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Proceedings of the Fourth Biennial Conference of Research on the Colorado Plateau

Report Series USGSFRESC/COPL/1999/16

United States Department of the Interior
U.S. Geological Survey

Editorial Staff

U.S. Geological Survey/FRESC

Cover photo:
Buttes and mesas of Monument Valley, Arizona typify the spectacular landforms of the Colorado Plateau. (© Al Richmond)

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Proceedings of the Fourth Biennial Conference of Research on the Colorado Plateau

Editors

Charles van Riper III
Maureen A. Stuart

Fourth Biennial Conference
of Research on the Colorado Plateau
Northern Arizona University
Flagstaff

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U.S. Geological Survey
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PREFACE

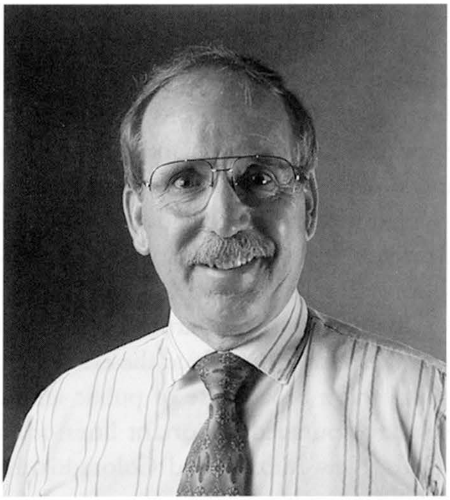
The 13 papers in this volume are contributions from federal, state, and private sector researchers, who come together at Northern Arizona University every other year to share scientific information with land managers on the Colorado Plateau. This is the fourth Proceedings for which I have had the pleasure of providing a Preface. This Colorado Plateau Biennial Conference series of publications focuses on providing information to USGS partners, particularly land managers on the Colorado Plateau. The papers of this fourth Proceedings contribute to the ever growing pool of scientific data that provides baseline scientific information pertaining to physical, cultural, and biological resources of the Colorado Plateau. Support for many of these studies have come from a spectrum of federal, state, and private partners concerned about the well-being of the Plateau's resources. I applaud the effort of the contributors. With modest funding and a broad base of public and institutional support, these authors have pursued important lines of work in the four states (Arizona, Utah, New Mexico and Colorado) that comprise the Colorado Plateau biogeographic region.

There remains much to be done. As a people, we face the prospect of extensive local and global environmental changes that continue to perturb the physical, cultural, and biological resources on lands of the Colorado Plateau. As the research branch for the Department of the Interior, we in the USGS are committed to identify, in a sound scientific manner, information that can be used by land managers to protect our resources from detrimental change due to modern human influences. We must develop the information necessary to alert our managers, leaders, and the public to the importance of their natural surroundings as elements of those basic resources that sustain us, inspire us, and represent our natural biological and environmental heritage. Our task has just begun.

DENNIS B. FENN

Chief Biologist
U.S. Geological Survey

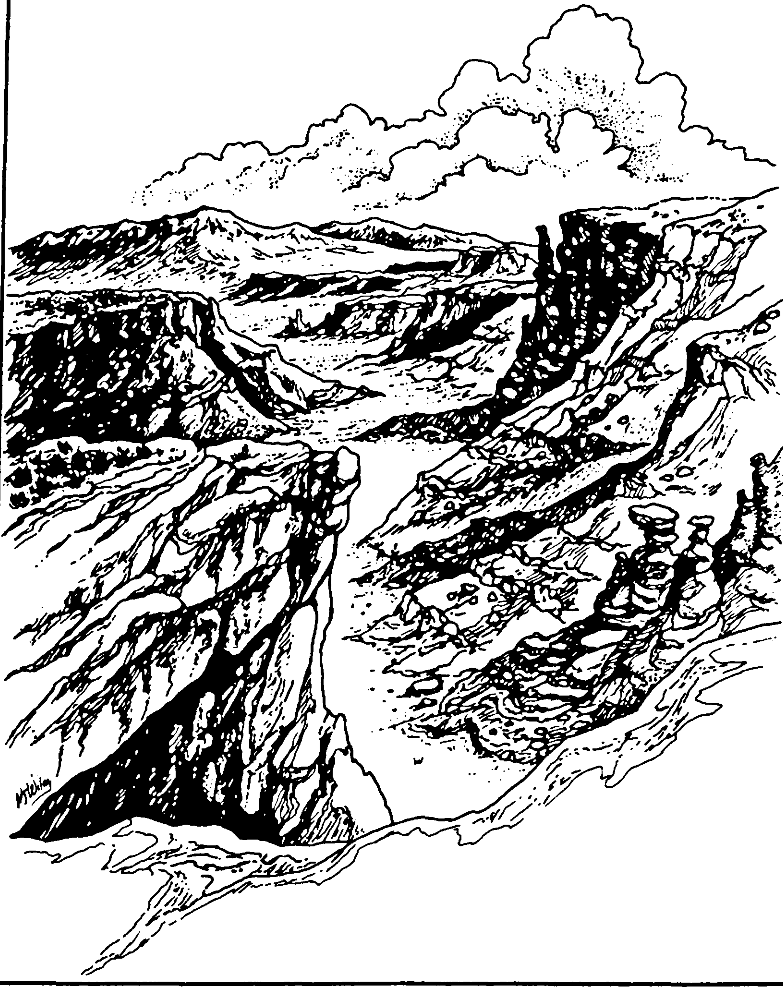
Dedication
to
Dr. Henry O. Hooper



This Proceedings of the Fourth Biennial Conference of Research on the Colorado Plateau is dedicated to Dr. Henry O. Hooper. Dr. Hooper has been an integral part of the growth and success of USGS Colorado Plateau Field Station (CPFS) and other federal partnerships on the Northern Arizona University (NAU) campus. After an illustrious career as a professor of Physics at Wayne State University and then the University of Maine, Dr. Hooper came to Arizona in 1981 as Associate Vice President for Academic Affairs and Graduate Dean. In 1989, Dr. Dennis Fenn of the National Park Service approached NAU regarding the possibility of placing a National Park Service Cooperative Park Studies Unit (CPSU) on campus. Dr. Hooper took an immediate interest in this matter, and continued to support, both financially and in concept, the CPSU at Northern Arizona University. For his efforts, in 1993 Dr. Hooper was awarded the NPS Regional Director's Natural Resources Award for his involvement with the CPSU.

In the fall of 1993 the CPSU was transferred to the newly created National Biological Service, and then in 1997 to the U.S. Geological Survey. Dr. Hooper met each change with the same enthusiasm that he directed to the former CPSU. Throughout this 1993-1998 transition period, Dr. Hooper devoted additional time and energy to assure that the Colorado Plateau Biennial Conference was continued on the NAU campus. His energies also contributed to the quality of the Biennial Conference Proceedings Series. Without the continued support of Dr. Hooper, the Colorado Plateau Biennial Conference Proceedings would not have been a continuous reality. As Dr. Hooper moves into retirement, following the 1999 academic year, it is important that we remember and recognize the contributions that he has made to science and research at NAU, to the USGS Colorado Plateau Field Station, and to federal, state and private land managers throughout the Colorado Plateau.

Introduction



Introduction to the Proceedings of the Fourth Biennial Conference of Research on the Colorado Plateau

The 13 chapters in this book were selected from the 75 research papers presented at the Fourth Biennial Conference of Research on the Colorado Plateau. The theme of this meeting centered around research, inventory, and monitoring on lands over the Colorado Plateau, with a focus on the newly created BLM Grand Staircase-Escalante National Monument. The conference, held on 15-18 September 1997 in Flagstaff, Arizona, was hosted by the USGS Forest and Rangeland Ecosystem Science Center Colorado Plateau Field Station (CPFS) and Northern Arizona University.

This is the fourth volume in a planned series of Colorado Plateau Proceedings, highlighting research and resource management efforts related to physical, cultural and natural resources within the biogeographic province of the Colorado Plateau. Many of the protocols and management techniques presently being utilized in land management units over the Colorado Plateau are a result of collaborative work between CPFS staff, university and agency scientists, and land managers. The scientific work published in this Proceedings Series contributes significantly to those collaborative efforts. It has been clearly demonstrated that, because of similarities across the Colorado Plateau, techniques that work in one management unit are applicable to other units throughout the province, and possibly to other areas of the country that have similar habitat and climatological parameters.

Each paper selected for publication in this Proceedings represents original research and has been peer reviewed by scientists of that particular research discipline. The papers are divided into two major sections: I. those that deal with **Biological Resources**; and, II. those addressing **Cultural Resources**. The Biological Resources section comprises the first 9 chapters of this book, with the first three chapters dealing with vegetation and the next six with studies of animal ecology. The final four chapters fall under Cultural Resources, evenly divided between archeology and policy chapters pertaining to human perceptions of managing cultural resources.

I. Biological Resources

It is fitting to begin this section, and in particular the book, with a chapter dealing with a unique aspect of the Colorado Plateau. The paper by Cole and Murray describes Holocene vegetation of Capital Reef National Park from packrat midden analyses. Fossil packrat middens are valuable sources of paleoecological information in arid regions of the southwest. On the Colorado Plateau, information on pre-settlement vegetation is often lacking, and analyses of packrat middens allow researchers to reconstruct these earlier vegetation communities. Such was the objective of this first paper, in that Capitol Reef National Park needed a baseline of vegetation community information from which to construct restoration guidelines. Information from packrat middens allowed Cole and Murray to demonstrate that the present vegetation community is apparently an artifact of overgrazing. The chapter clearly documents that vegetation species lost since pre-settlement were those that were more palatable to large herbivores. In fact, the authors argue that in their reconstruction of vegetation communities, some species reached their lowest levels in the past 5,400 years. Conversely, species typical of present-day over grazed ranges on the Colorado Plateau, were not present in the earlier packrat midden record. The authors also feel that the increase in Utah juniper (*Juniperus osteosperma*) pollen in their middens records over that past 200 years, has probably been a result of fire suppression at Capitol Reef National Park.

The second chapter of the Biological Resources section also examines vegetation changes, but in this instance switches time-frames, examining only historical forest structure. Garrett and Soulen provide an analysis of the changing over-story density of the Apache/Sitgreaves National Forest in eastern Arizona. They examine tree-density data from surveys in 1911, 1967, 1988 and 1994, concluding that the density of trees per acre has increased dramatically in all size classes up to 20" dbh. Computer simulated treatments utilizing analyses with a Geographic Information System, revealed that agencies would realize enhanced positive values if tree densities in the forests were brought into line with pre-settlement conditions.

The final vegetation chapter by Floyd-Hanna et al. deals with vegetation response to fire at Mesa Verde National Park. The authors document their efforts at monitoring vegetation response and mitigation to the lightning-initiated 'Chapin 5' fire in August 1996. The 4,781 burned acres were divided into 7 pre-fire vegetation communities and 2 principal geological substrates for monitoring purposes. Subsets of these 9 areas were monitored, and either aerially seeded or had mechanical removal of alien plant species. The authors demonstrated multiple pathways of native vegetation recovery from the 1996 fire, but also feel that in certain areas alien plants now dominate the landscape and are preventing the recovery of native vegetation communities. This will certainly present a challenge to the 'noxious weed' initiative of Mesa Verde National Park.

Chapter #4 of the Biological Resources section provides a transition into wildlife management, where Wakeling et al. examine the performance of aerial forward-looking infrared (FLIR) surveys on cattle, elk, and turkeys in the forests of northern Arizona. Wildlife managers are often challenged by techniques needed to determine total numbers of animals, whether it be for carrying capacity or in order to set hunting season bag limits. Aerial FLIR surveys became popular because they seemed to standardize and objectively survey large wildlife species without bias. Wakeling et al. conducted FLIR tests on known number of cattle, known turkey roosts, and known locations of elk herds using replications with fixed wing aircraft and then helicopters. Their findings demonstrate that FLIR is not yet suitable for small animals such as turkeys, and that not all large animals are observed. The authors recommend against the use of FLIR as a sole estimate of large-bodied wildlife species in Arizona, until correction factors for target species, timing, and habitat can be developed.

In the next chapter, Sisk et al. provide a unique insight into how they have developed a 'management team' approach to shape an experimental research program that examines the livestock grazing debate on the Colorado Plateau. The authors base their chapter on the assumption that domestic livestock grazing is the most pervasive human impact on lands of the Colorado Plateau. In fact, ranching versus environmental interests have made livestock grazing the most contentious issue in the southwestern United States. The authors feel that this polarization of interests has come about because there is a lack of scientifically sound, defensible information to support either side of the issue. Sisk et al. provide a plan of action where they take the claims of each interest group, reformulate these claims into testable hypotheses, and then provide research designs for each of the hypotheses. This chapter exemplifies a modern-day approach on how science must deal with volatile social issues, if there is ever to be any hope of bringing disparate groups together so that a solution can be reached which is acceptable to all parties.

Chapters #6 and #7 move into more wildlife specific information, both being radio telemetry studies that examine behavior of mammals. Lema et al. examine the social behavior of Abert's Squirrels (*Sciurus aberti*) in Chapter #6, presenting the results of a 12 month study on radio-collared squirrels near Flagstaff, Arizona. They demonstrate, for the first time, that this species exhibits extensive social behavior. According to the authors, it was previously believed that Abert's squirrels were solitary animals. Lema et al. found pairs and trios of squirrels occupying communal nests that included male/female and male/male combinations of varying age classes. They also found, in over half their observations, that more than one Abert's squirrel occupied a tree. The authors conclude this chapter suggesting that communal nesting behavior among Abert's squirrels may facilitate thermoregulation, and that this type of nesting and tree sharing may reinforce social bonding and resource sharing. In Chapter #7, Siders et al. examine foraging distances of two uncommon bat species on the Kaibab Plateau in northern Arizona. This radio telemetry study determined the foraging areas of seven lactating female spotted bats (*Euderma maculatum*), documenting daily movements of up to 42 km. It appears that although the bats forage in locations at 2500 m elevation, they prefer to day roost at lower elevations (e.g., approximately 1000 m elevation). The authors also provide information on maternity roosts and relative numbers of 18 bat species captured from between 1994 and 1998.

The final two biological chapters deal with studies of Merriam's turkeys. In Chapter #8 Wakeling and Goodwin examine over-winter survival of turkeys in the North Kaibab region of Arizona. During 1996, several severe fires occurred on the Kaibab Plateau, and the authors wanted to examine, with radio-collared birds, the potential influence of these fires on over- winter survival. They found significantly higher mortality in this area of Arizona in 1996 when compared to other regions of the state. First-year birds were more greatly affected, with a mortality rate of 90% versus 34% in adult females. All cohorts of turkeys experienced the greatest mortality between January and March, and the authors attribute the increased mortality to deep snow and limited food availability. This study supports the contention that winter food availability is closely tied with turkey over-winter mortality. In the last chapter of the Biological Resources section, Rogers et al. examine the impact of U.S. Forest Service transportation corridors on male turkey distributions. The authors found that turkeys avoided locations less than 200 m from roads, for all resightings and for all roost sites. However, improved high-traffic roads had a much greater negative influence than did unimproved, low-traffic roads. They were not able to ascertain what level of road use that turkeys found unacceptable.

II. Cultural Resources

Chapter #10 begins the Cultural Resources section of this book, with a study by Fawcett and Latady on an archeological survey of Black Ledge, a mesa immediately adjacent to Coombs site, the largest ancestral pueblo village in south-central Utah. The authors use archeological data from Black Ledge (principally lithic artifacts and site settings) to examine potential reasons for a prehistoric shift from formal (bifacial) technology to expedient (core) technology. In other words, they examined the question of why nomadic people of the Colorado Plateau settled into a more sedentary style of living. The theme of this chapter is the comparison of Late Archaic sites of mobile hunter-gathers with the equally ephemeral sites created largely by women, as they harvested, processed and transported wild resources for use during the Late Formative period. Fawcett and Latady conclude that their survey data support the same shift in organization of prehistoric lithic technology (from bifaces to cores) on the Colorado Plateau, that has been observed in many other places throughout the southwestern United States and around the world.

An archeological survey of Cedar Breaks National Monument in southern Utah, is the theme of Chapter #11. Canaday et al. subdivide their survey work at Cedar Breaks into two discrete locations of the Markagunt Plateau: those areas below 9,200 feet and those above 10,000 feet elevation. They found little prehistoric use in the lower site, but demonstrated extensive use of the higher elevations over the past 4,000 years. Procurement of chert from the Brian Head Formation for hunting purposes appears to have been the primary activity. The authors have also initiated a number of ancillary studies, such as trace mineral analyses and palynological (pollen) studies from a peat bog, to provide a better understanding of prehistoric use of Cedar Breaks and the Markagunt Plateau.

Chapter #12 provides a transition from purely archeological studies to human policy surrounding cultural resources. Balsom summarizes the benefits and drawbacks of the Spring 1996 'Experimental Habitat Building Flow' in Grand and Glen Canyons. In particular the potential loss/preservation of cultural resources from higher water volume releases of Glen Canyon Dam is examined. From 45 previously recorded sites, four were chosen to measure potential impacts on archeological resources. The author's overall conclusion was, with a few cautions, that habitat building flows were beneficial to the cultural resources along the Colorado River in Grand and Glen Canyon National Parks.

The final chapter of the Fourth Biennial Conference Proceedings is that of Nie, who examines the debate over establishment of wilderness in Utah, and particularly the Grand Staircase-Escalante National Monument. Through a number of personal interviews and a compilation of newspaper articles and federal legislation, the author weaves a complex picture surrounding the debate over Southern Utah Wilderness and how this fits into the framework of the 'true' West. It is apparent from this treatise that issues on the southern Colorado Plateau, and in particular Utah, transcends solely environmental protection, to a plethora of regional-specific themes and concerns. Nie argues that placing the debate only in terms of wilderness acreage is overly simplistic, and that one has to examine more closely the values of the local residents and focus on culture and place. It is only once these dimensions of cultural values are included in the equation, can the wilderness debate on the Colorado Plateau be understood and the conflict diminished.

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Any Proceedings is never a single effort, but a direct result of work by many individuals. This Fourth Proceedings is no exception. The dedicated Colorado Plateau Field Station staff (T. Arundel, K. Cole, M. Debold, E. & P. Deshler, C. Drost, K. Estes, J. Grahame, J. Hart, S. Jacobs, M. Johnson, E. Nowak, E. Paxton, A., A., & M. Rasmussen, M. Sogge, K. Thomas, V. Tondini, and D. Willey) provided much needed assistance during the conference. I would especially like to thank Maureen Stuart, who spent many hours of editorial assistance with the final drafts of each chapter and coordinated with GPO during the publication phase. Thanks are also extended to the many reviewers who unselfishly devoted their time and efforts to improving each chapter. The financial support that Drs. Michael Collopy and Henry Hooper provided for publication

of this Proceedings is greatly appreciated. Finally, I express deep appreciation to my wife Sandy, and our children Jacqueline, Kimberly, Carena and Charles IV for their support and understanding during the time that this Proceedings was in production.

This book, like the products of other symposia that are centered around a particular theme, should help to focus attention on some of the research presently being conducted on lands of the Colorado Plateau. In particular, it is hoped that the new BLM Grand Staircase-Escalante National Monument will be able to utilize some of the ideas and concepts presented within the Biennial Proceedings, to launch their efforts toward management and stewardship of their newly created lands on the Colorado Plateau. Finally, if the material in this volume, as that contained in previous Biennial Conference Proceedings, can act as a stimulus for future support of research and management of physical, cultural, and natural resources over the Colorado Plateau, it will make the organizational and editorial work of the past two years a worthwhile and productive effort.

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Biological Resources

Middle and Late Holocene Packrat Middens from Capitol Reef National Park

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Abstract. Twenty Holocene and two late Wisconsinan packrat middens were collected and analyzed from Capitol Reef National Park. The two older middens, collected at 1390 m elevation, were greater than 26,000 years in age and contained species typical of much higher elevations, such as Douglas fir, limber pine, Rocky Mountain juniper, and Knowlton hophornbeam. These ancient middens demonstrate the antiquity of many inaccessible deposits high in the Navajo Sandstone.

Nine Holocene middens were collected from Hall's Canyon, eight from the Hartnet Draw area, and three from other locations. A comparison of the middle and late Holocene middens to five modern middens and to modern vegetation suggests that vegetation changes taking place in the last several hundred years are more extreme than any changes occurring since at least the middle Holocene. The nature and timing of these changes imply that they were primarily caused by nineteenth century open-land sheep grazing.

Presettlement middens consistently contained abundant macrofossils of plant species palatable to large herbivores that are now absent or reduced, such as winterfat (*Ceratoides lanata*) and ricegrass (*Stipa hymenoides*), especially in the most complete series at Hartnet Draw. Macrofossils and pollen of pinyon pine (*Pinus edulis*), sagebrush (*Artemisia* spp.) and roundleaf buffaloberry (*Sheperdia rotundifolia*) were also recently reduced to their lowest levels for the 5400 year record. Conversely, species typical of overgrazed range, such as snakeweed (*Gutterrezia sarothrae*), viscid rabbitbrush (*Chrysothamnus* *visidiflorus*), and Russian thistle (*Salsola* sp.) were not recorded prior to the historic introduction of grazing animals. Pollen of Utah juniper (*Juniperus osteosperma*) also increased during the last 200 years, possibly due to the elimination of grassland fires.

Key words: Holocene vegetation history, grazing impacts, packrat middens, fossil pollen, presettlement vegetation

INTRODUCTION

The purpose of this study is to produce a vegetation history of Capitol Reef National Park, reconstructing past changes in vegetation, especially those accompanying the settlement era. A reconstruction of the presettlement vegetation, existing just prior to settlement of the area by European industrialized society, was needed by the National Park in order to set restoration guidelines. Also, a reconstruction of any vegetation changes brought about by settlement impacts was needed to understand the dynamics of ecosystem change in order to better manage the park. Among the methods of reconstructing this past vegetation were an analysis of fossil packrat middens (reported here) and a study of buried plant phytoliths (Fisher et al. 1995).

Reconstructing Past Vegetation with Packrat Middens

Fossil packrat middens are valuable sources of paleoecological information in arid regions of the southwestern United States (Cole 1990, Betancourt et al. 1990). Plant macrofossils in packrat middens are often identifiable to the species level and represent species that grew close to the midden location, most likely within 50 m. Because plant identification and location can be precisely known, this method has extremely high spatial and taxonomic resolution compared to other methods of reconstructing past vegetation.

Studies comparing trees and shrubs at midden sites with plant specimens from modern middens typically report similarities exceeding 80% using a Sorensen's Index of Similarity (Spaulding et al. 1990, Frase and Sera 1993, Cole and Webb 1985, Cole 1985). This is especially true when small macrofossils (< 2 mm) are identified using a 10X microscope. Similarity with forbs and grasses has been reported to be lower (Frase and Sera 1993), but inventories of current forbs are usually incomplete due to seasonal and yearly variability in the forb flora, and identification of diverse forbs and grasses within midden assemblages is difficult.

Fossil pollen within the middens can also be analyzed (King and Van

Devender 1977, Thompson 1985, Davis and Anderson 1988), emphasizing different types of vegetation, and representing a larger source area than the plant macrofossils. Interpretation of the fossil pollen abundances, like the macrofossil abundances, requires caution and experience, as some species are better represented than others. Through the consideration of both the macrofossil and pollen records, a more comprehensive understanding of past environments can be achieved.

Grazing History of Capitol Reef National Park

Settlement impacts to the vegetation of Capitol Reef can be attributed mainly to grazing by large introduced herbivores, because this was the primary economic use of these lands. Native large herbivores which may have been present in the study area during the last 5000 years include: bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), and possibly bison (*Bison bison*) and elk (*Cervus elaphus*) (Van Gelder 1928, Mead et al. 1991). Eurasian horses and asses (*Equus* spp.) were introduced to New Mexico by Spanish colonists as early as 1598 AD (Underhill 1971). By the late 1600's, feral horses were reported in parts of the west, but it is unlikely that they existed in the study area prior to the 1800's.

In the late 1800's introduced large herbivore populations increased dramatically in southern Utah with the widespread increase in open-land grazing. Livestock grazing within and near Capitol Reef National Park has been documented since at least the 1870's (Frye 1995). By 1909, more quantitative herbivore population estimates for the Capitol Reef area can be made using grazing permits issued for Powell (now part of Dixie) National Forest (Frye 1995). In 1909 the Forest Service issued summer grazing permits for 67,000 sheep and 11,000 cattle. The animals that grazed in these high summer pastures presumably spent the winter in the lower adjacent areas of Capitol Reef National Park.

A Bureau of Land Management survey described past use at the Hartnet Draw site:

> "Prior to the passage of the Taylor Grazing act in 1934, large numbers of livestock were brought from Wayne, Seiver, and Emery Counties to winter on these lands. Many of the animals remained on the range year-long, resulting in the progressive destruction of soils and vegetation. Reports from stockmen in the area indicate that many trespass horses used the area until about 1955. Prior to 1946 there were at least 163 cattle and 20 horses year-long in this area" (Hartnet Allotment File 1966).

MATERIALS AND METHODS

Approximately 1 kg of each midden was separated from the *in situ* larger masses using a hammer and chisel. In the laboratory, these 1 kg samples were then dissected producing horizontally stratified sub-samples typically measuring about 15 x 20 cm with a thickness of several centimeters. This midden sample is smaller than what is often used by some other investigators. But, it is of sufficient size to yield a full spectrum of identifiable plant macrofossils while minimizing the opportunity for intermixing of layers.

Weathering rinds and large rocks were removed from each subsample, yielding 300 to 600 g of the hardened midden material. This sample was then weighed and disaggregated in water. Pollen samples were taken from the wash water after several days of soaking, and processed using standard methods (Faegri and Iversen 1975, Murray 1989).

Plant, vertebrate, and invertebrate fossils, fecal pellets, and rocks were separated from the dissolved middens with a 1 mm sieve. The resulting matrix was dried and weighed, yielding 100 to 200 g of washed midden matrix. The dried matrix was sorted by hand under a 10X dissecting microscope. Packrat fecal pellets and rocks were removed and weighed. Identifiable plant macrofossils, vertebrate bones, and insect fossils were identified, counted, labeled, and stored in plastic vials.

Packrat fecal pellets were submitted to radiocarbon laboratories for dating. Calendar year ranges for the radiocarbon ages were calculated using the calibration program of Stuiver and Reimer (1993). Some undated middens were considered modern because of the presence of green leafy material, cow feces, and, in one sample, a peanut shell.

Data on midden contents were quantified by number and $\log_{10}$ of macrofossil concentration in midden matrix. In order to compensate for variability between middens, midden matrix weights were adjusted by subtracting the weight of the rocks and pellets from the dried washed matrix weight before calculation of the concentration. Using $\log_{10}$ of macrofossil concentration calculates a number similar to the semi-quantitative abundance scale used by several other authors, but has the advantage of being quantitative, allowing better comparisons between middens of differing size.

RESULTS

Midden dating

The ages of 22 middens ranged from 0 to greater than 39,600 yr B.P. (Table 1). One of the four collections of modern debris (containing loose green plant matter) was radiocarbon dated and found to contain

Table 1. Ages of middens based upon radiocarbon dates. Radiocarbon ages are calibrated to calendar years based upon Stuiver and Reimer (1993). Age classes are: PO=Postsettlement midden, TR=Transitional midden, PR=Presettlement midden. Probability of dating to post-1870 AD (at one sigma, extrapolated from Stuiver and Reimer 1993) shown in parentheses, PMC=Percent modern carbon (sample post-dates atmospheric testing of nuclear weapons). Modern debris was not dated except for Hartnet Draw #3. All dates except Hartnet Draw #5 (dated on *Pinus edulis* needles) are from *Neotoma* pellets.

Sample Name	Conventional Date (Probability of Dating to Postsettlement Period)	δ^{13} C	Lab ID No.	Calibrated Calendar Range	Class
LOWER HALL CANYON					
Baker Shelter #1	Modern Debris				PO
Narrows #5	Modern Debris				PO
Baker Shelter #3	20 ±80 (40%)	-24.0	A-5200	1693-1922 AD	TR
Hall Canyon #4	80 ±100 (33%)	-22.0	A-5202	1681-1940 AD	TR
Hall Canyon #6	105 ±70 (31%)	-22.5	GX-16779	1672-1955 AD	TR
Hall Canyon #7	170 ±100 (17%)	-12.5	GX-15551	1640-1955 AD	TR
Hall Canyon #8	265 ±100 (5%)	-21.5	GX-15552	1490-1954 AD	PR
Narrows #2	330 ±100	-27.2	A-5201	1450-1650 AD	PR
Baker Shelter #2	410 ±50	-22.9	A-5199	1438-1609 AD	PR
Hall Canyon #2b	28,050 ±2600	-21.4	GX-15399		PR
Hall Canyon #2a	>39,600	-22.9	GX-15400		PR
UPPER HARTNET DRAW					
Hartnet Draw #3	137 ±1.2 PMC	-22.2	A-5197	1950-1986 AD	PO
Hartnet Draw #2	330 ±60	-21.8	A-5204	1490-1637 AD	PR
Hartnet Draw #8	630 ±100	-21.2	GX-16259	1280-1410 AD	PR
Hartnet Draw #1A	1020 ±70	-21.7	A-5203	898-1152 AD	PR
Hartnet Draw #7b	1275 ±110	-20.8	GX-15554	640-890 AD	PR
Hartnet Draw #9	2570 ±135	-21.8	GX-15553	889-434 BC	PR
Hartnet Draw #5*	3615 ±70		AA-6447*	2128-1889 BC	PR
Hartnet Draw #6	5450 ±90	-21.8	A-5205	4363-4235 BC	PR
OTHER LOCATIONS					
Long Leaf Flat #1A	Modern Debris				PO
Long Leaf Flat #1B	1030 ±80	-23.4	A-5198	901-1148 AD	PR
Fremont River #1	7010 ±105	-25.3	GX-15550	5980-5740 BC	PR

* Tandem Accelerator Mass Spectrometer Date on *Pinus edulis* needles. Original unlikely date of 142 PMC on pellets is probably a lab error, sample contamination with artificial carbon isotopes, or a mislabeled sample.

137 percent modern carbon ("modern" is defined as 1950 AD levels). Thus, it post-dates the atmospheric testing of nuclear weapons.

Because of changes in the ratio of carbon isotopes in the atmosphere during the late Holocene, radiocarbon dates must be calibrated to calendar years to be correlated with historical events. The radiocarbon ages for this report have been converted to calendar years based on the calibration program of Stuiver and Reimer (1993) (Table 1). Unfortunately, because of the burning of fossil fuels, radiocarbon dates under 300 years can often represent several different time intervals during this period, and it may not be possible to determine the true age using existing methods.

In order to determine which middens dated prior to 1870 AD, which is approximately when settlement began in earnest, the probability distribution of the radiocarbon ages under 300 years was assessed. Middens that dated before 1870 AD were separated from those that dated after 1870 AD. Middens with significant possibilities of dating to both before and after 1870 AD (at one standard deviation) were placed into a third transitional group. This age assessment placed middens in one of three age categories; Presettlement (prior to 1870 AD), Postsettlement (after 1870 AD), and Transitional (dating range extending to before and after 1870 AD; possibly constructed throughout the settlement period). These determinations account for only one standard deviation (65% of the possible ages) on the measurement of ^{14}C activity in the sample, and do not account for the time span represented by the midden itself or other errors or contaminations that could have occurred before the radioactivity was measured. The amount of time that the packrat requires to construct the midden (the time period represented in the deposit) is variable, but is usually small when compared to the uncertainty associated with the radiocarbon date, especially in small samples such as these.

Hartnet Draw Site

Seven fossil and two modern middens were collected from Hartnet Draw in northern Capitol Reef National Park (Cole et al. 1997, Cole 1992). This site (38° 15' N, 111° 20' W; Fig. 1), at 1920 m elevation in Wayne County, Utah, was chosen because of its abundance of fossil packrat middens and remote location, free from most anthropogenic disturbances other than grazing.

The most abundant plant species at the site today are: Utah juniper (*Juniperus osteosperma*), Bigelow sagebrush (*Artemisia biglovii*), big sagebrush (*A. tridentata*), snakeweed (*Gutierrezia sarothrae*), Torrey ephedra (*Ephedra*

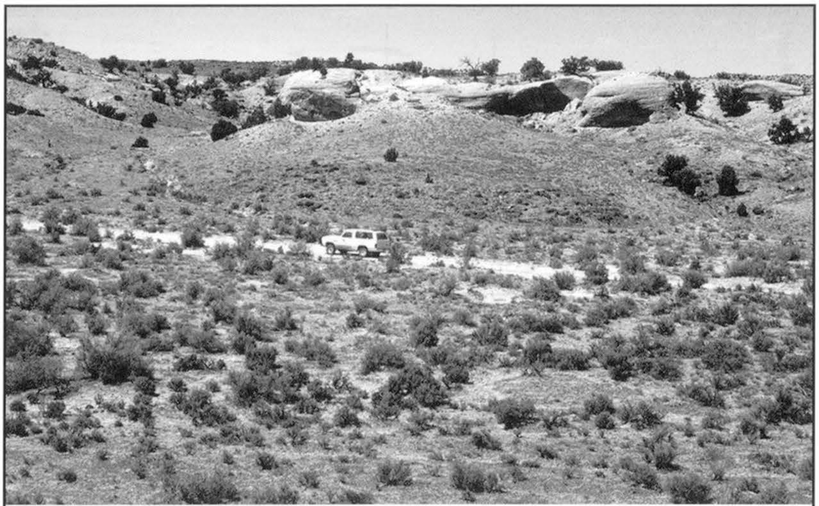
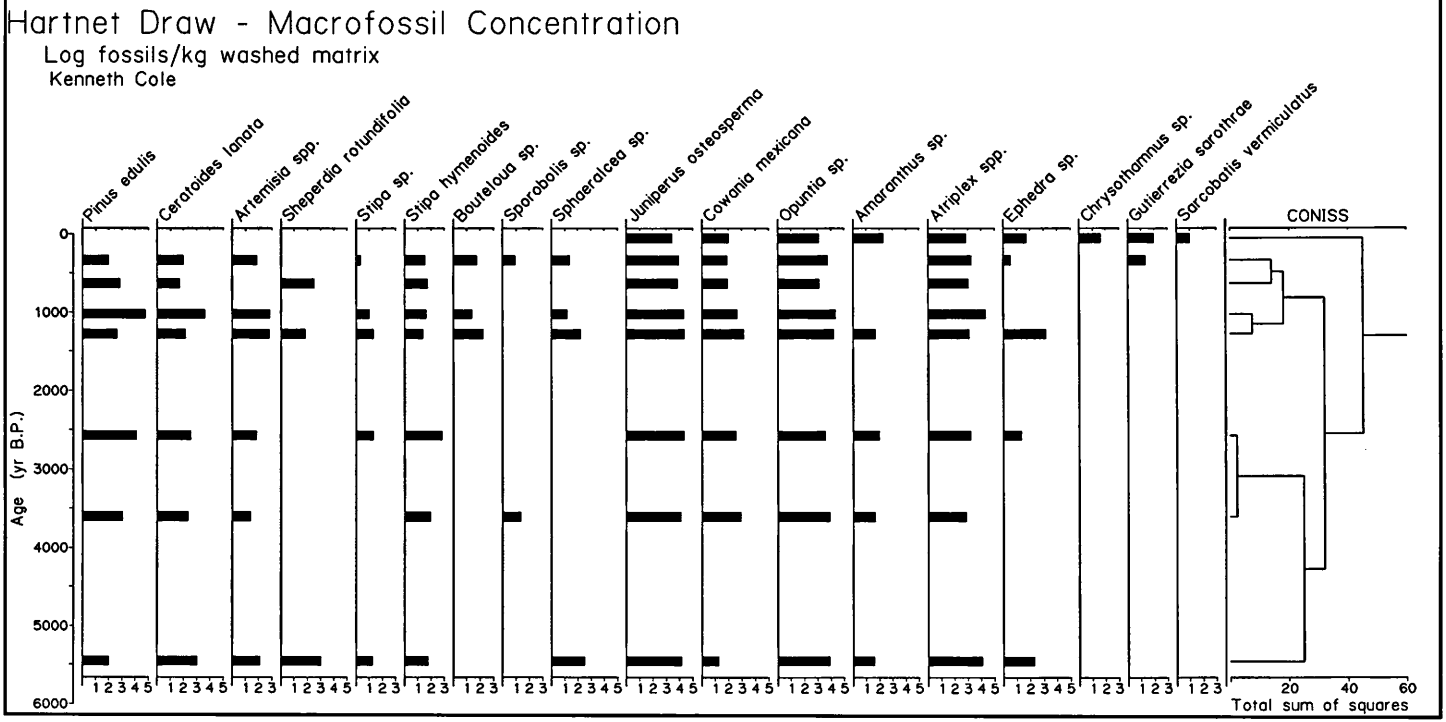


Figure 1. View of Hartnet Draw midden site. Middens were collected from small alcoves in distance.

torreyana), viscid rabbitbrush (*Chrysothamnus visidiflorus*), and central pricklypear (*Opuntia polyacantha*). Low areas with thicker soil support a sparse growth of the grasses: ricegrass, sand dropseed (*Sporobolus cryptandrus*), and blue grama (*Bouteloua gracilis*).

