CHANGES IN FUEL LOADING AS THE RESULT OF REPEATED PRESCRIBED FIRES WITHIN THE OZARK FORESTS OF MISSOURI

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ABSTRACT.— Buildups of wildland fuels have created problems and concern across the nation. The central hardwoods region has little information published on the fuel loading occurring within stands of oak-hickory and oak-pine forest. Fuel was sampled on a 2,500-acre restoration project located in the Missouri Ozarks. Samples were taken before dormant season fires during the years 1998 through 2003. Samples were stratified by aspect and by number of fires during the 5-year period. Pretreatment fuel loading ranged from 6.6 tons/acre in intermittent drainages to 10.9 tons/acre on ridges (neutral slopes). After 5 years and either 2, 3 or 5 burns, total fuel loads were not changed greatly, but the composition of the fuel bed was altered in all samples. Woody fuels in the 1-, 10-, and 100-hour size classes increased as herbaceous fuels (litter) decreased. Restoring a fire regime to these natural communities may require years to reach the desired state of "naturalness" with corresponding changes in fuel load tonnage and composition.

Natural cover fires have been part of the Ozark landscape for centuries (Guyette 1982). With the success of fire suppression programs by the US Forest Service and Missouri Department of Conservation initiated in the 1930's, the frequency of fires on the landscape has decreased greatly (Westin 1992). The reduction or cessation of anthropogenic wildfires has resulted in altered plant communities with altered structures and species and a concurrent buildup in forest floor fuels (Beilman and Brenner 1951). Little is known about the fuel loading of forested lands within the central hardwoods, either in terms of existing fuel loads or the changes in these fuel loads due to prescribed burning. Here I report changes in fuel loading following repeated prescribed fire from 1998 through 2003 in the Missouri Ozarks.

Study Area

The study site is a 2,500-acre block of oak-hickory and oak-pine Ozark woodlands located in Shannon and Carter Counties, Missouri (fig. 1). The study site is in the central portion of the 5,657-acre Chilton Creek Management Area owned and managed by The Nature Conservancy (TNC) and comprises the upper Chilton Creek Basin. The study site lies within the Current River Hills subsection of the Ozark Highlands (Keys and Carpenter 1995), an area characterized by rugged, steeply dissected valleys and hollows, and narrow ridges. Soils are primarily Alfisols and Ultisols, well drained and developed over dolomite and sandstone karst bedrock.

The goal of management on the Chilton Creek Management Area is to conserve the native biota in a mosaic of high quality native habitats. The sole management treatment is prescribed fire.

The treatment area is divided into five units (fig. 1) to facilitate fire management and to evaluate the role of varying frequencies in restoring the native mosaic on the landscape. One unit, Kelly North, was burned annually. The other units were burned at random, one- to four-year fire return intervals (table 1). All units were burned during the first year of treatment, 1998.

This portion of the Ozarks has a long fire history, primarily of anthropogenic origin. The mean fire interval for this area was about 7.1 years before Euro-American settlement (1820) and 2.2 years between 1820 and the late 1920's (Guyette 1997). The wildfire record indicates no major fires on the study site since the drought years of the mid-1950's when a major fire burned across most of northern Carter County to the west bank of Current River east of the study area. There was no prescribed burning on Chilton Creek prior to initiation of this study.

