Experimental study of local fire conditions and effects on surface or near-surface archeological resources at National Park Service units – Midwest Region.

JFSP Project Number: 06-2-1-05

JFSP Final Report

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Co-Principle Investigators:
Rod Skalsky, National Park Service, Theodore Roosevelt National Park
Cody L. Wienk, National Park Service, Midwest Regional Office

Archeological Technicians:
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MIDWEST ARCHEOLOGICAL CENTER
NATIONAL PARK SERVICE

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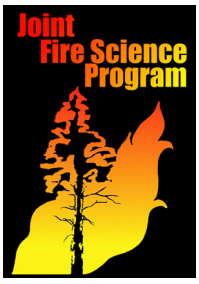


For information on this and other research programs please visit the following websites:

Midwest Archeological Center: http://www.nps.gov/history/mwac/index.htm

Joint Fire Science Program: http://www.firescience.gov/

This report has been reviewed against the criteria contained in 43CFR Part 7, SubpartA, Section 7.18 (a) (1) and, upon recommendation of the Midwest Regional Office and the Midwest Archeological Center, has been classified as

Available

Making the report available meets the criteria of 43CFR Part 7, Subpart A, Section 7.18 (a) (1).

Abstract

Today, park managers must routinely balance the restoration needs of natural resources with the preservation of cultural resources. This project was designed to provide park managers with scientific data on the impacts from wildland fire to archeological resources at National Park Service units in the Midwest Region. Experimental research was conducted at six parks to record data on fire conditions (i.e., fuels, fire temperature, and burn duration) and the impacts on multiple classes of archeological materials routinely observed at sites within the region. The experimental study of fire conditions in different regional environments addresses questions regarding the threats or non-threats to multiple archeological resource types. By gaining a more thorough understanding of the fire/archeology interface at select parks in different ecosystems, park managers will be able to more effectively coordinate the needs of natural resource management with archeological resource preservation.

Background

There is a growing base of literature regarding the fire/archeology interface. Previous studies have demonstrated that wildland/prescribed fire can have significant impacts on the archeological record and potentially lead to the loss or destruction of information about past cultural groups. Archeological studies on fire effects have ranged from pre- and post-burn archeological inventories used to assess the impacts or potential impacts on archeological resources (Buenger 2003; Cande and Pebworth 2004; Cannon and Phillips 1993; Connor, Cannon, and Carlevato 1989; Sturdevant 2005; Sturdevant et al. 2005; Traylor et al. 1990) to materials studies that have provided baseline information on the specific impacts fire has on archeological materials (Bennett 1999; Buenger 2003; Cannon, and Carlevato 1989; Cavaioli 2002; Deal 2002; Haecker 2002; Lentz et al. 1996; Scott 1979; Sayler, Seabloom, and Ahler 1989; Switzer 1974; Winthrop 2004). Other National Park Service regional offices have also attempted to develop region-wide cultural resource protocols for the occurrence of prescribed and wildland fires (SEAC 2005). All of these previous studies provide useful and relevant information concerning fire conditions and effects observed in Midwest Region parks. Previous studies have shown that impacts to the archeological record (i.e., surface artifacts) from fire can range from negligible to severe. However, most previous studies have focused on fire conditions and archeological resources in areas of the United States where major wildland fires occur on an annual basis, primarily the Intermountain and Southwest regions. Prior to the current study, Midwest Region parks lack specific information concerning the local fire conditions and impacts to resources.

This experimental project is directly related to a pilot study conducted by the Midwest Archeological Center (MWAC) in 2005 at Knife River Indian Villages National Historic Site (KNRI), North Dakota. The KNRI study was developed to address the prescribed burning of grasslands within medium density archeological sites. The 2005 experiments used current local fire conditions at the park to evaluate multiple firing techniques (head, backing, and flanking) during two different burn seasons (Spring and Fall) in an effort to determine the types of burns and techniques with the least potential to impact surface archeological resources. The KNRI study benefited the park by addressing knowledge gaps regarding fire conditions (i.e. provided data on fire

temperature/duration for multiple fire types) and the impacts to local archeological resources. The park now has current baseline information to move forward with a native prairie restoration program that will address issues of archeological resource preservation prior to prescribed burning by defining the fire techniques and burn season with minimal potential to impact surface archeological resources.

Project Overview

The National Park Service's Midwest Region covers a vast area of thirteen states and includes several distinct regional ecosystems from the Great Lakes to the Central Great Plains. Midwest Region parks also include a diverse set of archeological resources from 12,000 year old prehistoric sites to homes of former U.S. Presidents, historic Euro-American farmsteads, prehistoric mound sites, Civil War battlefields, and 18th to 19th century Native American villages. This region-wide diversity of ecosystems and archeological resources makes a "one size fits all" approach to the fire/archeology interface problematic. At the present time, park managers are forced to make decisions about the use of fire and the preservation of archeological resources without the benefit of scientific data that would enhance the decision making process and allow a more effective use of fire without impairing the preservation of the archeological record.

Figure 1. Map of the National Park Service's Midwest Region.

Therefore, a region-wide, multi-park, multi-environment experimental project was developed to provide scientific data specifically relevant to the local fire management and archeological resource needs of a wide range of parks.

Figure 2. Research team collecting data during burn experiments at WICA.

The objective of this project was to conduct experimental burns at six National Park Service units in the Midwest Region . These experiments addressed questions regarding local fire conditions and the potential impacts to archeological resources. Each park contains a unique set of conditions and archeological resources from which data can be collected and modeled that will be widely applicable to other land managers with similar conditions throughout the region. Two parks were selected from three environmental zones in the Midwest Region: (1) Great Plains; (2) Great Lakes/Eastern Woodlands; and (3) Ozark Highlands. Experiments were designed to accurately model the typical fire conditions and archeological resources at each park. The outcome from these experiments include (1) accurate data on the temperature and duration of fires, (2) a record of the impacts on archeological resources, (3) an assessment of the impacts to archeological resources, and (4) recommendations on alternatives for mitigating the impairment of the archeological record.