The nine Hartnet Draw middens ranged in age from modern to 5450 yr B.P. (Table 1). The results of the macrofossil analysis for major species from the Hartnet draw middens are shown in Figure 2. The complete macrofossil data from these middens can be found in Cole et al. (1997) or Cole (1992). All of the Hartnet Draw middens contain abundant macrofossils of Utah juniper, saltbush (*Atriplex* spp.), cliff rose (*Cowania mexicana*), and prickly pear (*Opuntia* sp.), which are all abundant at the site today (Fig. 2). The presettlement middens also contain pinyon pine (*Pinus edulis*), winterfat (*Ceratoides lanata*), sagebrush (*Artemisia* sp.) and ricegrass (*Stipa hymenoides*) which are absent from the one modern midden analyzed for macrofossils (Hartnet #3). Winterfat was not observed during the field work and pinyon pine was rare in the area. The rarity or absence of sagebrush and ricegrass from the modern midden suggests that they are less common now than prior to settlement. Similarly, globe mallow (*Sphaeralcea* sp.), needlegrass (*Stipa* sp.), blue gramma (*Bouteloua gracilis*), dropseed (*Sporabolis cryptandrus*), and roundleaf buffaloberry

Figure 2. Principal plant macrofossils from Hartnet Draw middens. Fossil values are displayed as Log_{10} of concentration. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).



(*Sheperdia rotundifolia*) are common in the presettlement middens but absent from the one modern midden.

In contrast, Hartnet #3, the modern midden, is the only midden containing viscid rabbitbrush (*Chrysothamnus visidiflorus*), greasewood (*Sarcobatus vermiculatus*), and Russian thistle (*Salsola* sp.) macrofossils. Only the two most recent middens (#3 and #2) contain snakeweed (*Gutterrezia sarothrae*). Rabbitbrush, snakeweed, and Russian thistle are frequent at the site today. The absence of these species from the presettlement middens indicates that these species were formerly absent, or so infrequent as to not be represented. Russian thistle is an introduced Eurasian species.

The cluster analysis (right side of Fig. 2) demonstrates the difference between the modern macrofossil assemblage and the other assemblages. The modern assemblage is the primary branch in the dendrogram even though the single occurrences of rabbitbrush, greasewood, and Russian thistle in the modern midden were disregarded in the analysis.

The results of the pollen analysis (Fig. 3; Murray 1989) are similar to the those from the plant macrofossils. The presettlement middens contained much more pine and sagebrush than the two modern samples (#3 and #4). Similarly, the percentages of grass and buffaloberry pollen were generally higher in the presettlement middens. In contrast, only the two modern middens contained pollen of the exotic Russian thistle and high amounts of juniper pollen. Like the macrofossil cluster analysis, the pollen cluster analysis (right side of Fig. 3) showed that the modern samples are very different from all of the presettlement middens.

Hall's Canyon Middens

Pleistocene Age Middens

Two Pleistocene-age sub-samples were collected from a large midden (Hall's Canyon # 2) located in a high alcove in the Navajo Sandstone near Hall's Canyon (Fig. 4). A picture of the midden itself can be viewed from the web page at: http://www.usgs.nau.edu/methods/middens.html. The front surface of this large midden measures about 2 m wide x 1 m high. The radiocarbon dates from two sub-samples, 28,050±2600 and >39,600 yr B.P., show that this midden is very old. Although the younger radiocarbon sample produced a finite date, dates of this age are less reliable than more recent dates simply because contamination with a minuscule portion of modern material could turn an infinite date (beyond the reach of the radiocarbon method) into a 28,000 year date. As a result, the true age of this midden is not precisely known, but it is definitely ancient, and possibly beyond the resolution of the radiocarbon

Figure 3. Principal fossil pollen from Hartnet Draw middens. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).

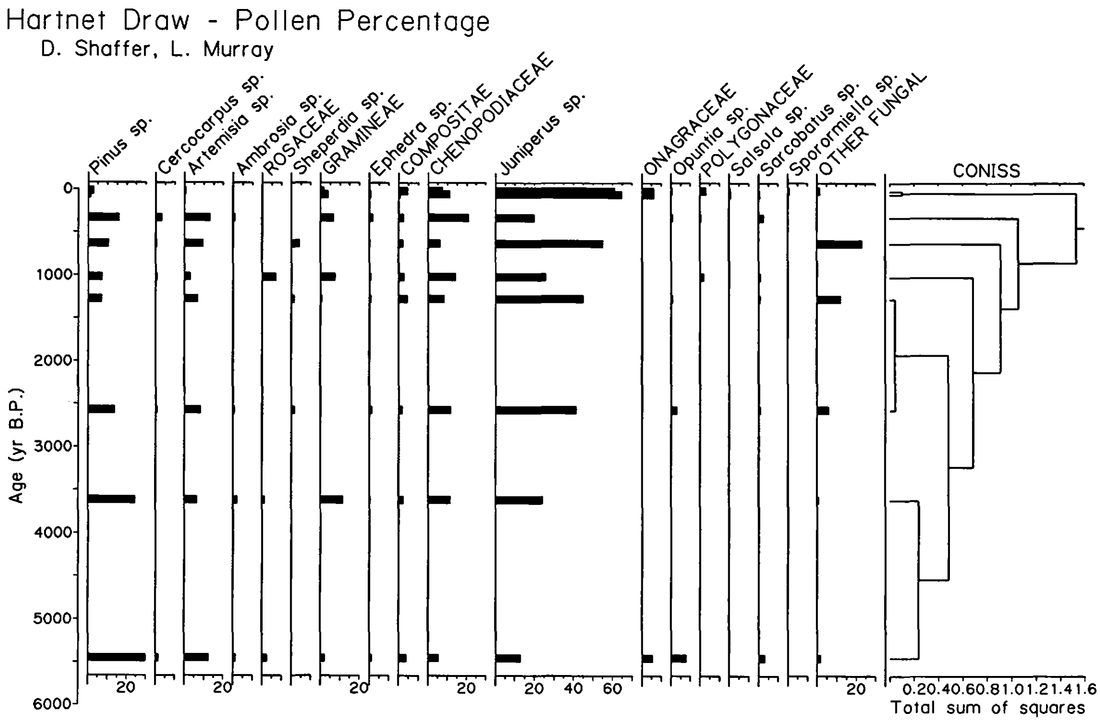


Figure 4. View of Hall's Canyon from alcove in which Hall's Canyon #2 is perched in Navajo Sandstone.

method (> 40,000 to 50,000). The plant macrofossil and pollen content of these samples are shown in Table 2.

Holocene Middens

Nine Holocene middens were collected from several parts of lower Hall's Canyon. Four middens from Hall's Canyon (Baker #3, Hall's Canyon #4, #6, and #7) have a significant probability of dating to either side of 1870 AD and must be considered of Transitional age (Table 1). A fifth midden (Hall's Canyon #8) had only a very small chance of post-dating 1870 AD and is considered Presettlement.

The plant macrofossils from the Hall's Canyon Middens are listed in Table 3 and the major taxa are shown in Figure 5. Sagebrush and winterfat are more concentrated in the Presettlement middens, while cheatgrass (*Bromus tectorum*) occurs in the Transitional and Postsettlement middens. The cluster analysis separates the middens into three groups: Presettlement, Transitional, and Postsettlement. A large difference is apparent between the Presettlement middens and the others. The diversity of taxa between these middens is high, reflecting the microhabitat diversity inherent in an

Table 2. Hall's Canyon #2: Pleistocene pollen and macrofossils.

	Pollen HC2A 28 k	Percent HC2B > 39 k		Macrofossil HC2A 28 k	Percent HC2B > 39 k
Juniperus	10.8	29.7	*Juniperus osteosperma*	73.1	32.8
			Juniperus scopulorum	0.0	1.3
Abies	0.4	0.4			
Picea	0.9	2.7			
Pseudotsuga	5.6	1.9	*Pseudotsuga menziesii*	0.8	39.9
Pinus Total	16.4	5.7	*Pinus flexilis*	0.1	2.2
Ceonot. - Rhamnus	0.4	0.4			
Betulaceae	0.0	0.4	*Ostrya knoltoni*	0.0	0.1
Cercocarpus	0.0	0.8	*Cercocarpus intricatus*	0.2	0.0
Quercus	0.0	1.5			
Ephedra Total	0.9	0.0			
Cheno. \Amar.	5.6	1.5			
Artemesia	27.6	14.1			
Ambrosia	5.6	1.5			
Compositeae	6.0	5.7			
Gramineae	0.0	2.3	*Oryzopsis* sp.	0.0	0.3
Polygonaceae	0.0	0.4			
Sambucus	0.9	0.0			
cf. *Amorpha*	0.0	4.9			
Crucifereae	0.4	4.6			
Labiateae	0.0	0.4			
Leguuminoseae	2.2	4.9			
cf. *Cleome*	11.6	4.6			
Fraxinus	0.0	8.0	cf. *Fraxinus anomala*	0.0	0.3
Juglans	0.0	0.4			
Populus	3.0	2.7			
Salix	0.4	0.0			
Unknowns	6.9	2.6			
Fungal spores	9.1	4.2			
			Yucca cf. *angustissima*	0.0	0.3
			Opuntia sp.	25.8	22.9
Pollen Sum	232	263	Number of Identified Plant Parts	720	1702

area with flat grassland communities adjacent to riparian and rock face habitats.

The results from Hall's Canyon (Fig. 6; Murray 1989) are similar to the macrofossil results. Pine, sagebrush, mountain mahogany (*Cercocarpus*), and Rosaceae are most abundant in the Presettlement middens, while the Postsettlement middens contain Russian thistle and greasewood pollen. The total herbaceous pollen is also more abundant in the Postsettlement middens, perhaps reflecting browsing and other damage to the shrubs.

Table 3. Lower Hall's Canyon plant macrofossils (log_{10} macrofossils per kg washed matrix).

Midden	BS 1	BS 3	HC 4	HC 7	HC 8	N 2	BS 2	HC 6
Age	Modern	20	80	170	265	330	410	105
Artemisia (wood)		1.62				2.28	3	
Artemisia dracunculus		0.84					2.18	
Artemisia filifolia ?			2.65					
Artemisia tridentata							2.74	
Amborsia acanthocarpa			2.47					
Atriplex canescens		0.84	1.07				1.85	2.62
Atriplex	2.34	1.44	3.72	2.53			3.4	
Atriplex confer-type seed			2.25				1.91	
Berberis sp.				2.34		1.33		1.85
Bromus tectorum	1.86			1.3				
Celtis reticulata	2.76	2.16				2.63	1.3	
Cercocarpus intricatus					2.04			
Chrysothamnus sp.								1.15
Coleogyne ramosissima	2.71	2.16	3.28		3.88		2.66	
cf. *Corispermum*			2.35					1.15
Cowania mexicana	1.56		2.59	3.13	2.71		1	2.79
Ephedra sp.		1.92		1.6	2.04	1.81	2.12	1.92
Eurotia lanata	1.86		2.12		2.64	1.93	2.87	1.75
Fraxinus sp.			2.57			2.03		3.1
Gutterezia sp.	1.86	1.84	2.19				3.69	
Juniperus osteosperma	3.34	2.98	3.26	3.95	4.35	2.33	3.73	3.89
Lepidium densiflorum		1.14	1.55			1.63	2.26	1.15
Opuntia sp.	3.73	3.31	2.73	2.38	3.76	2.03	3.7	2.95
Oryzopsis hymenoides	1.56	0.84	1.68		2.34	2.03	2.3	1.15
Phoradendron juniperinum				1.3				
Pinus edulis					3.3			
Plantago sp.			1.07				2.18	2.05
Populus fremontii	1.56	1.54					1.48	
Quercus turbinella					1.74			
Sclerocactus parviflorus	1.56				1.44			
Sporobolis flexosus			1.68			1.33		
Sphaeralcea	1.56						1.85	
Yucca angustissima	2.46	1.79	2.61		2.87		2.23	
small hispid grass	1.14					2.11		

The cluster analysis of the Hall's Canyon pollen samples is very similar to that of the plant macrofossils.

Long Leaf Flat Middens

Two midden samples, one Presettlement and one Postsettlement, were collected from an alcove near Long Leaf Flat adjacent to some

Figure 5. Principal plant macrofossils from Hall's Canyon Holocene middens. Fossil values are displayed as Log_{10} of concentration. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).

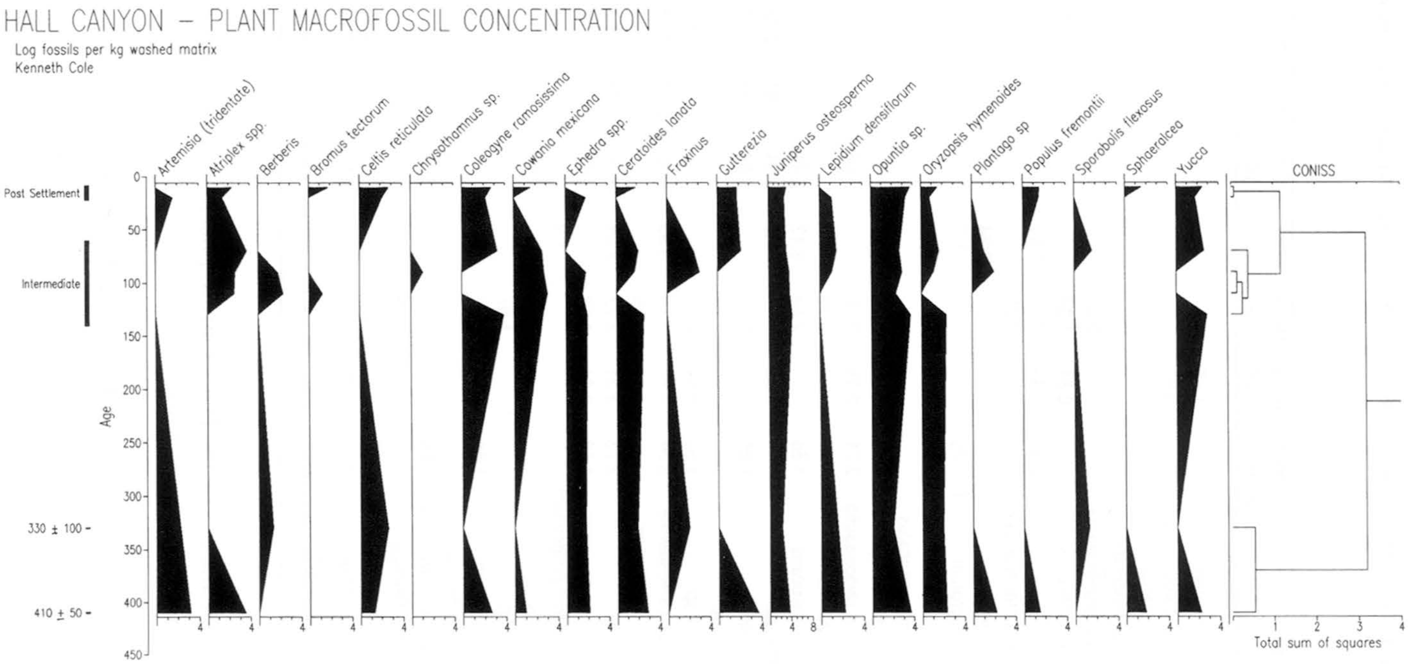
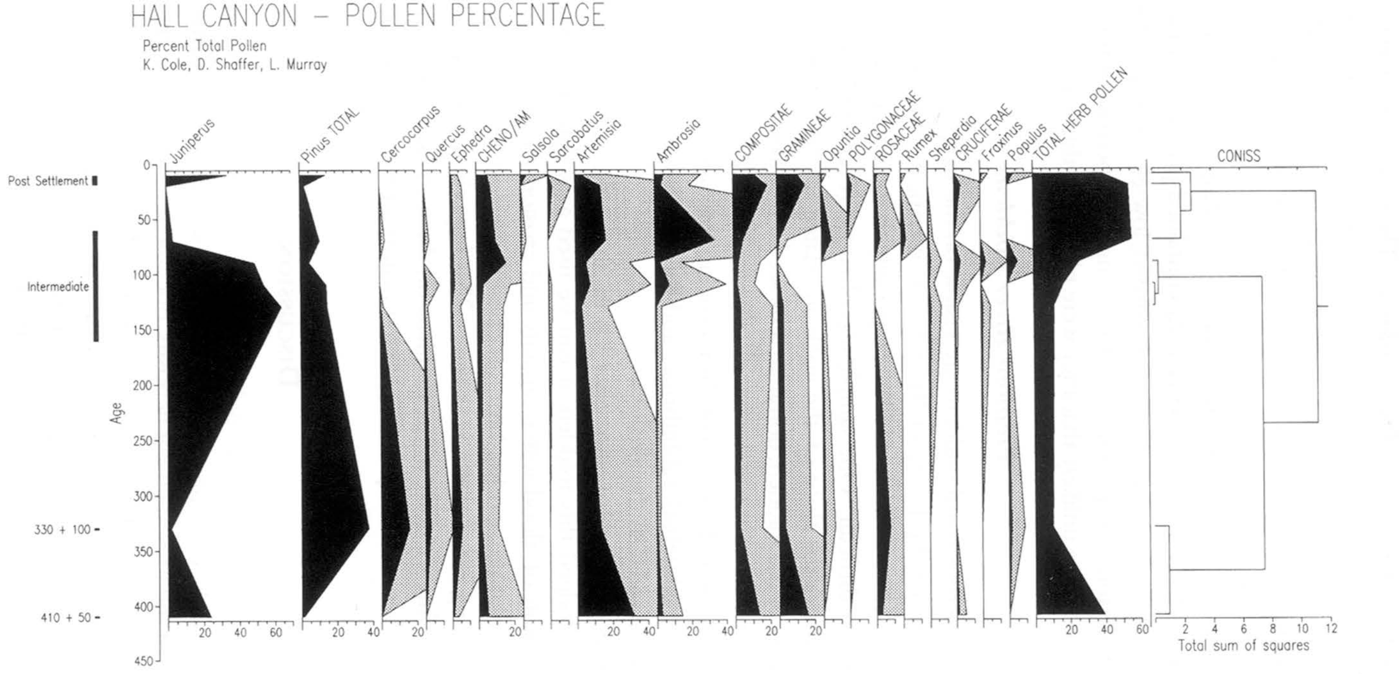


Figure 6. Principal fossil pollen from Hall's Canyon Holocene middens. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).



isolated ponderosa pine (*Pinus ponderosa*). The pine trees, growing at 1980 m elevation, 475 m below their normal lowest occurrence (Heil et al. 1993), appear to have possibly been planted because of their isolated distribution. They are growing at the base of a sandstone cliff where runoff is focused.

Both the Postsettlement midden (LLF #1a) and the Presettlement midden (LLF #1b; 1030±80 yr B.P.) contained ponderosa pine needles. These results demonstrate that the isolated, low-elevation ponderosa pine have probably occupied this site for a long time, perhaps throughout the Holocene. It is unlikely that they were planted at this site.

Fremont River Middens

Numerous fossil middens are visible on the steep canyon walls along the length of the Fremont River between park headquarters and Deep Creek. Access to these middens, especially those that appear to be old, is often very difficult. One sample was obtained (Fremont River #1) about 7.6 m above the floor of the wash and dated to 7010±105 yr B.P. The contents of the midden, dominated by seeds of squawbush (*Rhus trilobata*) with some Fremont cottonwood (*Populus fremontii*) and hackberry (*Celtis reticulata*), showed no signs of the recent invaders such as saltcedar (*Tamarix pentandra*), whitebark rabbitbrush, and Russian thistle (*Salsola kali*) that are abundant today at the site.

Because flood waters over 7.6 m above the modern wash would have dislodged this midden, it can be used as a datum to estimate the upper limit of flood water capacity and erosion rate along the river. It appears that erosion has been proceeding quite slowly along the river, at least during most of the Holocene. This hypothesis can easily be tested through further study of the middens on these cliffs, in addition to documenting a more complete vegetation history of the local riparian vegetation.

DISCUSSION

The macrofossil and pollen data from Capitol Reef National Park show that the contents of Postsettlement middens are very different from those of the Presettlement deposits, documenting vegetation changes that have occurred during the last several hundred years. All of the Presettlement middens are statistically more similar to each other than they are to the Postsettlement middens. This suggests that the change in vegetation during the last 150 years was far greater in magnitude than changes during the previous 5000 years. This result is most definitive at

Hartnet Draw, where the midden series spans 5000 years. In contrast, the Hall's Canyon middens, collected from cliffside ledges, emphasize cliff-dwelling shrubs. The limited time range of the series and the four Transitional age middens (which could not be clearly classified as Pre- or Postsettlement) limit the resolution of the Hall's Canyon data in determining settlement impacts.

The perspective of natural variation emphasizes the extreme severity of the recent vegetation changes. Formerly there was a greater coverage of grasses, winterfat, sagebrush, and pinyon pine, as indicated by the plant macrofossils and pollen. Although the vegetation probably fluctuated continuously throughout the late Holocene, this midden record suggests that previous changes were minor compared to the changes of the last 150 years. The presettlement plant community was likely more similar to the Pinyon-Juniper-Grass Community described by Romme et al. (1993) than the juniper-shrub community present at the Hartnet site today.

Drought History

The reductions in winterfat, pinyon pine, sagebrush, and ricegrass, and increases in juniper, rabbitbrush, and snakeweed might be attributed to droughts during the nineteenth or twentieth centuries. But, an analysis of the last 400 years of drought frequency for southeastern Utah (Cole et al. 1997) using tree-ring data compiled by Fritts (1991), suggests that the droughts of the nineteenth century were not unusually severe when compared to the seventeenth century. Less is known about the climatic variability between 400 and 5000 years ago (prior to this tree-ring record), but it seems unlikely that any climatic event of the last 200 years was sufficient to cause a change with no precedent during the previous 5000 years. Drought undoubtedly did assist in some of the dramatic vegetation changes of the last 200 years, but did not set the stage for them. This would require an event unprecedented during the previous 5000 years.

Fire History

Some of the changes recorded in the middens may have been caused by changes in fire regime. The recent increase in juniper could result from a decrease in fire frequency caused by the elimination of the grassy fuels by grazing. But this does little to explain the shift from palatable to non-palatable species or the reductions of pinyon pine, sagebrush, and buffaloberry just at the time that fire frequency would decrease.

Grazing Impacts

Impacts from introduced herbivores, especially large sheep herds in the late nineteenth and early twentieth centuries, are the most likely cause of the recent radical vegetation changes. The introduction of sheep, goats, cattle, and horses was without precedent during the previous 5000 years. Overall, the vegetation has shifted from palatable forage (grasses, winterfat, and buffaloberry), to less palatable forage (rabbitbrush, snakeweed, and greasewood). Rabbitbrush and snakeweed are typical invaders of overgrazed range (Benson and Darrow 1981, Heil et al. 1993, Cronquist et al. 1994).

Other studies conducted on grazing at Capitol Reef support this conclusion. Heil et al. (1993), in a survey of the vegetation of Capitol Reef National Park, state that, "Some of the most preferred plant species (for grazers), e.g., *Ceratoides lanata* and *Stipa comata*, may have been locally extirpated by grazing." This is demonstrated by the packrat midden series from Hartnet Draw site.

An analysis of grass opal phytoliths in buried soil horizons at Capitol Reef shows a reduction of palatable grass species over the last several hundred years (Fisher et al. 1995). In general, opal phytoliths from warm season grasses have recently increased at the expense of cool season grasses. The authors attribute this change to the winter grazing that has taken place on these lands.

In a comparison of bird usage of grazed areas near the Hartnet site with similar rarely grazed areas nearby, Willey (1994) found that grazed areas were significantly lower in bird species richness. He attributed the difference to a less complex structure in the grazed vegetation. His vegetative comparisons showed higher grass coverage in the rarely grazed areas, especially a higher coverage of ricegrass, further supporting the results of this study.

An analysis of riparian areas (Barth and McCullough 1988) indicated that dramatic changes had occurred prior to the Taylor Grazing Act of 1934. Forage plants were heavily used, and in many instances cover was entirely removed. Recent grazing has perpetuated this removal or reduction of species and inhibited potential recovery. In a lightly grazed area palatable shrubs and grasses have increased significantly.

Pinyon Pine Decline

Dramatic declines in pinyon, sagebrush, and buffaloberry occurring within the most recent several hundred years were probably also caused by grazing, but the effects on these species are less well understood. Pinyon-juniper woodlands have been reported to have increased in the

Great Basin during the historic period, especially when comparative photographic techniques which can not discriminate between pinyon and juniper are used (West et al. 1975, Tausch et al. 1981). This increase in pinyon-juniper woodlands is thought to have been caused by reduced competition from grasses and forbs, which were eliminated by grazing and by consequent reductions in fire frequency. However, studies discriminating between pinyon and juniper do not portray identical histories for both species. Juniper populations have been expanding rapidly, and in places such as western Oregon where it is not associated with pinyon, the expansion is clear, although there are numerous possible causes (Miller and Wigand 1994). Pine and sagebrush both declined while juniper dramatically increased during the settlement period at Peck's Lake, Arizona (Davis 1987). A study of tree age structure on a presently ungrazed site in the Needle Range in southwestern Utah found that during the nineteenth century many juniper and few pinyon were established. By 1915, the situation had reversed with far more pinyon becoming established in this century (Tausch and West 1988). These results demonstrate that pinyon and juniper respond differently to changing regimes of grazing, fire, or climate. The observation that heavy grazing causes an expansion of pinyon-juniper woodland (West et al. 1975) does not equate to the expansion of both species in all habitats.

The results of Tausch and West (1988) and those of the present study, suggest that pinyon may have been greatly reduced during the late nineteenth century/early twentieth century by the large numbers of sheep grazing the landscape during drought. Pinyon may now be recovering part of its former range, assisted by the absence of fire. Sheep readily consume pine needles and strip pine bark even in the absence of drought conditions (Anderson et al. 1985). Sheep accomplished the near complete elimination of the Bishop pine forest (*Pinus muricata*) on Santa Cruz Island, California, where they were not fenced out (Hobbs 1980). Cattle will also browse some pine when it is available (Pfister and Adams 1993), but are less likely to consume entire forests. This suggests that knowledge of the effects of cattle grazing at present stocking levels forms an inadequate basis for judging the effects of an overstocked sheep range during the droughts of the late nineteenth century.

Sagebrush populations may have a similar history despite observation of increases in sagebrush caused by the removal of their grass competitors (Young et al. 1978). Although sagebrush may be increasing on land presently grazed by cattle, this is not an appropriate analog for intense nineteenth century sheep grazing. Sagebrush is consumed by sheep during droughts. During the late nineteenth century, sheep severely reduced the populations of California sagebrush (*Artemisia californica*) on Santa Rosa Island, California, after first consuming the grass (Cole and Liu 1994).

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Changes in Character and Structure of Apache/Sitgreaves Forest Ecology: 1850-1990

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Abstract. This analysis of the Apache/Sitgreaves National Forest in eastern Arizona was undertaken to evaluate changing ponderosa pine (*Pinus ponderosa*) overstory tree densities and their potential environmental and economic impacts. Assessment of 100 years of forest overstory data on the Apache/Sitgreaves reveals significant change in overstory character and structure. Evaluation of early written observations by explorers, surveyors and naturalists indicate that tree densities of the 1850s were low, and the forest floor had minimal fuel loads. Recent research on the Forest indicates pre-European settlement tree densities were originally as low as 34 trees per acre above 4" dbh. Analysis of surveys completed in 1911, 1967, 1988, and 1994 reveals that the number of trees per acre in ponderosa pine type has increased significantly from approximately 34 trees per acre above 4" dbh in 1911, to 133 trees per acre above 4" dbh in 1994. Tree density increases have occurred in all diameter classes up to 20" dbh. The analysis determined that approximately 21 trees existed in these classes in 1911 and over 127 trees exist today. This represents a 500 percent increase in tree densities between 4" and 20" dbh over the century. The analysis also determined that of the average of 13 trees per acre above 20" dbh in 1911, 7 exist today, a loss of approximately 50%. Computer simulated treatments to the forest overstory that approach presettlement conditions reveal significant enhancement of forest ecosystem resources as compared to no treatment alternatives. Further, implementation of restoration treatments would realize positive net present values from public investments.

Key words: Forest ecosystem impacts, presettlement, fire suppression, forest resource assessment, tree densities, stand density index, economic evaluation

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This document presents a summary of findings from a study of past, present and potential future forest overstory conditions on the Apache/Sitgreaves National Forest. Brevity required in this summary permits coverage of only the most significant findings from two more comprehensive technical reports. The reader is referred to the full reports cited below for in-depth coverage of the forest assessment.

INCREASING TREE DENSITIES IN PONDEROSA PINE FORESTS: A NATIONAL PROBLEM

In a 1994 hearing before Congress, Dr. Jack Ward Thomas, Chief of the USDA Forest Service, reported that the ponderosa pine region of the interior west United States was being severely impacted by declines in forest health. He also noted that these forests have high potential risk of loss to catastrophic insect, disease and wildfire. The current administration has placed specific emphasis on the northern interior west ponderosa pine region, due to significant insect, disease and wildfire losses. Comprehensive analysis of forest health has been initiated in the region to develop more effective forest management alternatives for combating extensive degradation to forest ecosystems (USDA Forest Service 1994, Sampson and Adams 1994).

As declared in Chief Thomas' testimony to Congress, increasing tree densities is the primary factor contributing to degraded ecosystems and declining health in interior west ponderosa pine forests. These forests are the most extensive coniferous forest ecosystems in the western United States, dominating millions of acres of terrestrial environments (Sampson and Adams 1994).

Ponderosa pine forests have been determined to be fire-driven forest ecologies (Pyne 1982, Covington and Sackett 1985, Swetnam 1990). Over thousands of years, wildfires, unbridled by the suppression activities of man, moved at regular intervals across entire western landscapes. Recurring fires would burn through almost all accessible pine acreages at intervals of three to twenty years, depending on the regional location. In the southwest region of the United States, these ground fires created a forest landscape of 25-50 trees per acre, dominated by 10" dbh and larger trees (White 1985, Covington and Moore 1994a, Garrett et al. 1997).

Intensities of these historical wildfires were low, because the short recurring intervals between fires maintained fuel loads well below 10 tons per acre (Covington and Sackett 1985, Swetnam 1990). Older trees, especially trees greater than 10" dbh with developed thick bark, were largely resistant to damage from these ground fires. Smaller trees, such as seedlings and trees up to 5" dbh, were normally destroyed, with only a few surviving to maintain the open forest overstory of the period (Woolsey 1911, Pearson 1923).

Introduction of fire suppression activities in western forests at the turn of the century, combined with livestock grazing and other less significant factors, have contributed to the radical increases in tree densities noted in ponderosa pine forest stands today (Covington and Moore 1994b, Garrett et al. 1997). Critical concerns now exist that restraints on restoration management in this forest type could further aggravate already seriously overstocked conditions.

Increasing tree densities in ponderosa pine type and its impacts on forest health is now becoming a concern in the Southwest. For example, research completed in the past five years by university and government forest specialists have characterized significant increases in densities of ponderosa pine overstories in Arizona (Garrett et al. 1990, Ellenwood 1994, Johnson 1995). Selected research plots on the Kaibab and Coconino National Forests suggest that densities have increased across broad landscapes, from less than 50 trees per acre in the late 1800s to 300 or more trees per acre in the 1990s (Covington and Moore 1994b).

Assessments of changing overstory densities on all ponderosa pine forests in Arizona demonstrated that trees increased from an average of 272 per acre in 1962 to 314 per acre in 1985 (Garrett et al 1990). Analysis conducted on differing datasets for all species on all ownerships in Arizona and New Mexico reveals average trees per acre increased from 233 in 1962 to 296 in 1986 (Johnson 1995). In both assessments, the increases exceeded 10 percent in 23 years (Figs. 1 and 2). These increasing tree densities raise the specter of potential forest ecosystem degradation,

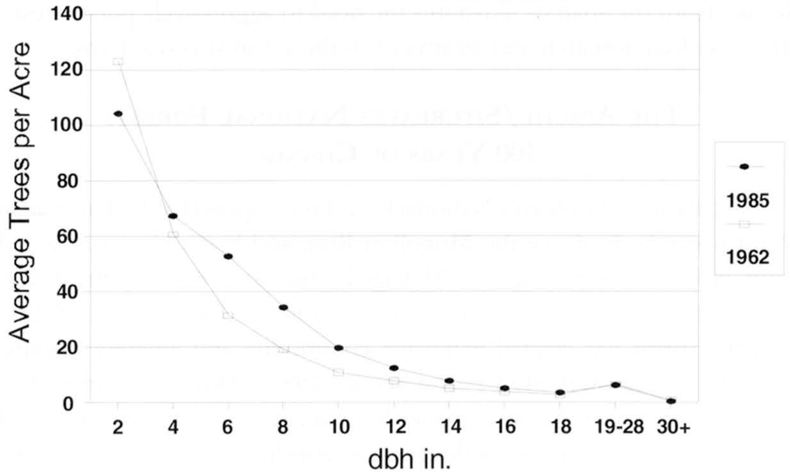


Figure 1. Comparison of average trees per acre on all Arizona ponderosa pine forests: 1962 and 1985. Adapted from Garrett et al. (1990).

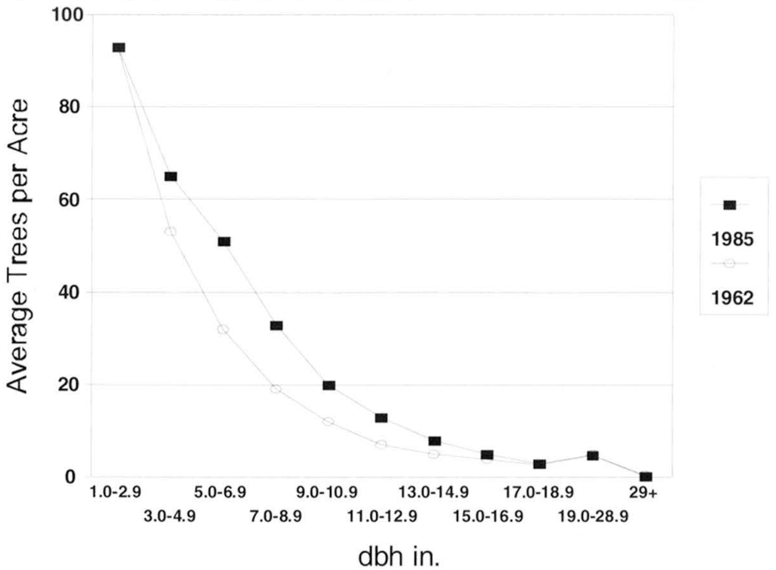


Figure 2. Comparison of average trees per acre for all species and all ownerships in Arizona and New Mexico: 1962 and 1985. Adapted from Johnson (1995).

due to expected impacts on other resources such as soil water, understory productivity, fuel loads, and wildlife habitat.

This analysis of the Apache/Sitgreaves National Forest in eastern Arizona was undertaken to evaluate changing ponderosa pine overstory tree densities and their potential environmental and economic impacts. Results from the analysis illustrates the need to aggressively pursue restoration ecology research and treatment in these forest ecosystems.

THE APACHE/SITGREAVES NATIONAL FOREST: 100 YEARS OF CHANGE

The Apache/Sitgreaves National Forest is comprised of high mountain forest watersheds above the Mogollon Rim, and lower elevation woodlands below the rim (Fig. 3). Managed since the 1890s by the USDA Forest Service and its predecessor division in the Department of Interior, the forest has yielded extensive commodity and amenity resource values to the region (USDA Forest Service 1988). However, during these same 100 years its forest overstories have changed significantly, responding to changing management direction established for the forest over the period.

The character of the extensive ponderosa pine ecosystems of the

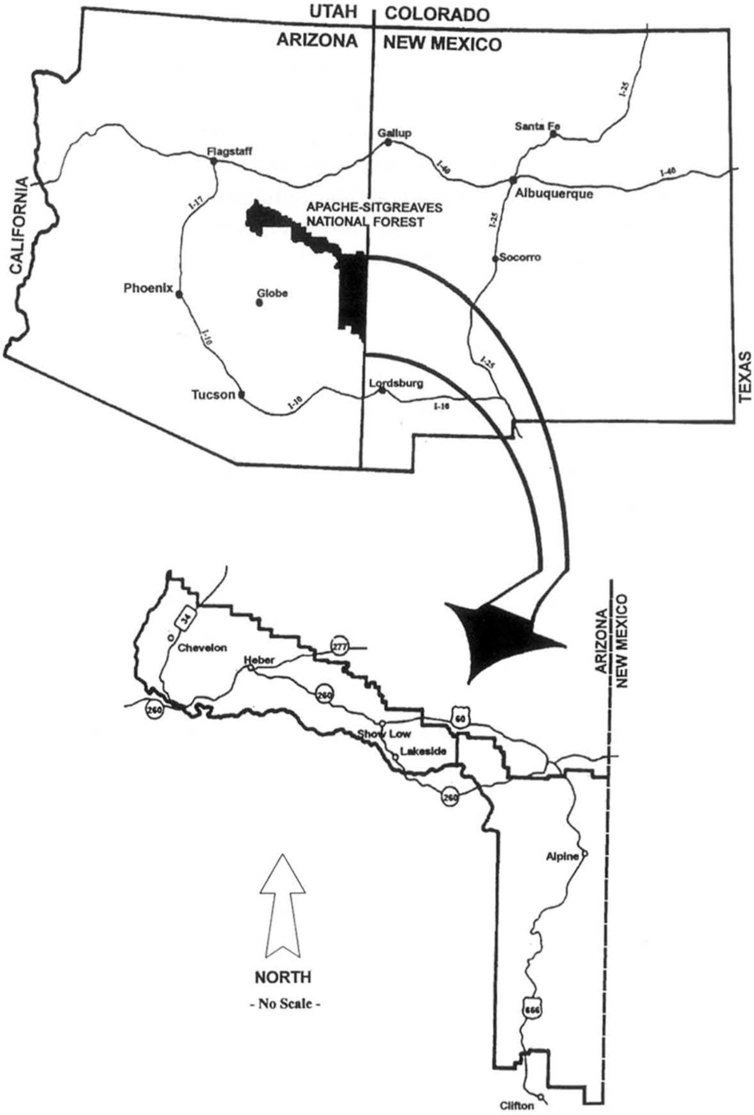


Figure 3. Location of the Apache/Sitgreaves National Forest in the Southwestern Region.