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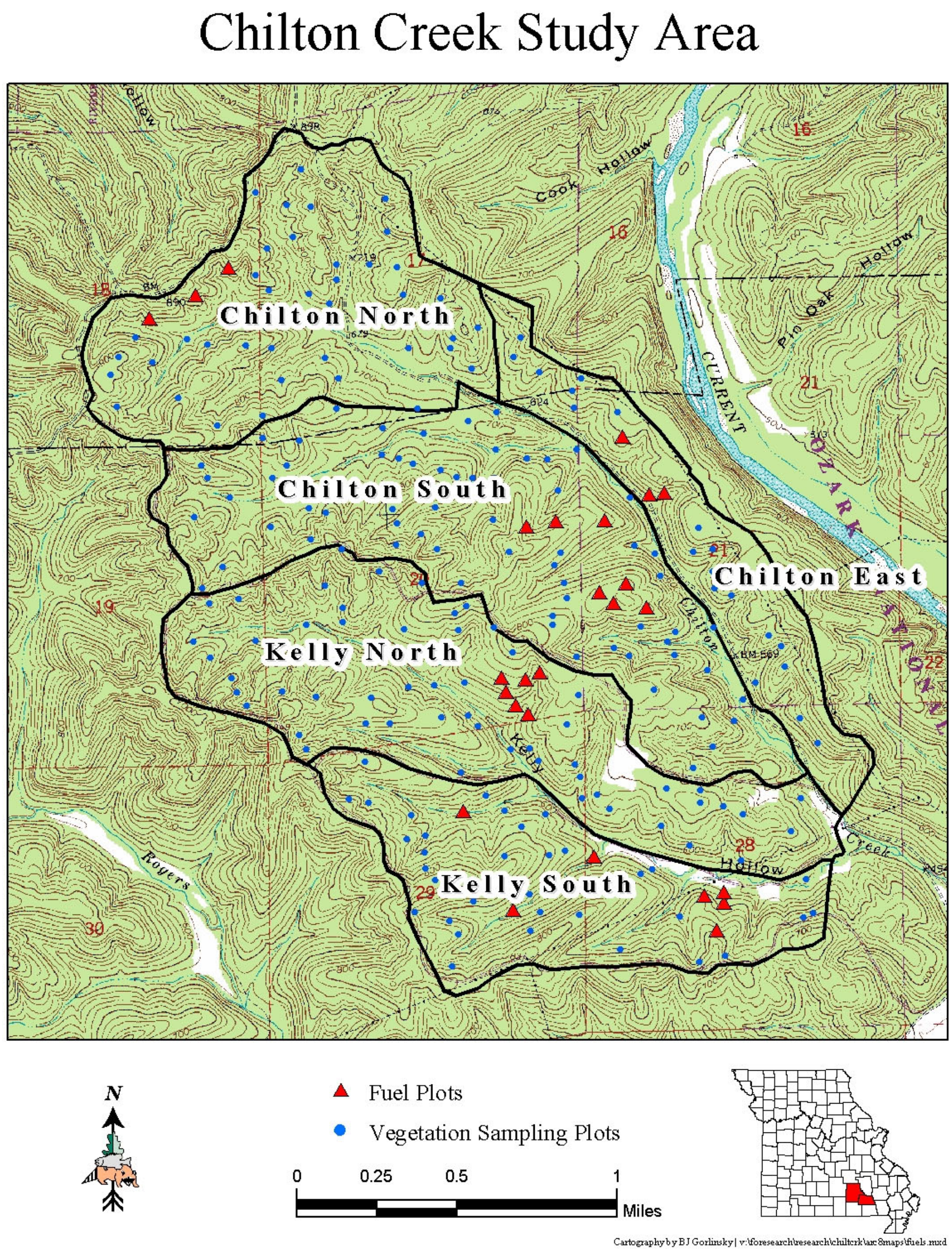

Figure 1.—Chilton Creek Study Area and the five fire management units (labeled). The Kelly North Unit was burned annually; the other units were burned at random, one-to four-year intervals (see Table 1). The twenty-six fuel plots were selected from the 250 permanent vegetation plots based on accessibility.

Table 1.—Units burned on the Chilton Creek Study Area, 1998-2002.

Fire Unit	1998	1999	2000	2001	2002
Kelly South	X		X	X	
Kelly North	X	X	X	X	X
Chilton South	X	X	X		
Chilton North	X				X
Chilton East	X				X

Methods

In 1996, 250 ½- acre plots were established to record changes in herbaceous and woody vegetation across the project in response to the fires. The study area was stratified by Ecological Land Type (ELT) based on slope, aspect, topographic position and geologic substrate (Miller 1981) prior to establishing plots. Twenty-six plots were selected for more intensive monitoring of fuels, fire behavior and differential mortality of small woody stems (Dey and Hartman 2003). Plot selection included all aspects (North, South, Ridge, Intermittent Drainage) and all burning frequencies (2, 3, or 5 burns). Due to the nature of the land treatment, rugged topography and safety issues, sites were selected in groups that could be accessed by ATV for equipment placement and removal and could be entered and exited safely by the observation crew during the prescribed burning activity. The 26 plot locations are shown on Figure 1.