Six parks were selected to participate in the Midwest Region experimental burn study. These parks were chosen because they reflect the regional diversity of environmental zones, archeological resources, and burn programs throughout the Midwest Region. Experimental burn locations and times were chosen at each park with the following criteria: (1) experimental plots were chosen to meet the local needs of each park, (2) experimental plots were placed at locations that reflect typical burn conditions (i.e., fuel types, fuel loads, moisture content, seasonality), (3) experiment plots utilized materials representative of archeological resources that are typical at each park, (4) burns were undertaken in conjunction with prescribed burns already planned and scheduled by the park, (5) test plots were accessible and did not require extraordinary efforts to undertake the experimental burns and recording of archeological data.

Figure 3. Prescribed fire on the landscape at TAPR.

The fire/archeology interface experiments addressed multiple questions relating to the fire conditions and archeological resources at each selected park. Some

Figure 4. Research team collecting data at VOYA.

Figure 5. Prescribed burn experiment at BUFF.

of the research questions addressed during the experimental study include: (1) what are the fire conditions typical for environmental zones within each park, (2) what conditions are created when different firing techniques are used (head, backing, flanking), (3) what impacts (if any) can be observed on artifacts subjected to different firing techniques (head, flanking, backing fires), (4) what environmental/fire conditions produce changes in surface archeological materials, (5) what artifact classes are most and/or least impacted during the experimental burns, and (6) can minor impacts such as combustive residue and sooting be removed during cleaning in the laboratory?

Overview of National Park Service Study Sites

Buffalo National River (BUFF), Arkansas

Located in the Ozark Highlands of north-central Arkansas, the Buffalo National River covers 135 miles of river encompassing 94,000 acres with numerous ecological zones including wooded uplands, riparian lowlands, springs, sinkholes, and small creeks and drainages. BUFF has an active prescribed burn program that is employed to promote and restore the Ozark woodland ecosystem. The park routinely conducts pre-burn archeological inventories prior to each burn in an attempt to locate, identify, record, and make recommendations for significant or potentially significant archeological resources that may be impacted or destroyed by fire (Cande and Pebworth 2004; Sturdevant 2005; Sturdevant and Baier 2008; Sturdevant et al. 2005; Sturdevant and McKee 2007). Currently, there are 650 known archeological sites recorded at BUFF. Examples of archeological resources include prehistoric bluffshelters and open village sites, historic Euroamerican homesteads, and late 19th century mining towns. Impacts of fire on the historic sites at BUFF are of particular interest since many have materials that can be damaged or destroyed by fire including wood, bone, shell, and leather. Prior to this study, there was scant scientific information available to evaluate fire conditions and the potential impacts at a local level in different ecozones (ex. uplands vs. river terraces) and on multiple archeological resource types (ex. prehistoric lithic scatters, historic farmsteads, etc.). Consequently, park managers have been forced to consider many types of archeological resources susceptible to impacts from fire without any scientific data to support their decision making and conclusions.

Effigy Mounds National Monument (EFMO), Iowa

Located in the Paleozoic Plateau region of northeastern Iowa, Effigy Mounds National Monument lies along the western edge of the Mississippi River. The park contains 2,526 acres of high Mississippi River Bluffs, valleys including the Yellow River, upland prairie, and wooded hillslopes. EFMO has a prescribed burn program and a fire management plan, as well as a program designed to address the Wildland Urban Interface by the removal of some trees and brush in interface areas. There are 52 known and recorded archeological sites in the park. These sites include at least 198 prehistoric Native American mounds. The animal effigy, conical, and linear mounds are the main features of the park; however, various prehistoric and historic habitation sites also exist and surround some of the mound groups. Other site types within the park include rock shelters, petroglyphs, and historic Euroamerican settlements.

Pea Ridge National Military Park (PERI), Arkansas

Pea Ridge National Military Park is located in the Ozark Highlands of northwest Arkansas. The park was established to preserve the 4,300-acre site of the 1862 Civil War battle between Confederate and Union forces. The landscape is diverse with rolling grassland prairies set in a mixed oak-hickory forest. The landforms range from rolling prairies to forested areas with shallow and steep-walled ravines rising to steep rocky hills. In addition to the archeological record of the 1862 Civil War battle, there are numerous prehistoric Native American sites and historic Euroamerican farmsteads that have also been documented at PERI. PERI conducts routine prescribed fires for natural resource management purposes. Previous studies (Buenger 2003; Sayler, Seabloom, and Ahler 1989) have indicated that, under certain fire conditions, battlefield materials such as lead can be extensively damaged or destroyed. Therefore, it is necessary for PERI land managers to have information available that addresses the specific local fire conditions that are encountered during prescribed or wildland fires.

Tallgrass Prairie National Preserve (TAPR), Kansas

Tallgrass Prairie National Preserve covers roughly 11,000 acres of rolling grassland in the Flint Hills of east-central Kansas. A small amount of the Preserve is actually owned by the National Park Service, with the majority of land now owned by The Nature Conservancy (TNC). The park is managed jointly by the NPS and TNC. Until recently, much of the land owned by the prior owner, the National Park Trust, had been leased for cattle grazing, with the leased lands intentionally burned each spring to stimulate new grass growth, a traditional activity that occurs throughout much of the Kansas Flint Hills. It is likely that some of the TAPR pastures have been intentionally burned upwards of 70 times over the past 100 years. Archeological resources within TAPR include abundant prehistoric quarry sites where chert was obtained for stone tool manufacture, together with a number of historic farmsteads dating to the late nineteenth century.