Apache/Sitgreaves National Forest and the Southwest were described by many early explorers, naturalists and geologists in the mid and late 1800s (Cooper 1961, Garrett et al. 1997). Of particular note are the descriptions by Beale (1858), Dutton (1882), and Woolsey (1911). Beale (1858) described the forest as follows:

> "We came to a glorious forest of lofty pines, through which we have traveled ten miles. The country was beautifully undulating, and although we usually associate the idea of bareness with the pine regions, it was not so in this instance: every foot being covered with the finest grass, and beautiful grand grassy veils extending in every direction. The forest was perfectly open and unencumbered with brushwood, so the traveling was excellent."

Dutton (1882) noted:

> "The trees are large and noble in aspect and stand widely apart, except in the highest parts of the plateau where the spruces predominate. Intervals of dense thickets where we are shut in by impenetrable foliage, we can look far beyond and see the tree trunks vanishing away like an infinite colonnade. The ground is unobstructed and inviting. There is a constant succession of parks and glades—dreamy avenues of grass and flowers winding between silvan walls or spreading out in broad open meadows."

And in 1911, Woolsey, a prominent forest specialist of the period, wrote:

> "A pure park-like stand made up of scattered groups of 2 to 20 trees usually connected by scattering individuals. Openings are frequent, and very great in size. Within the type are open parks of large extent whose origin may be due to peculiar soil conditions such as hard pan, or in other cases to periodic flooding."

The following visual description of typical 1800s ponderosa pine forests is interpreted from the above and other early writings:

> "The forest was open and park-like with less than 60 trees per acre, distributed in clumps, 3 to 30 trees in number. Large trees were dominant in the landscape, however, clumps of smaller trees existed. Open park areas were prominent, occupying 10 or more percent of the forest area. Southerly slopes had significant gamble oak and drainages, especially on northerly slopes, would have notable presence of aspen, Douglas fir and concolor fir. Forest floor debris was minimal, averaging less than 10

tons per acre across broad landscapes. Understory vegetation was dominated by grasses and forbs."

Early descriptions of the forest overstory have been recently corroborated by scientists involved in restoration ecology research and conservation biology (Covington and Moore 1994b, White 1985). Forest ecology specialists have, through scientific procedure, been able to reconstruct and successfully define the forest overstories of the southwest ponderosa pine type that existed 150 or more years ago. This research has documented the original pre-European settlement forest to have maintained less than 50 trees per acre across regional landscapes. Selected forest areas studied and the overstory densities determined for these areas are presented in Table 1. As noted, the general average range in tree stocking is approximately 25 to 50 trees per acre (Table 1). Two forest specialists of the period, Pearson and Woolsey, conducted surveys and evaluations of the southwest ponderosa pine type during the first decade of the century (Woolsey 1911, Pearson 1910, 1920). Woolsey (1911) summarized inventory assessments of southwest ponderosa pine forests that were conducted over the period 1900 to 1910. Figure 4 presents a graphic of the average number of trees per acre from surveys on six forests in the Southwest during the 1900-1910 period. Included is the Black Mesa Forest Reserve, known today as the Apache/Sitgreaves National Forest.

Woolsey's (1911) inventory analysis of the Black Mesa Forest Reserve revealed an average of 34 trees per acre above 4" dbh. This number of trees per acre lies at the mean of current assessments by restora-

Table 1. Density of southwestern ponderosa pine presettlement or yellow pine trees reported in the literature.[1]

Location	Trees/acre
Specific studies in Southwest:	
Ft. Valley, Coconino N.F.	15
Bar-M, Coconino N.F.	23
North Kaibab R.D., Kaibab N.F.	56
North Kaibab R.D., Kaibab N.F.	40-45
White Mountains, Apache/Sitgreaves N.F.	35-45
Southern Utah, Zion N.P.	22.7

[1]Adapted from Covington and Moore 1994, White 1985, Covington and Moore 1994a, Covington and Moore 1994b, Rasmussen 1941, Cooper 1960, and Madany and West 1983.

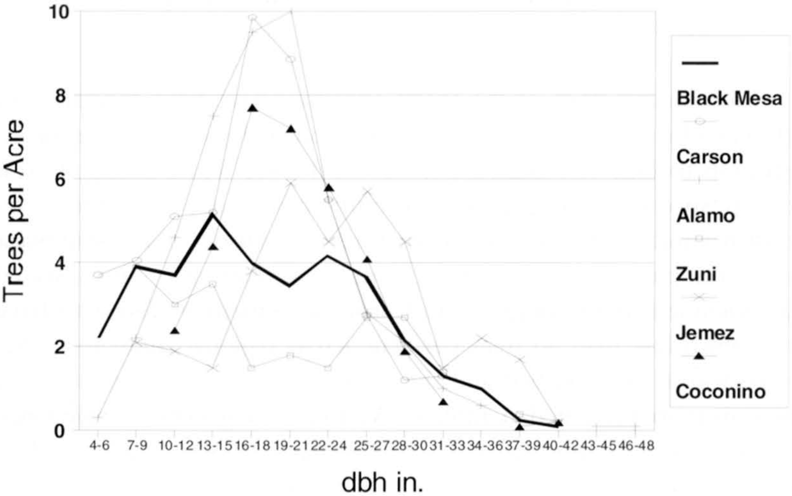


Figure 4. Trees per acre by diameter class from maximum stands of Western Yellow Pine on six southwest forests in 1911. Derived from Woolsey (1911).

tion ecologists (Table 1), and as noted in Figure 4, somewhat at the mean for the differing forest inventories evaluated by Woolsey (1911).

It is difficult to determine from these early surveys the average number of stems per acre below 6" or 4" dbh, because inventory specialists used differing techniques to determine the number of small trees. More importantly, data taken on 1"-6" trees in the first decade of this century might significantly overstate the number of trees that existed during the earlier presettlement period. This is due to the fact that in many forest areas, Anglo settlers' efforts to suppress ground fires had occurred for 10 to 30 years by 1910 (Pyne 1982, Swetnam 1990). This permitted time for establishment of not only seedlings, but trees up to 4" and 6" by 1910. Due to the above noted uncertainties in early data collection on small trees, most of our analysis focused on evaluating changes in tree densities over 4" dbh.

Since the first descriptions and inventories of the presettlement forests, there have been nearly 100 years of USDA Forest Service management activity on the Apache/Sitgreaves National Forest. The general guiding principles for this management direction was derived from the first U.S. Forest Service Chief Forester, Gifford Pinchot (1947). He defined his management principle as "wise use." The concept proposes perpetual protection of the basic biological and physical resources of forest ecosystems, while managing for "wise use" of forest resources such as timber, water, forage, etc. Pinchot's general philosophy and management concept is sustained today on declared "multiple use" areas of National Forests. The current philosophy of "ecosystem management," adopted in the 1990s, places more intensive focus on protection of basic biotic and physical resources, and to restore health and diversity of ecosystems (USDA Forest Service 1994).

The wise use overstory management philosophy was implemented via a silviculture method known as "selection harvest," and was used on National Forests up until the 1970s (Pinchot 1947, Pearson 1950, Schubert 1974). This procedure resulted in discriminate selection of diseased, deformed and overmature trees for harvest, and the removal of approximately 1500 board feet per acre during an entry (Pearson 1950, Schubert 1974).

In the presettlement pine forest many trees were overmature and 200-300 years in age. Since the average biological life of ponderosa pine is approximately 250 years, many presettlement trees would have succumbed to natural mortality over the first 100 year management cycle (i.e., 1900-2000). As such, a management direction was undertaken to remove the oldest and most susceptible trees to loss, during the first 100 year management period (Lang and Stewart 1910). This management regime was expected to yield a younger healthier forest at the end of the management period.

By the 1970s and 1980s, forest managers began to recognize that forest stands were becoming increasingly more dense due to regeneration and ingrowth. Insect and disease, especially dwarf mistletoe, was increasing, requiring modification in management regimes.

New integrated resource and integrated stand management (IRM, ISM) prescriptions were adopted in the 1970s and 1980s to reduce increasing densities. When implemented, these prescriptions removed nearly 3500 bd. ft. per acre from acres entered. This heavier removal of trees to address forest health issues was met by considerable resistance from segments of the general public. ISM prescriptions were discontinued by forest managers in the late 1980s in favor of current ecosystem management prescriptions.

The above noted management practices implemented over the past century, especially managed fire suppression and some harvest activities, have resulted in a changed forest overstory character and structure, which is clearly evident in Figure 5. This figure presents average trees per acre on the Apache/Sitgreaves National Forest from several survey years, rang-

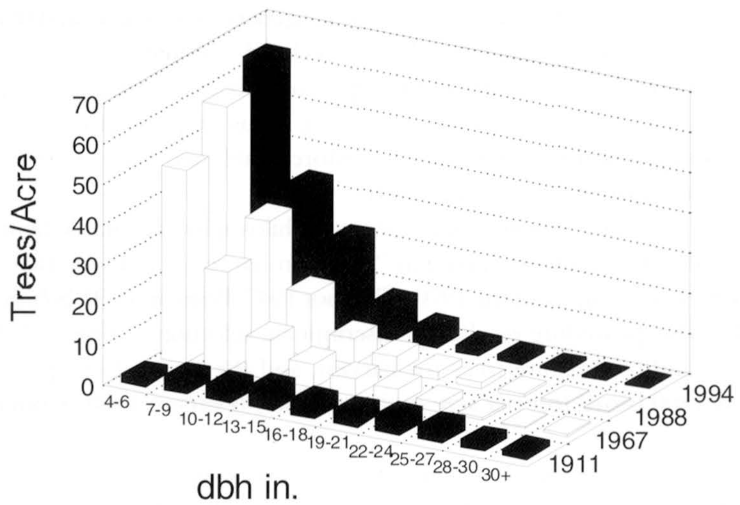


Figure 5. Comparison of average trees per acre on the Apache/Sitgreaves in 1911, 1967, 1988 and 1994.

ing from 1911 to the current forest assessments of 1994. Three general findings are obvious from these inventory assessments:

1. The number of trees per acre has increased significantly from approximately 34 trees per acre above 4" dbh in 1911, to 133 trees per acre above 4" dbh in 1994.
2. Tree density increases have occurred in all diameter classes up to 20" dbh.
3. A reduction in trees per acre has occurred in diameters over 20" dbh.

The analysis demonstrates that there have been significant increases in trees per acre from 4" to 20" dbh. The approximately 21 trees that existed in these classes in 1911 has increased to over 127 trees today. This represents a 500 percent increase in tree densities between 4" and 20" dbh over the century.

In the presettlement period, an average of approximately 10-13 trees existed above 20" dbh. Approximately 6-8 trees existed between 20"-25" dbh, and 4-5 trees above 25" dbh. Evaluations of early surveys indicate that an average of only 0.5-1.5 trees per acre existed above 30" dbh (Lang and Stewart 1910, Woolsey 1911, Pearson 1950).

There has been a decline in trees per acre over 20" dbh. Although the decline represents only 6-8 trees per acre on average, it is a loss of over 50 percent of the original numbers of trees that existed above 20" dbh. Most of the loss (2-4 trees) are in the 22"-27" dbh diameter classes. Losses are due primarily to harvests and natural mortality.

Today an average of only six trees exist above 20" dbh, indicating the above noted loss of 6-8 trees in these size classes. Some caution is noted regarding this conclusion. Woolsey's (1911) surveys on the Black Mesa Forest were of "maximum stands," indicating that average overall stocking across the forest might have been lower in large diameter classes.. For example, an early comprehensive survey on the North Kaibab revealed an average of only 7-9 trees per acre greater than 20" dbh (Lang and Stewart 1910, Ellenwood 1994, Garrett et al. 1997).

Forest Ecosystem Impacts of Past Forest Management Directions

The Forest Service new "ecosystem management" direction purports to focus more attention on the protection of intrinsic biophysical values associated with the land base. Protection of threatened and endangered plant and wildlife species is a critical part of ecosystem management (USDA Forest Service 1994). In so doing, standards and guidelines are written to accommodate increased levels of protection and, therefore, impose greater restrictions on management and use activities.

Protection activities for threatened and endangered flora and fauna and associated habitat has become a primary component of land resource management. However, excessive constraints on management activities in these habitats may not embody the basic philosophical intent of ecosystem management. For example, the current underlying management philosophy for threatened, endangered, or sensitive (TES) species is single species management, a concept potentially incongruent with ecosystem management. The USDA Forest Service mandate to protect intrinsic values of forest ecosystems may well become the basis for the Forest Service to implement aggressive and comprehensive restoration science and management activities in the western ponderosa pine type.

There are reasons to be concerned about the current status of southwest ponderosa pine forests. Scientific documentation now exists to not only characterize increasing tree densities, but also define the potential impacts of these densities to other resources of the forest ecosystem, such as water, soils, forage, wildlife habitat, and basic intrinsic values such as health, diversity and sustainability.

Research on southwest pine forests has demonstrated fully that increasing densities in this forest type is not a "natural phenomenon" (Cooper 1961, Schubert 1974, Ellenwood 1994, Covington and Moore 1994b). In fact, it is a phenomenon driven by man's imposed management activities. Suppression of natural, low-intensity ground fire in these forest ecosystems and other management activities previously noted, have created the current character and structure of the forest overstory.

Research on the resource impacts of increased tree densities has demonstrated that moderate and high tree densities in this forest type significantly impact soil water, fuel loads, understory plant productivity, wildlife habitat, etc. (Brown et al. 1974, Rogers et al. 1984, Covington and Moore 1994b). In general, these abnormally high densities have been demonstrated through science to:

1. Significantly increase intra-tree competition for moisture and nutrients so as to impose significant stress on all trees.
2. Increase the probability of loss of larger, over-mature trees, due to their inability to sustain themselves under the increased stress from intra-tree competition.
3. Increase the vulnerability of all trees in the stand to insect and disease infestation, and the spread of infestations once established.
4. Decrease average soil moisture content.
5. Decrease water movement to seeps, springs and instream flows in the forest environment.
6. Increase fuel loads.
7. Decrease grass, forb and shrub production.
8. Increase factors contributing to higher risk of catastrophic insect and disease outbreaks.
9. Increase factors contributing to higher risk of intense catastrophic wildfire on larger acreages.

POTENTIAL FUTURE OUTCOMES FROM ALTERNATIVE OVERSTORY MANAGEMENT REGIMES

To evaluate potential implications of permitting increased densities to be maintained on the Apache/Sitgreaves National Forest, we simulated 50 years of changing forest conditions associated with two different management regimes. The regimes and associated prescriptions selected for the simulations are deliberately divergent. This was done to demonstrate the wide matrix of opportunities and outcomes that exist in managing the diverse forest landscape.

Like all modeling efforts, the management alternatives are made simplistic to permit clear measure of impacts of the different treatments. Actual treatments applied across broad forest landscapes would be much more complex and involve a mosaic of overstory character and structure. Tree densities would also vary significantly. However, in many forest areas, average forest structure and tree densities can be significantly changed with restoration treatments, as they are changed in our computer derived examples.

The treatments that were implemented are as follows:

- A no management treatment to the forest overstory. This treatment assumes no removals of any overstory trees through the selected management period of 50 years. Thinnings, harvest removals, and timber stand improvement removals are all excluded as management activities. Regeneration occurs through the period, as well as minimal insect and disease control.
- A Pre-European settlement overstory treatment. This management alternative restores the forest overstory to the presettlement character and structure defined by overstory surveys at the turn of the century. It requires implementation of several management activities including prescribed burns, fuel removals, thinnings, harvests, etc.

Using the southwest ponderosa pine ECOlogy SIMulator; ECOSIM, forest overstories and associated resources (i.e., understory forage, instream water, fuel loads, wildlife habitat, scenic quality, etc.) can be projected into the future (Rogers et al. 1984, Covington et al. 1986). The system is driven by management activities selected by the manager and/or analyst. The choice of management activities are broad, and can include overstory and understory treatments, watershed improvements, wildlife habitat improvements, prescribed burns, etc.

Defining The Current Forest Condition

Before one can proceed to project future change with the computer model ECOSIM, one must first define the current state of the forest. Figure 6 is a characterization of the average number of trees per acre by diameter class that currently exist on the Apache/Sitgreaves National Forest. This average stand condition is developed from a sample of 15 analysis areas on the forest, representing over 130,000 acres (Fig. 7).

Table 2 provides descriptive data on the current average stand conditions on six of the above noted analysis areas (Fig. 7). Baca, South Fork, Middle Mountain, Grapevine, Cottonwood and Blue Ridge Morgan analysis units were selected for evaluation of various future resource impacts under our two proposed management alternatives. The average

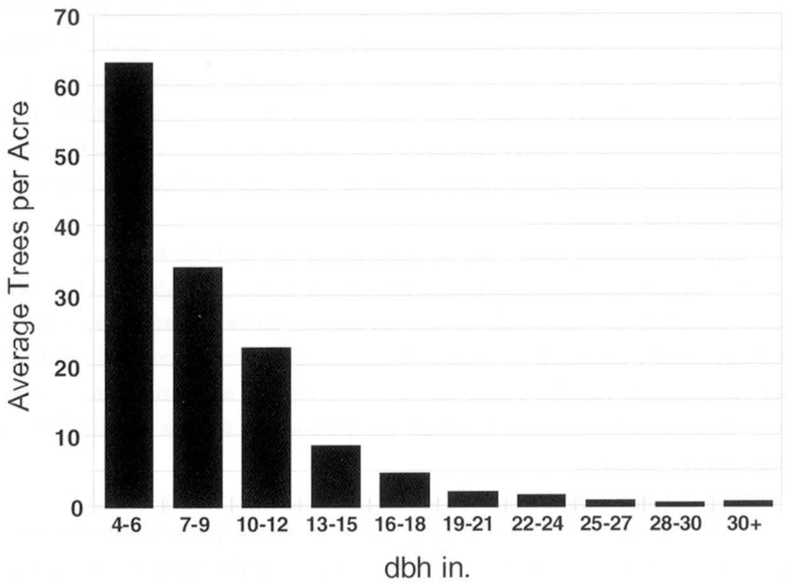


Figure 6. Average trees per acre on the Apache/Sitgreaves National Forest, 1994.

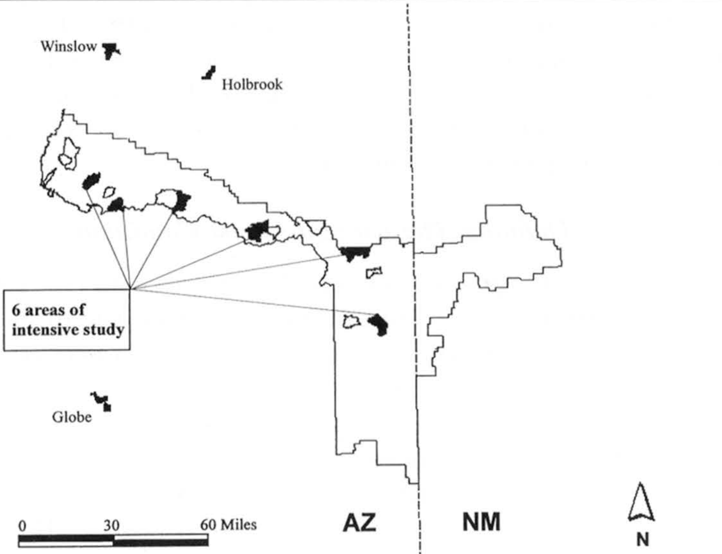


Figure 7. Location of 15 analysis areas and the six areas used for more intensive study.

Table 2. Current average stand conditions per acre on six selected analysis areas on the Apache/Sitgreaves National Forest.

Analysis Area	% of PP in Stand	Average Basal Area	Average SDI	Percent Max-SDI	Average Trees/ac	Acres
Baca	71.01	130	267	59.33	942.2	9,570
Blue-Ridge Morgan	63.25	140	326	72.44	457.1	17,034
Cottonwood	69.10	91	204	45.33	1022.0	18,725
Middle Mt.	67.62	101	200	44.44	333.7	13,110
Southfork	59.70	109	226	50.22	509.0	16,807
Grapevine	86.22	96	103	42.89	940.9	9,240

overstory conditions across the forest and on the six individual analysis areas are similar.

Forest ecologists utilize differing measures to both monitor densities, and relate increasing densities to degradation in other resources. Basal area, the measure of square foot cross sectional area of tree stems on a site, has been used to assess increasing densities, intra-tree competition, shading, etc. (McTague 1991). A second measure used by forest specialists is stand density index, a factor that takes into effect the relative incidence of differing diameter trees in the stand (Ellenwood 1994, Garrett et al. 1997, McTague 1991).

When evaluating the overall average basal area on the six analysis areas, it was found to be greater than 100 square feet per acre, or in the upper middle range of basal areas for this forest type in the Southwest. Basal areas determined for average forest conditions on the Black Mesa Forest Reserve at the turn of the century, ranged between 50 and 80 square feet per acre.

More importantly, the computed percentage of maximum stand density index for the Apache/Sitgreaves National Forest is determined to now be 45 percent. This is more than double the average of 22 percent that existed on the Black Mesa Forest Reserve in 1911 (Table 3).

Percent of maximum stand density indexes determined for the Black Mesa Forest Reserve (Apache/Sitgreaves) and other forests at the turn of the century ranged from 12-30 percent (Table 3). These are considered to be low, and very safe levels by forest specialists, and would contribute to more healthy forest ecosystem conditions (Schmid et al. 1994).

Table 3. Comparison of average percent of maximum stand density index on southwest forests in 1911 and on the Apache/Sitgreaves National Forest in 1994.

	Quadratic Mean Diameter	SDI	Percent Maximum SDI
Carson	19.5	111	25
Alamo	19.6	137	30
Zuni	18.7	54	12
Jemez	21.7	122	27
Coconino	20.8	111	25
Datil	19.9	72	16
Apache	22.3	105	23
Sitgreaves	19.9	93	21
Apache/ Sitgreaves 1994	**7.9**	**200**	**45**

Forest specialists have determined that percent of maximum SDIs exceeding 54 are considered high and damaging to health, diversity and sustainability of ponderosa pine forest ecosystems (Schmid et al. 1994). Stands with 34-54 percent of maximum SDI are considered to have moderate to high tree densities, which are negatively impacting other resources on site. Overstory treatments to reduce densities are advised for all stands above 35 percent of maximum SDI. As noted above, percent of maximum SDI below 33 is not considered a threat to other resources.

Figure 8 presents the average percent of maximum SDI for 15 selected analysis areas across the forest. The 15 analysis areas represent a range in percent of maximum SDI from 27-72 percent, and an average of 45. Two are in the low range, 12 are in the moderate range, and one is in the high range.

As noted previously, given the current state of tree densities, restoration ecology management prescriptions should be evaluated for potential application on the forest. The following evaluations of no management and restoration management options characterize probable impacts of "doing nothing" or "restoring" the forest landscapes.

Forest Ecosystem Change Under No Overstory Treatment

The no overstory treatment alternative restricts the forest manager from implementing any overstory management actions during the 50

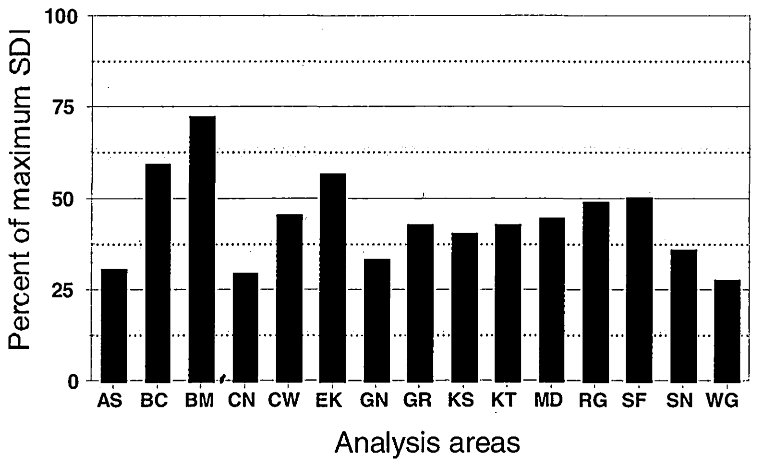


Figure 8. Average percent of maximum SDI's in 1994 for fifteen study areas across the Apache/Sitgreaves National Forest.

year analysis period. No tree thinnings or harvests can occur. The initial stand conditions are as described for the six analysis areas in Table 2. Each of these analysis areas already have high tree densities.

Figure 9 characterizes average changes in critical resources on the six analysis areas over a 50 year projection period without treatment. Stand density index, fuel loads, forage production, and water yield are projected, as well as changes in percent of maximum SDI.

The obvious result of implementing the no treatment alternative is that basal area and intra-tree competition for nutrients and water continue to increase. Tree stagnation occurs, increasing litter fall and the buildup of ground fuels to what fire ecologists would consider dangerous levels, exceeding 20 and 30 tons per acre. Soil moisture and instream flows are decreased. Herbage productivity in the form of grass, forbs and shrubs is suppressed, decreasing the pounds of forage produced per year for both wildlife and domestic stock. And, reduction in ground plant cover contributes to increased sedimentation.

Nutrients and water resources are withheld from the understory as tree density increases. As a result, flora diversity of the stand is lowered, which impacts diversity of fauna. Declines in vigor occur in both overstory and understory plants, as well as wildlife that use the forest environment as a source of energy. Declining health, although not explicitly defined in the model prediction, increases the vulnerability of the stand to catastrophic insect and disease attack. Such attacks create even higher fuel loads and standing dead inventory of trees, greatly increasing the risk of catastrophic wildfire loss.

The Pre-European Forest Treatment

The second alternative evaluated requires intensive management of the overstory to restore the forest ecosystem to a pre-European settlement forest condition. That overstory requires a much larger average diameter, and a significantly smaller number of trees per acre than currently exists (Fig. 4). The percent of maximum stand density index for this desired future condition is in the low range of percent of maximum stand density indexes, or 20-30 percent.

The proposed presettlement alternative does permit removal of trees in all diameter classes; however, removals are accomplished so as to insure previously lost trees in larger diameter classes are restored. Permitting no removals in larger diameter classes would be inconsistent with an actual treatment because many large trees would need to be removed to assure forest health, decreased fire risks, and plant diversity.

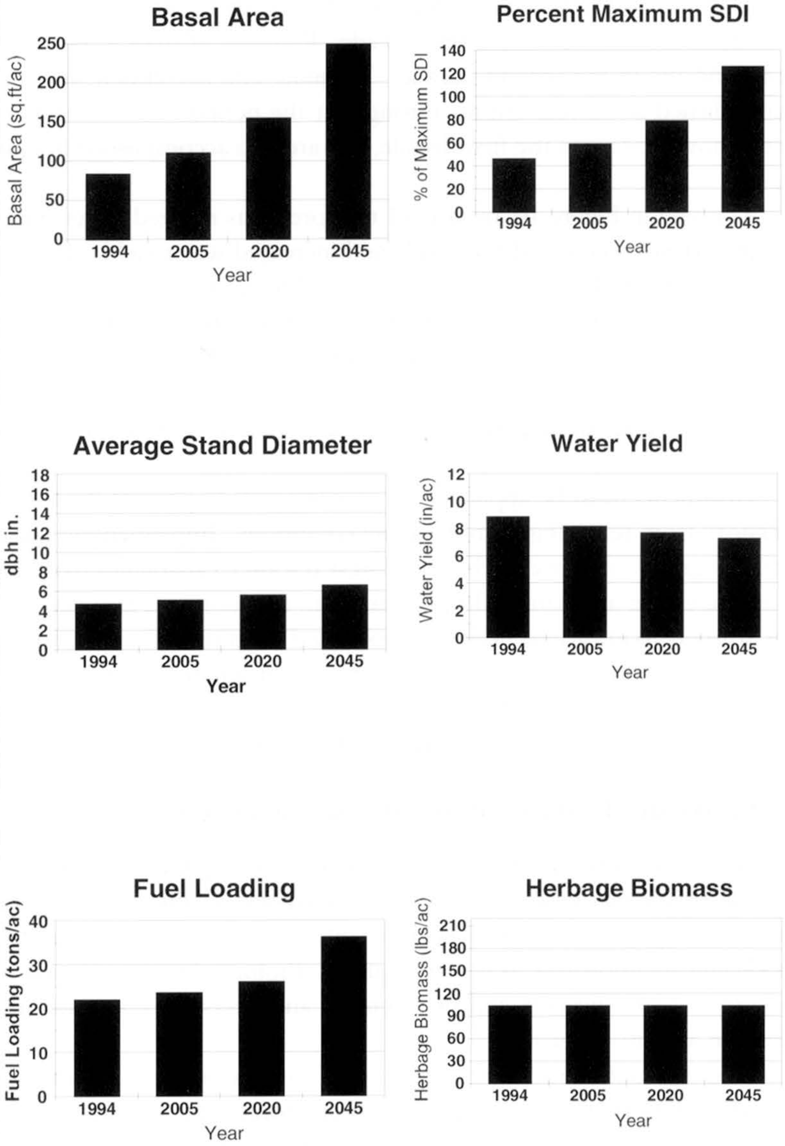


Figure 9. Changes in resource outputs on six selected analysis areas under no treatment alternative.

Figure 10 presents the levels of the various resources predicted when the forest is returned to the presettlement forest condition over the 50 year restoration period. This is accomplished by intensive thinning of smaller trees, restoration of understory grasses, forbs and shrubs, and reductions in fuel loads in the first decade. Removal of trees 9" dbh and greater occurs in the second decade. Thinning and prescribed fires are accomplished at 10 year entries throughout the period. Overstory harvest removals occur in the first decade, and are also accomplished in year 48.

As noted in Figure 10, by year 11 the forest has realized lower stand density indexes, decreased fuel loads and increased water yield. The resource benefits will be lost if trees are allowed to again dominate the site. Thinning and controlled fire treatments at 10 year intervals will maintain low densities through the period. Larger tree removals occur late in the cycle (year 48) to insure restoration of previously lost larger trees. At the end of 50 years, the dependant forest resources remain at improved levels.

Treatments must be applied at 10 year intervals to prevent the forest overstory from returning to more dense conditions. Implementing these activities greatly improves individual forest resource capabilities over the no management alternative. Improvement in the resources also contributes strongly to improved health, diversity and sustainability of the forest ecosystem. Further, all of the larger old trees that originally existed in the presettlement period have been restored to the forest overstory, and the density of small trees has been reduced significantly.

ECONOMIC EVALUATION OF MANAGEMENT ALTERNATIVES

Biophysical analysis of alternative management regimes indicates restoration treatments could benefit forest ecosystem health and diversity. The state of physical resources such as soils, water, fuel loads, and nutrient cycling are improved, as is scenic quality. Biological resources such as understory plant diversity and productivity, and overstory character and structure are also improved.

Wildlife habitat indexes would be significantly changed to favor species who adapt best to more open forest environments. Obviously, forest landscape planning could be incorporated to permit spatially dispersed dense stands to accommodate species requiring these type habitats.

Overall, the restoration treatments would return the forest to a more open, natural state. Scientific inquiry in ponderosa pine type would indi-

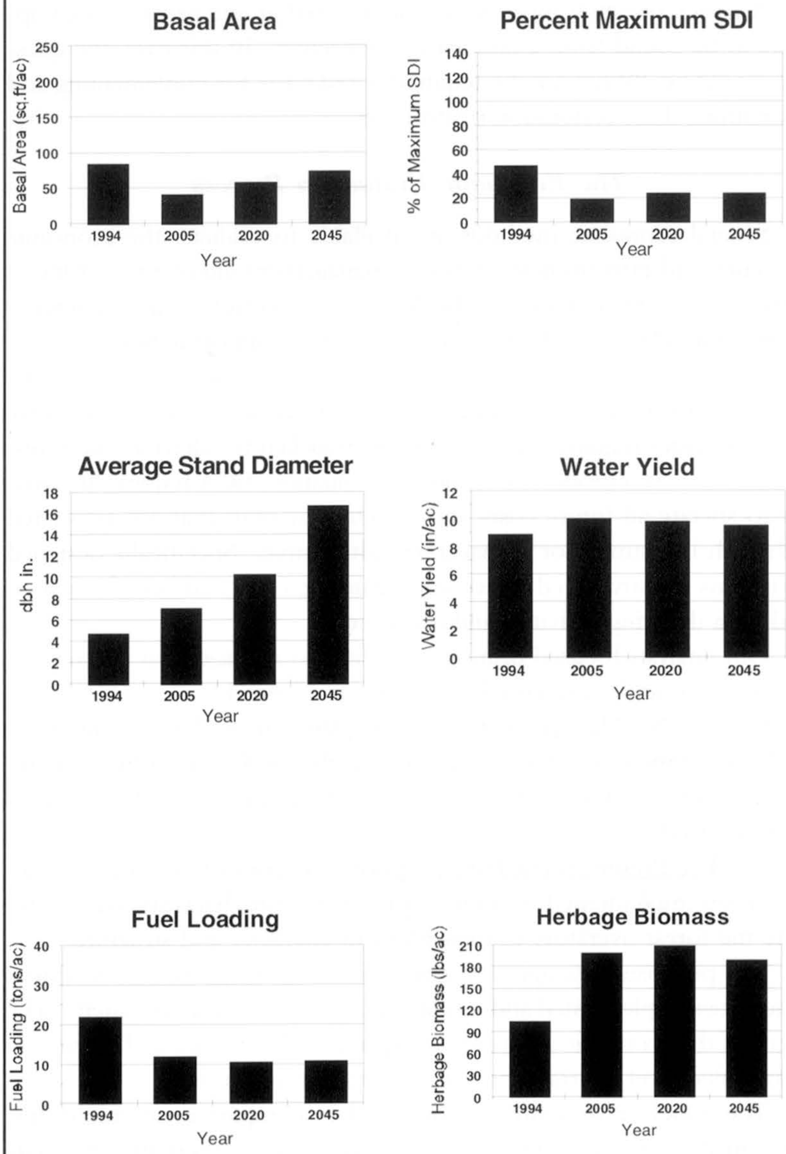


Figure 10. Changes in resource outputs on six selected forest analysis areas under the presettlement forest treatment alternative.

cate that conditions that approach a more open forest support healthier, more diverse and more easily sustained forest ecosystems (Brown et al. 1974, Rogers et al. 1984).

A policy question must always be directed at any proposal that appears to be sound from a biological perspective. In this case, the question would be, "What are the required social costs for implementing and maintaining these restoration treatments?"

The Economic Evaluation Process

Several economic methods are available to evaluate the economic efficiency and effectiveness of forest management alternatives. One in particular, benefit cost analysis, BCA, has proven effective in characterizing the suitability of differing public investment opportunities.

Benefit cost analysis is a process that can be used to evaluate the current worth of all future benefits and costs associated with alternative forest activities required in managing overstocked ponderosa pine forest ecosystems. As a model for economic evaluation, BCA requires the analyst to specify all future costs and benefits, by year, that are associated with each investment or management alternative. Specifically designed algorithms are structured to accommodate the costs and benefits associated with differing activities and outcomes.

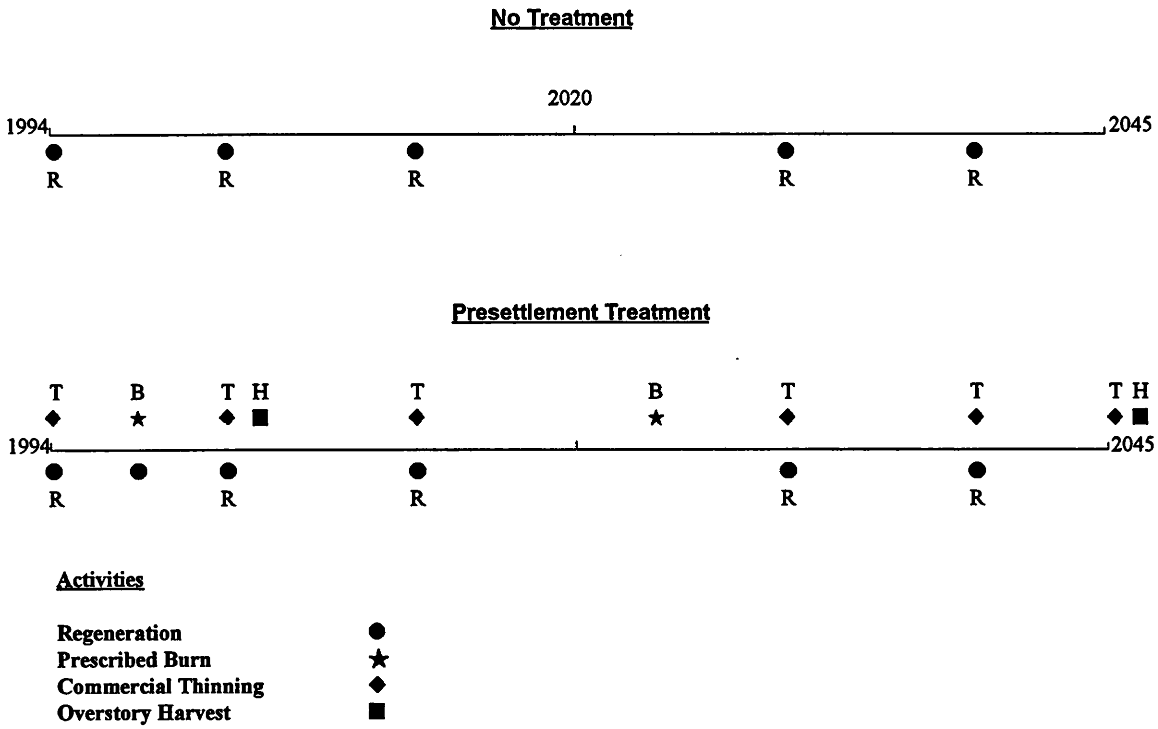
Our analysis focused primarily on the two management alternatives noted earlier, and represented graphically in Figure 11.