Sampling was conducted on all 26 plots one month prior to the 1998 and 2003 prescribed burns. Two 50-foot down, dead woody (ddw) transects were established in cardinal directions with transect centers at the vegetation sampling plot center. Ddw transects segregated woody fuels into 1-, 10-, 100- and 1,000-hour timelag fuels. Ddw transects were sampled following the system described by Brown (1974).

Mean litter depth was recorded at 5-foot intervals along each transect. Litter and herbaceous vegetation were sampled within 1- by 2- foot quadrats at each end of each transect. Exact location of the quadrats was shifted at each sampling due to the reduction of litter within the quadrat when sampled. Litter/herbaceous samples were dried at 60^{o} C for 24 hours to produce oven dry weights. This sampling scheme yielded a total of 52 transects, 104 herbaceous samples and 520 litter depth measurements per sampling year. Results were averaged and mean values per plot were analyzed.

Results

Results from the sampling indicate there may be changes in fuel loading with both aspect and frequency of burns, but variability within the samples was too great to draw any statistically valid conclusions. Therefore, the mean fuel weights of the sample plots on all units (n=26) were combined and analyzed and the results are shown here with examples of changes by fire frequency and aspect.

Initial mean fuel loads, recorded in 1998 before the first burn, ranged from a high of 10.9 (±4.0) tons per acre on ridges to a low of 6.6 (± 2.4) tons per acre on intermittent drainages (table 2). North slopes had 8.6 (± 1.4) tons and south slopes 9.4 (± 1.6) tons per acre. Herbaceous fuel (primarily leaf litter) composed 37 percent of the total fuel load. Fuels that contributed most to fire intensity (herbaceous, 1-, and 10-hr fuels) comprised 49 percent of the preburn samples by weight.

After 5 years, mean total fuel loads ranged from 9.7 (± 2.3) tons per acre on south slopes to 6.4 (± 1.8) tons per acre on intermittent drainages. Ridge plots contained 7.7 (± 2.3) tons per acre and north aspect plots contained 7.0 (± 1.3) tons per acre. Herbaceous fuel (still primarily leaf litter) was reduced to 25 percent of the total fuel load. Light fuels (herbaceous, 1-, and 10-hr) were reduced slightly to 43 percent of the total.

Initial mean litter depth was 1.8 inches (table 2). This parameter was reduced to 1.6 inches by 2003. The structure of the litter was changed from a matted layer to a less dense, fluffy layer more conducive to combustion. Litter also became more irregular in distribution, as indicated by twice as many sample points having bare ground after the burns.

The only fuel component to be significantly reduced (95 percent Confidence Interval on the mean) from pre- to post-treatment was the herbaceous fuel load (fig. 2). Significant increases were detected in both the 1- and 10-hour fuel load components. Trends within the 100-hr fuels were higher and 1,000-hr fuel loads trended lower. The only aspect to indicate an increase in 1,000-hr fuels was South slopes, which typically burn hotter than other exposures. Increased fire intensity is expected to increase mortality on larger standing stems. The mean 1,000-hr fuel weight on south slopes increased from 4.1 (± 1.6)to 5.5 (±2.0) tons/acre.