Voyagers National Park (VOYA), Minnesota

Voyageurs National Park is positioned in the Border Lakes Region along the U.S./Canadian border where the northern hardwood forest merges into the northern boreal forest. The park is within the vast (18,000 square mile) Rainy River drainage system and consists of over 218,000 acres of forests and lakes. Characteristics of both forest types are visible in the park although boreal species predominate in about 70% of park lands. The park area has been subject to the effects of fire since the end of the Pleistocene and fire continues to shape the character of the park's vegetation. The effects of natural ignitions and prescribed burns on park vegetation have been studied for many years, but the impacts of these fires on archeological resources remain largely unknown. Over 400 archeological sites are formally recorded within the park and many more remain to be discovered. They range in age from Late Paleoindian (circa 10,500 BP) through the early 20th century. Prehistoric sites contain rich artifact deposits, usually including numerous prehistoric pottery sherds and faunal elements in addition to large numbers of chipped stone artifacts. The park's numerous historic sites include more than four dozen Ojibwe occupation and special use sites and a variety of Euroamerican sites ranging from logging and fishing camps to gold mines and homesteads. Due to the typically shallow soil conditions encountered in the bedrock-dominated landscapes of VOYA, most archeological deposits occur within 50 centimeters of the ground surface, and in many cases the artifacts are positioned immediately under the forest duff zone. At the historic sites, artifacts are typically exposed on the ground surface and/or incorporated into the forest humus zone.

Wind Cave National Park (WICA), South Dakota

Wind Cave National Park was created on January 3, 1903, as the seventh national park and the first to protect a cave. While the original legislation applied only to the cave and surface developments needed for its management and care, the purpose of Wind Cave National Park has since evolved to protect both subsurface and surface ecosystems and has grown to encompass 28,295 acres. The park is located in the Black Hills of western South Dakota. WICA incorporates four major topographic features (the Hogback Ridge, the Red Valley, the Limestone Plateau, and the Central area), each with its characteristic vegetation, fauna, and natural resources. The Black Hills are also a sacred place for most Northern Plains Native American tribes. Wind Cave itself is of major cultural significance for the Lakota whose traditions and oral history identify the park area and the cave in particular as their place of origin. The Lakota, therefore, consider WICA's prehistoric sites to be significant as locations where their ancestors resided from the beginning of time.

Study Methodology

The experimental fire effects study utilized a multi-step comparative analysis approach to identify and assess impacts to archeological resources. Information on fuel types, fuel loads, fire temperatures, and burn durations provided a measure of fire conditions that could be linked to individual artifacts and impacts observed on each item. By employing these experimental techniques, the qualitative artifact analysis

Stone projectile point.

Replica kaolin pipe.

Replica brass "US" civil war era belt buckle.

Stone projectile point.

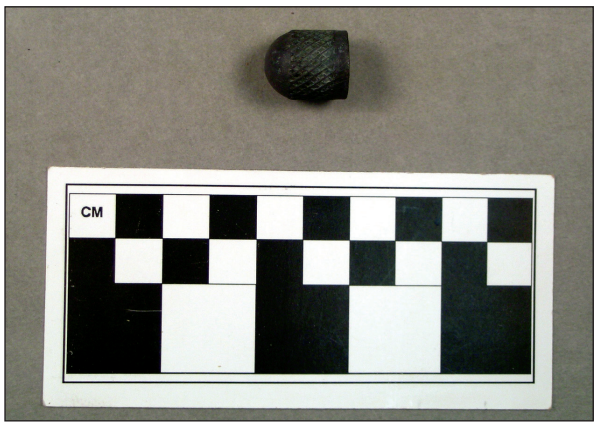
Figure 6. Example archeological materials in their pre-burn condition.

was linked to burn conditions that would assist in assessing the impacts from a prescribed burn.

Sampling was completed by selecting a minimum of two study sites at each park with each study site incorporating three 20 x 20 meter experimental plots that contain materials representative of the archeological sites found throughout the park. The experimental burn plots were then subjected to a different firing technique including a head fire, a flanking fire, and a backing fire. Firing techniques were assigned to each plot based on the logistics and firing conditions during the prescribed burn at each park.

Experimental artifact assemblages were compiled to approximate prehistoric and historic archeological resources at each study park. Each study assemblage contained a sample of both prehistoric and historic objects that may be found at each park. Prehistoric artifacts included stone tools, prehistoric pottery, bone, and shell. The sample of historic objects was typically much more diverse and included whiteware ceramics, stoneware, kaolin pipe fragments, bottle glass, lead munitions, buttons, cans, leather, metal tools, domestic wares, and other objects that may be unique to a particular

Bison bone.



Lead Minnie ball.

Figure 7. Archeological materials showing pre-burn condition.

park or site type. Artifact assemblages at each park typically contained a mix of archeological objects obtained via de-accessioned collections or purchased replica items that are a close approximation of actual historic objects such as Civil War belt buckles, kaolin pipe fragments, and lead munitions.

Pre-Burn Analysis

The initial task for researchers was to procure an assemblage of replica and un-provenienced or de-accessioned artifacts that could be subjected to prescribed fire. It was acknowledged in the initial planning stages of this study that all NPS units involved have separate cultural resource needs. Some units have higher proportions of prehistoric sites; others have higher proportions of historical sites. This research project was designed to customize artifact assemblages to reflect the cultural resources of each park. This meant that observations needed to span a wide range of materials (i.e. prehistoric to historic) and characteristics (e.g. cracking on prehistoric bones to crazing on historic ceramics). These faux artifacts were used to assess the impacts of prescribed fire on material items that have not been affected by weathering or the impacts of previous fires. Representative materials included replica prehistoric stone tools and waste debris, un-provenienced prehistoric pottery, bone, shell, and historic materials such as ceramics, bottle glass, kaolin pipes, metal cans, lead projectiles, and constructions materials. A key component of analysis was making the pre-burn observations on the artifacts that would be subjected to fire experiments in the field.