- The No Management Treatment Alternative. No man-imposed land management activities are placed on the landscape. Only maintenance activities to reduce threats of insect and disease and wildfire events are permitted.
- The Presettlement Forest Option. A series of management activities are implemented (thinnings, prescribed fire, harvests, etc.) to restore the forest overstory to presettlement character and structure.

The proposed management alternatives differ significantly in extent of activities implemented and modifications to the forest ecosystem. The intent of the economic analysis is to represent all activities and outputs in dollar values and contrast them at year 0 as present values.

The benefit cost analysis is designed to compare economic differences in the two alternatives. The no management alternative has only protection activities to help mitigate increasing insect and disease and wildfire risks. These risks increase as the forest gets more dense over the 50 year period. Benefits, such as forage production and water, are mea-

Figure 11. Time sequence of activities in the no management and presettlement management alternatives: 1994-2045.



surable dollar outputs from the alternative, although they decline through the period.

The presettlement alternative requires significant activities and costs to restore and maintain the overstory to presettlement character and structure. Thinnings, prescribed fire and harvests are necessary through the 50 year period. Dollar benefits from wood products, forage and water are all realized from these investments. Further, lower insect and disease protection costs result from the more healthy forest.

Assessment Algorithms

Two economic algorithms were chosen to measure the differences between the no management and presettlement alternative: net present value and benefit cost ratio. Net present value (NPV) is the difference in benefits and costs occurring across a management period, in this case 50 years, and discounted back to the year a program is initiated. Benefit cost ratio (BCR) is a ratio derived by dividing all future program benefits discounted to year 0 by all future costs discounted to year 0. Desirable investment opportunities have benefit cost ratios >1.00 at an acceptable interest rate.

Net Present Value and Benefit Cost Ratios of Management Alternatives

Figure 12 provides developed net present values derived for the no management and presettlement alternatives using 4, 7 and 10 percent discount rates (interest rates) and average costs and revenues. Interest rates used on public investments vary with federal agency, and normally range between 4 and 10 percent. We have chosen 7 percent as an average rate.

Cost and revenues also vary, and sensitivity analysis is used later to evaluate ranges in these factors. Average values used in the analysis are as follows: timber stumpage $150/Mbf, pulpwood stumpage $5/cord, fuelwood $10/cord, water $30/acre foot, and forage $1.50/AUM. Average costs used were: timber sales administration $60/acre, prescribed burning $120/acre, thinning $125/acre, insect and disease control $20/acre, and brush disposal $9/Mbf.

As is noted in both alternatives, present net worth is positive. However, the present net worth of the presettlement alternative at a 7 percent discount rate is 10 times as great, at $155.15 per acre, as the no management alternative. Even though significantly more costs were borne to restore the forest ecosystems, the values of the harvested wood prod-

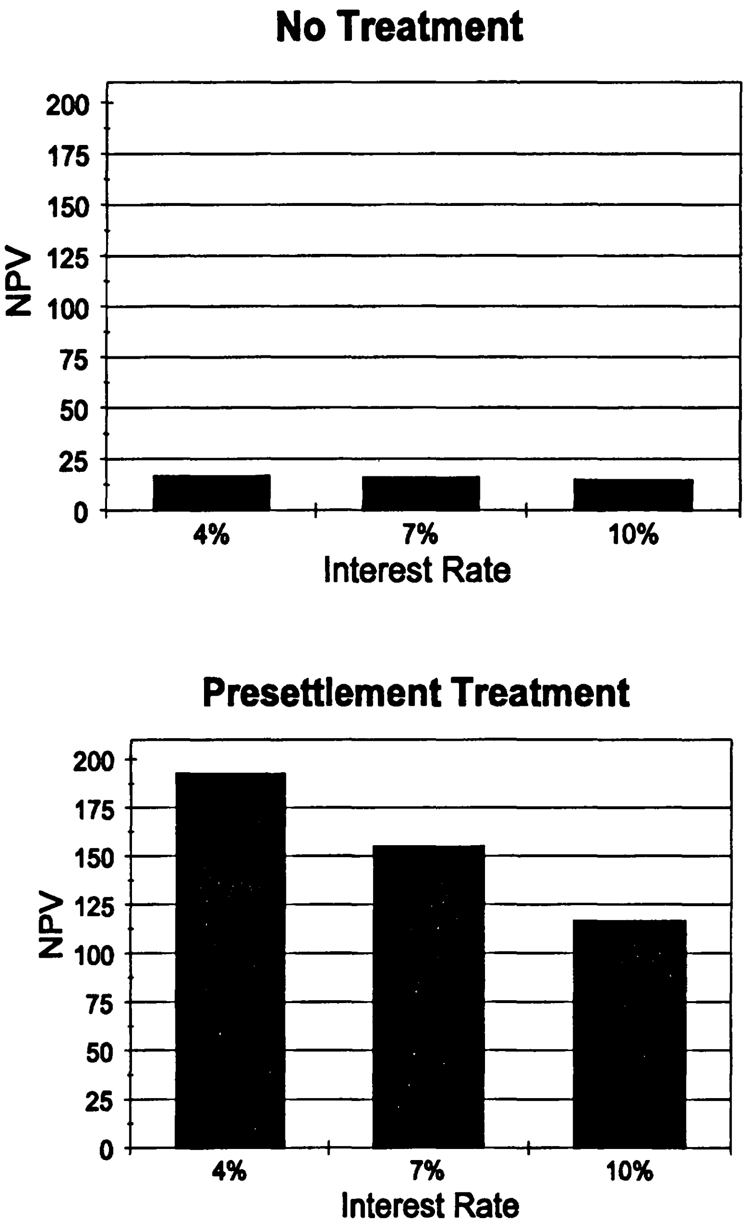


Figure 12. Net present values per acre for the no treatment alternative and the presettlement alternative using average costs and revenues.

ucts and the increased incremental returns from forage and water more than offset these costs.

The no management alternative also yielded returns from water and forage. Yet, even with minimal management costs for insect and disease control, the alternative yielded a NPV of only $16 per acre at a 7 percent interest rate.

Benefit cost ratios were positive for both alternatives (Fig. 13). However, the presettlement alternative with a 1.50 BCR was slightly lower than the 1.7 BCR for the no management alternative at the same interest rate. BCR for the two alternatives are similar at most rates.

Sensitivity Analysis

Figures 14, 15, 16, and 17 contrast the effects of varying costs, and revenues on NPV and BCR for the two alternatives. The analysis is most sensitive to variance in resource revenues, although considerable variance in NPV and BCR is also created when interest rate is varied from 4-10 percent. NPV and BCR show little sensitivity to changing cost levels. High and low values for revenues and costs are 30-50 percent departures from the average values.

Of greatest interest is that NPV stays above $30/acre even at moderate interest rates and low revenues for the presettlement alternative. The no management alternative also stayed positive but its NPV per acre at a 7 percent rate and low revenues was only $1.16/acre.

Benefit cost ratios also varied significantly with revenues. However, they are less sensitive to interest rates. Even with moderate interest rate and low revenue, the BCR for the presettlement alternative was 1.1. The BCR for the no management alternative was 1.0.

The Risk of Wildfire

Although we have accommodated insect and disease management in the analysis (except for catastrophic outbreaks), we have not attempted to evaluate the cost of wildfire. Wildfire is treated under the umbrella of risk and uncertainty in land resource management. An in-depth analysis of this factor was beyond the scope of this project. Although we know when we are incurring greater risk of large catastrophic wildfire, we are uncertain of exactly when they will occur, and the cost of any single event.

However, as noted in the analysis, we have knowledge of increased probabilities of large wildfires associated with increasing tree densities. For example, there is a much greater probability that a large wildfire will

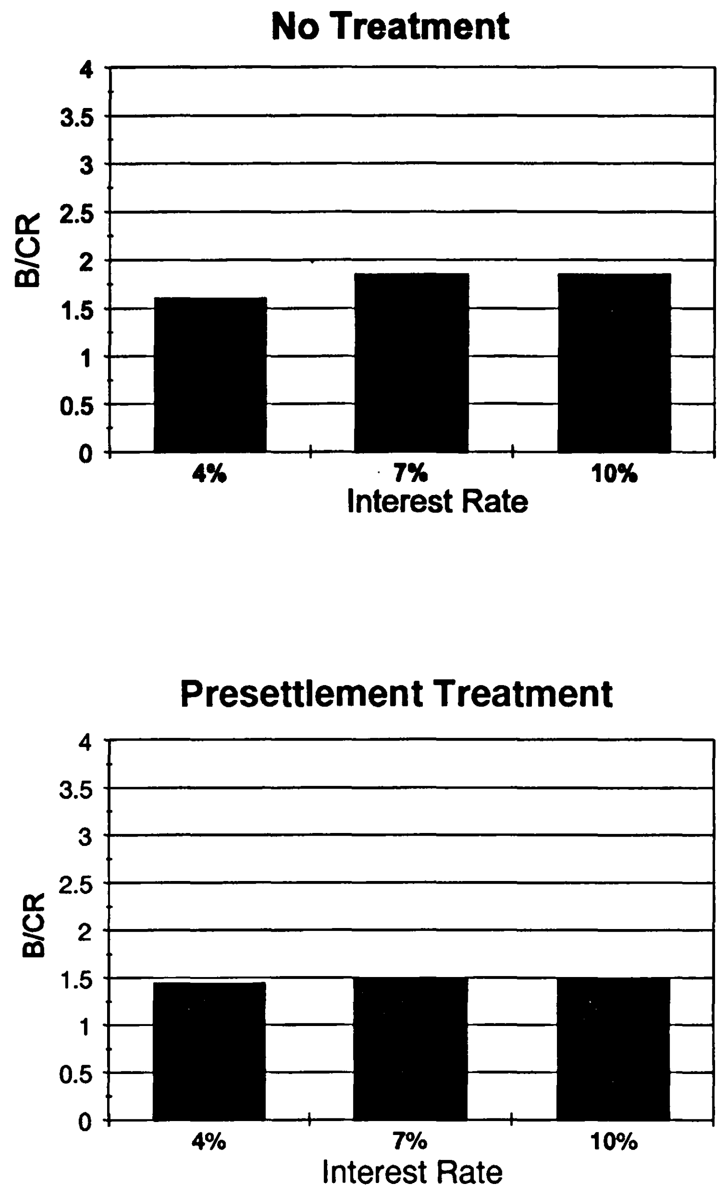
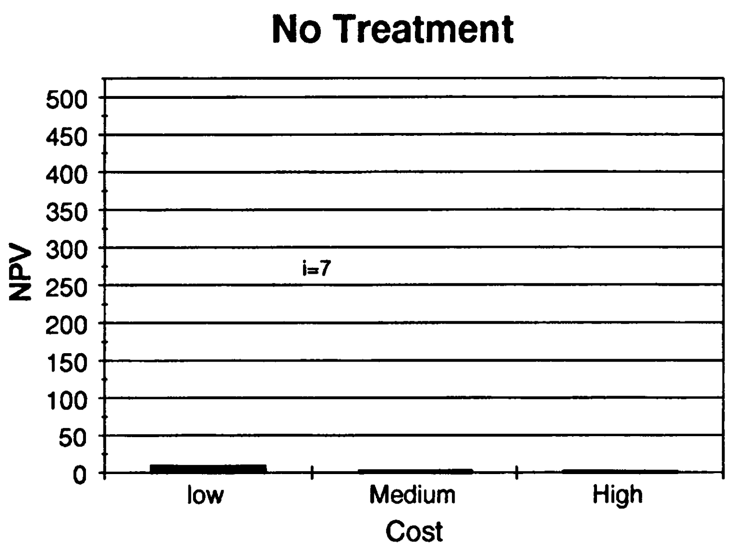


Figure 13. Benefit cost ratio for the no treatment alternative and the presettlement alternative using average costs and revenues.



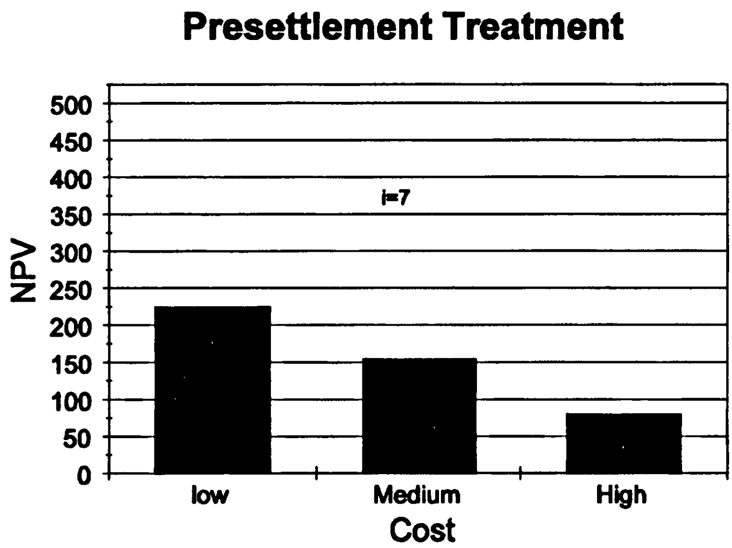


Figure 14. Net present values per acre at low, medium and high costs; revenues average.

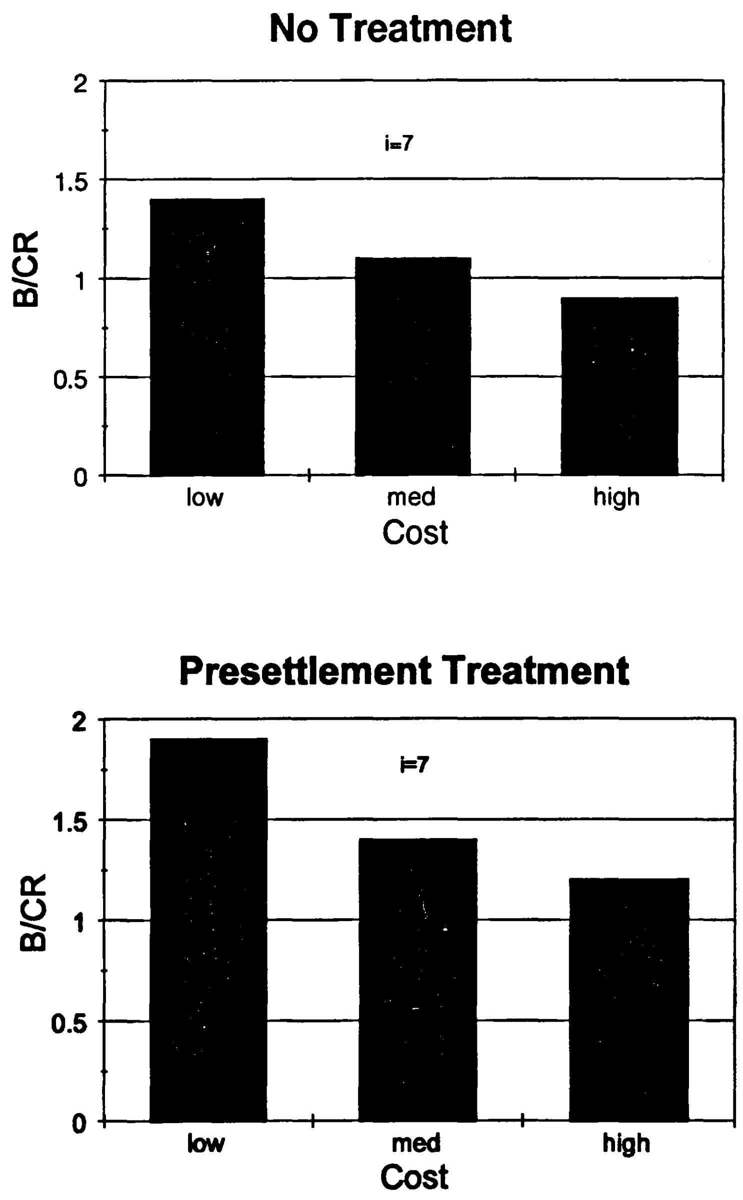


Figure 15. Benefit cost ratio at low, medium and high costs; revenues average.

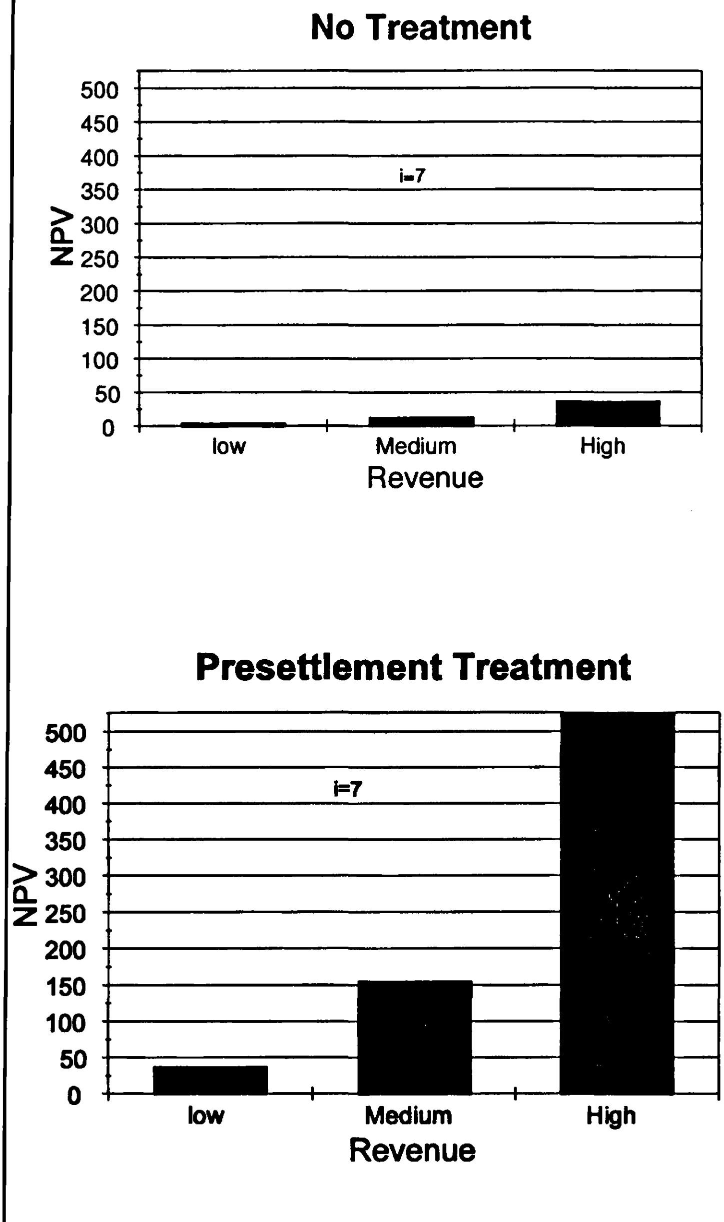


Figure 16. Net present value per acre at low, medium and high revenue; cost average.

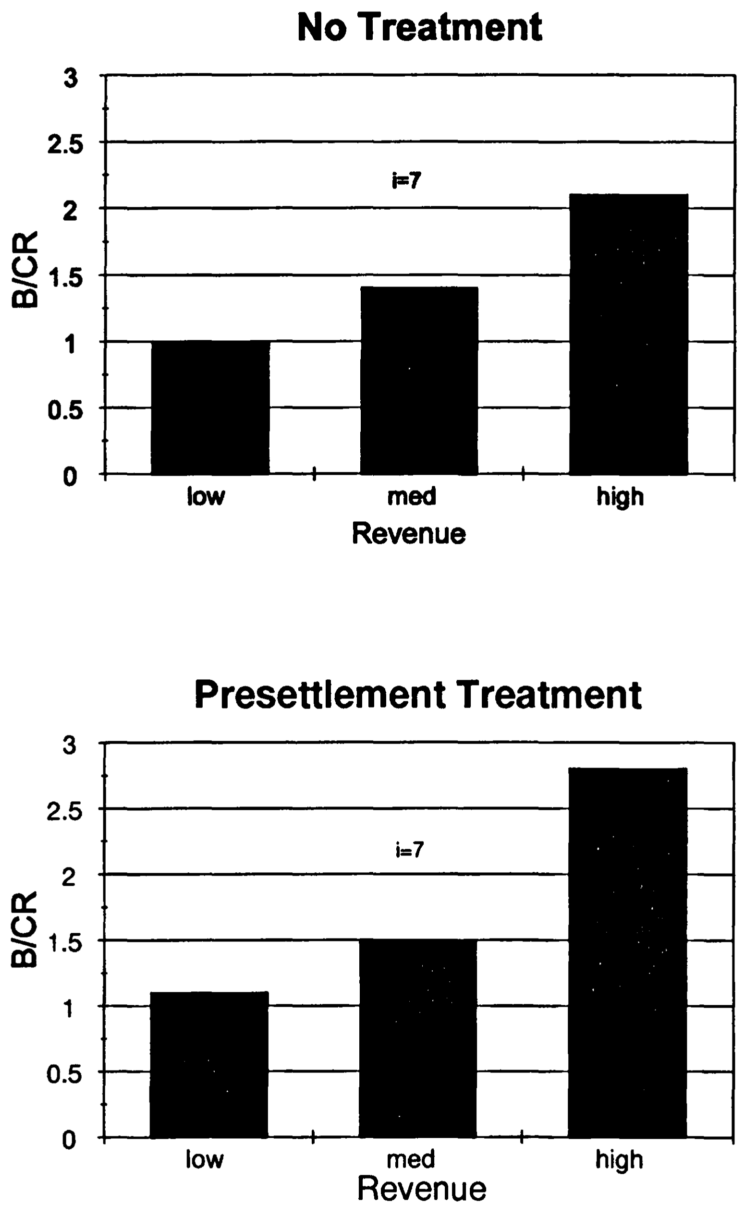


Figure 17. Benefit cost ratio at low, medium and high revenue; cost average.

occur sometime between year 30 and 50 in the no management alternative than in the presettlement alternative. Using this knowledge, we can structure a hypothetical "one event" cost for the two treatments in year 40.

We can assume that the probability of incurring the cost of one 15,000 acre and one 300 acre wildfire in year 40 would be 80 percent and 20 percent respectively in the no management alternative. The probabilities can be reversed for the presettlement alternative, because treatments would reduce the risk of large wildfire. If we then assume that the large fire would cost $20,000,000 to suppress and the small fire $1,000,000, we can structure one time costs.

The expected costs for these events in year 40 would be [($20,000,000 • .80) + ($1,000,000 • .20)] or $16,200,000 for the no management alternative and [($20,000,000 • .20) + ($1,000,000 • .80)] or $1,200,000 for the presettlement alternative. When these costs are entered into the baseline analysis (i.e., average costs, revenues and interest rates), we find that the NPV for the no management alternative is significantly negative. However, the presettlement treatment, which affords significant lower risk of large fires is still maintained as a reasonable social investment.

DISCUSSION

The evaluation of forest overstory change in the ponderosa pine forests of the Apache/Sitgreaves National Forest over the last 100 years clearly demonstrates several patterns as follows:

1. The number of trees per acre across the landscape has significantly increased from levels of approximately 34 trees per acre to current levels of approximately 133 trees per acre above 4" dbh. Decreases of 6-8 trees per acre have occurred above 20" dbh.
2. These increased densities have resulted in impacts to other resources in the forest, including higher risk of continued loss to large over-mature trees, increased fuel loads, decreased water availability to other resources, decreased forage productivity, etc.
3. These changes have increased and are continuing to increase environmental degradation of the forest ecosystems.

Defined changes in the forest ecosystems are resulting in increased occurrence of insect and disease infestations and high-intensity, larger wildfires. The overall comprehensive changes in resources is resulting in decreases in forest health, diversity, and sustainability of the forest.

As such, there is an urgent need for adaptive management/science programs to evaluate restoration approaches that could be undertaken in these ecosystems. If restoration to presettlement overstory conditions or some similar level were to occur, there would be significant improvements in health, diversity and sustainability.

Computer simulated treatments to the forest overstory that approach presettlement conditions, reveal significant enhancement of forest ecosystem resources as compared to no treatment alternatives. On site water as well as understory plant productivity is increased, while fuel loads are decreased. Further, implementation of restoration treatments would realize positive net present values as public investments. Pursuing a no management alternative will greatly increase the risk of high-cost, larger wildfires and significant losses in public investments in forest resources.

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Chapin 5 Fire Vegetation Monitoring and Mitigation

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Abstract. The Chapin 5 Fire ignited on 17 August 1996, burning 4,781 acres of Mesa Verde National Park. With Burn Area Emergency Rehabilitation (BAER) funding, we are (1) evaluating residual vegetation, (2) monitoring post-fire native plant recovery, and (3) treating non-native plant invasion. To evaluate residual seeds and grass rootstocks, we developed an effective test using the physical strength of the remaining bunch grasses, the "pull test." Residual vegetation was low; grass frequency (average=.52) was reduced (average=.18) after the fire (t=7.3, P<.05) and few species germinated or re-sprouted in 1996. Vegetation recovery is being monitored at 75 points randomly placed in 20 habitat types defined in a GIS environment. By August 1997, 210 vascular plant species occurred in the burn area. Fire-facilitated species include *Gayophytum ramosissimum, Nicotiana attenuatam* and *Collomia grandiflora.* Re-sprouting shrubs account for 41-60% of the vegetative cover in the mountain shrubland habitats. The intensely burned pinon-juniper habitats support 23-40% forb cover, 14-40% grass cover and bare soils are common. Non-native species are aggressively invading bare soils as well as previously disturbed areas. An integrated pest management approach—seeding native grasses, mechanical removal, herbicide spot-spraying, and 5 biological control agents—is being used to prevent the spread of non-native species.

Key words: wildfire, Mesa Verde National Park, non-native species, monitoring, mitigation, Colorado

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SCOPE OF THE PROJECT, YEAR 1

The lightning-initiated Chapin 5 fire in Mesa Verde National Park (MVNP), Colorado, burned 17-24 August 1996. The fire began in the dense pinon-juniper/purshia woodland on Chapin Mesa, and after a short run to the south, continued essentially northward, burning Soda Canyon, Little Soda Canyon, and large portions of the research area Park Mesa, when it stopped at the Visitors Center and hotel complex in the dense oak and serviceberry shrublands. The fire covered 4,781 acres, 7 pre-fire vegetation communities, 2 geologic substrates (Menefee Shale and Cliffhouse Sandstones), and numerous soil types. Using primary soil hydrophobic characteristics, the BAER hydrologic team mapped levels of burn intensities. In addition, pre-fire vegetation communities became the basis for predicting probable post-fire vegetation responses. We identified a "revegetation response potential" for each vegetation community. Communities which included re-sprouting shrubs *Quercus gambelii* and *Amelanchier utahensis* were considered likely to recover rapidly; those which lacked significant re-sprouting understory shrubs would recover slowly.

The first year evaluation of vegetation recovery in the Chapin 5 fire, funded under the Burned Area Emergency Rehabilitation (BAER) program, focused on the following objectives:

- vegetation was monitored across the diversity of habitats burned to determine if plant recovery was adequate to prevent erosion,
- vegetation was monitored to determine if plant recovery was adequate to prevent alien species invasion,
- endemic plant species were surveyed to determine the status of post-burn recovery, and
- mitigation was carried out to prevent the proliferation of non-native weedy plant species.

In the first post-fire year (late fall 1996 through fall 1997) the BAER Vegetation team monitored the recovery of vegetation and initiated mitigation practices to meet the stated objectives. A summary of our methods and first year results is presented in this report.

METHODS

The 4,781 acre burn area was classified into 19 different ecological habitats. This classification was accomplished in a GIS environment

(IDRISI) by cross-tabulating the spatial extent of pre-fire vegetation communities, geologic substrate, and slope. Sampling points (78) were defined in IDRISI with a random point generation function.

Examination of Residuals

The BAER document proposed that a thorough evaluation of the residual seeds and grass rootstocks be made, especially where re-sprouting shrubs were absent. This evaluation took place during September 1996, and uncovered the potential for natural recovery, especially of native grasses. While other means of evaluation, for example the use of tetrazolium chloride to detect dehydrogenase enzymes, were used, the most telling was the "pull test." At each sample point, a 2x20 meter belt transect was laid out and grasses were evaluated for (a) re-sprouting or (b) whether the grass remained intact and rooted when "yanked." If it passed the yank test, we assumed it would re-sprout the next year. The result of this screening led us to carry out aerial seeding of native grasses (see below) in the most severely affected areas.

We returned to each sampling point in May 1997 to evaluate the precision of this method. At 63 of the 78 points, we relocated precisely the transect location, and then measured the distance to individual grass which had been evaluated last year. We determined from re-sprouting of grasses, whether our pull test assessment had been correct.

Documentation of Plant Recovery

Each sampling point was visited in May and late August-September 1997. In May, we documented the plant species within an approximately 100 meter radius of each point. We also laid out an identical belt transect to that described above, documenting for each grass clump whether re-sprouting had occurred. In late August-September, we determined the flora of each site as well as the cover of each plant type (forb, grass, shrub, dead shrub, non-native species, etc.) utilizing a point frequency frame (Mueller-Dombois and Ellenburg 1974). Frequency of each group is an estimate of cover.

We surveyed for the presence of *Astragalus schmollae* and *Hackelia gracilenta*, two endemic species which are restricted in habitat to Mesa Verde and were identified as sensitive species in the BAER plan. Post-fire invasion into the Chapin 5 fire was documented and permanent monitoring plots were established on Park Mesa surrounding a new population of *A. schmollae.*

Seeding of Park Mesa

The pull test indicated that recovery of at least 30% of the perennial grasses was not expected in the severely burned areas (Table 1). Grass recovery on Menefee Shale was better than on Cliffhouse Sandstone (Table 2). Therefore, we aerially seeded the most severely burned 200 acres of Park Mesa with native grass species. This was done in an effort to retard the invasion of non-native species onto the relatively sterile soils, and to stabilize soils and prevent erosion.

Native seeds were difficult to obtain due to the number of fires requiring rehabilitation in 1996. We were able to purchase or obtain Mesa Verde's own native seeds of the following species:

Poa fendleriana, Mutton Grass
Kohleria cristata, June Grass
Oryzopsis hymenoides, Indian Rice Grass
Agropyron trachycauloum, Slender Wheat Grass
Sitanion hystrix, Squirrel-tail Grass

Table 1. Interpretive information defining the habitat types used to direct the placement of sampling points. Habitats were defined based upon underlying geologic substrate, slope, and pre-fire vegetation type.

Habitat Code	Substrate	Slope	Vegetation Type
1	Cliffhouse (1)	Low (1)	Meadow (4)
2	Menefee (2)	Low (1)	Meadow (4)
3	Cliffhouse (1)	Low (1)	Mtn. Shrub (5)
4	Menefee (2)	Low (1)	Mtn. Shrub (5)
5	Cliffhouse (1)	Mod (2)	Mtn. Shrub (5)
6	Menefee (2)	Mod (2)	Mtn. Shrub (5)
7	Cliffhouse (1)	High (3)	Mtn. Shrub (5)
8	Menefee (2)	High (3)	Mtn. Shrub (5)
9	Cliffhouse (1)	Low (1)	Oak woodland (6), PJ-Oak (7), PJ Forest (8)
10	Menefee (2)	Low (1)	Oak woodland (6), PJ-Oak (7), PJ Forest (8)
11	Cliffhouse (1)	Mod (2)	Oak woodland (6), PJ-Oak (7), PJ Forest (8)
12	Menefee (2)	Mod (2)	Oak woodland (6), PJ-Oak (7), PJ Forest (8)
13	Cliffhouse (1)	High (3)	Oak woodland (6), PJ-Oak (7), PJ Forest (8)
14	Menefee (2)	High (3)	Oak woodland (6), PJ-Oak (7), PJ Forest (8)
15	Cliffhouse (1)	Low (1)	PJ-Purshia (9)
16	Menefee (2)	Low (1)	PJ-Purshia (9)
17	Cliffhouse (1)	Mod (2)	PJ-Purshia (9)
18	Menefee (2)	Mod (2)	PJ-Purshia (9)
19	Cliffhouse (1)	High (3)	PJ-Purshia (9)
20	Menefee (2)	High (3)	PJ-Purshia (9)

Table 2. Effects of the Chapin 5 fire on the abundance of bunch and sod grasses. Abundance is measured as frequency in 75 sample points across the burned area.

Grass Type	Present Pre-fire	Passing Pull Test	Alive 1996
Bunch Grasses	.85	.59	.31
	±.22	±.40	±.30
Sod Grasses	undetectable	.34	.05
		±.23	±.08

We created two mixes with these seeds, simulating as much as possible the native grass community for the elevation, substrate, and pre-fire vegetation, one for north and one for south ends of the burn. We applied the seed by helicopter on October 20 and 21. It began snowing on October 21 and the winter precipitation was high during 1996/1997.

We evaluated the success of seeding in August by setting out a series of circular plots (radius 10 m^2) at approximately 50 meter intervals on a north-south line across Park Mesa (Fig. 1). The number of seeded grasses was counted for each seeded grass species. While we may have included non-seeded individuals of the same species, this is unlikely to have contributed many individuals (see control values below). A similar transect was placed on the adjacent mesa in an untreated area (Fig. 1).

Evaluation and Mitigation of Non-Native Plant Species

Mechanical treatments

Most of our treatment efforts have been directed toward mechanical removal of Musk and Canada thistles. The treatments consisted of removing the fully formed seed heads, and heat destroying them by keeping them tightly bagged, and throwing them away. The entire plant, stem, and root was removed. If an obvious archeological site was present, the thistle plants were chopped at the surface, but not uprooted to prevent disturbance to subsurface archeological materials. Small patches of the rhizomatous Canada thistle were dug up as well. Approximately 326 acres have been treated mechanically in 116 person-days.

Biological control

We are coordinating our efforts with those of Dr. Deb Kendall, Fort Lewis College. The areas chosen for release of biological control

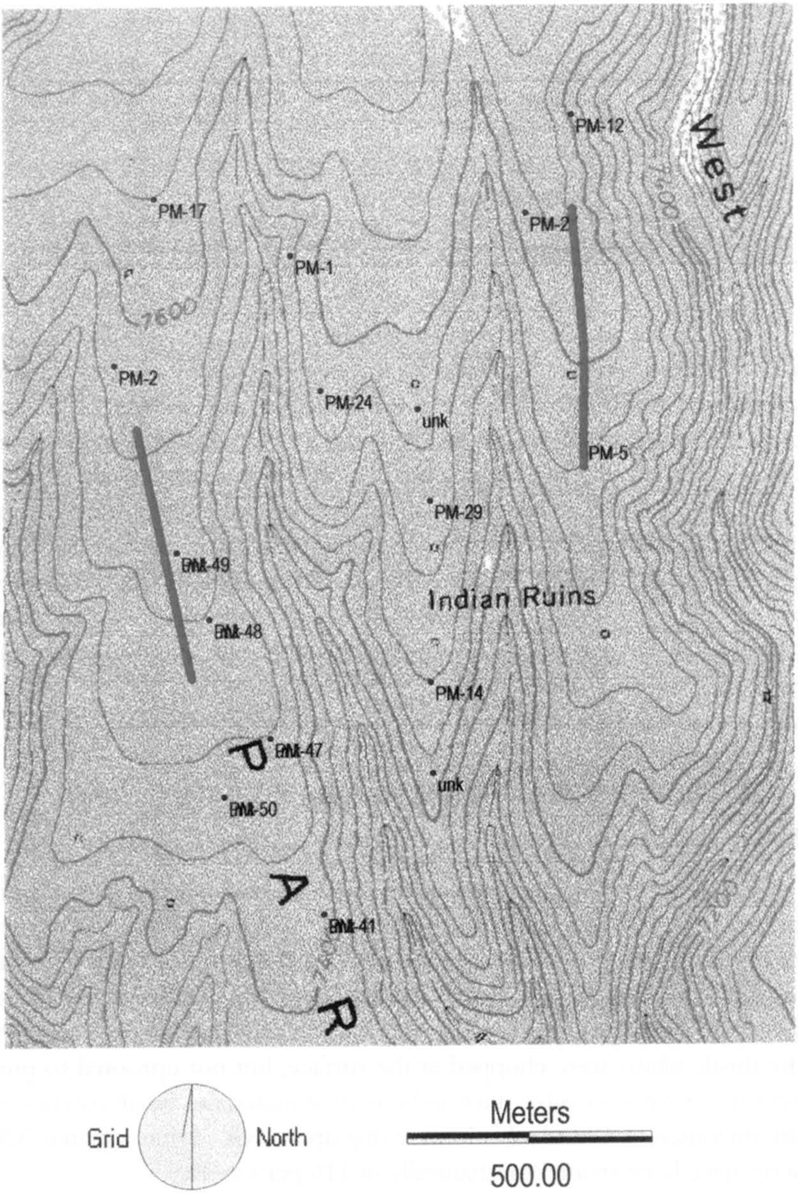


Figure 1. Grass seed monitoring transects.

agents did not receive other treatment, except in some cases the removal of seed heads. Dr. Kendall has released on Canada thistle in the Far View Sewage Lagoon and downstream areas: the Canada thistle gall fly, Urophyora cardui; the seed head weevil, Larinus; and she expects to release the stem weevil, Ceutorhynchus litura, when insects become available. Dr. Kendall also released Tricocericaulus horridus on Musk thistles.

