GA)[c]	+	Δ	+ rich,- even					Δ	+ rich,- even
Longleaf Pine Flatwoods (FL)[d]	=	Δ‡	+ rich†	=	=	=	=	Δ‡	+ rich†

[a]Schmalzer 2003
[b]Weekley et al. 2008
[c]Brockway et al. 2009
[d]Kreye 2012
‡change reflected as a decrease in saw palmetto cover
†Marginal differences were reported.

Q. myrtifolia, Q. geminata)-saw palmetto scrub and coastal scrub (*Q. virginiana*) on the Merritt Island/ Cape Canaveral Barrier Island Complex in Florida. Height and cover of scrub were substantially reduced by mastication and were still less than pretreatment levels and prescribed fire only six years following treatment. Recovery of oaks, however, was rapid following either prescribed burning or mastication. Weekley and others (2008) evaluated scrub response to mastication at two sites at the Lake Wales Ridge Wildlife and Environmental Area in Florida. Woody cover was significantly reduced, a primary objective, but not as successfully as in sites that were burned, either with or without prior mastication. Woody plant heights remained low up to five years after all treatments. Mastication changed plant composition, as compared to controls, but they became more similar over time. Composition in sites that were burned, with or without mastication, remained different from that of controls and masticated sites. Abundance of rare herbaceous species, however, was only increased in sites that were burned without prior mastication.

Kreye (2012) examined the effects of mastication, burning, and their combination in mature longleaf pine/ palmetto-gallberry flatwoods on the Osceola National Forest in north Florida. Mastication reduced the dominant shrub component with little effect to trees. Similar to Kreye and others (2014b), recovery of palmetto and woody shrubs (primarily gallberry, *Vaccinium stamineum,* and *V. myrsinites*) was rapid. Saw palmetto density and cover, however, was reduced in masticated sites, including those subsequently burned, but recovered within a year in sites that were only burned. Woody shrub cover rebounded across all treatments within a year, but their heights were still reduced in all masticated sites. Similar to suggestions by Schmalzer and others (2003), the reduction in palmetto likely resulted from damage to meristems by machinery, while woody shrubs resprouted. Marginal evidence of increased species richness may have reflected herbaceous response to reductions of saw palmetto cover or increased bare ground, especially in masticated sites that were burned. Herbaceous cover and plant richness, however, were still quite low. Where treatment objectives include increasing herbaceous plants and understory plant diversity, single treatments alone are unlikely to be successful. Follow-up repeated mastication and/or fires may promote herbaceous plant cover and diversity, but these combinations have not been evaluated in any ecosystem.

Brockway and others (2009) examined vegetation response to mastication treatments in longleaf pine sandhills at Fort Benning in the western Georgia Fall-line Sandhills. They examined plant community response to mastication, but also the effects of burning in masticated sites in different seasons (winter, spring, summer). Mastication treatments targeted all hardwood trees, primarily *Liquidambar styraciflua, Quercus nigra,* and *Q. hemisphaerica*, and small pines (≤20 cm DBH), primarily loblolly pine, both of which had developed in the mid- and overstory following fire exclusion. Mastication reduced tree density by 79 percent, but basal area was only reduced by 26 percent, highlighting the effect to small-diameter trees. Tree seedling cover was also lower 13 months following treatment, but shrubs, vines, forbs, and grasses all increased. All vascular plant cover increased within 2 years post-treatment except for *Vaccinium corymbosum* and *Q. hemisphaerica*. Burning in masticated sites increased plant cover in general, but season-of-burn had differential effects on plant cover: shrubs and vines increased the most following winter and spring burning; grasses following winter burns; and forbs following summer burns. Herbaceous frequency and cover was generally low in sites prior to treatments, indicative of the dominance of woody establishment. Following all treatments, understory species richness increased significantly. Decreases in evenness occurred through time following treatments as a few species began to expand to a greater extent than others. Mechanical treatments altered stand structure by reducing ladder fuels and shifted overstory composition to more desired conditions (larger fire-tolerant pines). As understory woody species respond to treatments (e.g., via resprouting), repeated burning can be utilized to maintain or promote understory herbaceous diversity.