Identifying the qualitative and quantitative characteristics of each artifact was a critical task that was completed before any artifacts were placed into test plots. The pre-burn analysis was necessary in order to describe all the changes observed on artifacts after they had been burned by prescribed fire. A representative assemblage of 192 artifacts was accumulated for each park. This allowed for an arrangement of four artifacts per thermocouple or 32 artifacts per plot. A recent study on fire effects (Buenger 2003) had outlined similar methodologies for assessing the impacts to archeological resources and provided a basis for analytical methods used during this project. All artifacts were analyzed for previous wear, damage, and condition prior to

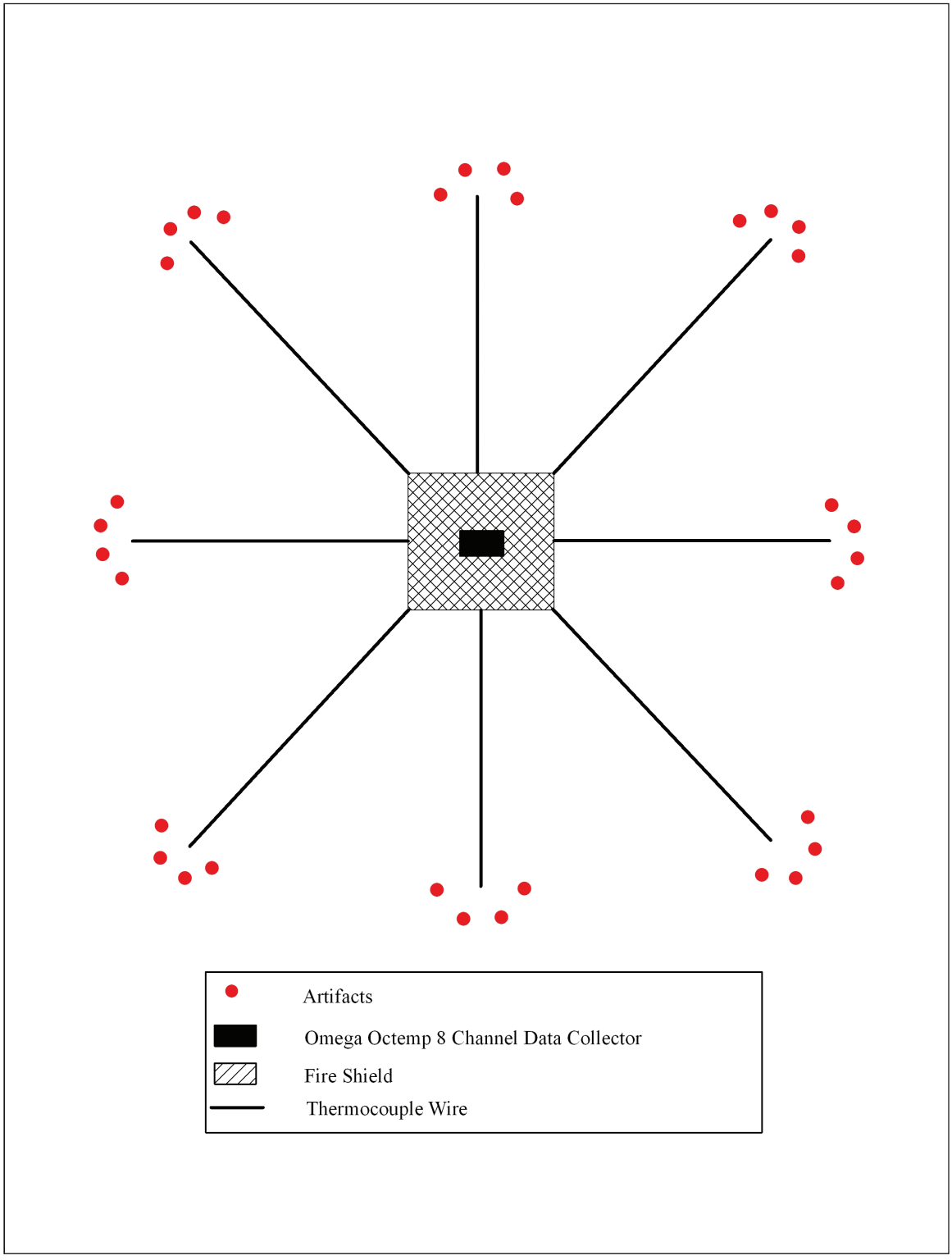


Figure 8. Diagram of experimental plot arrangement.

Figure 9. Prescribed burn experiment in grass fuels at EFMO.

Figure 10. Experimental artifacts in-situ following the prescribed burn at EFMO.

Melted lead Minnie ball.

Stone projectile point with combustive residue.

Figure 11. Archeological materials showing post-burn condition.

being subjected to prescribed fire experiments. Artifacts were then measured, weighed, and photographed prior to burning.

Prescribed Fire Experiments

Beginning in 2006, our project team completed the prescribed fire experiments at all the parks participating in this study. Experimental plots were established in sets of three at two locations representative of the typical archeological and environmental conditions for the individual park. Weather, soils and fuel load data for individual plots were collected prior to each experimental burn. Data on fire temperature and burn duration through each plot were recorded using Omega OM_CP_OMTTEMP eight channel thermocouple data logger with Type K thermocouples placed in the center of each plot. The eight-channel data loggers collect simultaneous readings for each of the eight thermocouples at five second intervals. The collection points for each data logger were located at the ends of eight 12-foot thermocouple wires arranged in a radial pattern from the center of the plot. Ignition of individual experimental plots (head, flanking and backing) allowed the research team to estimate fire monitoring data such as flame length, flame depth and rate of spread.

Post-Burn Analysis

Post-burn analysis was conducted using similar methods and analytical categories that were used during the pre-burn analysis. Impacts such as cracking, charring, sooting, combustive residue, fracture, scorching, and melting were recorded for artifacts where changes occurred during the burn experiments. Artifact weight, dimensions, and color change were also measured and a sample of items was photographed to document the impacts that were sustained. The post-burn analysis created a comparative data set that would demonstrate the amount and types of changes that were introduced to artifacts during a prescribed burn. Linking these variables with the data on burn temperature and duration will allow researchers to assess the impacts on the replica artifact assemblages following a burn.

Artifact Weathering and Conservation Methods

Artifact Weathering

A select group of twenty-seven artifacts from the PERI experimental burn were chosen to gather baseline information on post-burn artifact weathering. A sample plot was established in Lincoln, Nebraska to expose the burned artifacts to seasonal weathering and monitor the changes on a longer-term scale to assess the permanence of impacts resulting from fire. The weathering plot was designed to contain a representative sample of material types and post-burn conditions that would demonstrate the effects of natural weathering on burned artifacts. The plots were allowed to weather for seventeen months (2007-2009) and then re-analyzed and photographed using post-burn methods.