Table 2.—Chilton Creek fuels summary - pre and post burn

Aspect	Year	n	1-hr (se[1])	10-hr (se[1])	100-hr (se[1])	1000-hr (se[1])	Herb (se[1])	Total (se[1])	Litter Depth
			Fuel Weights						
			tons per acre						- inches -
South	1998	12	0.2 (0.02)	0.8 (0.11)	1.1 (0.32)	4.1 (1.61)	3.5 (0.19)	9.7 (1.68)	2.0
North	1998	7	0.3 (0.04)	1.4 (0.24)	1.2 (0.48)	2.4 (1.35)	3.3 (0.19)	8.6 (1.37)	1.6
Ridge	1998	4	0.2 (0.03)	0.6 (0.13)	0.5 (0.32)	5.8 (4.11)	3.8 (0.34)	10.9 (4.00)	2.0
Int Dr	1998	3	0.2 (0.04	0.5 (0.07)	0.0 (0.00)	3.0 (2.26)	3.0 (0.31)	6.6 (2.35)	1.3
Preburn	1998	26	0.2 (0.02)	0.9 (0.09)	0.9 (0.21)	3.8 (1.05)	3.4 (0.12)	9.2 (1.07)	1.8
South	2003	12	0.3 (0.03)	1.2 (0.16)	1.1 (0.46)	5.5 (1.98)	1.6 (0.09)	9.7 (2.26)	1.4
North	2003	7	0.3 (0.02)	1.4 (0.26)	1.2 (0.71)	1.7 (0.73)	2.5 (0.18)	7.0 (1.29)	1.9
Ridge	2003	4	0.4 (0.04)	1.8 (0.43)	0.3 (0.26)	3.0 (2.52)	2.4 (0.12)	7.7 (2.33)	1.6
Int Dr	2003	3	0.4 (0.13)	1.0 (0.35)	2.6 (1.73)	0.2 (0.23)	2.1 (0.26)	6.4 (1.80)	1.6
Postburns	2003	26	0.3 (0.02	1.3 (0.13)	1.2 (0.35)	3.5 (1.03)	2.0 0.09)	8.3 (1.17)	1.6

[1]se = standard error
[2]Int Dr = Intermittent Drainage

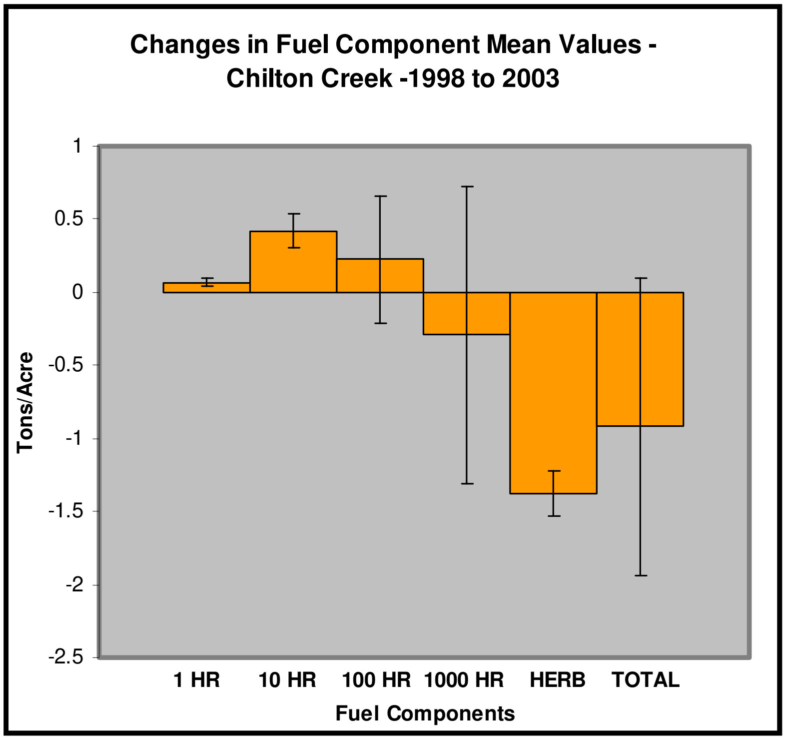

Figure 2.—Changes in Fuel Component Mean Values from1998 to 2003 at the Chilton Creek Study Area. Error bars are 95 percent confidence intervals.

Discussion

Fuel loads prior to treatment were greater than those reported for unburned and unharvested Ozark woodlands by Kolacks and others (2003), 9.2 versus 7.2 tons per acre. Herbaceous litter plus 1-hr woody debris weights within 40-year-old, unburned stands sampled in April by Loomis (1975) yielded 5.3 tons per acre. Paulsell (1957) found in his January sampling of an oak-hickory flatwoods undisturbed for 15 years that "litter" (undefined) was 7.5 tons per acre in 1949. The same tract in 1957, still undisturbed, yielded 6.1 tons of leafy and herbaceous material and 0.6 tons of woody material, considerably greater than the 3.7 tons of herbaceous and 1-hr fuels found on this study and the 3.0 tons reported by Kolacks and others (2003). Inclusion of larger diameter woody fuels in the earlier calculations of "litter" could account for the increased weights.