Herbicide application

In particularly dense Canada thistle stands, the 2-4 D derivative herbicide "Curtail" was applied. Herbicide was also used on particularly dense patches of Musk thistle if mechanical treatment was not possible. In mid-April we spot-sprayed Curtail on individual plants throughout the most severe infestation in the Far View Sewage lagoon area. This was done early to alleviate disturbances on native vegetation. Quanah Spencer, a Park employee certified to apply herbicides, also applied Curtail in several areas on Park Mesa. The location and extent of each treatment is shown in Figure 2.

RESULTS

Examination of Residuals

We returned to each of 78 sampling points distributed in 19 ecological habitats during May 1997 and evaluated the usefulness of the pull test to determine potential grass re-growth after fire. While overall the average percentage of correct calls was 30%, our success varied across the sites (the range was from 0% to 100%) (Table 1). There was a significant difference in our pull test results in Menefee and Cliffhouse substrates ($F=10.6$, $P<.05$): we were better able to detect grass recovery potential on Menefee Shale (mean=44%) than on Cliffhouse sandstone (mean=20%). There was a significant correlation ($r=.54$, $P<.05$) between 1996 bunch grass frequency (e.g., pre-fire) and the grass recovery in 1997 indicating that a large proportion of the bunch grasses present after the fire re-sprouted.

One reason for the lower than expected success of the pull test was our inability to distinguish between burned bunch grasses and burned upland sedges, *Carex geyerii*; overall the bunch grasses had a greater success of re-spouting than did the upland sedges. Another problem was our inability to relocate each grass clump using only distances from the sampling transect. While the pull test is the best way which we have found to determine the potential for residual grass recovery, we suggest that other methods be designed and evaluated.

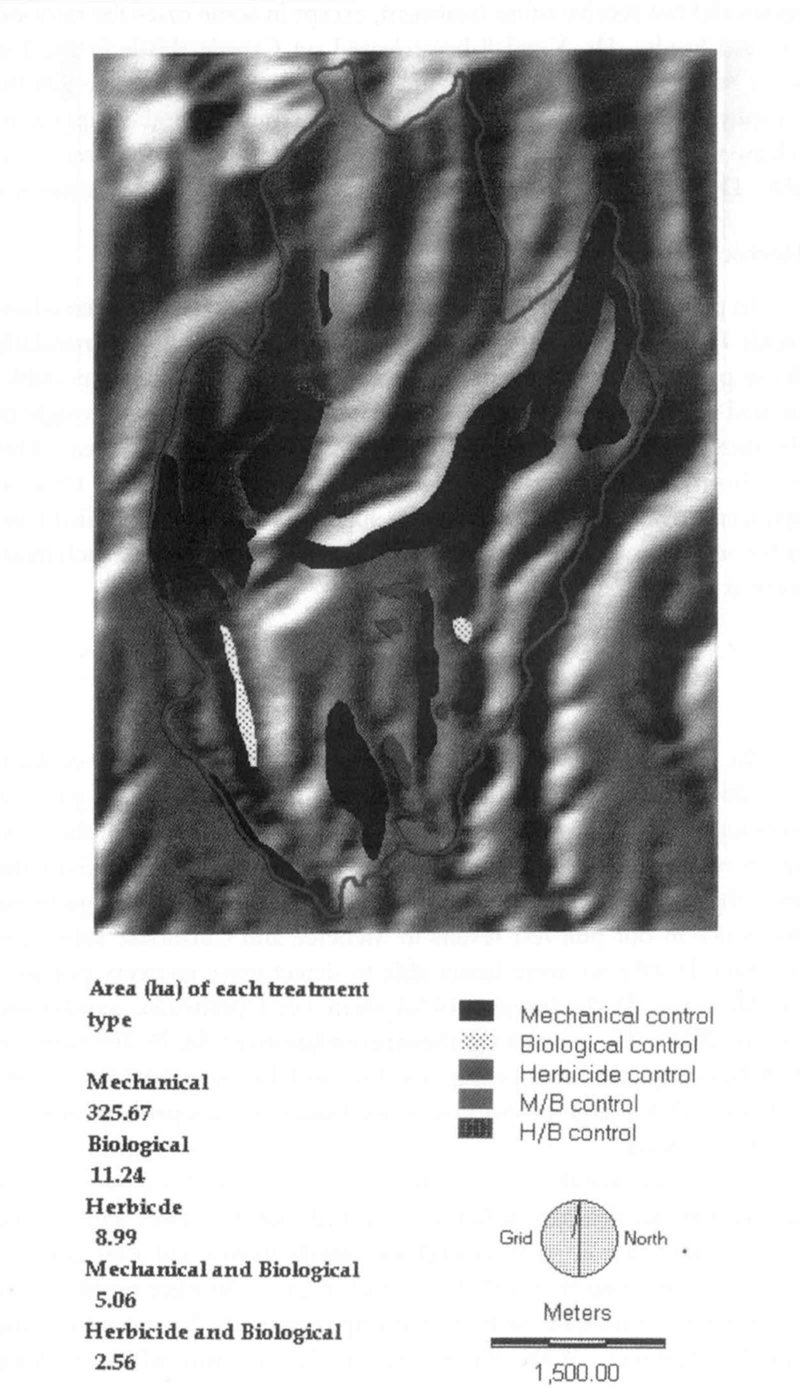


Figure 2. Thistle treatment areas, Chapin 5 burn.

Seeding of Park Mesa

Throughout the summer of 1997, grass seedlings on Park Mesa were informally monitored. The deposition of grass seed appeared to be clumped, probably because runoff patterns moved the seed into small drainages. In August 1997, we evaluated the density of grasses in a series of plots (Fig. 1). We chose density, rather than cover, as the most realistic variable this year because grass growth was significantly increased by the fertilization effect of the fire. Rather than overestimate grass importance by its cover, we determined the number of clumps, each a result of germination of one seed. Grass density was significantly higher in the seeded areas (mean=6/75 m^2) than control areas (mean=.5/m^2, $F=13.7$, $P<.05$; Table 3) on Park Mesa. The success of the seeding treatment was enhanced by greater densities of all species when seeded areas were compared to control plots (partial $F=3.1$, $P<.05$) except Indian Rice Grass. Indian Rice Grass often germinates several years after seeding and we can expect that as testa deterioration occurs, the seeds will germinate. All species flowered and produced seeds this year.

While we demonstrated a successful seeding effort, we cannot yet determine the effect grass competition will have on the invasion of non-native exotics. During the next field season, we will be able to evaluate whether the increase in grass cover actually decreases the incidence of non-native invasions.

Documentation of Plant Recovery

We monitored post-fire recovery on 78 randomly generated sample points. We established the sampling points immediately after the burn (September-October 1997) and returned to each point twice in the 1997 growing season—in early May and in September—in order to determine post-fire vegetation recovery. By September, one year after the fire, vegetation cover (total cover, the sum of all vegetation components)

Table 3. Comparison of grass densities (#/75m^2) between seeded and unseeded areas.

Species	Seeded Area	Control
Poa fendleriana	11.8	1.0
Sitanion hystrix	5.9	0.0
Oryzopsis hymenoides	0.54	1.0
Agropyron trachycaulum	5.62	0.0

varied significantly across vegetation categories—lowest (22%) in pinon woodlands and highest (56%) in re-sprouting shrublands (Table 4). A significant difference was detected in the bare soil cover, which was the highest in the pinon-juniper and pinon-juniper/purshia vegetation categories, leaving soils highly exposed to erosion and alien species invasions. Forb cover was not significantly different across the vegetation categories. Grasses are lowest (12%) in pinon-juniper woodlands.

The total vegetation cover was significantly different across geologic types—the mean cover on Menefee Shale was 48% while the mean cover on Cliffhouse Sandstone was 34%.

In addition, the pattern in vegetation recovery in the burned pinon-juniper woodlands—in which intercanopy spaces support forbs and grass, yet the canopy areas are almost entirely bare—may have interesting consequences for erosion and archeological site stabilization. This patchiness in vegetation recovery is being investigated by Resource Management (Colyer pers. com.).

Mountain shrublands, which include Quercus gambelii ("oak wooklands" in Fig. 3) or *Amelancheir utahensis* ("mtn shrub" in Fig. 3) are nearly half covered with re-sprouting oaks. Erosion is unlikely, and non-native species are experiencing competition; therefore, we propose no treatments for the re-sprouting areas.

One ascomycete fungus, *Pyronema domesticum*, formed widespread, confluent patches under logs or rocky ledges, especially in the pinon-juniper woodlands. While it was most visible immediately after the burn, it reappears with significant precipitation.

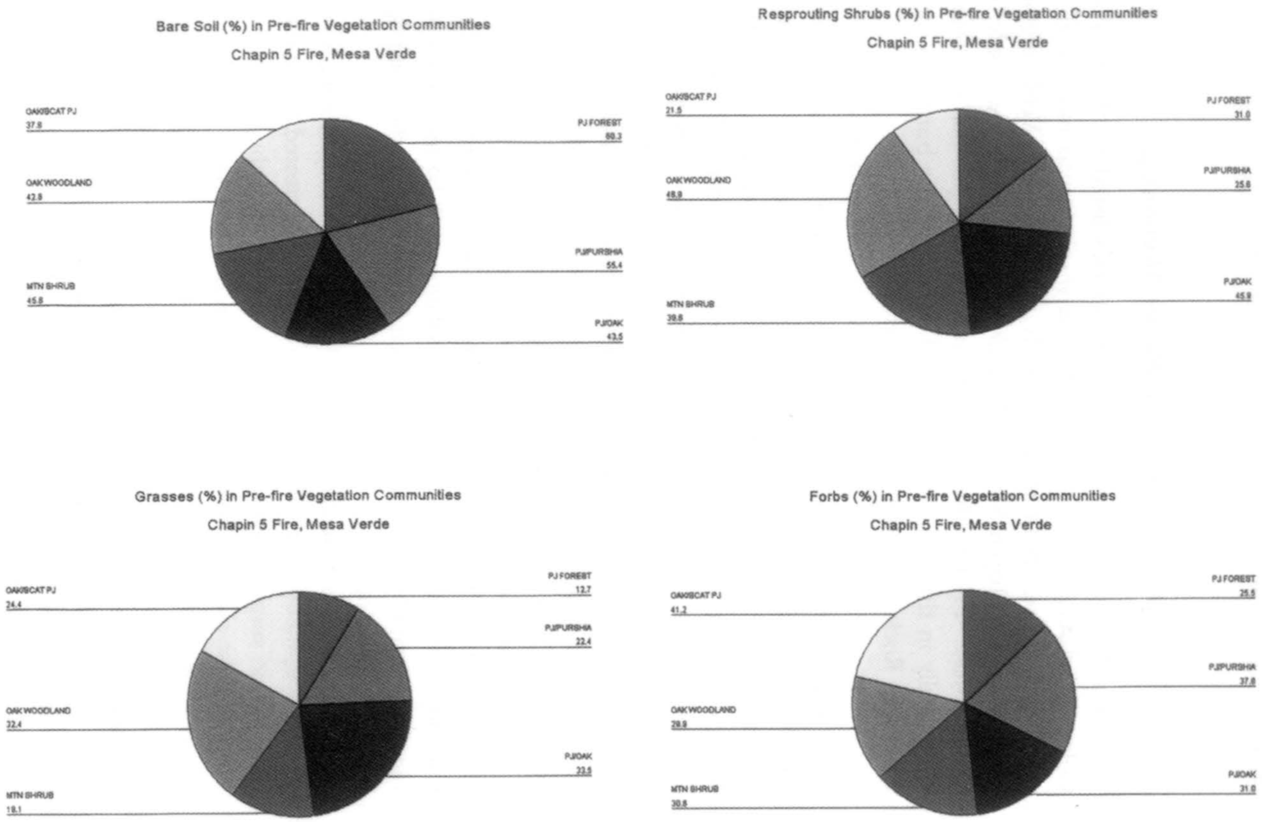
At each of the sampling points, the flora was recorded during late August-September 1997. As defined above, the samples had been randomly placed in 19 habitat types (Table 1).

Some floristic trends were obvious. *Chenopodium fremontii* occurred in all 19 habitat types, sometimes occupying up to 100% of the sample

Table 4. Frequency of bunch grasses resprouting within the Chapin 5 fire by geologic substrate. Data collected 2 months after the burn.

Geologic Substrate	Presence Pre-fire	Resprouts within 2 months	Seedlings within 2 months
Menefee Shale	.95	.42	.84
	±.07	±.31	±.64
Cliffhouse Ss.	.78	.24	1.21
	±.24	±.27	±1.21

Figure 3. The average cover of bare soil, forbs, grasses, and resprouting shrubs by pre-fire vegetation community, Chapin 5 fire.



points in a habitat type. At the other end of the spectrum, *Gayophytum ramosissimum* was found at only 3 of the 19 habitat types, yet it was locally abundunt (e.g., it was found in 100% of the sample points in habitat 2 and 50% of the points in habitat 6).

Endemic, Sensitive Plants Monitoring

The recovery of two endemic plant species listed by the State of Colorado, *Astragalus schmollae* and *Hackelia gracilenta*, was monitored in the Chapin 5 fire. Both are known only from the Mesa Verde region, and before the Chapin 5 burn, *Astragalus schmollae* was known only on Chapin Mesa. Prior to the Chapin 5 burn, *Hackelia gracilenta* was found sporadically in the Park on Wetherill Mesa, and in the burn area, near Battleship Rock (pers. obs., Colyer pers. com.).

We discovered a population of over 400 *A. schmollae* plants on Park Mesa in June 1997. The plant appeared mature and many were flowering; therefore their origin (vegetative or germination) could not be reliably determined. However, we also identified new seedlings in the Park Mesa population by the presence of cotyledons. A "control" population on Chapin Mesa shown no signs of germination—populations persisted strictly by vegetative growth. There is no significant difference in immature and mature plant densities in the Park Mesa population and "control" population on Chapin Mesa. Thus, we have reason the believe that expansion of this species range is fire-dependent.

Non-flowering *Hackelia gracilenta* plants were detected in previously known habitats (Battleship Rock) and new habitats (south end of Soda Canyon) in the burned area. These populations will be monitored next year to determine if they reproduce, their health and whether the population is expanding.

Nicotiana attenuata, wild tobacco, has been found throughout the Southwest in conjunction with archeological sites and fire treated fields; therefore, it is no surprise that both the Long Mesa fire and the Chapin 5 fire support these species. Seeds may remain in the seed bank for hundreds of years, germinating after fire when perhaps heat, nitrogen loading, or lack of competitors converge. We have found tobacco primarily on Cliffhouse Sandstone, rocky slopes, in dense patches of up to 500 plants. Mesa Verde Resource Management will be following the population structure, reproductive output, and persistence of 2 of the largest tobacco populations over time in an associated project (Steitz 1977).

Evaluation and Mitigation of Non-Native Plant Species

Past experience with the Long Mesa fire in 1989 has made it clear that Musk and Canada thistles, cheat grass, stickseed and other alien species will possibly dominate the severely burned areas (Floyd-Hanna and Romme 1995). In fact, native species have not yet outcompeted non-native plants, 6 years after the Long Mesa fire, but rather non-native species have expanded their area by 260% (Klein 1997). Populations of Canadian thistle were well-established in the Far View Sewage Lagoon area before the Chapin 5 fire, and they have spread downstream in Little Soda and Soda Canyons. These populations re-sprouted immediately after the burn. Musk thistle was also evident in 1997, but small and extensive populations were scattered throughout the southern portions of the burn.

Most of the first year's effort has been focused on preventing the expansion of Musk and Canadian thistles into the Chapin 5 burn. At varying density, nearly 40% of the burn has been infested with one of these species. The BAER plan defined an integrated pest management plan—limited herbicide application, biological control agents, and manual treatments—and each has been implemented (Fig. 2). One of the primary goals of the second field season will be to determine the effectiveness of our treatments.

Permanent monitoring plots have been established in Little Soda and Soda Canyons in which the density of Canada thistle is being monitored annually. Thus far, no permanent plots have been established for Musk thistle.

DISCUSSION

Each objective outlined in the vegetation monitoring and threatened/endangered plant sections of the BAER plan for Mesa Verde National Park has been addressed during this first field season. Vegetation monitoring has shown multiple pathways of vegetation recovery, each suggesting a unique monitoring and treatment program. The northern sector of the burn, which has revegetated by re-sprouting shrubs, had nearly 50% vegetation cover after one growing season; therefore, we have no reason to predict that non-native species will become established in the coming years unless conditions change considerably. We suggest that monitoring of this area continue for at least one additional growing season to insure the proliferation of native species (not non-native weeds) and to coordinate with the erosion treatment efforts by the BAER archeological team. At this time, no mitigation treatment is suggested for the burned mountain shrubland areas.

However, on the southern portions of the burn, and on the slopes of Soda Canyon, bare soils still dominate the landscape after the first growing season, and vegetation recovery is more than one half that of the northern sector. Non-native species are gaining a significant hold. We have treated isolated Musk thistle and Canada thistle stands with mechanical, chemical, and biological measures. We have also aerially seeded the most severely burned portions of Park Mesa. We are using the post-fire vegetation of Long Mesa fire (Floyd-Hanna and Romme 1995, Klein 1997) to model and predict what will likely occur in the southern portion of the Chapin 5 fire. The non-native vegetation of Long Mesa has spread by 260% since our last assessment in 1993, and we have no reason to believe that native species will eventually outcompete the aggressive, non-native species (Floyd-Hanna et al. 1993). This has clearly pre-empted the influx of native plant species and is not a desirable condition from the standpoint of natural resource management. Therefore, we recommended that treatment, specifically removal of non-native plant species, continue. Mesa Verde National Park has made a commitment to managing noxious weeds in their recent resource management initiative (L. Towle pers. com.), and our treatments are therefore in keeping with the overall Park goals. During the next growing season, 1997-1998, we will begin to evaluate the effectiveness of each treatment. We also propose a continuation of monitoring which leads to specific treatments of erosion and non-native species problems related to the Chapin 5 fire.

Therefore, the objectives proposed by the BAER Vegetation group for the 1997-1998 growing season are:

- Monitoring the 78 sampling points for vegetation recovery.
- Evaluate the effectiveness of treatments for non-native plant species invasions.
- Continue to treat non-native plant species invasions and monitor treatment success.
- Establish a monitoring program for *Hackelia gracilenta* and continue to monitor the population size and health of *Astragalus schmollae.*

ACKNOWLEDGMENTS

The authors would like to recognize the important contributions made by Dr. William Litzinger, the project taxonomist, and Marilyn Colyer, Resource Manager for Mesa Verde National Park, whose extensive knowledge of the park was invaluable in making management decisions regarding native plant species. We also thank Charlotte Thompson and Tess Johnstone for their excellent field work.

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Performance of Aerial Forward-Looking Infrared Surveys on Cattle, Elk, and Turkey in Northern Arizona

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Abstract. We conducted performance tests of aerial forward-looking infrared (FLIR) technology to assess its capability to survey cattle, elk (*Cervus elaphus*), and Merriam's turkey (*Meleagris gallapavo merriami*) in forested habitat. Fixed-wing FLIR surveys of known numbers of cattle were inaccurate, but linear correlations explained 86% of the variation, and initial estimates could be corrected to provide accurate estimates. We observed no relationship among fixed-wing FLIR, helicopter FLIR, and visual fixed-wing surveys for elk. In three attempts, we were unable to detect roosting turkeys in night-time aerial, fixed-wing FLIR overflights. FLIR surveys seem to be capable of quantifying large-bodied wildlife, but corrections for sightability need to be developed for each species, season, and habitat that will be surveyed. This correction will probably require several populations of known number to evaluate. Small-bodied wildlife may prove problematic. We recommend against the use of aerial FLIR surveys as the sole estimate of large-bodied wildlife species until correction factors can be developed.

Key words: Arizona, cattle, *Cervus elaphus*, elk, FLIR, infrared, *Meleagris gallopavo merriami*, Merriam's turkey, survey

Game management agencies typically survey many wildlife species by direct observation using visual ground, fixed-wing aircraft, and helicopter surveys (Davis and Winstead 1980). Resource managers and resource user groups have questioned the accuracy and precision of visual surveys because observers cannot quantify the number of undetected animals with these survey protocols or may not be able to ensure that the proportion of undetected animals remains constant (Shupe and Beasom 1987, White et al. 1989). Because contemporary resource management requires increasingly precise and accurate information for guidance, we investigated the performance of aerial forward-looking infrared (FLIR) technology to determine if it could objectively survey specific wildlife species or indicate necessary improvements to existing survey protocols.

Aerial FLIR surveys have become popular in the scientific literature because they seem to standardize and objectively survey large wildlife species with acceptable bias (Adams et al. 1997, Garner et al. 1995, Naugle et al. 1996, Wiggers and Beckerman 1993). Hansen and Beringer (1997) summarized the limitations of aerial FLIR surveys as the (1) inability to consistently differentiate between the radiation of target wildlife and the background, (2) inability to differentiate among species, (3) presence of forest canopy that retards the detection of infrared radiation, and (4) high cost. Recent literature (Garner et al. 1995, Naugle et al. 1996, Wiggers and Beckerman 1993) suggests that advances in FLIR technology have overcome some of the limitations that historically reduced the effectiveness of FLIR in conducting wildlife surveys.

We tested the performance of aerial FLIR to detect free-ranging ungulates and roosting turkeys in forested habitat in northern Arizona. Our objectives were to (1) evaluate the efficacy of aerial fixed-wing FLIR surveys to count cattle in pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.) woodlands, (2) contrast observations of elk (*Cervus elaphus*) among standard aerial fixed-wing visual, aerial fixed-wing FLIR, and helicopter FLIR surveys, and (3) determine if aerial fixed-wing FLIR could detect Merriam's turkeys (*Meleagris gallopavo merriami*) on night-time roosts in ponderosa pine (*P. ponderosa*) habitat.

STUDY AREAS

Cattle Surveys

We selected four fenced livestock allotments on the Prescott National Forest to evaluate the ability of FLIR to detect a known number ungulates. The allotments were on four ranches located 40-80 km northwest of Prescott, Yavapai County, Arizona. The Hitt allotment encompassed 1,024 ha, the South allotment 1,536 ha, the Juniper allotment 2,560 ha, and the K-4 allotment encompassed 12,544 ha. The predominant plant community on each allotment was Great Basin conifer woodland (pinyon pine-juniper [*Juniperus scopulorum*]). These woodlands are broken with interstitial areas comprised of plains grasslands, interior chaparral, ponderosa pine, and interior deciduous riparian communities (Brown 1994). Elevations range from 914 to 1,524 m.

Elk Surveys

We addressed our second objective in two study sites within the Apache-Sitgreaves National Forests in Navajo County, Arizona. The first study site is located about 16 km northeast of Heber, Arizona. It encompassed 250 km^2 of primarily open canopy pinyon-juniper grassland. About 1,500 ha is in agricultural production. Mean elevation is 1,830 m with relatively level topography except for bluffs along the northern portion and two washes in the southwest corner.

The second study site is located about 5 km east of Show Low, Arizona. This site encompassed about 110 km^2 of ponderosa pine and pinyon-juniper woodland. Open meadows as large as 500 ha are present. Elevation averages 2,075 m with little topographical relief except for seven wooded knolls composing less than 5% of the area.

Turkey Surveys

Our final objective was studied at three turkey roost sites about 16 km south of Flagstaff, Coconino County, Arizona, within the Coconino National Forest. These roosts were located within predominantly ponderosa pine forest stands. We followed radio-marked Merriam's turkeys to locate the roost sites.

METHODS

Aerial fixed-wing surveys were flown using a Cessna 337G twin-engine aircraft (operated by AirScan, Inc., Titusville, FL). We used a Bell Jet Ranger 206 helicopter (operated by the USDA Forest Service) to conduct our helicopter FLIR surveys. FLIR surveys were conducted using FLIR High Performance Infrared Imaging 2000 A/B units, with a temperature sensitivity of ±0.2°C. These units had a 10 power zoom lens that could be used to identify wildlife after detection. Standard fixed-wing visual surveys were conducted from a Cessna 182 single-engine aircraft. FLIR surveys were conducted with a pilot and a scanner operator-observer. FLIR surveys were recorded on VHS video tape and were reviewed after the survey. Visual fixed-wing surveys were conducted with a pilot and two trained observers familiar with the area.

Cattle Surveys

Although our primary interest in aerial FLIR technology involved wildlife surveys, we surveyed cattle to meet our first objective because they approximated the body size of elk and the number of adult cattle within each allotment was known. Cattle were the main ungulates within the allotments, but elk, mule deer (*Odocoileus hemionus*), and domestic horses were present in lower numbers. In addition, cattle were calving during the survey period on three of the four allotments and the exact number of young was unknown.

We conducted two replicate blind surveys on consecutive days, 21 and 22 February 1997. During the first survey flight, wind speeds aloft were 20-75 km/hr, but decreased during the next flight. Winds during the first survey affected the pilot's ability to maintain the aircraft on transects and produced ground speeds that varied depending on flight direction. We planned to move cattle between survey efforts to change the number of target animals within several allotments. We informed the observers that cattle numbers would change between survey efforts. However, we chose not to change cattle numbers because of complex logistic requirements and a short time period between survey efforts. The observers were unaware that cattle numbers within each allotment were not altered between survey efforts.

We provided the pilot with the perimeter coordinates of each allotment. The K-4 allotment is comprised of two allotments that were combined to include a common area of private land between them. The pilot was directed to select the optimal time, flight altitude, and airspeed to produce the highest detection rate. The first survey began at 0730 hrs. To provide better detection contrast, the pilot initiated the second survey at 0620 hrs. Flight altitudes varied from 610-760 m AGL, and airspeed was selected at 150-165 km per hour. The pilot flew non-overlapping survey transects defined by the aircraft on-board global positioning system. The pilot flew orbits over animals that surveyors detected. The aircraft returned on transect when the surveyor was satisfied that all animals detected were enumerated.

We used a paired t-test (Zar 1984) to test for differences between surveyed cattle and known numbers. We also used linear regression to test for a linear relationship between known and surveyed numbers of cattle. We used the regression equation to adjust surveyed numbers and again tested the adjusted numbers with minimum known numbers using a paired t-test.

Elk Surveys

We conducted comparative aerial surveys for elk on two study sites during 18 and 19 February 1997. We selected early winter mornings for this survey because of low thermal loading of the landscape and the greatest potential temperature differential between survey targets and the background landscape. The first study site had three separate surveys flown the morning of 18 February 1997. All observers and pilots were supplied with maps of the survey area and perimeter coordinates. The helicopter FLIR and the visual fixed-wing surveys each flew 18 transect lines in this study area, which were approximately 0.8 km apart. Fixed-wing FLIR surveys were conducted on 14 transects and were about 1.1 km apart. The observations from this latter survey were adjusted to correspond to the transect lines for the other two survey methods. The three aircraft flew the transect lines sequentially so that animal detection availability would remain similar among flights. Parallel north-south transects were flown beginning on the east side. Transect lines were about 750 m apart. Animal observations were recorded by transect line. We flew surveys sequentially, beginning with the survey at the highest altitude. We flew aerial fixed-wing FLIR surveys at 610 m AGL, helicopter FLIR surveys at 155 m AGL, and visual fixed-wing surveys at 60 m AGL. We believed that the chance for animal disturbance would increase as AGL of surveying aircraft decreased. The fixed-wing FLIR survey began about 0500 hrs, the helicopter FLIR survey began at 0715, and the visual fixed-wing survey began at 0740. The surveys required about two hours to complete.

The second study site was surveyed on the morning of 19 February 1997, using the same protocol. We used only the helicopter FLIR and visual fixed-wing surveys in this area. The helicopter FLIR survey began at 0710 hrs and the visual fixed-wing survey followed at 0730 hrs. The surveys were again completed within two hours.

Because we could not ensure that we were surveying the same animals with each subsequent survey, we did not attempt to statistically test for differences among survey methods. We did, however, use linear regression to test for a linear relationship among survey methods.

Turkey Surveys

We followed radio-marked Merriam's turkeys to their night-time roosting sites. These turkeys had been marked as part of another study (see Wakeling and Rogers 1998 for a description of capture and marking details). We recorded the coordinates of two roosts that we had visual confirmation of turkey use and one that we had radio-triangulated the approximate location. These coordinates were provided to the pilot to locate the roost sites.

We placed ground observers within 100 m of the two visually confirmed roost sites during the survey. The ground observers maintained radio communications with the aerial observers and provided a thermal reference point during the survey efforts. Survey efforts began at 0400 hrs and 610 m AGL. When the flight arrived at the roost site location, the aircraft made concentric orbits of <1 km around the roost site. Concentric orbits reduced in altitude until the final orbit was flown at 305 m AGL. Survey efforts alternated among the three roost sites until the turkeys left their roosts at about 0700 hrs.

RESULTS

Cattle Surveys

Aerial fixed-wing FLIR surveys did not accurately measure the number of cattle in the four allotments (t =3.283, 7 df, P=0.013; Table 1). The surveys had a strong linear relationship with minimum cattle numbers (Y=65.21+1.79X, r^2 =0.865, P=0.001). Adjusted surveyed cattle numbers did not differ from minimum known numbers (t =0.004, 7 df, P=0.992; Table 2).

Table 1. Allotments, size, minimum cattle present, and number surveyed with aerial fixed-wing FLIR during two survey efforts on the Prescott National Forest, Yavapai County, Arizona, during February 1997.

Allotment	Allotment Size (Ha)	Cattle Numbers	Survey 1	Survey 2
Hitt	2,560	150	0	2
South	3,840	28	0	5
Juniper	6,400	25	0	7
K-4	31,360	394	201	161
Total	44,160	597	201	175

Table 2. Allotments, size, minimum cattle present, and adjusted (Y=65.21+1.79X, r^2=0.865, P=0.001) number surveyed with aerial fixed-wing FLIR during two survey efforts on the Prescott National Forest, Yavapai County, Arizona, during February 1997.

Allotment	Allotment Size (Ha)	Cattle Numbers	Adjusted Survey 1	Adjusted Survey 2
Hitt	2,560	150	65	69
South	3,840	28	65	74
Juniper	6,400	25	65	78
K-4	31,360	394	425	353
Total	44,160	597	620	574

Elk Surveys

The surveys of the first study site were variable in the number and species of wildlife observed among survey methods (Table 3). Fixed-wing FLIR observers detected 37 elk in three herds and one group of seven pronghorn (*Antilocapra americana*). Helicopter FLIR observers detected 18 elk in two herds. Visual fixed-wing survey observers detected 77 elk in 11 herds, approximately 100 pronghorn in 10 herds, eight mule deer in three herds, and three coyotes. No linear relationship explained more than 35% of the variation in elk observations between any two survey methods.

The second study site produced similar variable results, except that the helicopter FLIR observers detected more elk than the visual fixed-wing observers (Table 4). The visual fixed-wing survey noted 24 mule deer, 45 pronghorn, and a flock of turkeys not recorded by the helicopter FLIR survey. A linear relationship explained less than 6% of the variation in elk observations between the two survey methods.

Turkey Surveys

The turkey surveys did not successfully detect the target wildlife. No turkeys were detected with the fixed-wing FLIR at the three roost sites. The ground observers were detected at the two roost sites where they were placed, and non-target elk were also observed.

Discussion

Although the fixed-wing FLIR cattle surveys did not provide accurate results, the adjusted survey numbers did not differ from the mini-

Table 3. Wildlife observed by transect line with fixed-wing FLIR, helicopter FLIR, and visual fixed-wing surveys on 18 February 1997, near Heber, Arizona.

	Wildlife Observed by Survey Method		
Transect Number	Fixed-wing FLIR	Helicopter FLIR	Visual Fixed-wing
1	0	0	10 elk, 10 pronghorn, 3 coyotes
2	0	0	12 pronghorn, 3 mule deer
3	0	0	2 pronghorn, 1 coyote
4	0	0	4 elk, 8 pronghorn, 1 mule deer
5	0	10 elk	15 elk
6	36 elk	8 elk	15 elk, 11 pronghorn
7	0	0	4 elk
8	0	0	23 pronghorn
9	1 elk	0	12 pronghorn
10	0	0	20 elk
11	0	0	4 mule deer
12	0	0	0
13	0	0	0
14	0	0	9 elk, 22 pronghorn
15	0	0	0
16	7 pronghorn	0	0
17	0	0	0
18	0	0	0
TOTAL	37 elk, 7 pronghorn	18 elk	77 elk, 8 mule deer, 4 coyotes, 100 pronghorn

Table 4. Wildlife observed by transect line with helicopter FLIR and visual fixed-wing surveys on 19 February 1997, near Show Low, Arizona.

	Wildlife Observed by Survey Method	
Transect Number	**Helicopter FLIR**	**Visual Fixed-wing**
1	0	0
2	0	0
3	0	0
4	0	0
5	74 elk	22 elk
6	0	20 mule deer
7	0	72 elk, 2 antelope, flock turkeys
8	91 elk	69 elk
9	182 elk	10 elk
10	114 elk	139 elk
11	0	34 elk, 9 antelope
12	0	71 elk, 22 antelope
13	0	0
14	0	0
15	0	6 elk
16	243 elk	0
17	0	0
18	0	0
19	0	2 elk
20	91 elk	91 elk, 4 mule deer
21	0	0
22	0	0
23	0	0
24	0	21 antelope
25	0	0
26	0	95 elk
TOTAL	795 elk	611 elk, 24 mule deer, 54 antelope, 1 flock turkeys

mum numbers of adult cattle. A linear relationship explained 86% of the variation between cattle observations by the fixed-wing FLIR surveys and known minimum adult cattle numbers. Because cattle in three of the four allotments were calving during the survey effort, the results of the survey are less precise than they appear. Although the difference in size between adults and calves was sometimes detected, such differences could not be consistently assessed for each observation.

When comparing elk observations among the three survey methods, neither FLIR survey seemed to detect more elk than conventional visual fixed-wing surveys. The one exception was the number of elk observed on 19 February, when 795 elk were detected by the helicopter FLIR versus 611 elk during the visual fixed-wing survey. A group of 243 elk was detected by the helicopter FLIR, but was not seen by the visual observers approximately 20 minutes later. The FLIR scanner operator stated that the elk herd was moving out of a meadow into dense canopy cover. When the visual fixed-wing observers flew that transect the herd may have been undetected because they had moved into the tree canopy.

Another apparent difficulty with FLIR surveys was the apparent inability of the FLIR to detect smaller wildlife such as pronghorn and mule deer. The fixed-wing FLIR survey detected a herd of seven pronghorn, but no others were detected. The visual surveys detected approximately 100 pronghorn in the same area, and the helicopter FLIR did not detect any smaller wildlife.

The inability of FLIR technology to document smaller wildlife is further supported by the lack of detection of roosting turkeys. Turkeys may have been obscured by dense ponderosa pine tree canopies, but their thermal images were too small to detect with current technology. Despite some early success in detecting turkeys in other studies (Garner et al. 1995), free-ranging turkeys seem to be difficult to detect with aerial FLIR efforts.

Aerial FLIR surveys promise to be valuable wildlife management tools. However, further research and technological advances are needed to identify the accuracy and precision of estimates from those surveys. Our experience suggests that the limitations of aerial FLIR surveys noted by Hansen and Beringer (1997) are still prevalent. We believe that the ability to correct for the cattle surveys with a simple linear relationship is encouraging, but this strongly suggests that any survey of a wildlife population of interest would need to be adjusted. This adjustment should be conducted for each species, habitat, and season when FLIR surveys were of interest. Further, this adjustment would require several populations of known numbers to develop sound relationships.

Despite its appeal, we recommend that aerial FLIR surveys should not be relied upon to provide sole population monitoring information on wildlife species. Aerial FLIR may be valuable in documenting occurrence of free-ranging, large-bodied wildlife, but the accuracy and precision of those surveys are unknown. Until such time as these factors are documented, FLIR is of little value beyond documenting the presence of large-bodied wildlife.

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Assessing Impacts of Alternative Livestock Management Practices: Raging Debates and a Role for Science

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Abstract. Grazing of domestic livestock is the most pervasive and persistent human impact on the grasslands and shrublands of the Colorado Plateau. Impacts on ecosystem function and biological diversity are thought to be great, but few studies have attempted to characterize such effects and compare the impacts of alternative livestock management practices. The dearth of pertinent, defensible information has contributed to the polarization of ranching and environmental interests, and has exacerbated what is one of the most contentious social issues in the southwestern USA. We discuss the role of ecological science in deriving and disseminating information that will help focus and perhaps resolve the impasse over grazing impacts and other natural resource issues. Specifically, we describe results of our involvement in "management teams" that include ranchers, environmentalists, public servants, and interested citizens, and how this collaborative process has helped shape an experimental research program that would be impossible to execute without the involvement of divergent interests in the grazing debate. Claims of various interest groups are reformulated as testable hypotheses, and a research design is presented.

Key words: arthropods, biological diversity, conflict resolution, cooperative research, plant communities, grazing, net primary productivity, ranching

INTRODUCTION

Grazing of domestic livestock is the most pervasive and persistent human impact on grasslands and shrublands of the arid Southwest (Fleischner 1994). The practice of livestock grazing affects approximately 70% of western states (Fleischner 1994), and 86% of the land surface in Arizona (Mayes and Archer 1982). Since the 1860's, the cattle industry has played a significant role in the social, cultural and political development of Arizona (Schlegel 1992) and, along with other factors, it has brought profound ecological change (Hastings and Turner 1965, Bahre 1991).