Laboratory Conservation

Eighteen artifacts were chosen for conservation experiments based on three criteria: material, fuel type where the artifact was burned, and degree of fire damage. The materials chosen were: shell, ceramics, pottery, bone, ferrous metal, flaked stone, brass, tin, lead, pewter, and glass. These were considered representative of the artifacts used at all six parks. Three bone and three flaked stone artifacts were chosen from different parks, each chosen in regard to fuel type. One of each was chosen for grassland fuels, grassland/woodland fuels, and woodland fuels. Finally, artifacts that showed more significant imacts such as medium combustive residue, scorching, and charring, were chosen in order to see if the very worst fire effects could be removed.

Using dry and wet procedures mapped out in studies detailing cleaning procedures used at museums that had been burned during structural fires (Roberts et. al. 1988, Spafford-Ricci and Graham 2000). Artifacts were cleaned in a stepped process that began with dry techniques followed by wet cleaning techniques. Dry techniques included brushing with a soft-bristle brush, use of groom/stick, and soot sponges. Wet techniques included various weak detergents (Orvus Paste, Ivory soap) mixed with warm water and applied with cotton swabs and, if necessary, more potent chemicals (such as ethanol, alcohol, ammonium hydroxide, mineral spirits) distilled with water and mixed with Ivory soap as necessary. These chemicals were also applied with cotton swabs. All techniques employed were geared toward minimizing lasting damage to an artifact. Cleaning was stopped when an effective method was found. Photographs were taken both before and after cleaning to show results. Time involved usually included about 45 minutes per artifact, but more difficult artifacts requiring use of potent chemicals could take up to two hours to clean the intended area of the artifact.

Key Findings

Evaluating the Experimental Program

This multi-park research program has provided valuable data for assessing the impacts and potential for damage to the archeological record from applications of prescribed fire throughout the Midwest Region. By producing data specific to the many environmental zones in the Midwest, park managers will be better equipped to

evaluate the fire/archeology interface than if they relied solely on data generated from other parts of the country. However, following the completion of this project a host of questions will remain and will need to be addressed through future research endeavors including impacts to geophysical investigations and the long-term cumulative effects from prescribed burning. The Midwest Region fire effects research is only the first step to establish baseline data for the region. Future studies will be able to use this baseline to explore numerous other questions regarding the fire/archeology interface in the Midwest.

Summary of Impacts

Analysis of data from the six parks has shown both expected and surprising results. The majority of artifacts subjected to fire during prescribed burns did not exhibit any significant impacts. A significant impact to an artifact was defined to include irreversible change to an object and a loss of its inherent information potential, destabilization of an object that would lead to degradation and loss of information potential, or the complete destruction of an object. The adherence of combustive residue to artifacts was the most frequent impact observed on artifacts. Between 48% and 75% of artifacts exhibited low to high amounts of combustive residue. Significant impacts to artifacts such as scorching, fracturing, cracking, spalling, or melting were typically observed in only 5% to 10% of assemblages. However, experimental plots with higher fuel loads or longer burn residence times did increase the occurrence of these impacts into the 20 – 25 % range. Parks with experimental plots that yielded more significant impacts include BUFF, VOYA, and WICA. The incidence of major or significant impacts to the artifact assemblages was likely a combination of fuel type/fuel load and artifact material. Artifacts such as bone, shell, leather, wood, and lead exhibited more frequent significant impacts when compared to materials such as ceramic, stone, metal, and glass. The majority of impacts observed are reversible, did not destabilize an object, did not lead to a loss of information potential, and did not completely consume the object.

Impacts to archeological resources, whether heavy or light, typically are a result of burn duration and intensity, amount of fuel consumption, and artifact material type. Burn duration and intensity are directly related to available fuels and firing technique used (i.e. backing, flanking, or head fire), and are a key indicator of potential impacts. When available fuels have the potential to increase burn duration and intensity, increased incidence of significant impacts to archeological resources may result. For example, grass fuels typically are of short burn duration and relatively low intensity resulting in minor impacts such as the adherence of combustive residue. In plots where fuels increased burn duration and intensity, the potential for impacts increases, especially on artifact materials that are susceptible to modification at lower temperatures and shorter burn duration such as lead, leather, wood, and shell. The amount and consumption of fuels on the ground surface (e.g. duff and leaf litter) also influences the impacts observed on artifacts. In some cases leaf litter and duff served to insulate the artifacts lying underneath because the fuels were not entirely consumed by fire. In other cases the leaf litter/duff layer did not contain the density of fuels necessary to sustain fire through an experimental plot.

Table 1. BUFF Post-burn Incident Summary.

	Material Class												
	Bone	Ceramic	Glass	Nonferrous					Pottery	Shell	Stone Flaked	Incident	
				Brass	Copper	Lead	Tin	Pewter				Total	%
Incident													
No Change	-	-	-	-	-	-	-	-	1	-	1	2	1
Charring													
Minor	4	-	-	-	-	-	-	-	-	-	-	4	1
Medium	1	-	-	-	-	-	-	-	-	-	-	1	0
Heavy	1	-	-	-	-	-	-	-	-	-	-	1	0
Color Change	5	-	-	2	-	-	1	1	1	-	3	13	5
Combustive Residue													
Minor	2	3	1	-	-	1	-	-	15	8	4	34	12
Medium	10	10	7	-	1	4	-	1	7	2	4	46	17
Heavy	17	25	12	9	-	-	4	2	4	8	29	110	39
Crazing													
Minor	-	1	-	-	-	-	-	-	-	-	-	1	0
Medium	-	-	-	-	-	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-	-	-	-	-	-
Fracturing	10	-	3	-	-	-	-	1	-	7	1	22	8
Cracking	4	-	-	-	-	-	-	-	-	-	-	4	1
Melting	-	-	-	-	-	1	-	-	-	-	-	1	0
Scorching													
Minor	15	-	-	-	-	-	-	1	-	-	-	16	6
Medium	6	-	-	-	-	-	1	-	-	-	-	7	3
Heavy	3	1	-	-	-	-	-	-	-	-	-	4	1
Spalling	1	-	-	-	-	-	-	-	-	16	-	17	6
Incident Total / Material Class	**79**	**40**	**23**	**11**	**1**	**6**	**6**	**6**	**28**	**41**	**42**	**283**	**100**

Fuels Variability

This study demonstrated that there is significant inter- and intra-park variability in fuels and corresponding burn durations and temperatures. Our study has produced a measure of burn conditions at each park but the variability in fuels at several of the parks could produce varying impacts to archeological resources. Because the type and amount of fuels is one of the primary components related to fire impacts on archeological resources, understanding the fuel conditions at each park is a key to predicting potential impacts to archeological resources. Additional data collection is needed in order to account for some of the fuels variability observed in parks with mixed fuels environments.