The only statistically significant reduction in the fuel loadings was the reduced weight of herbaceous fuel on the plots. Herbaceous fuel, leaf litter in this case, is the most volatile fuel component and carries the fire until the woody fuels can be preheated sufficiently to ignite. In a landscape that is subjected to multiple fires after a long fire free interval, the finest fuels would be expected to be reduced with repeated burns.

In an unburned forested system with a developed midstory and woody understory, increased dead woody fuel loadings would be the expected result from mortality of the smaller woody stems the first years following initiation of fire management. The mean 1000-hr component across the study area was reduced numerically, but the 1-, 10- and 100-hr woody fuel components were increased by 25 percent, 39 percent, and 26 percent respectively (fig. 2). The same general trend was recorded by Paulsell (1957) following repeated burns on an annual and a 4-year fire return cycle. These smaller diameter woody fuels should add to the fire intensity of future burns and may enhance the effectiveness of the burns as the landscape returns to a fire induced state of openness.

The Chilton Creek Management Project is a long term effort by The Nature Conservancy and The Missouri Department of Conservation. Tracking of fuels and vegetative changes over time will document the continued progression as the landscape moves toward the desired future condition of a dynamic, fire regulated Ozark landscape.

Acknowledgments

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Literature Cited

Beilman, A.P.; Brenner L.G. 1951. **The recent intrusion of forests in the Ozarks.** Annals of the Missouri Botanical Garden. 38: 261-282.

Brown, J.K. 1974. **Handbook for inventorying downed woody material.** GTR-INT-16. USDA Forest Service, Intermountain Forest and Range Experiment Station. 24 p.

Dey, D.C.;Hartman G.W. 2003. **Effects of different large-scale prescribed burning regimes on advance reproduction in the Missouri Ozarks.** In Spetich, M. ed. Proceedings, Upland oak ecology: history, current conditions and sustainability, a symposium. 7-10 October 2002 Fayetteville AR. Gen. Tech. Rep. SRS - # USDA Forest Service Southern Research Station, Asheville NC. (in press)

Guyette, R.P.; Dey D.C. 1997. **Fire and logging history at Huckleberry Hollow, Shannon County, Missouri.** Forest Research Report 1. Missouri Department of Conservation. Jefferson City. 10 p.

Guyette, R.P. 1982. **Climatic patterns of the Ozarks from tree-rings.** Master's Thesis. University of Missouri – Columbia. 70p.

Hartman, G.W.; Heumann, B. 2003. **Prescribed fire effects in the Ozarks of Missouri: the Chilton creek project 1996-2001.** In Proceedings of the Second International Wildland Fire Ecology and Fire Management Congress, 16-22 Nov, 2003, Orlando FL. CD Rohm, American Meteorological Society, Boston MA.

Keys, J.E.; Carpenter C.A. ed. 1995. **Ecological units of the eastern United States; first approximation.** USDA Forest Service, Atlanta GA 83p.+ map

Kolacks, J.J.; Cutter B.E.; Loewenstein E.F.; Grabner K.W.; Hartman G.W.; Kabrick J.M. 2003. **Fuel Loading in the Central Hardwoods.** In Proceedings of the Second International Wildland Fire Ecology and Fire Management Congress, 16-22 Nov, 2003, Orlando FL CD Rohm, American Meteorological Society, Boston MA.

Loomis, R.M. 1975. **Annual changes in forest floor weights under a southeast Missouri oak stand.** USDA Forest Service, North Central Forest Experiment Station, Research note NC-184. St. Paul, MN. 4 p.

Miller, M.R. 1981. **Ecological land classification subsystem – a basic inventory system for planning management of the Mark Twain National Forest.** Rolla, MO: USDA Forest Service, Mark Twain National Forest. 56p.

Paulsell, L.K. 1957. **Effects of burning on Ozark hardwood timberlands**. Univ. of Missouri research bulletin 640. Columbia, MO. 24p.

Sasseen, A. 2003. **Using ecological land type phase (elt-p) to evaluate the effect of management on Missouri Ozark vegetation.** Columbia, MO; University of Missouri. 185 p. Masters thesis.

Westin, S. 1992. **Wildfire in Missouri.** Unpublished report. Missouri Department of Conservation – Forestry Division. Jefferson City. 161 p.