Today, the ubiquitous practice of cattle grazing in the arid West, in general, and Arizona, in particular, is an intensely contentious social issue (Dagget 1995). Widespread rangeland degradation has led public interest groups to challenge traditional grazing practices and demand a policy that will insure long-term productivity of public rangelands and the conservation of native biological diversity (e.g., Cooperrider and Wilcove 1995, Southwest Forest Alliance 1996). Meanwhile, ranchers facing weakening markets and declining profits, have fiercely resisted cutbacks in grazing allotments, increased fees, and greater regulation (Hecox and Ack 1996). Polarization of the policy debate has led to an impasse among ranchers, environmentalists, and resource managers regarding appropriate management of public lands (Brown and McDonnell 1995, Cooperrider and Wilcove 1995). Continuing debate, court actions, and pending lawsuits may have profound impacts on ranching and the future use of public lands in the Southwest. While it is clear that livestock grazing will remain an important economic activity and land use on the Colorado Plateau and throughout the region, it is also clear that grazing will be restricted or eliminated on some public lands. Which lands to graze, and how best to graze them, are pressing questions. How these questions are answered will greatly impact the ecological condition of the arid Southwest, as well as the future of one of the region's few significant food production systems.

A ROLE FOR SCIENCE

Like many environmental issues, the grazing debate is so polarized that it often seems that there is little room for science. Positions have been staked out for years, and scientific input often is reduced to a parade of "expert witnesses" presenting opposing interpretations of existing information. Yet many environmental issues rise to public prominence precisely because existing scientific information is equivocal or inadequate and, therefore, subject to misuse or misinterpretation (Ehrlich and Ehrlich 1996). Certainly there is no shortage of published research addressing many aspects of domestic livestock raising; however, much of this information fails to address directly the issues that have become pivotal to the grazing debate, namely the impacts of grazing on rangeland productivity and biological diversity. The impacts of domestic livestock on arid rangeland productivity and biological diversity are thought to be great, but quantitative information comparing different grazing approaches is scant. Furthermore, many studies comparing grazed and ungrazed areas have been criticized on methodological grounds because they rely on small exclosure areas for ungrazed sites (Bock et al. 1993), employ questionable photographic comparison techniques, or employ unreplicated designs in field comparisons (Brown and Waller 1986).

Objective evaluation of the many conflicting statements regarding the impacts of overgrazing or the benefits of certain range management techniques are further complicated by the failure of many advocates to clearly articulate specific claims and the response variables being discussed. Terms like "rangeland health," "biodiversity," "overgrazing," and "overrest" can mask the specifics and make it tempting to drown legitimate debate in arguments over vague generalities. The current grazing controversy, for example, often focuses on two distinct topics: ecosystem productivity and biological diversity. Unfortunately, references to these very different issues are often confused and muddled in discussions of "range condition" or "ecosystem health."

For these reasons, we have initiated a study of ecological factors that we believe undergird much of the controversy over grazing practices in the Southwest. Our first objective is to identify the points of conflict that emerge from differing claims regarding the ecological impacts of livestock grazing. We believe that if scientists are to contribute to solving real environmental problems they must strive to understand the issues that underlie and sustain conflict. By focusing research on these issues, we hope that it will be possible to engage a diverse group of landowners, public servants, and interested citizens to support and participate in efforts to improve our understanding of certain ecological factors that all agree are important determinants of environmental quality on arid rangelands (Table 1).

For the past three years we have participated in "management teams" – loosely organized groups of ranchers, environmentalists, agency officials, and interested citizens who are working collectively to improve management practices on private and public rangelands in Arizona. This experience has helped us to develop a research program that addresses questions of import to land managers and is broadly understood and appreciated by people on different sides of the grazing debate.

COMMON GROUND: SUSTAINABLE ECOSYSTEMS

One idea that is shared almost universally is the importance of managing grassland ecosystems for long-term, sustainable use. While the concept of sustainability has been widely embraced (e.g., Goodland 1995), inadequate definition combined with frequent use has diluted its meaning substantially. Nevertheless, sustainability is a central concept in the grazing debate and constitutes the common ground upon which any real resolution of the issue is likely to be founded. Clearly, for any type of agriculture to persist it must be both economically and ecologically sustainable (Crews et al. 1991). Across much of the arid West, economics

Table 1. Scientists, managers, landowners, and public interest groups often disagree on the role of science in land and resource management. Researchers attempting to illuminate controversial issues should strive to understand the conflict and assess the potential contributions of new research before launching investigations. Our experiences suggest the following sequence of steps for developing research projects that address scientific issues underlying conflict.

Steps for Turning Conflicting Claims Into Questions, and Then Into Testable Hypotheses:

- Study the controversy; understand the conflict.
- Restate contradictory claims as questions or hypotheses.
- Discuss questions/hypotheses with all parties.
- Get "buy-in" on research approach from the affected parties. If unsuccessful, repeat previous step, or change the approach.
- Design research through an open process, with opportunities for discussion and dialog.
- Initiate the study and guard scientific independence.
- Maintain channels of communication and provide regular updates.

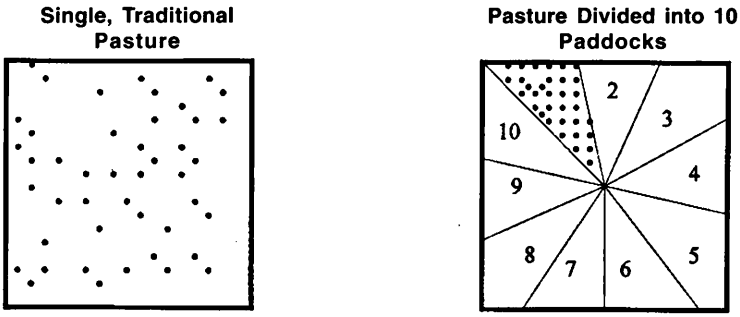
has tended to dictate what is achievable ecologically, rather than ecology dictating what is achievable economically. This has resulted in a short-term perspective that sacrifices ecosystem sustainability for short-term economic viability. As ranchers struggle increasingly to stay afloat financially, it is increasingly evident that further ecological deterioration is unacceptable to many. Moving to an ecological viewpoint, while remaining economically viable, is the challenge facing many ranchers and resource managers. While economic analyses are beyond the scope of this paper, it is important to note that ecological knowledge must be integrated with economic strategies if livestock grazing is to be truly sustainable.

In this paper we focus on two important aspects of ecological sustainability: ecosystem productivity and biological diversity. Ecological sustainability is concerned with the production of digestible plant material over the long term (decades to centuries), without significant external inputs, such as diverted water and fertilizers. Biological diversity reflects the ability of the land to support viable population of native species, from soil microorganisms to plants to the herbivores that consume them. These two issues lie at the heart of the grazing debate. Does grazing reduce or enhance the productivity of rangelands? Is the diversity of native organisms higher or lower on grazed lands? These are very different, though related questions, and the scientific approaches for answering them are also quite distinct. We are working with diverse management teams, on lands under active management, to investigate simultaneously these two aspects of ecosystem sustainability.

ALTERNATIVE APPROACHES TO RANGELAND MANAGEMENT

For the past 120 years, traditional cattle operations in Arizona have turned animals out onto large pastures for relatively long periods of time (Schlegel 1992). It is not unusual to see stocking densities of one animal per 100+ acres, with herds being moved between summer pastures at higher elevations and winter pastures in lower, desert grasslands. The result is relatively low grazing pressures over relatively long periods of time (Fig. 1). Stocking densities are manipulated in an attempt to maximize production without degrading range quality and the future ability of the system to produce forage. Hereafter, we will refer to this approach as "traditional grazing."

An alternative approach involves much higher stocking rates for relatively short periods of time (Fig. 1). Grazing episodes are followed by long periods of complete rest from the impacts of domesticated livestock, allowing time for the heavily impacted rangelands to recover prior



Example:

50 head of cattle graze 5,000 acres of rangeland for 5 months, continuously.

Low stocking rate, low animal impact, long-term disturbance, no rest.

50 head of cattle graze 500 acres of rangeland for 15 days, then move to a new paddock.

High stocking rate, high animal impact, short-term disturbance, followed by $4^1/_2$ months of rest.

Figure 1. Alternative grazing practices employed in the arid Southwest include season-long grazing on large pastures, at relatively low stocking densities (referred to as "traditional grazing" in this paper), and relatively rapid rotation of cattle among multiple small pastures, followed by long periods of rest (we refer to this as "HRM-style grazing"). The diagram contrasts two hypothetical grazing strategies for the same herd.

to the next introduction of cattle (Savory 1978). Stocking densities and rotation times may vary, often in response to prevailing economic or ecological conditions, but in virtually all cases the stocking density is several times that of traditional grazing systems, and the cattle are left in a particular pasture for a period of several days to weeks, rather than several months (Fig. 1). High density, short duration grazing is frequently implemented as part of a system called Holistic Resource Management (HRM, see Savory 1988) that has gained many enthusiastic adherents among ranchers, some public range managers, and some members of the environmental community (Dagget 1995).

While there is a considerable body of work on the effects of livestock grazing on native species and ecosystem function (e.g., Jeffries and Klopatek 1987, Belsky 1987, Belsky and Blumenthal 1997), and on the removal of livestock from rangelands (e.g., Bock et al. 1984, Brady et al. 1989, Milchunas and Lauenroth 1993) few studies have examined the relative impacts of alternative strategies. This is unfortunate because the actual policy decisions made by land managers seldom involve the introduction of livestock onto previously ungrazed lands, or the complete removal of livestock from current rangelands. Instead, development of sustainable grazing policy demands that ranchers and public lands managers choose an appropriate management strategy and stocking level to protect the integrity of the grazed ecosystem. The current project attempts to assist decision makers by providing information on grazing impacts on both ecosystem function and biological diversity, under alternative management strategies.

RESEARCH APPROACH

Involvement with ranchers, anti-grazing activists, and management teams has identified numerous conflicting claims regarding the ecological effects of grazing. Our first task was to turn these claims into clear questions that could be stated as testable hypotheses that are amenable to scientific inquiry. We include here three examples of the contradicting claims and the approaches that we have taken in addressing them through field research. For illustrative purposes, we have presented direct quotes from two published sources that are widely cited by activists on opposite sides of the grazing controversy.

Question 1. Do rates of organic matter decomposition and related nutrient cycling vary with grazing intensity?

- "In brittle environments...most dead plant material breaks down through slow oxidation and weathering. Large accumulations of unrecycled plant parts suppress plant growth and reduce uptake of those nutrients that eventually do get below the soil" (Savory 1988).
- "Grazing disrupts the fundamental ecosystem functions of nutrient cycling and succession....On the Colorado Plateau...a single footprint can bring a local nitrogen cycle almost to a halt" (Fleischner 1994).

Approaches:

1) Decomposition: Undertake a 3-year grass decomposition experiment using litter bags and grass stems to compare rates of decomposition (mass loss), as well nitrogen and phosphorus release rates (both immobilization and mineralization). Measure rates of soil respiration across a gradient of grazing intensity.

2) Nutrient availability: Over 3 years, measure the availability of important soil nutrients using buried anion and cation exchange resin bags, and analysis of leaf tissue nutrient concentrations and soil-extractable nutrients.
3) Nitrogen fixation: Using the natural abundance of ^{15}N, as well as acetylene reduction, determine whether grazed grasses support more or less rhizosphere-associated nitrogen fixation than ungrazed grasses.

Question 2. Do rates of water infiltration vary according to grazing intensity?

- "Tools that break up a sealed or "capped" surface, or increase the soil's organic content and crumb structure, speed penetration. A loosened, rough surface or one covered by old, prone plant material achieves this" (Savory 1988).
- "Microbiotic crusts in arid ecosystems have been correlated with...increased soil water infiltration.... Grazing has repeatedly been shown to decrease water infiltration" (Fleischner 1994).

Approach: Compare soil moisture in matched grazed and ungrazed plots immediately following rainfall events.

Question 3. How do native plant diversity and community composition vary with grazing intensity?

- "Periodic high animal impact...could remove old material, invigorate existing plants without exposing soil, create conditions for new plants to establish and move succession away from forbs and woody plants; ...prolonged rest does not favor perennial grass plants" (Savory 1988).
- "Decreases in density of native plant species and diversity of native plant communities as a result of livestock grazing activity have been observed in a wide variety of western ecosystems" (Fleischner 1994).

Approach: Quantify plant community composition under different grazing practices; implement controlled, replicated experiments and document plant communities before and after treatments, over several years. Measure living/dead plant material, species composition, and plant abundances under a replicated, spatial sampling design.

Response Variables and Sampling Design

These examples illustrate an approach to research that is driven not only by the scientific questions but also by the context of the debate over grazing impacts and the management of arid rangelands. We believe that this approach offers an opportunity for doing sound science that will help illuminate real land use issues. Table 2 lists the response variables that we are monitoring and provides a brief reference to the methods that we will employ.

Our sampling design is based on the Modified-Whittaker plot, which

Table 2. Response variables measured and methods employed in integrated studies of rangeland productivity and biodiversity. All measurements are made contemporaneously on common research plots.

RESPONSE VARIABLE	METHODS EMPLOYED
Productivity Variables	
Net Primary Productivity	Aboveground annual productivity harvests. Soil respiration measurements after rainfall events.
N and P availability	Buried anion and cation resin bags. In-lab mineralization using KCl extracts. Grass leaf tissue analyses. Measurements of immobilization and mineralization throughout decomposition experiments.
Decomposition / Soil Organic Matter	Mass loss of tethered grass bundles and litter bags. Soil carbon fractionation analysis.
Nitrogen fixation	Measurement of rhizosphere N-fixation activity using acetylene reduction. Estimate of rhizosphere fixation using natural abundance of ^{15}N.
Soil Water Infiltration	Bulk density and water infiltration capacity throughout soil profiles. Soil water content by depth following rainfall events.
Biodiversity Variables	
Plant Species Richness, % Cover by species, % Native species.	Exhaustive survey of nested Modified-Whittaker subplots; frequency sampling in smallest subplots to estimate percent cover.
Plant Biomass, by growth form	Aboveground harvests and dry biomass of grasses, forbs, and woody perennial.
Arthropod Diversity and Abundance (at various taxonomic levels)	Pitfall trapping associated with smallest Modified-Whittaker subplots; sweep-net sampling along transects within Modified-Whittaker plot.
Arthropod Biomass, by taxon	Dry weight of sorted pitfall and sweep-net samples.

has been shown to capture spatial variability in grassland studies, and to more accurately estimate species richness (Stohlgren et al. 1995). The largest plot, 20m x 50m, contains subplots of differing sizes and varying amounts of replication (Fig. 2). The approach permits estimation of variance among subplots, providing a measure of spatial variability. Recent studies suggest that the Modified-Whittaker approach also is effective at detecting rare plants (Stohlgren et al. 1997) and the presence of exotic species. We have integrated measurements of a host of grazing response variables (Table 2) with the Modified-Whittaker design. For example, ion exchange bags, pitfall traps and sweep-net transects have been associated with vegetation subplots, permitting similar analytical approaches for ecosystem variables, vegetation, and arthropod data when comparing the effects of different grazing treatments. In some cases, we employ additional plots and/or transects to increase replication and/or spatial independence of sample points.

STUDY SITES

We have begun work at three sites in Arizona to test productivity and biodiversity response variables (Fig. 3).

Reed Lake Site

Located at 2190 m on the Colorado Plateau, and classified as Plains and Great Basin Grassland (Brown 1994), the Reed Lake site is com-

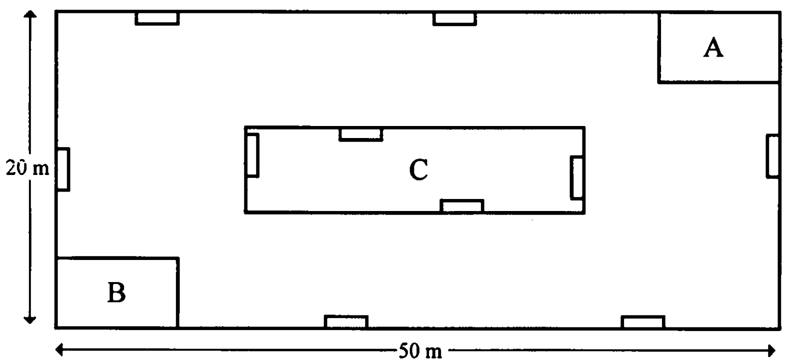
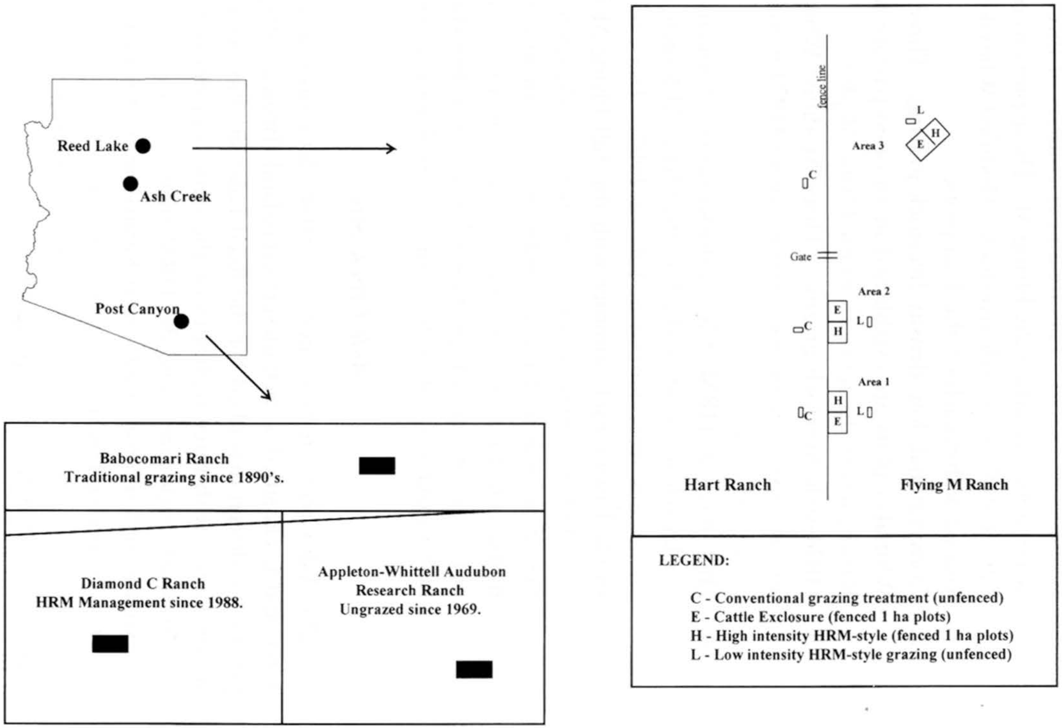


Figure 2. The Modified-Whittaker plot combines aspects of traditional plot and transect methods. Small subplots capture spatial variability; these and the larger subplots (A, B, C, and the 20m X 50m outer plot) permit estimates based on species:area relationships (Stohlgren et al. 1995). Modified-Whittaker plots are employed in each treatment type at all study sites.

Figure 3. Research is underway at three study sites, one in a desert grassland in a monsoonal climate (Post Canyon), one in a mid-elevation high desert grassland (Ash Creek), and one in a high-elevation summer pasture on the Colorado Plateau (Reed Lake). At the Post Canyon site, comparison of three treatment types is made possible by the presence of the Appleton-Whittell Research Ranch which has not been grazed since 1969. At Reed Lake and Ash Creek, replicated experimental plots supplement sample plots on adjacent ranches employing different grazing strategies.



prised of two working ranches, the Flying M and the Hart Ranch. The Flying M Ranch has practiced Holistic Resource Management, including relatively high stocking rates with long periods of rest, beginning in 1988. The experimental design we are using at Reed Lake consists of plots that receive 4 levels of livestock grazing—

1. Livestock excluded. This treatment consists of three, 1 ha replicate plots located on the Flying M. These plots were fenced in July of 1997 to exclude livestock. Modified-Whittaker plots are located within each of the 1 ha plots.
2. Conventional, low density livestock grazing. Three Modified-Whittaker plots are established in an open pasture of the Hart Ranch, across the fence from the Flying M plots.
3. HRM-style livestock grazing. Three Modified-Whittaker plots are established in an open pasture under HRM management on the Flying M Ranch.
4. High-intensity HRM-style livestock grazing. Adjacent to the livestock exclosures established on the Flying-M Ranch, three, 1 ha enclosures were fenced in July of 1997. The exclosures are stocked twice each summer with the full Flying-M herd (typically 300-500 animals) for 3-8 hrs per plot, depending on number of animals and range condition. This treatment does not mimic actual ranching practices; it is designed to provide an opportunity for testing hypothesized mechanistic links between animal impact, ecosystem function, and biological diversity.

Ash Creek Site

The Ash Creek site is located at 1280 m elevation near Dugas, Arizona, and is classified as Semidesert Grassland (Brown 1994). The experimental design described for the Reed Lake site has been duplicated at Ash Creek, with three replicates of the same four grazing treatments. The livestock exclosure plots, the HRM managed rangeland plots, and the extreme high-intensity plots are all located on the Orme Ranch, which has been practicing HRM since 1985. The project has been endorsed by the Orme Ranch management team and the Prescott National Forest. Field work was initiated in Spring 1998.

Post Canyon Site

Located at 1520 m in the Sonoita Valley of SE Arizona, the vegetation of the Post Canyon site is classified as Plains and Great Basin Grassland (Brown 1994). The experimental design of the Post Canyon site differs from that of the Reed Lake and Ash Creek sites. At Post Canyon, the three land management treatments of interest converge at one point (Fig. 3) — The Diamond C Ranch has been managing livestock according to HRM principles since 1984; the Babocomori Ranch uses conventional, low intensity livestock management practices; and the Appleton-Whittell Audubon Research Ranch has excluded livestock from its premises since 1969. We have taken advantage of these three well established "treatments" by setting up Modified Whittaker plots, supplemented by stratified random samples on comparable land forms within 1 km of the convergence of the three ranches.

CONCLUSIONS

Environmental issues are often so polarized that there appears to be little room for objective scientific analysis. Yet few pressing environmental issues can be resolved without sufficient scientific understanding. The debate over grazing impacts and the proper use of public rangelands in the Southwest presents quite a "Catch 22" situation, with different interests advancing forceful arguments, each claiming that their position is based on sound science. Environmental scientists often find themselves called upon to bolster one side of the argument or the other, rather than doing what they are trained to do: identify important questions, design rigorous studies to address them, and analyze and interpret the results. If scientists wish to contribute to resolving real management issues, such as those posed by livestock grazing in the Southwest, they must understand (and target for research) the notions that underlie and sustain conflict. Developing an objective research approach that is broadly understood by all affected parties is a difficult task, but one that is essential to conducting relevant research that will be considered by decision makers.

We have worked with ranchers, environmentalists, agency scientists, and interested citizens to identify appropriate scientific questions and design approaches for field research. Exposure to a wide range of perspectives and interactions with many committed individuals have helped us develop a research effort that many agree is addressing key questions that are relevant to the future management of southwestern rangelands. While our geographic, taxonomic, and conceptual approaches are necessarily focused on particular issues and locations, the interactive process, which continues as our field work progresses, provides an encouraging indication that the results (whatever the outcome) will be considered by ranchers, public officials, and involved citizens – those individuals whose opinions and actions will determine future grazing policy.

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Social Behavior of Abert's Squirrels in Ponderosa Pine Forests

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Abstract. During an ongoing 12 month radio-telemetry study, apparent social behavior was observed in Abert's squirrels (*Sciurus aberti aberti*) at two study sites near Flagstaff, Arizona. Although considered mostly a solitary species, approximately 53% of the radio-collared squirrels (n=28) exhibited communal nesting behavior at least once during the period from November 1996 through early May 1997. The pairs and trios of squirrels occupying communal nests included male/male combinations and male/female combinations. Furthermore, nest sharing occurred between both squirrels of the same age class (adult/adult, juvenile/juvenile) and squirrels of different age classes (adult/juvenile). Tree sharing behavior was also observed among the squirrels. Approximately 59% of the radio-collared squirrels (n=32) were visually located in a ponderosa pine (*Pinus ponderosa*) concurrently occupied by one or more squirrels at least once during the course of the study. Communal nesting behavior among Abert's squirrels may facilitate thermoregulation, and both communal nesting and tree sharing may reinforce social bonding and resource sharing.

Key words: Abert's squirrel, communal nesting, tree sharing, thermoregulation, social bonding

Abert's squirrels are one of six subspecies of tassel-eared squirrels endemic to ponderosa pine forests of the southwestern United States and Mexico (Brown 1984, Hoffmeister and Diersing 1978). These animals are intricately associated with the ponderosa pine ecosystem. Squirrels feed on the cones, inner bark of pine shoots, and symbiotic mycorhizal fungi of the pines (Keith 1965, States et al. 1988, Allred et al. 1994). Tree nests are constructed from pine shoot clippings (Keith 1965). In addition, Abert's squirrels represent an important prey for the northern goshawk and hence are a vital intermediate in the forest food chain (Pogany and Allred 1995, Reynolds et al. 1992). Since this animal plays an integral role in the ecosystem, the Abert's squirrel may be considered an indicator species of ponderosa pine forest health (Allred and Gaud, 1999).

Abert's squirrels are generally considered solitary animals except during the breeding season which usually occurs from April through June (Brown 1984). However, research by Allred and Pogany (1996) has provided data that expand the known breeding period. Aside from territorial displays during the mating season, all other aggressive exchanges are thought to occur between animals occupying a common feeding area (Brown 1984). Although considered rare, communal nesting among the subspecies *S. a. ferreus* has been documented in the Rocky Mountains in Boulder County, Colorado (Halloran and Bekoff 1994). Unrelated female/male pairs constituted the majority of observed shared nests (Halloran and Bekoff 1994). However, nest sharing among kin has been documented among gray squirrels (Koprowski 1991), and researchers have suggested that female Abert's squirrels may permit one offspring to remain with them through the young's first winter (Keith 1965).

Since tassel-eared squirrels are denoted as a non-gregarious species (Brown 1984), until this research, no studies documented social behavior among this subspecies. Unlike the many colonial species of ground squirrels, sociality among these tree squirrels has not been apparent.

This study presents evidence for social behavior among Abert's squirrels in ponderosa pine forests of northern Arizona. Both nest sharing and tree sharing behaviors were documented during non-breeding months among radio-collared animals. Both of these behaviors may facilitate social bonds. In addition, as proposed by Grodzonski (1985, Golightly and Ohmart 1978), nest sharing may provide thermoregulatory benefits. Tree sharing may result from an abundant food resource, such as ovulate cones, provided by the tree.

METHODS

Abert's squirrels were trapped using Tomahawk Live Traps (#104) and radio-collared at two study sites within 20 miles of Flagstaff, Arizona. The Marshall Mesa site, an uneven aged stand with interlocking canopies, was considered good quality habitat for squirrels (Patton 1984). In contrast, the Fort Tuthill site, most recently logged in 1992, was a fairly even aged stand with few interlocking trees, a poorer quality squirrel habitat (Patton 1984). The trapping grid at each study site was composed of 144 small mammal traps and an area of 153 acres at Fort Tuthill and 177 acres at Marshall Mesa (Dodd pers. com.).

Data for this study were collected during a 12 month period from September 1996 through August 1997. Adult squirrels were trapped and radio-collared in August 1996. Juvenile squirrels were collared in October 1996. The weight of the Telonics' radio-collars was approximately 18 grams with a battery life of 10 months. Each squirrel was tracked with a hand-held H-antenna twice a week. Visual observations were used to verify each located squirrel. When the battery life of the collars terminated, individual squirrels were trapped and recollared. New squirrels were radio-collared to replace those animals lost to predation.

Data from both sites were pooled for G-Test analyses. Communal nesting behavior was observed among a sample of 28 squirrels during the period from November 1996 through early May 1997. Nest sharing was not observed during the remaining portion of the year. Tree sharing behavior was examined from a total sample of 32 squirrels during most of the 12 month period. These samples included both sexes (male, female) and age classes (adult, juvenile) of squirrels.

RESULTS

Data were collected from September 1996 through August 1997. Communal nesting behavior was defined as at least one observation of a radio-collared squirrel sharing a nest with another squirrel. Tree sharing behavior was defined as the observation of a radio-collared squirrel sharing a tree with another squirrel on at least one occasion.

Communal Nesting Behavior

Communal nesting was observed from November 1996 through early May 1997 (Fig. 1). Approximately 53%, of the radio-collared squirrels (n=28) were located in a nest simultaneously occupied by another squirrel. At least 50% of the squirrels exhibited nest sharing behavior

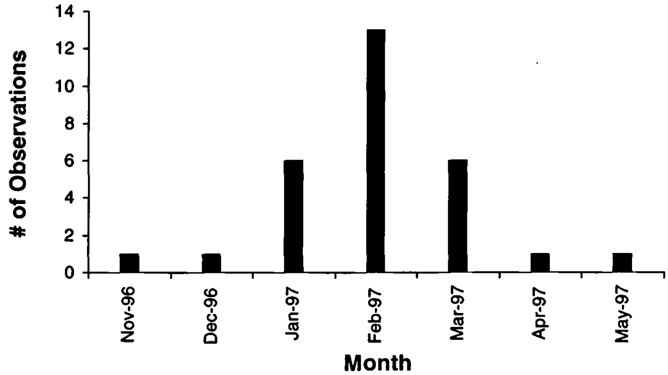

Figure 1. Months during which communal nesting was observed.

($G_{adj[0.05,1]}$=2.28, P<0.05). A total of 234 nest observations were collected from the 28 radio-collared animals during the period from November through May. Shared nesting was observed in 12% of the cases. Most of the observations of nest sharing were between radio-collared squirrels. The radio-collars allowed verifications of the location of multiple squirrels in the same nest without visual observations of the animals. However, three of the shared nest observations were of one radio-collared squirrel and one non-collared animal. In these instances, the squirrels exited the nest, thereby enabling the researchers to make visual confirmations of the animals.

Sex and age class (adult, juvenile) of squirrels that exhibited communal nesting varied greatly (Table). However, the highest percentage of observations involved an adult female with an adult male (20%) or two

Table. Squirrel combinations in shared nests.

Squirrel combination	# of observations	% of observations
juv male / juv male	6	20
adult male / adult female	6	20
adult male / adult female / juv female	4	13
adult male / juv female	3	10
adult female / juv female	3	10
adult male / adult male	2	7
juv male / unknown	2	7
adult female / unknown	2	7
adult male / unknown	1	3

juvenile males (20%). The predominance of an adult male and an adult female sharing a nest has also been documented among the subspecies *S. a. ferreus* in Colorado (Halloran and Bekoff 1994). Other combinations of nest sharers among the radio-collared squirrels included adult female and juvenile female (10%), adult male and adult male (10%), and adult male and juvenile female (7%). Furthermore, a trio of radio-collared squirrels, an adult male, adult female, and juvenile female, were located in the same nest on four occasions (13%).

Tree Sharing Behavior

Tree sharing behavior was observed from September 1996 through August 1997 (Fig. 2). Of the total radio-collared squirrels (n=32), 59% (19) were located in a tree occupied by at least one other squirrel, not necessarily a radio-collared animal. Again, as with communal nesting behavior, at least 50% of the animals exhibited this behavior ($G_{adj[0.05,1]}$=1.11, $P<0.05$). Of the total observations (n=1341) of radio-collared squirrels, 1.6% (22) were observations of multiple squirrels in the same tree. From these 22 observations, 20 were of two squirrels sharing the same tree, and two were of three squirrels in the same tree.

Also, many of the radio-collared animals (n=28) exhibited both nest sharing and tree sharing behaviors (Fig. 3). Approximately 33% of the squirrels exhibited both behaviors, 25% were observed in a shared tree, 21% were observed in a shared nest, and 21% exhibited neither behavior.

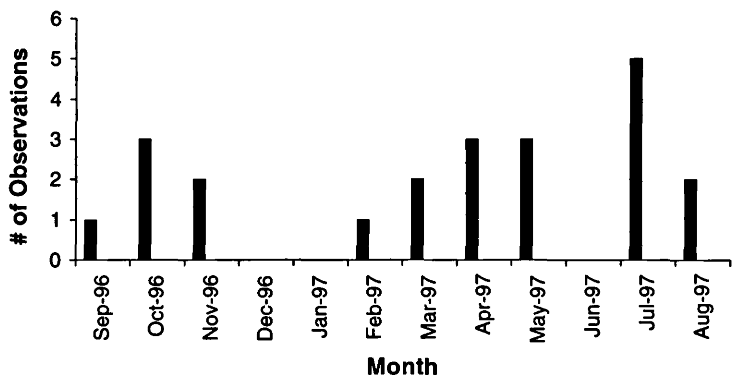

Figure 2. Months during which tree sharing was observed.

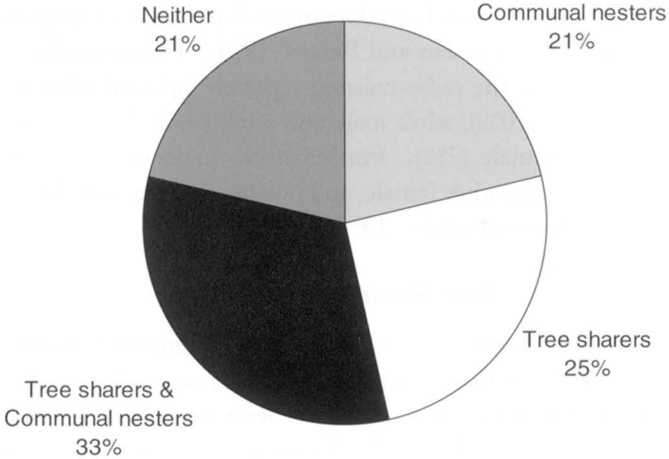

Figure 3. Proportion of radio-collared squirrels (November through early May) that exhibited social behaviors.

DISCUSSION

Data from this study suggest that *S. a. aberti* are more social than previously reported. At least 50% of the radio-collared animals were observed in a shared nest. In addition, at least 50% of the squirrels were observed in a shared tree.

Nest sharing behavior was observed from November to early May. Thus, such behavior may facilitate thermoregulation during months of cold temperatures (Golightly and Ohmart 1978). If the squirrels can reduce the loss of body heat, then less time will be required for foraging, an activity which exposes the animals to both cold temperatures and increased risk of predation. In addition, communal nesting may reinforce social bonds between animals. This may be especially true between mothers and offspring, siblings, or male/female breeding pairs. Although not observed, communal nesting may also occur during the warmer months. During the summer, the squirrels are active in early morning. Researchers did not radio-track the animals before dawn, hence any shared nesting behavior may have been missed during those months.

Tree sharing behavior was observed among the radio-collared squirrels throughout most of the year. Again, this behavior may reinforce social bonds among the animals. However, this behavior may also be the result of an abundant food resource, for example, ovulate cones or palatable terminal shoots (Keith 1965, Allred et al. 1994). The peak in tree sharing during July appears to correspond to the peak in cone production in the pines. In addition, when located in a shared tree, squirrels were frequently observed peeling cones. Consequently, it is possible that the only attractant for the squirrels to occupy a shared tree is the food resource. The animals may simply tolerate the presence of other squirrels in order to obtain the valuable cones.

Social behavior, nest sharing and tree sharing, among Abert's squirrels may be more common than this study indicates. These data are from the observations of radio-collared animals. During the 12 months of this study, the uncorrected population estimate within the trapping grid at Marshall Mesa averages approximately 39 squirrels (Dodd pers. com.). About 35% of the animals were radio-tracked. At Fort Tuthill, the uncorrected population estimate is approximately 26 animals in the winter and 43 animals in the summer (Dodd pers. com.). Squirrel movements appear to respond to food resources at that site and, therefore, population size fluctuates. Still, only approximately 32% of the squirrels were radio-tracked. Also, a visual location of each squirrel twice a week equates to about one half hour of observation time per squirrel per week. Squirrels may perform many behaviors not observed. This study provides one window into aspects of the social behavior of Abert's squirrels.

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Long Foraging Distances in Two Uncommon Bat Species (*Euderma maculatum* and *Eumops perotis*) in Northern Arizona

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Abstract. The Kaibab Plateau of north-central Arizona is a high elevation, limestone plateau on the northern edge of the Grand Canyon. We used radio telemetry to determine foraging areas for seven lactating female spotted bats (*Euderma maculatum*) and located roosts for four of these bats. We also captured greater western mastiff bats (*Eumops perotis*) and located a single roost for this species. Roosts for both spotted and mastiff bats were in xeric cliffs in or near Grand Canyon National Park (GCNP) at approximately 650 to 1040 m elevation. Distances from capture location to maternity roosts ranged from approximately 28 to 42 km. Capture sites and foraging areas were located at approximately 2600 m elevation for spotted bats and 1900 m for mastiff bats. We caught 18 bat species during mist net surveys conducted from 1994 through 1998. The high species diversity that we observed may be due to the proximity of the Kaibab Plateau to the Grand Canyon, and the great range of elevations and habitats available from the floor of GCNP (600 m elevation, desert) to the meadows (2600 m elevation, subalpine) on the Kaibab Plateau.

Key words: foraging, western mastiff bats, *Eumops perotis*, spotted bats, *Euderma maculatum*, Kaibab Plateau, Arizona, Grand Canyon National Park, surveys

INTRODUCTION

Once thought to be extremely rare, spotted bats (*Euderma maculatum*) are widely distributed throughout western North America and probably have a discontinuous, patchy distribution (Fenton et al. 1987, Nagorsen and Brigham 1993). Much of what is known of spotted bat behavior and ecology has been gained from three locations where they are relatively common: the Okanagan Valley in southern British Columbia, Canada (Leonard and Fenton 1983), Big Bend National Park in southern Texas (Easterla 1970), and Fort Pierce Wash on the Utah-Arizona border (Ruffner et al. 1979). High cliffs were nearby in all three of these locations. Radio tracking of three spotted bats in British Columbia (Wai-Ping and Fenton 1989) found that bats foraged all night and did not travel farther than 10 km from cliff day roosts. Preferred foraging habitat appears to be open areas surrounded by ponderosa pines (Woodsworth et al. 1981, Leonard and Fenton 1983, Wai-Ping and Fenton 1989).