Cleaning Techniques

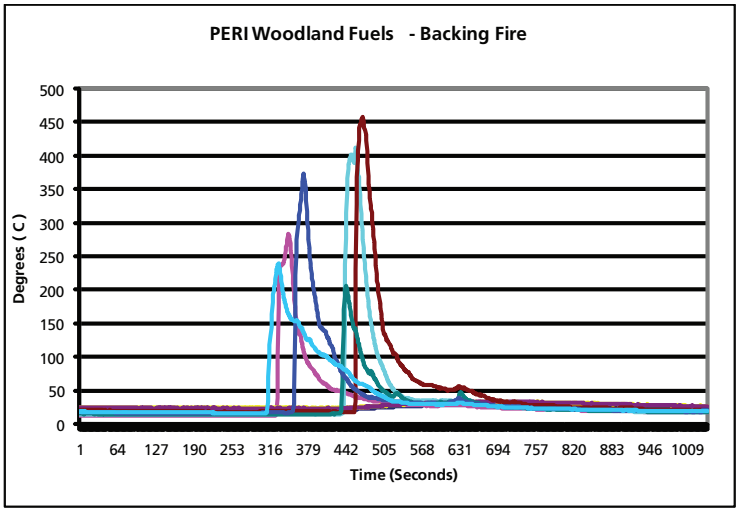
Excluding bone and some ceramics, most of the artifact material types responded well to wet cleaning involving simple, easily obtained detergents and water. A vast majority of the combustive residue in the test areas on the artifacts was removed. Certain metals, bone, and ceramics proved more difficult to clean. However, use of reasonably safe and easily obtained chemicals (mineral spirits, ammonium hydroxide diluted with water, and ethanol) proved effective at removing combustive residues. Despite this, unglazed portions of ceramics and charred/scorched portions of bone and other artifacts proved virtually impossible to clean. The unglazed portions of ceramics typically absorbed the combustive residues into the interior vessel body and also showed signs of scorching that could not be removed. The bone had been so severely scorched and charred in regions that it was difficult to clean these chemically altered areas with any success. Corroded iron seemed to resist cleaning because of its very rough and pitted surface. In conclusion, conservation cleaning after an artifact is burned is possible, and most effects of a fire, unless extreme (scorching, charring, fracturing, etc.), can be removed with a minimal investment of time and resources.

Permanence of Impacts

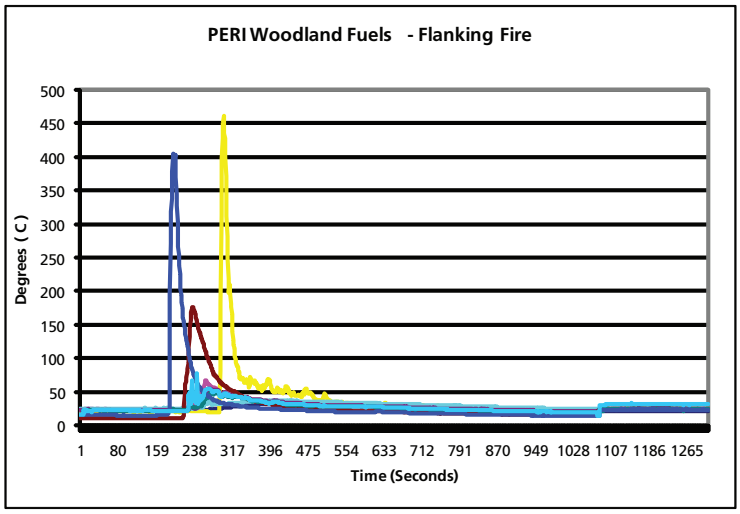
Artifact weathering and curation experiments demonstrated that a majority of impacts observed during the post-burn analysis are non-permanent and removable. For example, both weathering and cleaning of artifacts were able to remove combustive residue from the surface of an artifact. Impacts of a more permanent nature such as cracking, fracturing, melting, or spalling could not be reversed but were observed infrequently on burned artifacts. This indicates that many of the impacts observed during this study are of a non-permanent nature and can be removed via weathering or cleaning in a laboratory.

Firing Technique

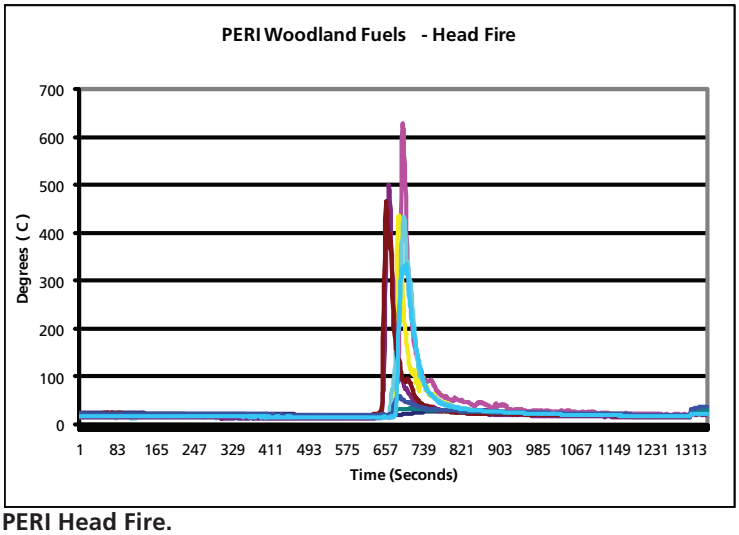
The results of using three separate firing techniques to manipulate burn conditions varied between parks and fuel types. In areas with a uniform fuel type (ex. grass fuels), firing technique can be used to alter burn duration and intensity. In areas with more variable fuels the use of a different firing technique was either masked by



PERI Backing Fire.