CONCLUSIONS

As both a fire-hazard mitigation treatment and a restoration tool, mastication is used as an initial treatment in long-unburned Southeastern pine forests where fire-sensitive species have invaded and herbaceous understories have declined. As a stand-alone treatment, mastication is an impractical long-term solution for fire hazard reduction and maintenance of understory plant diversity. Following mastication, prescribed fire is easier to implement. The divergence of fuels and potential fire behavior resulting from mastication may complicate long-term fuel and vegetation dynamics. Future research efforts should focus on mastication in other ecosystems where it is being employed, understanding the effects of seasonality of treatments or their repeated use, and evaluating fire behavior and effects under growing season and wildfire conditions.

ACKNOWLEDGMENTS

Support was provided by the Joint Fire Science Program under projects JFSP 10-1-01-16 and JFSP 12-1-03-31.

LITERATURE CITED

Busse, M.D.; Bussea, M.D.; Fiddler, G.O. [and others]. 2005. Lethal soil temperatures during burning of masticated forest residues. International Journal of Wildland Fire. 14: 267-276.

Bradley, T.; Gibson, J.; Bunn, W. 2006. Fire severity and intensity during spring burning in natural and masticated mixed shrub woodlands. In: Butler, B.W., Cook. W., eds. Fuels management – how to measure success: conference proceedings. RMRS–P–41. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station: 419-428.

Brockway, D.G.; Outcalt, K.W.; Estes, B.L.; Rummer, R.B. 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.

Collins, B.M.; Collins, O.M.; Moghaddas, J.J.; Stephens, S.L. 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.

Glitzenstein, J.S.; Streng, D.R.; Achtemeier, G.L. [and others]. 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.

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

Knapp, E.E.; Varner, J.M.; Busse, M.D. [and others]. 2011. Behaviour and effects of prescribed fire in masticated fuel beds. International Journal of Wildland Fire. 20: 932-945.

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

Kreye, J.K. 2012. Efficacy and ecological effects of mechanical fuel treatments in pine flatwoods ecosystems of Florida. Gainesville, FL: University of Florida. 185 p. Ph.D. dissertation.

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

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

Kreye, J.K.; Varner, J.M.; Dugaw, C.J. [and others]. 2013b. Pine cones facilitate ignition of forest floor duff. Canadian Journal of Forest Research. 43: 512-516.

Kreye, J.K.; Brewer, N.W.; Morgan, P. [and others] 2014a. Fire behavior in masticated fuels: A review. Forest Ecology and Management. 314: 193-207.

Kreye, J.K.; Kobziar, L.N.; Camp, J.M. 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.

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

Moghaddas, J.J. 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.

Ostoja, S.M.; Brooks, M.L.; Dudley,T.; Lee, S.R. 2014. Short-term vegetation response following mechanical control of Saltcedar (*Tamarix* spp.) on the Virgin River, Nevada, USA. Invasive Plant Science and Management. 7: 310-319.

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

Ottmar, R.D.; Sandberg, D.V.; Riccard, C.L.; Prichard, S.J. 2007. An overview of the Fuel Characteristic Classification System-quantifying, classifying, and creating fuel beds for resource planning. Canadian Journal of Forest Research. 37: 2383-2393.

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

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

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

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

Schroeder, M. J.; Buck, C.C. 1970. Fire weather: a guide for application of meteorological information to forest fire control operations. Agric. Handb. 360. Washington, DC: U.S. Department of Agriculture. 229 p.

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

Weekley, C.W.; Menges, E.S.; Rickey, M.A. [and others]. 2008. Effects of mechanical treatments and fire on Florida scrub vegetation. Final Report to U.S. Fish and Wildlife Service. Vero Beach, FL: Vero Beach Office. 37 p.

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