Roost sites for greater western mastiff bats (*Eumops perotis*) were not known from the state of Arizona since the 1970s, and was not known north of the Grand Canyon until we captured eight lactating females in 1995. These captures were a range expansion for the species (Castner et al. 1996). Roost sites have been described for California (Cockrum 1960, Dalquist 1946, Howell and Little 1924), Texas (Ohlendorf 1972) and Arizona (Cox 1965). In general greater western mastiff bats live in high, dry places, and roosts are in locations that allow the bat to drop >3 m to launch into flight (Freeman 1981). In the southwestern United States, roosts are typically found in rugged rocky canyons and cliffs (Barbour and Davis 1969, Dalquest 1946). Little is known about the foraging habitat for this species. The purpose of this study was to locate day roosts and foraging areas used by spotted and mastiff bats on the North Kaibab Ranger District (NKRD) of the Kaibab National Forest, in northern Arizona.

METHODS

During July - August 1995, July 1996, July - August 1997, and August 1998 we caught bats with mist nets set across small ponds (ca. 15 to 35 m across) in subalpine meadows on the NKRD, north of Grand Canyon National Park (GCNP). Spotted bats were captured in meadows from approximately 2400 to 2650 m in elevation that were linked across the landscape to form a series of meadow systems. These meadows were surrounded by ponderosa pine (*Pinus ponderosa*) forests that included Douglas-fir (*Pseudotsuga menziezii*), white fir (*Abies concolor*), and patches of aspen (*Populus tremuloides*) Mastiff bats were captured in similar meadows from approximately 1900 to 2400 m elevation.

We attached radio transmitters to captured spotted and mastiff bats with surgical glue, and followed them to day roosts. We placed transmitters (0.68 g, BD2, Holohil Inc., Ontario, Canada) on six (1 male, 4 lactating females, 1 post lactating female) spotted bats in 1995, six (four lactating and two non-reproductive adult females) spotted bats in 1996 and seven (all lactating adult females) spotted bats in 1997. We also placed 1.28g transmitters on six (all lactating female) mastiff bats in 1995, one (non-reproductive adult female) mastiff bat in 1997, and one (lactating adult female) mastiff bat in 1998. Radio telemetry was conducted through a combination of vehicle pursuit, stationary positions, and airplane.

RESULTS

The presence of many audible (low-frequency) spotted bat echolocation calls and feeding buzzes (increased rates of echolocation calls associated with insect detection and pursuit; Griffin et al. 1960) in the meadows indicated that spotted bats were locally common and that the meadow systems were heavily used as foraging areas. Over 13 weeks, during four summers, we caught 25 spotted bats and 18 mastiff bats in 44 nights of netting, and we heard many spotted bat and mastiff bat calls. We caught other bats that also used the meadows for foraging (big free-tail, *Nyctinomops macrotis*; Mexican free-tail, *Tadarida braziliensis*; and Allen's big-eared bat, *Idionycteris phyllotis*), but spotted bat and mastiff bat calls are distinctive (Fenton et al. 1987, Cockrum 1960) and we could distinguish their calls from the others. Although we primarily netted ponds within forested habitat on the NKRD, we rarely heard and never caught spotted or mastiff bats in forested areas.

Spotted Bats

Spotted bats are rapid flyers (Woodsworth et al. 1981, Wai-Ping and Fenton 1989) and the rugged topography and few roads on the NKRD made nighttime pursuit difficult. While radio tracking from the ground, foraging bats were rarely detectable >1.5 km due to effects of forest canopy and topography. When in open country or from lookout towers, we were sometimes able to detect the bats from greater distances.

Initial attempts to detect signals from roosting bats during daylight, even from aircraft, were unsuccessful. However, by using a combination of vehicle pursuit and hilltop radiotelemetry sites, several bats were relocated sufficiently to obtain general flight directions during early morning when bats left meadows and were presumably en route to day roosts.

In July 1996, we tracked one lactating female to a day roost in a remote area of GCNP, 38 km from the capture site (Rabe et al. 1998; Table 1). We located the roost from an airplane overflight after triangulating transmitter signals from the canyon rim in early morning. The day roost was at an elevation of ca. 700 m in a south-facing limestone cliff ca. 150 m above and 200 m from the Colorado River. The roost site was located in Sonoran Desert habitat with predominantly catclaw (*Acacia greggii*) and mesquite (*Prosopis glandulosa*) vegetation.

The bat followed a predictable pattern in its foraging movements. In four sequential nights of monitoring, we first detected the signal from the canyon rim (we could detect signals near the river 8 to 15 km distant) at 2010 h to 2030 h (170 to 190 minutes after sunset) each night the bat emerged from its cliff roost. It arrived in the same meadow system each night at about 2130 h, and foraged until ca. 2400 h to 0100 h, when it night-roosted in the same patch of aspen on the south face of a small ridge, 1 km east of the meadow. Radio signals indicated no movement during this night-roosting period, but the bat did not appear torpid. The bat was easily disturbed and would fly away if approached. Each night, the bat left the night roost between 0330 h and 0350 h (103 to 83 nimutes before sunrise) and flew directly towards the cliff roost, 38.5 km away. The animal did not seem to forage after night roosting and we lost the signal over the rim of the Grand Canyon 40 to 45 minutes after depart-

Table 1. Spotted bat capture and roost site elevations and roost-to-capture-site distances.

Year	Bat	Capture Elevation (m)	Roost Elevation (m)	Elevation Change (m)	Distance (km)
1996	102	2499	700	1799	38.7
1997	216	2536	1024	1512	42.7
1997	246	2536	ca. 1000		
1997	275	2536	1036	1500	39.4
1997	301	2597	768	1829	41.3
1997	325	2597	ca. 1000		
1997	371	2524	1134	1390	38.2
1997	406	2597			

ing the night roost. This resulted in a flight speed of approximately 50 km/h.

In July 1997, we tracked four additional lactating females to four day roosts in remote areas of GCNP and Kanab Creek Wilderness on the NKRD. Distances from the capture sites ranged from 38.2 km to 42.7 km (Table 1). We located the bat roosts from airplane overflights after triangulating transmitter signals from the canyon rims in early morning. Day roosts ranged in elevation from ca. 700 m to 1080 m. One roost was approximately 850 m from the Colorado River. The three roosts located within Kanab Creek canyon were all <100 m from Kanab Creek. Roost sites were located in Sonoran Desert habitat with predominantly catclaw (*Acacia greggii*) and mesquite (*Prosopis glandulosa*) vegetation. Because these roosts were located in very rugged, isolated desert country, we visited only one roost for an exit count. The Kanab Creek roost was visited on two occasions, 18 July and 24 July 1997. The exact roost site could not be determined during exit counts; however, the general location was on a cliff face, approximately 20 m from the base of the cliff, in the top one-third of the cliff. The bat exited the roost at approximately 2015 h (ca. 30 minutes after sunset) each night and returned to roost at approximately 0420 h. Based on audible echolocation calls and radio telemetry signals, this was the only bat to exit.

In 1996 and 1997, female spotted bats averaged three hours foraging in the high elevation meadows. With extensive radio telemetry on six lactating female spotted bats in 1997, there appeared to be an overlap of foraging territories (Fig. 1). In 1997, we again noticed night roosting behavior in some of the females; however, they also appeared to arrive in the meadow systems later and leave earlier than in 1996. Because we were tracking spotted bats slightly earlier in the season from 1996, we thought that perhaps the females could not leave younger offspring for long periods of time due to feeding demands. Bats arrived in the meadow systems at approximately 2300 h and left at approximately 0200 h. Again, bats flew straight lines back to their canyon day roosts and did not appear to forage on the return trip.

Greater Western Mastiff Bats

In 1995 we captured eight greater western mastiff bats, six of which where lactating females. Since all eight females were captured relatively early in the evening (60 to 100 minutes after sunset), we speculated that a roost site was nearby. We placed transmitters (BD-2, Holohil) on the six lactating females and attempted to follow them. Mastiffs are very rapid

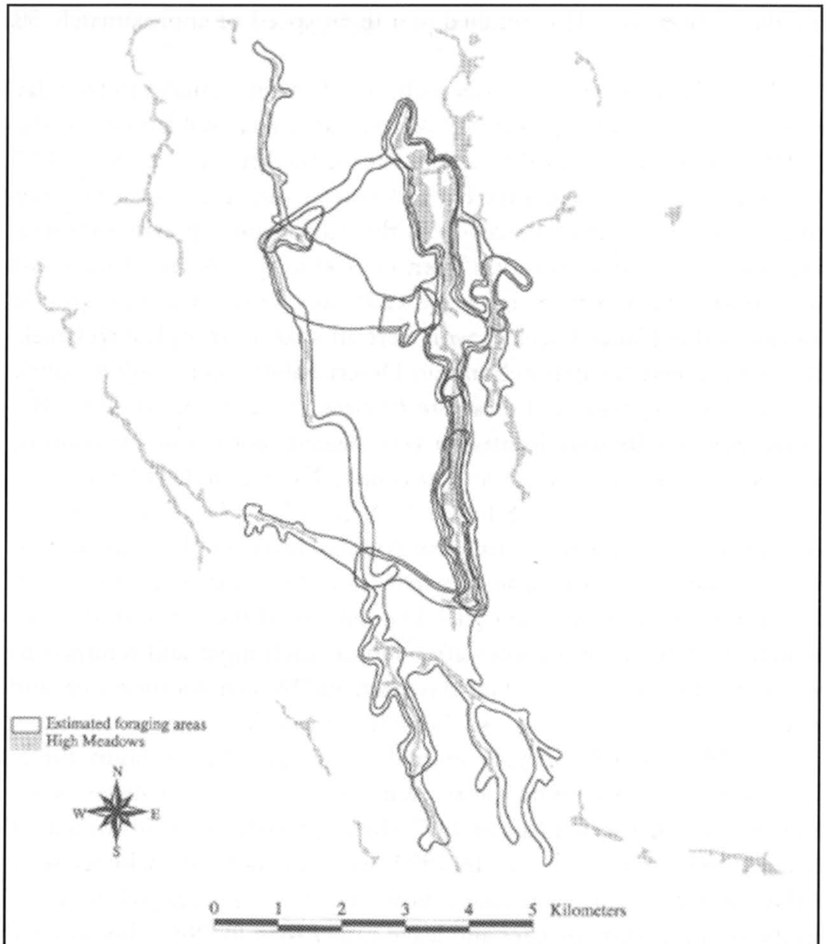

Figure 1. Estimated foraging areas for six spotted bats in 1997. Foraging areas were estimated from radio telemetry observations of individual bats.

fliers and we were able to follow them for only a short period that night. We detected only one faint signal the next day in a cliff a few miles south of the trap site, but quickly lost the signal. We detected no signals over the next few nights despite substantial effort.

In 1997 we captured several greater western mastiff bats at higher elevation meadow tanks. Because we assumed that the 1995 trap location was near the maternity roost, we waited to attach radios until we returned to that trap location. Although many mastiff bats were heard at the 1995 location at various times during the summer, we were only able to capture one non-reproductive female in 1997. We held her until early morning (ca. 0400 h) when a plane we had arranged to be overhead arrived. Equipped with telemetry receiver and antenna, the plane was able to track her until just after sunrise, when she roosted in a tall ponderosa pine tree near the rim of the Grand Canyon, ca. 19.5 km from the trap site. Over six nights of telemetry from stationary points along the rim of the Grand Canyon, we were able to triangulate on a 20 km^2 area along the Colorado River (ca. 29 km from the trap site) where the bat appeared at ca. 2000 h and ca. 0500 h each day (Table 2). On day six, no signal was detected, and it was assumed that the bat dropped its transmitter at the roost. A plane made an overflight of the area two days later, but did not detect any radio signal.

Although we did not attempt to determine the foraging areas for the mastiff bat, it did return to the plateau and headed in the general direction of the trap site each night. Mastiff bats were also heard in several locations on the plateau in meadows, where they appeared to travel in groups. Hoffmeister (1986) suggested that these bats forage in groups, keeping contact with their roost mates.

In 1998, we again attempted to capture mastiff bats at several locations. It appeared to us that fewer feeding buzzes were detected at several locations compared to previous years. One lactating female was finally captured at the 1995 trap location and a radio transmitter attached. A general roost location was determined from three telemetry points along the rim of the Grand Canyon, very close to the 1997 location. An airplane overflight determined the exact roost location, which appeared to be near an overhang of an east-facing cliff in a side drainage approximately 1000 m from the Colorado River. The location was accessible only from the river, with no feasible overland route. We accompanied GCNP personnel to the site during a scheduled river trip on September 18, but could not determine if mastiff bats were in the area.

Distances from the capture sites to apparent roosts were approximately 28 km in 1997 and 29.1 km in 1998. The apparent day roost we

Table 2. Greater western mastiff bat capture and roost site elevations and roost-to-capture-site distances.

Year	Bat	Capture Elevation (m)	Roost Elevation (m)	Elevation Change (m)	Distance (km)
1997	015	1889	ca. 606-883		ca. 28
1998	155	1889	737	1152	28.7

located in 1998 was at 737 m elevation. The site was located in Sonoran Desert habitat, similar to the spotted bat roosts.

DISCUSSION

Female spotted and mastiff bats appear to forage long distances from their night roosts and use completely different roosting and foraging habitats. The differences between the foraging behaviors of spotted bats in British Columbia and the Kaibab Plateau may be explained by a lack of suitable high-cliff roost sites near the meadow systems on the Kaibab Plateau. In British Columbia, observed spotted bats (1) foraged in open areas 6 to 10 km from day roosts in cliffs, (2) foraged continuously while away from cliff roosts, and (3) flew at about 19 km/h while foraging (Wai-Ping and Fenton 1989). The night-roosting that we observed may be a response to the high energy demand of long distance flight. The faster flight speeds we report probably indicate that bats on the Kaibab Plateau were not foraging on their return flight and may approximate the actual flight speed capabilities of spotted bats.

The long distance traveled by spotted bats from roost to foraging habitat (77-86 km round trip) is substantially longer than previously reported distances for this species (Wai-Ping and Fenton 1989). Spotted bats have very low frequency echolocation calls that may enable them to detect insects at relatively long distances but probably limits them to resolving large (>10 mm) prey (Woodsworth et al. 1981, Leonard and Fenton 1984). Spotted bats may, therefore, prefer open foraging areas because uncluttered habitats allow detection of large prey items at relatively long distances.

Little has been described about the foraging habitat and habits of mastiff bats. Due to the timing of our first and last radio signals each day, we feel confident that the 1997 bat was roosting near the Colorado River in the Grand Canyon and may be the same roost as that found in 1998. This results in a relatively long distance traveled by this mastiff bat from roost to trap site (58 km round trip).

For both the spotted and mastiff bats to travel such distances, we suspect there may be an abundance of insect prey in the high meadow systems sufficiently valuable to justify the energy expenditure of such long flight distances. The large elevation and temperature differences between the low, hot desert cliff roost in GCNP and the high, cool subalpine meadows on the NKRD present an opportunity to forage in several habitat types, but high energetic demands of lactation (Racey 1982) should force lactating females to choose the most productive foraging habitat. Although we have not yet analyzed insect sampling data, large moths appeared abundant in meadows on the NKRD during July and August. Further research should document whether the long day-roost to foraging distance and night roosting behavior of these bats is typical of local spotted and mastiff bats and what insect species bats select in these meadows.

ACKNOWLEDGMENTS

This project was a cooperative effort between the Arizona Game and Fish Department (AGFD), and the North Kaibab Ranger District of the U.S. Forest Service. Funding was provided by an AGFD Heritage grant, the U.S. Forest Service and the AGFD Research Branch. We thank W. Alber, T. Bricker, B. Breyer, L. Bunting, D. Garcia de la Cadena, P. Campbell, S. Castner, K. Covert, W. Draper, D. Emmons, C. Funari, J. Foster, R. Gordon, L. Gowey, G. Grasso, H. Green, G. Harding, M. Herder, T. Hiserodt, R. Hoverman, M. Howard, J. Jackson, J. Kendall, J. Lowsky, A. Miller, A. McIntire, M. Painter, N. Plomgren, R. Plomgren, W. Porter, R. Revis, D. Sinton, R. Steffensen, D. Ward, and L. Williams for assistance in the field. J. Petterson, S. Cherry, R. Ward, E. Leslie, and M. Vandzura of GCNP and R. Miller, S. MacVean, A. Holycross, and J. C. deVos, Jr. of the AGFD provided valuable logistical support.

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Merriam's Turkey Winter Survival on the North Kaibab Ranger District Following the Bridger Knoll Complex Wildfires

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Abstract. During the winter of 1996-1997, we studied the survival of 34 radio-marked Merriam's turkeys (*Meleagris gallopavo merriami*) on the North Kaibab Ranger District (NKRD) of the Kaibab National Forest following the Bridger Knoll complex wildfires. We studied these turkeys because food availability seemed limited and the fires had substantially altered part of the traditional turkey winter range. During winter 1996-97, adult female turkeys from NKRD had lower ($P < 0.001$) body weights at capture than those from other Arizona habitats. Adult female over-winter survival was greater ($Z = 3.901$, $P < 0.001$) than survival of subadult turkeys, but did not differ from mean adult female turkey over-winter survival in north-central Arizona ($Z = 0.861$, $P > 0.195$). On the NKRD, subadult turkeys experienced 10.4% over-winter survival while adult females experienced 66.2% over-winter survival. Turkeys experienced the greatest mortality during late January and throughout March, generally in conjunction with adverse weather conditions and increased snowfall. Limited food availability and deep snow negatively influenced turkey survival. Although this study was prompted by concerns about the wildfire effects on the NKRD, we believe that limited winter food availability would have resulted in depressed survival rates even if the wildfires had not occurred. Our study supports the contention that winter food availability is closely tied with turkey over-winter survival.

Key words: Arizona, food, *Meleagris gallopavo merriami*, Merriam's turkey, mortality, survival, winter

During late June 1996, several lightning-ignited wildfires merged and burned 217 km^2 on the Kaibab National Forest North Kaibab Ranger District (NKRD) (Fig. 1). These fires, known as the Bridger Knoll complex, burned across a substantial portion of traditional turkey winter range. Because turkeys select specific winter habitat characteristics (Rumble and Anderson 1993, Rumble and Anderson 1996a, Wakeling and Rogers 1996), have selective diets (Rumble and Anderson 1996b, Wakeling and Rogers 1996), and respond differently to various habitat changes (Scott and Boeker 1977, Wakeling et al. 1997), this large-scale alteration could affect the quality of the turkey winter range in two ways by: (1) changing physical habitat attributes, and (2) removing winter food sources.

During late fall 1996, observations on the unburned portion of the traditional winter range disclosed limited mast production and availability. Mast items are a critical component of turkey winter diet (Wakeling and Rogers 1996). The lack of available mast on NKRD suggested that turkeys using this range during the winter of 1996-97 might be nutritionally stressed.

We studied turkey survival on the NKRD during the winter of 1996-1997 to determine if seasonal survival would correlate with relative seasonal habitat quality. Eastern turkey (*M. g. silvestris*) populations in northern habitats where food is seasonally limited experience lowest survival rates during winter (Austin and DeGraff 1975, Wunz and Hayden 1975, Porter et al. 1980). Wakeling (1991) speculated that winter food availability might have the greatest influence on over-winter survival in the Southwest as well.

Our objective was to ascertain winter survival rates of turkeys among age and gender classes on the west side of the NKRD and relate those rates to nutritional status. Specifically, we tested hypotheses that body weights did not differ during winter capture efforts on the NKRD from turkey body weights during winter in other Arizona habitats, and that winter survival did not differ among age and gender classes on the NKRD and adult females studied by Wakeling (1991).

STUDY AREA

Our study was conducted on 1,511 km^2 of the western portion of the NKRD of the Kaibab National Forest in northern Arizona (Fig. 1). Elevations ranged from 914 to 2,838 m. Great basin conifer woodland (45.8%), petran montane conifer forest (26.7%), petran subalpine conifer forest (13.8%), great basin desertscrub (12.4%), and subalpine grassland

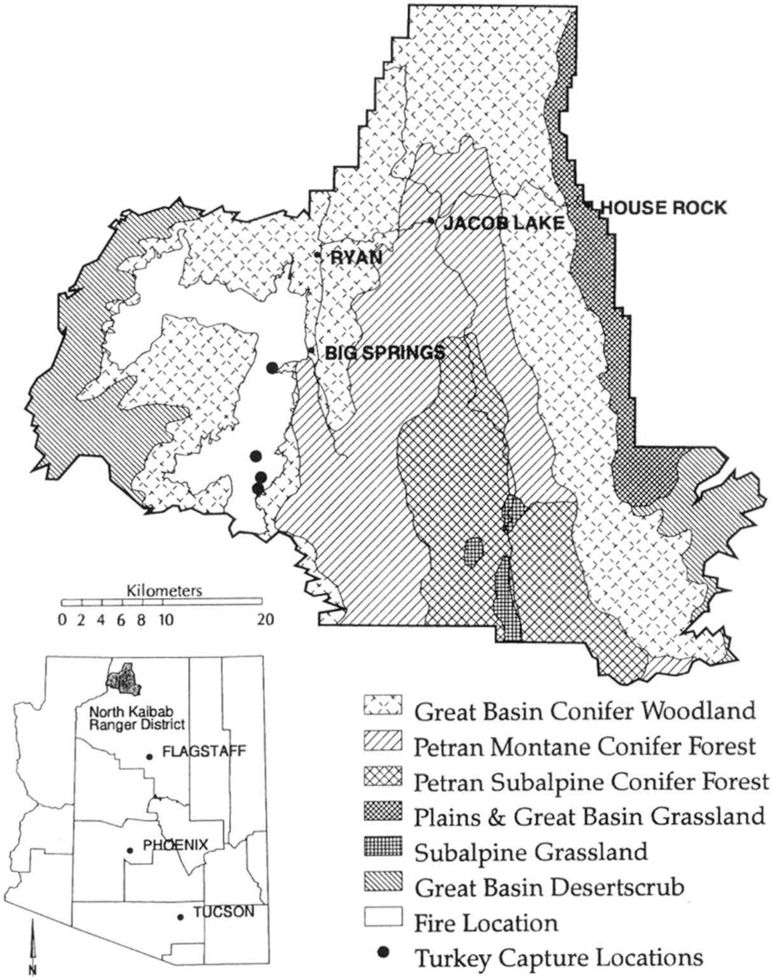

Figure 1. Boundaries of the Bridger Knoll complex wildfires, habitat types, and turkey trap locations on the North Kaibab Ranger District, Arizona, during the winter of 1996-97.

(1.3%) comprised the habitat types within the study area (Brown et al. 1980; Fig. 1).

The NKRD averages 25.7 cm of precipitation during December through April and receives 53.9 cm throughout the year. Temperatures during December through April averaged 3.2°C, with lows rarely exceeding -20 °C (National Oceanic and Atmospheric Administration 1997). Timber harvesting, livestock grazing, and recreation are the predominant land uses on the NKRD, with extremely limited activities during the winter.

METHODS

We captured turkeys with rocket nets (Bailey et al. 1980) at sites baited with whole oats between December 1996 and February 1997 on the traditional NKRD western winter range. Each turkey was weighed and fitted with a backpack-mounted, motion-sensing, radio-telemetry unit (Telonics model LB 400, Mesa, AZ) that was secured with a 5-mm bungee harness. We released each turkey at the site of capture.

Because of deep snow, turkeys were monitored aerially ≥1X every 2 weeks. Mortality signals were estimated to occur at the midpoint of the time interval since the bird was last heard alive (Heisey and Fuller 1985). Birds that did not survive at least 2 weeks following radio instrumentation were eliminated from analysis. Monthly precipitation data were provided by the National Oceanic and Atmospheric Administration.

We compared weights from adult female turkeys captured in 1997 in our study area with weights of female turkeys captured during January and February in other areas of Arizona, specifically west of Prescott, Arizona (Camp Wood [CWSA] Stone 1993), south of Winslow, Arizona (Chevelon [CSA] Wakeling 1991, Mollohan et al. 1995, Wakeling and Rogers 1995, Wakeling and Rogers, 1998), and south of Flagstaff (Mormon Lake [MLSA] Wakeling and Rogers, 1998). We used Analysis of Variance (SAS Inst. Inc. 1985) to test for differences among mean body weights by geographic area. Individual class differences were tested using Scheffe's mean separation procedure (Zar 1984).

The Kaplan-Meier technique (Pollock et al. 1989) was used to calculate survival rates. We evaluated survival rates among 5 intervals (12 Dec-11 Jan, 12 Jan-31 Jan, 1 Feb-28 Feb, 1 Mar-31 Mar, and 1 Apr-17 Apr) and by age-gender classes (adult F, subadult M, subadult F). We compared over-winter survival among age-gender classes and with adult hen survival rates on the CSA (Wakeling 1991). Pair-wise comparisons in survival rates were made with the Z statistic (Heisey and Fuller 1985).

RESULTS

We captured turkeys on 12 December 1996 (3 subadult M, 6 subadult F, 2 adult F), 12 January 1997 (9 subadult M), and 31 January 1997 (29 adult F). Fifteen birds died within 2 weeks of capture and were eliminated from analysis. Survival rates of subadult male and subadult female turkeys did not differ and were pooled for further analysis.

Turkey weights from birds captured on NKRD differed from those captured elsewhere. Specifically, adult female turkeys captured during January 1997 on the NKRD weighed less than female mean weights from elsewhere in Arizona ($F = 12.302$, $P < 0.001$; Table 1). No differences were detected among January and February weights from adult females captured in other Arizona habitats.

Survival of subadult turkeys on the NKRD decreased in conjunction with increased precipitation (Fig. 2). During the interval in which survival was lowest for both subadults and adults (1 Mar-31 Mar), the NKRD received a large amount of snowfall (which made the weather station inaccessible). During the interval in which subadults experienced the second lowest survival (12 Jan-31 Jan), several deep snowfalls also occurred. Six adult female, 10 subadult male, and 3 subadult female turkeys died during the study period.

Over-winter survival rates for adult females were higher than for subadult turkeys ($Z = 3.901$, $P < 0.001$; Table 2). Although substantially lower, over-winter survival rates for adult females on the NKRD did not differ significantly from those observed for adult females in north-central Arizona ($Z = 0.861$, $P > 0.195$; Fig. 3).

Table 1. Body weights, standard errors, and sample sizes of female turkeys captured during January and February on the North Kaibab Ranger District (NKRD), the Camp Wood study area (CWSA), the Chevelon study area (CSA), and the Mormon Lake study area (MLSA), Arizona.

Study Area	Weight (kg)[a]	SE	n
NKRD	4.04*	0.045	29
CWSA	4.50	0.103	19
CSA	4.51	0.039	119
MLSA	4.52	0.053	47

[a] Overall F ratio = 12.302, 210 df, $P < 0.001$, * denotes weight that differs from all others based on Scheffe's mean separation procedure.

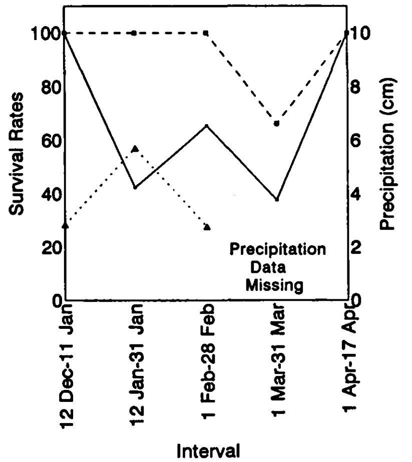

Figure 2. Monthly survival rates of adult female and subadult turkeys and precipitation on the North Kaibab Ranger District, Arizona, during the winter of 1996-97.

DISCUSSION

Over-winter survival influences population size. Turkeys suffered lower than average survival rates on the NKRD during the winter of 1996-97. The greatest mortality occurred in the subadult segment of the population, virtually eliminating an entire age cohort. Because yearling females in the Southwest rarely nest (Wakeling 1991), the removal of the yearling cohort will necessitate a two-year lag in the recruitment of addi-

Table 2. Merriam's turkey survival rates (95% confidence intervals) among age and interval classes on the North Kaibab Ranger District during the winter of 1996-97.

Class	12 Dec-11 Jan	12 Jan-31 Jan	1 Feb-28 Feb	1 Mar-31 Mar	1 Apr-17 Apr	Over Winter
Subadult (all)	100.0	42.4 (25.3-74.6)	65.5 (39.6-100.0)	37.7 (14.3-100.0)	100.0	10.4 (3.5-51.4)
Adult F	100.0	100.0	100.0	66.2 (48.7-92.2)	100.0	66.2 (48.7-92.3)

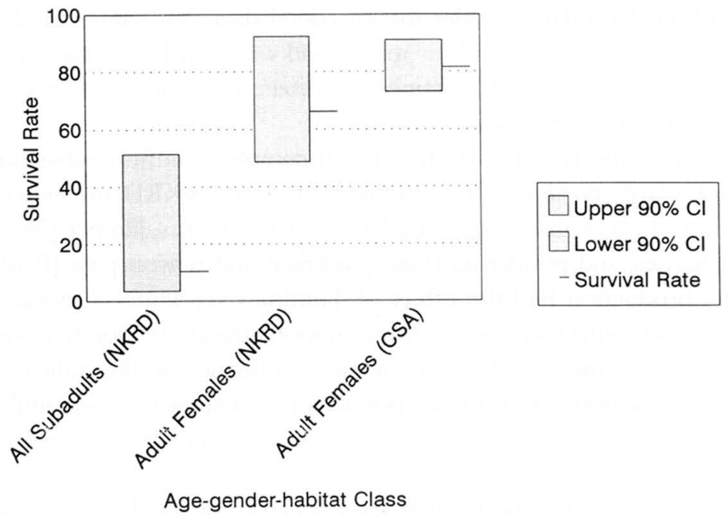

Figure 3. Over-winter survival of subadult turkeys and adult female turkeys on the North Kaibab Ranger District, Arizona (NKRD), during the winter of 1996-1997 and mean over-winter survival of adult female turkeys on the Chevelon study area, Arizona (CSA, Wakeling 1991).

tional breeding females into the population and will result in a substantial population fluctuation. Among-year fluctuations in turkey survival and populations are common (Wakeling 1991, Vangilder 1996), and depressed subadult survival may be common and responsible for observed fluctuations in turkey populations and recruitment.

Weight and survival appear to be influenced by food availability. Based on mid-winter body weights, adult female turkeys on the NKRD seemed to be nutritionally stressed. Hoffman et al. (1996) noted that subadult females with low body weights were less likely to nest and renest, demonstrating that weight affected productivity. Vangilder (1996) was only able to find a weak relationship between acorn production and fall survival on one of his study areas, but Wakeling (1991) suggested a stronger relationship between total mast production and subadult winter survival. Wakeling and Rogers (1996) speculated that winter food availability and diversity directly influenced the stability of turkey use of winter ranges.

Weather seems to have influenced food availability in our study area. Most mortality occurred in association with inclement weather, which may have covered meager food resources or driven turkeys into less suitable habitats. According to Haroldson (1996), an adult female in our study would require about 13.1 kg of acorns to survive a 120 day winter. We collected no data, besides the anecdotal data that winter food was limited, that would suggest how much food was available on the NKRD, but deep snowfall could certainly exacerbate conditions that were already unfavorable for turkey survival.

Despite the fact that Bridger Knoll complex wildfires substantially altered a large portion of the traditional western NKRD turkey winter range, we believe that range-wide limited mast (acorns, juniper [*Juniperus* spp.] berries, and ponderosa [*Pinus ponderosa*] and pinyon pine [*P. edulis*] seeds) production had the effect of limiting over-winter survival. In addition, we believe that our research supports the contention that winter food diversity and availability has a strong influence on the stability and density of southwestern turkey populations. The lack of subadult female nesting may pose the greatest obstacle to rapid turkey population recovery.

Finally, we acknowledge that the left-censoring of the 15 handling-related mortalities, while prudent to control $\propto$ and Type I errors, may have been unnecessarily restrictive. The proportion of handling-related mortalities in our study was greater than we have encountered in similar studies (Wakeling 1991, Mollohan et al. 1995, Wakeling and Rogers 1995) and may reflect unfavorable environmental conditions rather than handling-related mortality. This conservative approach may have artificially inflated survival rates. Had censoring not been necessary, more and larger differences in survival rates might have been observed. Resource managers should recognize the trade-off between Type I and Type II errors in our study and expect the possibility of greater mortality rates than we reported during winters of poor food availability.

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Merriam's Turkey Distribution in Relation to the U.S. Forest Service Recreational Opportunity Spectrum Forest Classification and Road Proximity in North-Central Arizona

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Abstract. We studied male Merriam's turkey (*Meleagris gallopavo merriami*) summer distribution in relation to the U.S. Forest Service Recreational Opportunity Spectrum (ROS) habitat classifications and road proximity to determine if the potential indices of disturbance influenced turkey habitat and roost site use. The ROS habitat classification proved of limited use, but turkeys avoided habitats <200 m from roads for both total locations and roost site locations. Improved high-traffic roads seem to negatively influence turkey habitat use, although turkeys were often found in association with unimproved, low-traffic roads. We did not ascertain what level of road use turkeys found unacceptable.

Key words: Arizona, disturbance, habitat, *Meleagris gallopavo merriami*, Merriam's turkey, roads, ROS

Habitat use by many wildlife species is influenced by human-related activities including vehicular and pedestrian traffic, although the magnitude of that influence is rarely quantified. For example, turkeys avoided habitats surrounding paved roads with >70 vehicles/hr (McDougal et al. 1990). Little is known about turkey response to lesser-traveled roads and habitats receiving varying degrees of recreational use. Understanding the factors that influence disturbance, and turkey response, is useful when planning for the recreational demands of Arizona's growing population.

Because human disturbance was identified as an important factor influencing turkey distribution at a recent turkey management workshop (Holland et al. 1996), we studied the summer distribution of male Merriam's turkeys in a habitat receiving substantial summer recreational activity. Our objective in this study was to determine how turkey distribution and habitat selection varied in relation to ROS classification and road proximity. Further, we wanted to be able to infer from these data how disturbance influenced turkeys during summer high-recreational-use periods.

STUDY AREA

We conducted our study in the Coconino National Forest south of Flagstaff, Arizona, in Game Management Unit (GMU) 6A. Precipitation averages 47 cm annually. Summer temperature highs range from 21-32°C, rarely exceeding 35°C, with summer average daily temperature at 12°C (National Oceanic and Atmospheric Administration 1997).

The study area encompassed 1,655 km^2 delineated by a minimum convex polygon with a 0.5 km buffer around all summer-time male turkey locations. Elevations ranged from 1,829 m in the south to >2,440 m in the north. Vegetation communities included pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.) with scattered grasslands at lower elevations to ponderosa pine (*P. ponderosa*)-Gambel oak (*Quercus gambelii*) at mid-elevations and mixed-conifer habitats at higher elevations. Improved road density on our study area averaged 0.82 km/km^2. Most improved roads received greatest traffic during the summer months.

METHODS

Using rocket nets, we captured and radio-marked (Telonics, Inc., model LB400, Mesa, AZ) male Merriam's turkeys during the winters of 1995-96 through 1996-97 at sites baited with whole oats. All birds were released at the capture site.

Between 1 June and 10 September 1996 and 1997, we located turkeys once per week from the ground using a hand-held telemetry unit (Telonics, Inc., model TR-2, Mesa, AZ). All relocations were plotted on 7.5' USGS topographic maps and the Universal Transverse Mercator coordinates were recorded then transferred to an ARC/INFO Geographic Information System (GIS).

We obtained a GIS file from the Coconino National Forest documenting ROS classifications of habitats within our study area (Fig. 1). The classifications within ROS described the characteristics that visitors

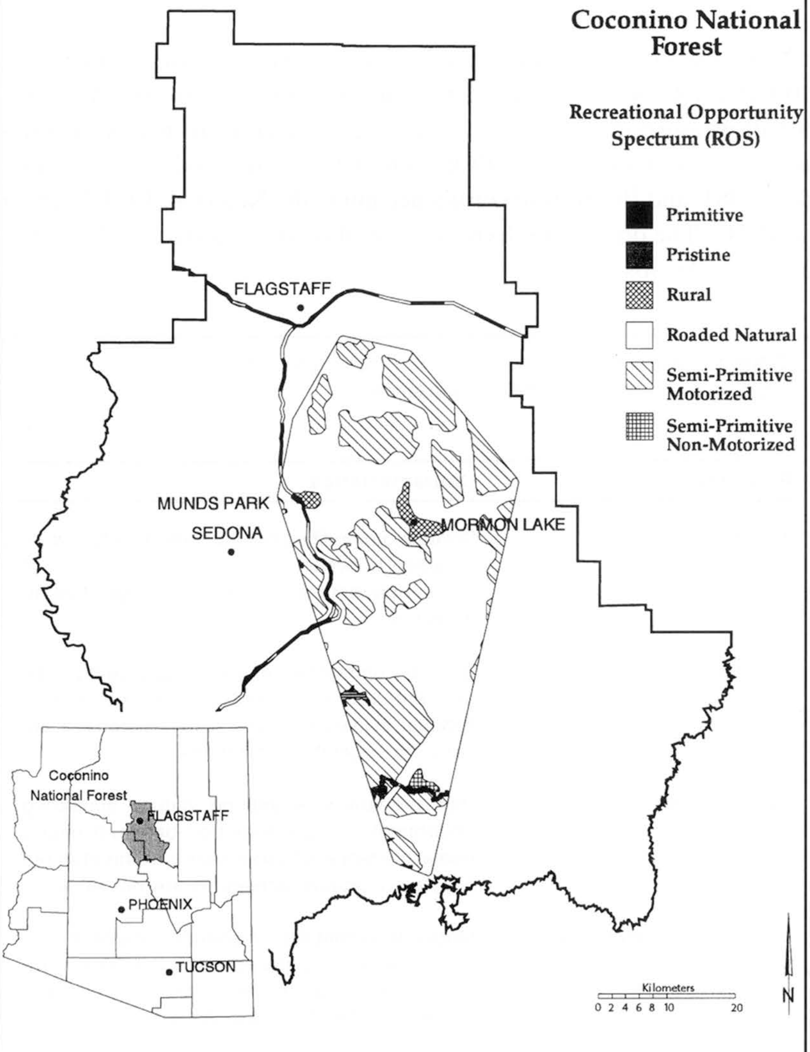

Figure 1. Habitats classified with the U.S. Forest Service Recreational Opportunity Spectrum (ROS) within our study area in the Coconino National Forest, Arizona.

could expect in these habitats (Table 1). USGS Digital Line Graphs (DLG) were then used to identify improved roads within our study area (Fig. 2). Most of these roads were improved and numbered U.S. Forest Service roads, but others were paved municipal, state, and interstate roadways.