PERI Flanking Fire.



PERI Head Fire.

Figure 12. Data charts from woodland plots at PERI.

Table 2. JFSP Park Fuel Summary.

Park	Plot	Fuel Type	Avg. Fuel Load (tons/acre)	Burn Duration			Max. Temp (°C)			Avg. Temp (°C)		
				B	F	H	B	F	H	B	F	H
VOYA												
	C, A, B	Woodland	6.7	1:24:35	1:10:15	1:27:30	513	449	57	47	41	29
	D, E, F	Woodland	3.5	2:46:05	1:10:55	3:08:00	477	47	622	92	26	109
BUFF												
	A, B, C	Woodland	10.0	0:43:40	0:33:20	0:25:25	545	577	671	115	106	102
	D, E, F	Woodland	25.4	1:23:45	1:14:35	0:22:45	833	694	679	112	109	116
WICA												
	A, B, C	Grassland	9.8	33:55	19:30	35:35	439	579	745	55	108	129
	E, F, D	Grass/Wood	19.5	1:23:05	2:41:05	1:06:10	747	768	100	142	97	25
TAPR												
	C, B, A	Grassland	2.4	9:25	7:15	6:15	492	208	403	96	47	83
	F, E, D	Grassland	1.7	n/a	4:20	4:50	n/a	451	375	n/a	106	66
PERI												
	B, A, C	Grassland	4.4	28:35	31:45	26:50	462	459	630	57	91	95
	D, E, F	Woodland	16.2	15:55	8:55	7:05	254	383	377	56	94	77
EFMO												
	A, B, C	Grassland	8.4	31:25	22:30	17:30	649	649	536	85	91	81
	F, E, D	Woodland	11.0	n/a	n/a	14:50	n/a	n/a	368	n/a	n/a	53

n/a = plots did not burn
Burn method = B backing fire, F flanking fire, H head fire
Plot listing order corresponds left/right with burn method order.

fuels that burn for an extended period once the flame front had passed or did not result in any significant difference in fire conditions. Separate firing techniques could not be used on several plots during the study because of logistical reasons during some of the prescribed burns. Additional research is needed to better understand the relationship between firing technique and fire conditions in a variable fuel environment.

Management Implications

Identifying Archeological Resources Threatened by Wildland Fire

Parks and land managers will be able to use the information from this research project to evaluate the potential impacts from a prescribed fire based on the fuels and archeological resources present within a burn area. The intent of the experimental research program was to provide land managers with information to identify archeological resources that are susceptible to significant impacts from wildland fire. This will allow managers to focus efforts on resources threatened by fire and devise treatments to reduce or mitigate anticipated negative impacts. This will reduce the burden on land managers to account for the impacts to all archeological resources under all conditions and instead focus their efforts on the archeological resources that have the potential for loss of information during a fire. There may also be cases where the preservation of archeological resources could be enhanced by the use of wildland fire including fuel reduction, ground clearing, and reducing vegetation for archeological investigations.

Review of fire programs under the National Historic Preservation Act (NHPA)

A practical outcome of this research project will be the application of the results to reviews of fire program activities under Section 106 of the National Historic Preservation Act by providing Federal land managers and fire personnel with a better understanding of the potential to adversely effect archeological resources. Data from this research project indicate that there are fire conditions within the Midwest Region that will not adversely effect archeological resources and some conditions that may cause serious damage to the archeological record. The information generated from the experimental burns will provide managers with the flexibility to concentrate efforts on fire conditions that have the potential to adversely effect archeological resources and develop solutions to mitigate or reduce those negative impacts.

Cooperation between the Archeology and Fire Programs

This research program would not have been completed without the effective collaboration between the NPS Fire and Archeology programs. The JFSP research project facilitated the first integrated research effort between the Fire and Archeology programs in the Midwest Region. The collaborative effort that was necessary for the successful completion of our research also led to a better understanding of broader program goals and how fire and archeology staff can work together to achieve effective fire use and preservation of archeological resources. Continued dialogue and

Post-burn condition of stone tool showing combustive residue.

Stone tool showing the removal of combustive residue following experimental cleaning.

Figure 13. Example of post-burn cleaning of a stone tool artifact.

Post-burn condition of bison bone.

Condition of bison bone following natural weathering experiment.

Figure 14. Example of post-burn weathering of a bone artifact.

collaboration will strengthen both the Archeology and Fire programs and will help meet the needs of NPS units throughout the Midwest Region.

Recommendations for Future Study

- There is a need for a nation-wide research program that would investigate the interface of wildland fire with archeological resources. This research should attempt to account for real-world fire conditions and archeological resources in different environmental settings across the country. Regions for consideration include:
    - Southeastern Woodlands and Appalachia
    - Great Lakes and Northeastern Woodlands
    - Atlantic Coastal and Caribbean Islands
    - Southern Great Plains
    - Northern Rocky Mountains
    - Southwest and Great Basin
    - California and Pacific Coast
    - Hawaiian and Pacific Islands
    - Areas with an abundance of surface archeological resources or resources that are potentially vulnerable to the impacts of fire
- The current research project provides information on the results of a single burn episode in each park. A long-term research project is needed to address the impacts from multiple cycles of burning. Multiple burn episodes may produce cumulative impacts or exacerbate impacts from a single burn that may not be evident from a single burn episode. An experimental research program that can address questions of cumulative impacts and changes in fuel types and densities is needed in order to assess the cumulative effects of cyclical burn programs.
- Conduct post-burn assessments for archeological sites within the six study parks to confirm or revise the results of the experimental burn program. This would help assess the effectiveness of the experimental burn program.
- Utilize the Rocky Mountain Research Station or similar laboratory to model different fuel types, burn cycles, and weathering modeled on the previous study conducted by Buenger (2003).

- Develop a best practices and techniques for protecting archeological resources.
- Conduct experimental burns to investigate the effects on geophysical instruments and signatures.
- Continue to collect and refine fuels data to address variability within parks.
- Study the effectiveness of pre- and post − burn inventories and develop a protocol for when these archeological investigations may be needed.

Table 3. Deliverables Cross-Walk Table.

Deliverable	**Description**	**Status**
JFSP Final Report	Summary report of project and findings.	Completed – posted on JFSP website
Web Page	http://www.nps.gov/history/mwac/jfsp/index.htm	Update as needed
MWR Workshop	Presentation of JFSP research project to the 2009 NPS Midwest Region FMO meeting.	Completed
GWS Conference	Present poster on project findings at George Wright Society conference, Portland OR, March 2009.	Completed – posted on JFSP website
Midwest Archeological Conference	Present project findings at the 2009 Midwest Archeological Conference, Iowa City, IA.	October 15-17, 2009
Archeological Journal Article	Professional paper describing project and findings for appropriate archeological journals such as American Antiquity, Journal of Field Archeology, Journal of Archeological Science, or Mid-Continental Archaeology.	Projected for 2010
Curation Journal Article	Paper based on cleaning experiments conducted on burned archeological materials.	Projected for 2010
Park Science Article	Paper based on the final report submitted to Park Science for dissemination of information to NPS staffs.	Projected for 2010

References Cited

Bennett, Joanne L.
1999 Thermal Alteration of Buried Bone. *Journal of Archaeological Science* 26:1-8.

Buenger, Brent A.
2003 *The Impact of Wildland and Prescribed Fire on Archeological Resources*. Unpublished Ph.D. dissertation, Department of Anthropology, University of Kansas, Lawrence.

Cande, Kathleen H. and Jared S. Pebworth
2004 *A Reconnaissance-Level Pre-Burn Cultural Resources Survey of Twelve Prescribed Burn Units, Buffalo National River, Marion, Newton, and Searcy Counties, Arkansas*. Arkansas Archeological Survey, Fayetteville, Arkansas. Report on file, National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Cannon, Kenneth P. and Patrick Phillips
1993 *Post-Fire Inventory and Evaluation In Yellowstone National Park, Wyoming: The 1989 Field Season*. Midwest Archeological Center Technical Report No. 24. National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Cavaioli, Maryjane
2002 Fire Reveals New Pictographs at the Kuehl Site: The Effects of Wildfire on Pictograph Sites. In *Cultural Resources and Fire Management Planning Instructor Manual*. National Park Service, Stephen T. Mather Training Center, Harpers Ferry, West Virginia.

Connor, Melissa, Kenneth P. Cannon, and Denise C. Carlevato
1989 The Mountains Burnt: Forest Fires and Site Formation Processes. *North American Archaeologist* 10:293-310.

Deal, Krista
2002 Fire Effects to Lithic Artifacts. In *Cultural Resources and Fire Management Planning Instructor Manual*. National Park Service, Stephen T. Mather Training Center, Harpers Ferry, West Virginia.

Haecker, Charles M.
2002 Effects of Fire on Historic Structures and Historic Artifacts. In *Cultural Resources and Fire Management Planning Instructor Manual*. National Park Service, Stephen T. Mather Training Center, Harpers Ferry, West Virginia.

Lentz, Stephen C., Joan K. Gaunt, and Adisa J. Willmer
1996 *Fire Effects on Archeological Resources, Phase I: The Henry Fire, Holiday Mesa, Jemez Mountains, New Mexico*. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Roberts, Barbara et. al.
1988. An Account of the Conservation and Preservation Procedures Following a Fire at the Huntington Library and Art Gallery. *Journal of the American Institute for Conservation* 27(1):1-31

Sayler, Rodney D., Robert W. Seabloom, and Stanley A. Ahler
1989 *Impacts of Prescribed Burning on Archeological and Biological Resources of the Knife River Indian Villages NHS*. Report on file, National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Scott, Douglas D.
1979 *Don't Burn that Wickiup! A Value at Risk Some Considerations of Cultural Resources in Fire Management*. Bureau of Land Management. Report on file, National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Southeast Archeological Center (SEAC)
2005 (Draft) *Cultural Resource Protocols for Fire and Fire Management Activities, National Park Service, Southeast Region*. Report on file, Southeast Archeological Center, Tallahassee, Florida.

Spafford-Ricci, Sarah, and Fiona Graham
2000. The Fire at the Royal Saskatchewan Museum, Part 2: Removal of Soot From Artifacts and Recovery of the Building. *Journal of the American Institute for Conservation* 39(1).

Sturdevant, Jay T.
2005 *Archeological Inventory of the 2006 Prescribed Burn Units, Marion, Newton, and Searcy Counties, Buffalo National River, Arkansas*. Report on file, National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Sturdevant, Jay T. and Melissa A. Baier
2008 *Archeological Inventory of the 2009 Prescribed Burn Units, Buffalo National River, Marion, Newton, and Searcy Counties, Arkansas*. Midwest Archeological Center Technical Report No. 106. National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Sturdevant, Jay T., William J. Hunt, Jr., and Caven P. Clark
2005 *Archeological Inventory of the 2004 Prescribed Burn Units, Newton, and Searcy Counties, Arkansas*. Report on file, National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Sturdevant, Jay T. Arlo McKee
2007 *Archeological Inventory of the 2008 Prescribed Burn Units, Buffalo National River, Marion and Searcy Counties, Arkansas*. Report on file, National Park Service, Midwest Archeological Center, Lincoln, Nebraska.

Switzer, Ron R.
1974 The Effects of Forest Fire on Archeological Sites in Mesa Verde National Park, Colorado. *The Artifact* 12(3):1-7.

Traylor, Diane, Lyndi Hubbell, Nancy Wood, and Barbara Fiedler
1990 *The 1977 La Mesa Fire Study: An Investigation of Fire and Fire Suppression Impact on Cultural Resources in Bandelier National Monument*. Southwest Cultural Resources Center Professional Papers Number 28. National Park Service, Branch of Cultural Resources Management, Division of Anthropology, Santa Fe, New Mexico.

Winthrop, Kate
2004 *Bare Bones Guide to Fire Effects on Cultural Resources for Cultural Resource Specialists*. Bureau of Land Management.

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National Park Service
Midwest Archeological Center
Lincoln, Nebraska
2009