We used GIS to analyze male turkey habitat use, placing buffers of 200, 201-400, 401-600, and >600 m around improved roads. We tested for disproportionate habitat use among distance-from-road categories and habitats classified with ROS using Chi-square goodness-of-fit tests (Zar 1984) and Bonferroni confidence intervals (Neu et al. 1974, Byers et al. 1984). The degree of selection was evaluated using Jacobs' *D* selectivity index (Jacobs 1974).

Table 1. Classifications within the U.S. Forest Service Recreational Opportunity Spectrum (ROS) and their characteristics.

ROS class	Characteristics
Pristine	Solitude, unmodified natural setting, very low interaction between users, minimal evidence of users, non-motorized access, no vegetative alterations.
Primitive	Solitude, unmodified or natural appearing environment, very low interaction between users, minimal evidence of users, non-motorized access, no vegetative alterations.
Semi-Primitive, non-motorized	High probability of solitude, natural appearing environment, low interaction between users, some evidence of other users, nonmotorized access, vegetative alterations are not evident.
Semi-primitive, motorized	Moderate probability of solitude, predominantly natural appearing environment, low concentration of users, often evidence of others on trails, vegetative alterations visually subordinate.
Roaded natural	Limited solitude, mostly natural appearing environment, user interaction common, conventional motorized travel including sedans and trailers, vegetative alterations to meet Forest objectives.
Rural	Little solitude, natural environment modified, high user interaction, excellent vehicular access.

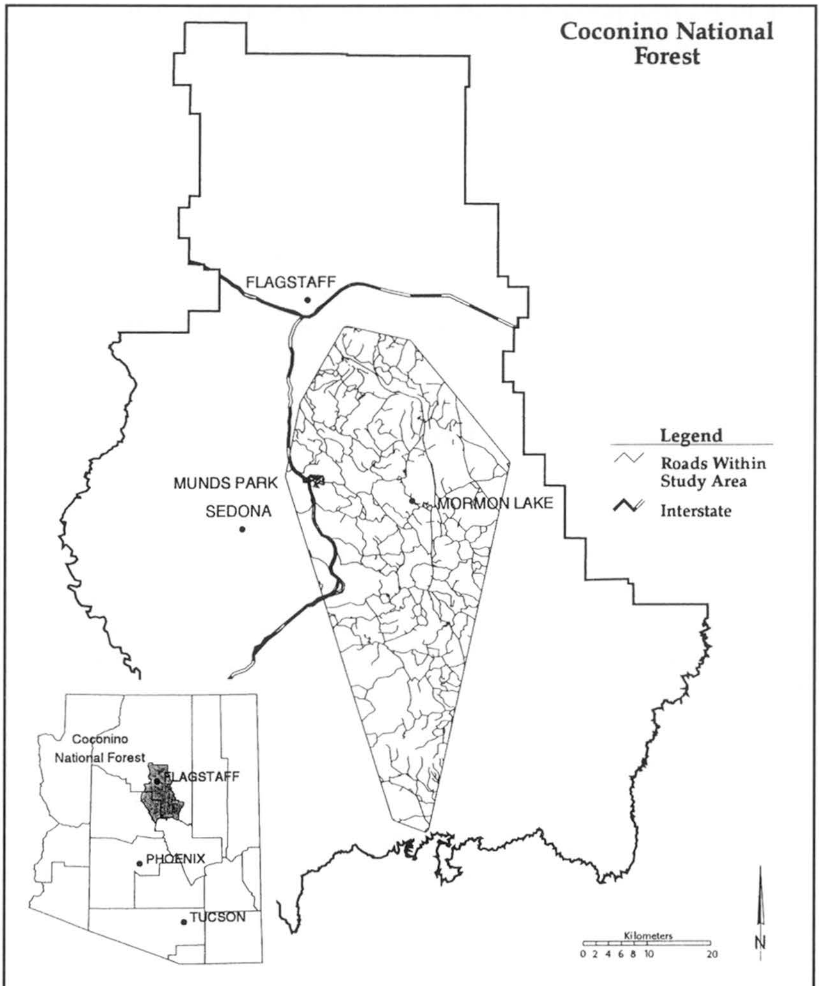

Figure 2. Improved roads within our study area in the Coconino National Forest, Arizona.

RESULTS

We obtained 114 locations from 32 marked and seven unmarked male Merriam's turkeys, with 89 locations used in our analysis. Twenty-five locations were eliminated because multiple marked birds were located together simultaneously. No single turkey contributed >7.9% (9) of locations. Twenty-one roost sites were also located and used in our analysis.

When considering all locations, male turkeys used habitat classified with ROS disproportionate with availability (χ^2 = 13.541, 2 df, P = 0.002; Table 2). While the birds selected habitats classified as roaded natural, they avoided habitats classified as semi-primitive motorized. Roosting turkeys used habitats classified with ROS proportionate with availability (χ^2 = 1.202, 1 df, P = 0.285; Table 3).

Between all locations and roosting locations, male turkeys showed consistent use of distance-from-road categories (Tables 4 and 5). Male turkeys used habitat disproportionately for all locations (χ^2 = 13.120, 2 df, P = 0.005) and for roosting locations (χ^2 = 11.890, 2 df, P = 0.005), in both cases avoiding habitats within 200 m of roads. All other distance-from-road categories were used proportionate with availability.

DISCUSSION

The ROS classification system did not seem to provide a useful tool for describing habitat use by male Merriam's turkeys during summer. Although turkeys used habitats classified with ROS disproportionately during our study, insufficient quantities of many habitat classifications were present to adequately evaluate their use by turkeys. Turkeys used the roaded natural classification, the most commonly available habitat classification the most, but a great deal of heterogeneity of microhabitat characteristics occur within this gross-scale classification and these characteristics influence turkey habitat selection (Wakeling and Rogers 1998). Further, the ROS system did not provide any classification that adequately described male turkey roosting habitat. The ROS habitat classification system, while valuable for evaluating recreation, is probably inadequate for evaluating turkey habitat.

We did explain summer male turkey use for all locations and roosting location using road proximity. We believe that the physical characteristics of roads were not the factor that the birds were avoiding, rather they avoided the disturbance associated with those roads. Many of the locations occupied by male turkeys were in close proximity to closed or low-grade roads not noted on the USGS DLG maps.

Avoidance of roads by turkeys has been attributed to roads associated with open habitats, fences, or specific topographic features (Eichholz and Marchinton 1975, McDougal et al. 1990). In our study, the heterogeneity of these associations limited the probability of such a relationship. Increased habitat use by turkeys in Arizona summer habitats is usually associated with areas of greater horizontal cover (Mollohan et al. 1995, Wakeling and Rogers 1998). Burbridge and Neff (1975) noted that vehicles moving rapidly on roads were less disturbing than vehicles

Table 2. Male Merriam's turkey summer use (all turkey locations) of habitats classified with the U.S. Forest Service Recreational Opportunity Spectrum (ROS) in north-central Arizona, 1996-1997. Overall $\chi^2 = 13.541$, 2 df, $P = 0.002$.

ROS Class[a]	Area (km²)	Locations	Observed Proportion	Expected Proportion	Expected Locations	Bonferroni Confidence Intervals	Selection[b]	Jacobs' *D*
PM-SPNM	14.9	3	0.033	0.009	0.8	-0.012-0.078	=	
SPM	561.0	18	0.202	0.348	31.0	0.100-0.304	-	-0.357
RNA	1037.8	68	0.764	0.643	57.2	0.656-0.872	+	0.285

[a] ROS classes include primitive-semiprimitive non-motorized (PM-SPNM), semi-primitive motorized (SPM), and roaded natural (RNA).
[b] Classifications may be selected (+), avoided (-), or used as available (=).

Table 3. Male Merriam's turkey summer roosting use of habitats classified with the U.S. Forest Service Recreational Opportunity Spectrum (ROS) in north-central Arizona, 1996-1997. Overall $\chi^2 = 1.202$, 1 df, $P = 0.285$.

ROS Class[a]	Area (km²)	Locations	Observed Proportion	Expected Proportion	Expected Locations	Bonferroni Confidence Intervals	Selection[b]	Jacobs' *D*
SPM	561.0	5	0.238	0.351	7.4	0.030-0.446	=	
RNA	1037.8	16	0.762	0.649	13.6	0.554-0.970	=	

[a] ROS classes include semiprimitive motorized (SPM), and roaded natural (RNA).
[b] Classifications may be selected (+), avoided (-), or used as available (=).

Table 4. Male Merriam's turkey summer use (all turkey locations) of distance-from-road categories in north-central Arizona, 1996-1997. Overall $\chi^2 = 13.120$, 2 df, $P = 0.005$.

Distance from Road (m)	Area (km²)	Locations	Observed Proportion	Expected Proportion	Expected Locations	Bonferroni Confidence Intervals	Selection[a]	Jacobs' *D*
0-200	470.4	12	0.135	0.284	25.3	0.044-.0225	-	-0.435
201-400	363.5	26	0.292	0.220	19.6	0.173-0.410	=	
401-600	272.4	22	0.247	0.165	14.7	0.134-0.361	=	
>600	547.2	29	0.326	0.331	29.5	0.203-0.448	=	

[a] Distance-from-road categories may be selected (+), avoided (-), or used as available (=).

Table 5. Male Merriam's turkey summer roosting use of distance-from-road categories in north-central Arizona, 1996-1997. Overall $\chi^2 = 11.890$, 2 df, $P = 0.005$.

Distance from Road (m)	Area (km²)	Locations	Observed Proportion	Expected Proportion	Expected Locations	Bonferroni Confidence Intervals	Selection[a]	Jacobs' *D*
0-200	470.4	1	0.048	0.284	6.0	-0.069-.165	-	-0.774
201-400	363.5	4	0.190	0.220	4.6	-0.024-0.404	=	
401-600	272.4	9	0.423	0.165	3.5	0.153-0.693	=	
>600	547.2	7	0.333	0.331	7.0	0.076-0.590	=	

[a] Distance-from-road categories may be selected (+), avoided (-), or used as available (=).

moving slowly, although less often, on lower quality roads. Our study does not negate this possibility, but suggests that the disturbance associated with improved roads is sufficient to dissuade turkey use. However, turkeys have demonstrated the ability to habituate and acclimate with certain types of vehicular disturbance (Wright and Speake 1975).

Vehicular and other associated disturbance that occurs along roads may be a critical factor influencing turkey distributions in Arizona, as male Merriam's turkeys apparently avoid habitats within 200 m of high-traffic roads. In habitats supporting turkey populations below habitat potential, resource managers should carefully evaluate open road quality and density. We suggest that closing high traffic roads may favor turkey populations in habitats that receive a substantial amount of recreational disturbance. On the other hand, the closure of low-traffic, low-quality roads may not be as beneficial for turkeys. Further research into quantity and composition of road-related disturbance sufficient to displace turkeys is warranted.

ACKNOWLEDGMENTS

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Cultural Resources

Changes in the Organization of Technology and Labor among Archaic and Ancestral Pueblo Peoples in the Vicinity of the Coombs Site, South-Central Utah

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Abstract. Archeologists have proposed alternative explanations (decreased mobility, risk avoidance, adoption of agriculture, sexual division of labor) to account for the shift from formal (bifacial) technology to expedient (core) technology. We examine these alternatives through an analysis of lithic artifacts and site settings documented through an archeological survey of Black Ledge—a mesa immediately adjacent to the Coombs site, the largest ancestral pueblo village in south-central Utah. We contrast the sites associated with more mobile hunter-gatherers during the Late Archaic, to the equally ephemeral sites created largely by women as they harvested, processed, and transported wild resources for use in their Late Formative village at Coombs.

Key words: archeology, Utah, Coombs site, Black Ledge, lithic artifacts, Late Archaic, Late Formative

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Throughout North America archeologists have perceived a change in chipped-stone from formal (bifacial) technology to expedient (core) technology. They have variously attributed this technological change to decreased mobility, the adoption of agriculture, the availability and quality of raw materials, risk avoidance, and sexual division of labor. We further this discussion by contributing an analysis of data obtained from our recent archeological survey near the Coombs site (42Ga34)—the largest pueblo existing in south-central Utah between 1150 and 1200 AD. We contrast the organization of lithic technology at Late Archaic sites—much older than Coombs—with what we observed at Late Formative sites—contemporary with Coombs. Our analysis is by no means complete, but outlines a program of additional research in the region.

BACKGROUND TO COOMBS

Noel Morse (1931) investigated the Coombs site for Harvard University. He recognized that the site had puebloan affiliation based on ceramics and architecture. As part of the Glen Canyon project, the University of Utah excavated architectural features within the Coombs site during the summers of 1958 and 1959 (Lister 1959, Lister et al. 1960, Lister and Lister 1961). Since the site became Anasazi State Park in 1960, small-scale excavations, primarily between 1970 and 1991, have added to the collections.

Based on their analysis of the ceramics and architecture, Lister and Lister (1961) linked Coombs Village to the Kayenta Anasazi. They believed that Coombs was rapidly colonized and settled by Kayenta immigrants because the entire settlement seemed to be constructed according to a master plan and no evidence was found for the existence of ancestral villages either below this settlement or in the immediate vicinity (Lister and Lister 1961). The Kayenta-style jacal and masonry rooms were arranged in two unit pueblos—one L-shaped and the other U-shaped. About 100 rooms once existed in the two adjacent units. Over two-thirds of these rooms were used for storage. The ten pitstructures and a ramada are believed to be contemporary with the unit pueblos. Based on the internal architecture, the pitstructures are believed to have been constructed and used for habitation, rather than as kivas. The absence or rarity of kivas and prevalence of storage rooms has also be noted at Virgin Anasazi settlements to the west (Lyneis 1995, 1996).

Tree-ring, radiocarbon and ceramic dates place the most likely age estimate for Coombs between 1150 and 1200 AD (Bannister et al. 1969, Prince et al. 1998). At the time Coombs was established by Kayenta colonists from the south, the eastern-most Virgin Anasazi settlements were being abandoned (Lyneis 1996). Even though Coombs was the largest village in the region, it still probably included no more than 200 people, presuming that the 30-40 habitation rooms and pitstructures were all contemporary. The isolated position and size of Coombs very likely contributed to the brief (50 year), unsustainable occupation of the village.

Coombs was not isolated from more distant communities. The presence of trade wares from many portions of the ancestral pueblo world (e.g., Mesa Verde, Kayenta, Chaco, and Virgin) and Fremont, as well as locally-made pottery in the Kayenta style (Morgenstein and Latady 1998) probably indicated attempts by Coombs villagers to foster long-distance alliances through exchanges of ceramics and artifacts of exotic materials (marine shells from the Pacific and turquoise from a single, but unknown source; Prince et al. 1998).

Based on the size and planned layout, Lister and Lister (1961) proposed that Coombs was inhabited year-round. In contrast, Jennings (1966) and Lipe (1970) proposed that many villages were occupied on a seasonal basis. Lipe (1970) argued that large upland villages, like Coombs, only represented winter occupations. Small parties left their upland villages in the spring, and then traveled to the low, hot, and well-watered lowland canyons along the Colorado River where they planted and tended their crops. Part of their harvest was transported back to upland (winter) villages, while the remainder was stored in the canyons to provide food and seed for the following year. Given the kinds and diversity of architecture at Coombs, as well as the finding of numerous short-term logistical settlements in our survey of a nearby mesa (Black Ledge), we also propose that Coombs was inhabited year-round.

The Listers (1961) concluded that the occupants of Coombs were primarily farmers because they found numerous examples of corn and squash, relatively few wild plant remains (e.g., pinyon, indian rice grass and chenopodium), stone hoes (tchamahias), trough metates, and two-handed manos. Trough metates and larger, two-handed, manos are generally presumed to have been used to mill cultigens, while slab metates and smaller manos are presumed to have been used with wild plants and pigment (Hard 1990, Mauldin 1993, Nelson and Lippmeier 1993, Schlanger 1991).

Coombs was located near West Deer Creek. Other perennial streams flow south off the Aquarius Plateau enabling villagers to engage in more intensive, but predictable, irrigation-based horticulture. The first Mormon settlers discovered ancient ditches in the vicinity of the by-then-abandoned Coombs site that might represent the remains of a former irrigation system.

A palynological study of the village and a packrat midden from an adjacent mesa provides additional evidence for the existence of agricultural fields (Prince et al. 1998), and adds support to claims for year-round occupation. The reduced coverage of pinyon-juniper woodlands continued after the abandonment of Coombs in about 1200 AD, until about 1650 AD. This persistence of cleared/disturbed vegetation, after the abandonment of Coombs, was attributed to the efforts of Numic peoples, although very little evidence of Numic or Late Prehistoric occupations has been found in the surrounding area (see Madsen and Rhode 1994 for elaboration on the Numic spread and Late Prehistoric).

The residents of Coombs also hunted large and small animals. Among the larger faunal remains bighorn sheep predominate, followed by fewer mule deer and even less frequent pronghorn. Cottontail and jackrabbit bones dominate the smaller mammal remains. The remains of a few dogs have been found.

We are uncertain where the villagers hunted game animals, whether they concentrated on agricultural fields or on more distant uplands and less inhabited places. We suspect that deer and rabbits were obtained from the fields, while the more human-sensitive sheep were hunted in remote locations, such as the mesa tops.

Earlier sites associated with Archaic hunter-gatherers (8000-3000 BP) and incipient horticulturalists (3000-1500 BP) are known from other portions of the Colorado Plateau (Geib 1996, Janetski 1993, Parry and Smiley 1990). Many of the early sites are either buried or destroyed by erosion. The people who created these sites lived at low population densities and organized their lives towards high mobility to exploit seasonal resources as they became available. As reliance upon farming increased and mobility declined during the Formative, ancestral puebloan peoples made greater use of local raw materials (Parry and Smiley 1990) and relied more on expedient (flake) tools made from cores. In contrast, for reasons explored below, bifaces are more common in Archaic sites (Parry and Kelly 1987, Kelly 1988, 1992).

ORGANIZATION OF LITHIC TECHNOLOGY

Archeologists have repeatedly noted the shift over time from formal bifaces to informal cores in lithic assemblages from many areas of North America, especially where sources of raw materials were spatially restricted. They offer several explanations for this shift: (1) decreased mobility (Kelly 1988, Kelly and Todd 1988, Parry and Kelly 1987); (2) risk avoidance (Torrence 1989); and, (3) increased horticultural production (Abbott et al. 1996).

(1) Mobility

Parry and Kelly (1987, Kelly 1992) propose that mobile people produce and use bifaces because they need long-lasting, flexible, and reliable tools to carry and use in places where raw materials are lacking. Bifaces served both as tools and as cores from which to strike flakes that could also be used as tools (Kelly 1988). They were often made from better, but more locally restricted, materials to insure their reliability and extend their use-life.

Parry and Kelly (1987) argue that the change from bifacial to expedient core technology coincided with sedentism. By living in one place, people could stockpile materials and recycle older artifacts. Because sedentary people use their tools mostly at their residential sites, there is little spatial incongruity between raw material and tool use.

As Sassaman (1992) notes, expedient core technology has been observed among mobile hunter gatherers who also used formal bifacial technology in places with a super-abundance of raw materials. Biface technology was restricted to anticipated needs and expedient to immediate needs. Sassaman (1992) also points out that where people continued to make logistical trips—traveling from sedentary villages—to hunt game, we might expect a continuation in biface production and use, both as cores and as weapons. Instead of presuming that the entire group moves together (residential mobility), it is probably more useful to consider differences in tool movement arising from sexual division of labor.

(2) Risk Avoidance

Torrence (1989) proposes that greater risk is associated with hunting than with gathering because prey animal are mobile and less predictable. Hunting tools should consist of complex, formal (bifacial) tools designed for reliable, long-lasting use. They should be easily repaired. Incorporating these technological features averts the risk and uncertainty of hunting by minimizing the chance of technological failure. The timing and severity of risk are less among gatherers, encouraging them to use simple, short-term, expedient tools made on flakes from cores. Torrence proposes that the shift from biface to core technologies coincides with the transition to food production or horticulture.

As Sassaman (1992) indicates, instead of seeing the two technologies as replacing one another, we should more often expect both hunting and gathering to operate simultaneously with a sexual division of labor, involving both formal (bifaces) and expedient (core) technologies. The co-occurrence of formal and expedient technologies would depend upon the organization of land-use, duration of occupation, site reoccupation, and the availability of raw materials. Hunting continued, and even intensified in the vicinity of more sedentary horticultural villages, but as Sassaman notes (1992), by then bifaces, and especially smaller projectile or arrow points, were made on flakes. Expedient core technology converged and incorporated aspects of bifacial technology.

(3) Agriculture

Abbott et al. (1996) reject the other two alternatives, as well as Sassaman's, because they involve behavioral variables. Instead, they argue for a Darwinian selectionist approach. The change in replicative success of the technologies (the decline in the relative frequency of biface technology and increase in flake technologies over time) might be the product of stochastic processes, selection, or sorting. After eliminating stochastic and sorting, they argue for selection due to the clear directionality of change. Because selective agents by definition are environmental, they conclude by proposing two possibilities: (1) 'flake technology is proximately the product of reduced mobility...and reduced mobility the product of selective agents favoring increased maize production...'; and, (2) '...if flake technology is associated... with the mechanics of agricultural production, increases in the proportion of flake technology in the record may be a product of subsistence shift toward increased agricultural production, because of the increased importance of technology associated with agriculture, and perhaps because of the decreased importance of technology associated with hunting.'

The exact ways in which flake technology is linked to agricultural production remains unclear, and unspecified. We return to this problem later.

ANOTHER ALTERNATIVE

Sassaman (1992) demonstrates that the bifacial technologies did not always stand in opposition to those based on cores. Furthermore, the shift that archeologists have perceived is attributable to the greater attention archeologists award to hafted bifaces (projectile points) during the preceramic (Archaic) and ceramics during the Formative for the determination of temporal placement and cultural identity. The archeologists' research methods make bifaces more visible in Archaic sites, and cores more visible in more recent, Formative sites. As Sassaman (1992) says among both Archaic hunter-gatherers and Formative farmers, hunters and gatherers we might expect the manufacture, distribution, and consumption of stone tools to both shape and reflect the division of labor by sex. We should not presume that men were exclusively the stone tool makers and users (Gero 1991), in that both men and women influenced each others decisions about lithic technology. Because the presumed shift from bifacial to core technologies coincides with the advent of pottery and increased reliance upon horticulture, it may be attributable to changes in sexual division of labor.

Again following Sassaman (1992), 'bifacial and expedient core technologies varied from being independent to being interdependent.' Away from sources, bifaces served both as tools and as cores for flakes. Women would have been dependent on men for flakes, if we assume that men were the makers and users of bifaces.

With increased population density and sedentism during the Formative, access to good and distant raw material sources probably declined. The adoption of the bow and arrow enabled people to use smaller projectile points, readily made by bifacing flakes. Expedient core technology wastes less material and can be accomplished with poorer quality material than biface technology.

Similar demands on women's time and energy, to those outlined by Sassaman (1992) for the Woodland period in Eastern North America, shaped the lives of women in the American Southwest. Puebloan peoples practiced a mixed economy, involving horticulture, hunting of wild game, and gathering of wild plants. Based on various cross-cultural studies and ethnographic analogies, Crown and Wills (1995) propose that Puebloan women were responsible for much of the everyday agricultural labor, food processing and preparation, house cleaning and clothing laundry, the manufacture of clothing, mats, baskets, leather products, and pottery, primary child care, and collection of firewood and water. With even a portion of these demands, Pueblo women would have faced a time and energy crisis.

In response to the crisis, Puebloan women sought out local raw materials—encountered during other tasks—to manufacture their own stone tools. To minimize their time investment, they manufactured tools from flakes struck from expedient cores. Such cores could be made with materials too small, or too poor in quality for bifacial technology. Women scavenged and recycled lithic refuse from other, and often more ancient, sites. With unmodified and slightly modified flakes, women could accomplish many of the tasks outlined above. Grinding stones, used for processing plant foods away from the village, were cached near the places where the plants grew in anticipation of future use. As Sassaman (1992) suggests, both women and men probably produced expedient cores at residential places, with some of the flakes being bifaced to produce arrow points. He also proposes that formal bifaces remained in male domain, but now to create artifacts for use in ceremonies and rituals, perhaps representing a form of male resistance in response to their loss of control over lithic production.

Many studies of lithic technology in the American Southwest have focused on the more substantial residential settlements. In contrast, our study examines more ephemeral artifact scatters and camps located on a mesa near the Coombs site. We intend to compare the ways more mobile Archaic hunter-gatherers manufactured and used chipped-stone tools, to the more recent sites associated with the Coomb site. We also examine how changes in the sexual division of labor structured lithic technology.

THE BLACK LEDGE SURVEY

Black Ledge is a large mesa located just east of Boulder, UT and the Coombs site (Fig. 1). We surveyed 900 acres of private land that has been subdivided for residential housing.

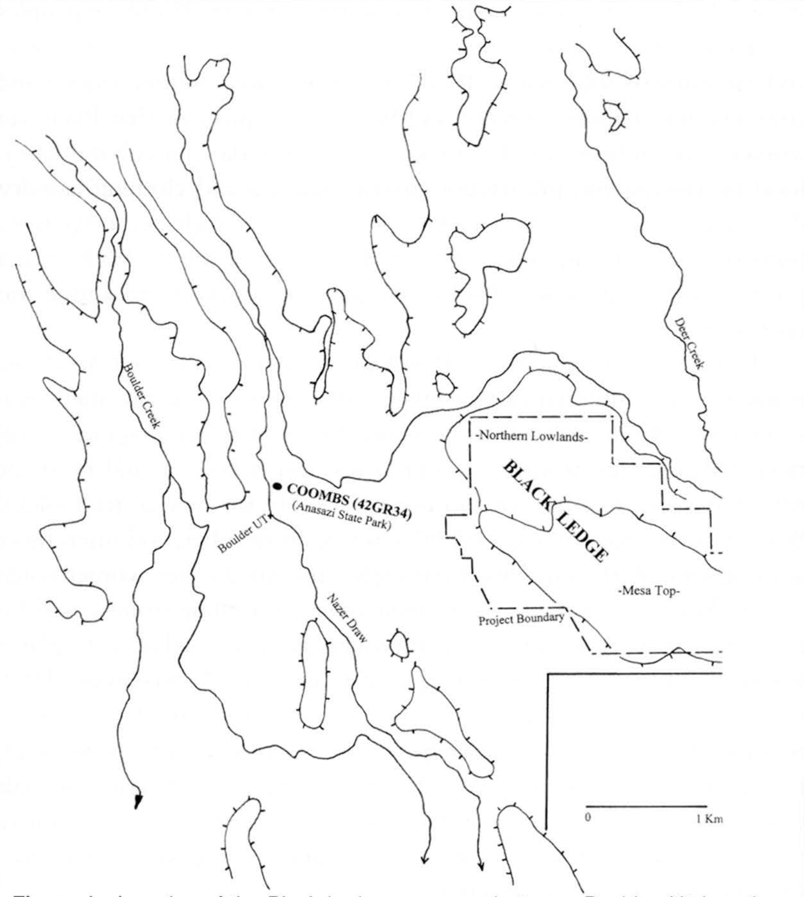

Figure 1. Location of the Black Ledge survey project near Boulder, Utah and the Coombs site.

The authors and Celeste Clegg led three 3-4 person groups of student volunteers. A maximum of 30 m spacing was maintained between survey members while walking survey transects. Isolated artifacts and archeological sites (defined as localities exhibiting evidence for multiple activities with considerable accumulations of artifacts) were plotted on 7.5' USGS topographic maps and flagged as they were located. Later we returned to the sites to record them on IMACS forms and to complete infield tabulations of artifacts.

Thirty-six prehistoric sites were located during our survey. They occur in two major settings: on the lowlands to the north of the mesa (21 sites) and atop the mesa (15 sites). The sites on the northern lowlands tend to be smaller and more concentrated than the ones located on the mesa top. The only natural water sources occurring today are depressions in the Navajo sandstone where water collects after summer thundershowers and spring snowmelt. Sites cluster around these bedrock water holes and along a ephemeral wash in the northern lowlands. In the same setting we observed many pieces of ground stone, numerous cores, and several cultural features (hearths and other pit-features). Some of the features were exposed in backhoe trenches excavated by the landowner. Time diagnostic artifacts were limited to a few arrow points and several black-on-white potsherds. We suspected that most of the sites in the northern lowlands are contemporary with Coombs, and represent short-term (one-day and over-night) trips to procure and process wild plant resources that were either stored for later use or transported back to the village.

On the mesa top we recorded more extensive and discrete sites than in the northern lowlands. No cultural features were observed, although subsurface hearths are suspected given the existence of discolored aeolian sands at several sites. Ground stone and cores were scarce, and most time diagnostic artifacts date from the Late Archaic (mostly Elko dart points)—predating the Coombs site. A Desert side-notched arrow point found at one site provides the only evidence for occupations post-dating Coombs. The prevalence of projectile points, combined with the location of several of the sites on overlooks (from which game animals would have been visible) suggests that many of the mesa-top sites were associated with hunting activities. The shattered remains of a single Tusayan Corrugated Coombs variety jar was recorded as an isolated find. No other sites occurred nearby. This jar would be contemporaneous with the occupation of Coombs.

No archeological sites were located on the southernmost portion of the mesa. While the southern tip of the mesa is now slickrock, areas to the north are still covered with dense pinyon-juniper so that it seems unlikely that site destruction through erosion can be used to explain the absence of sites in the south.

Analysis of Survey Data

Ancient peoples made considerable use of Black Ledge for hunting and plant gathering, including processing; however, no evidence exists for farming on or immediately adjacent to the mesa. We did not find any unit pueblos, farming implements, trough metates, two-hand manos, field houses, or agricultural features (check dams, ditches, fields, etc.). All of the sites appear to have been created as short-term camps and places where limited activities were accomplished.

The key questions is whether many of these sites were contemporary with the Coombs site. The scarcity of time diagnostic artifacts, especially projectile points and ceramics, in part due to prior artifact collection by persons unknown, make this question somewhat difficult to address. However, as we demonstrate below, the settings of Archaic and Formative sites appear to have been distinct.

Upon examining the few (17 out of 37) sites with diagnostic artifacts we found that Archaic sites were located significantly further from Coombs than Formative sites, contemporary with the village (Fig. 2; Table 1). Archaic sites are also concentrated at higher-elevations, on the mesa

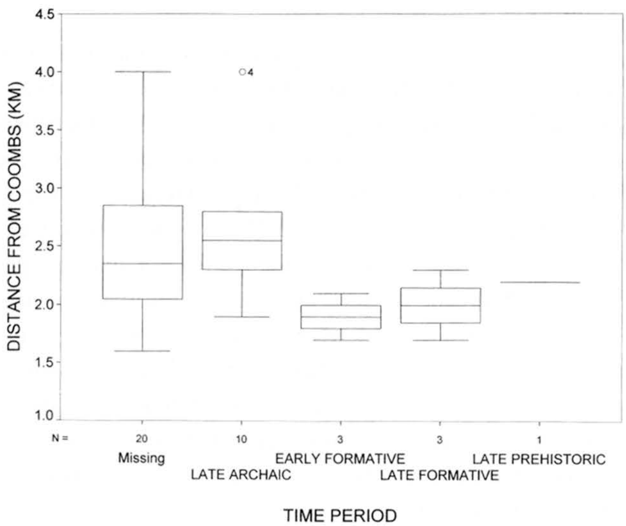

Figure 2. Boxplot depicting the distance from Coombs for sites of various time periods.

Table 1. Comparison between Late Archaic and Formative sites according to their distance (in km) from the Coombs site.

Time Period	Mean	S.d.	n
Late Archaic	2.63	0.55	10
Formative	1.99	0.23	7

$t = 3.28$
d.f. = 13
$P = 0.006$

top, while the Formative sites occur at lower-elevations, mostly on the northern lowlands (Fig. 3; Table 2). Closer examination of the 17 sites with diagnostic artifacts revealed that nearly all of the Archaic sites are located above 6800' and over 2.3 km from the Coombs site, and Formative sites occurred at lower elevations, closer to the village.

After applying this classification scheme to assign presumed ages to the remaining (20) sites, we evaluated the age estimates by examining the prevalence of cores in relation to bifaces. As in previous studies that have focused on the organization of technology, bifaces predominate more frequently at presumed Archaic sites, and cores at presumed Formative sites (Table 3). Notice that far more of the 'misclassified' ages are

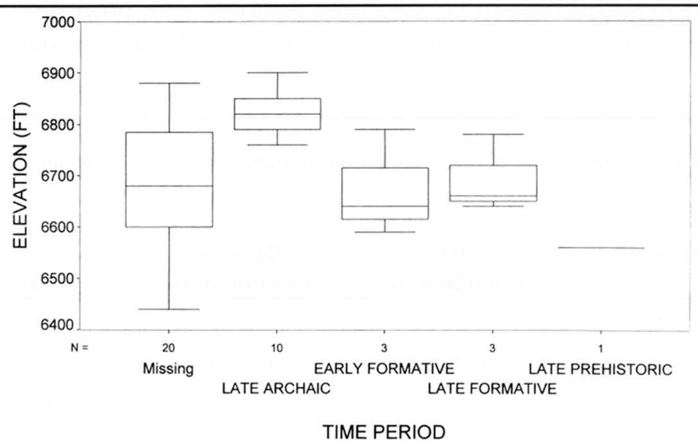

Figure 3. Boxplot depicting the elevation of sites on Black Ledge from various time periods.

Table 2. Comparison of elevation (in feet) between Late Archaic and Formative sites.

Time Period	Mean	S.d.	n
Late Archaic	6825	44	10
Formative	6666	88	7

$t = 4.40$
d.f. = 8
$P = 0.002$

among sites presumed to date from the Formative (at 8 presumed Formative sites bifaces outnumber cores).

This pattern can be attributed to recycling of older bifaces during the later Formative. Recycling probably also accounts for the scarcity of Archaic sites at lower elevations and closer to the Coombs site. Other Archaic sites, yet to be discovered, may have existed in the fields and beneath the town of Boulder, but they have yet to be recorded. They were probably impacted to an even greater extent through later recycling of lithic materials by Formative villagers.

Most of the presumed Formative sites are concentrated at lower elevations on the northern lowlands. At these sites we observed numerous examples of one-hand manos and slab or basin metates—forms of ground stone believed to be associated primarily with processing wild plants. Ground stone only rarely occurred among the sites presumed to

Table 3. Predominance of cores or bifaces at Archaic and Formative sites.

Presumed Age	Cores Predominate	Bifaces Predominate	Total
Late Archaic	15 (10.8)	1 (5.2)	16
Formative	8 (12.2)	10 (5.8)	18
Total	23	11	34

$\chi^2 = 9.41$
d.f. = 1
$P = 0.002$
( ) = Expected

date from the Late Archaic, and were strongly associated with presumed Formative sites where cores also predominate (Table 4).

DISCUSSION

The relatively few examples of Archaic sites at Black Ledge are concentrated on the mesa top. The assemblages and settings of these sites suggest that they were very short-term camps associated with hunting activities. Both the contents and settings are redundant, and almost certainly the Archaic sites only represent a small fraction of the annual or seasonal round over which their creators moved. Mobility and the absence of abundant, high-quality raw materials, probably contributed to the predominance of formal (bifacial) technology at the Archaic sites. Artifacts that archeologists have often associated with women's work (scrapers for processing hides and plant fiber, ground stone for mealing seeds, and flake tools) rarely occur within the Archaic sites. Their absence and the existence of a sexual division of labor probably contributed to the brief nature of the utilization of Black Ledge during the Archaic.

Based on our analysis, we propose that most of the sites on the northern lowlands date from the Formative and were created while wild plant resources were harvested and processed, before they were transported (< 1 mile) back to the village at Coombs. Ground stone, cores, and flakes occur in great abundance on the lowland sites. Whether these sites can be attributed to the efforts of task-groups of women is debatable, but would agree with the ethnographic and cross-cultural studies reviewed by Crown and Wills (1995) that include firewood and plant collection, and food processing among the tasks accomplished by women in villages with mixed economies. The prevalence of core-based tech-

Table 4. Association of Ground Stone with Formative sites.

	Ground Stone (manos/metates)		
Time Period	**Absent**	**Present**	**Total**
Late Archaic	15 (12.4)	2 (4.6)	17
Formative	12 (14.6)	8 (5.4)	20
Total	27	10	37

$\chi^2 = 3.71$
d.f. = 1
$P = 0.05$

nology, using poorer-grade, local raw materials and recycled bifaces, to produce flakes and flake tools supports our proposal that much of the archeological record on the northern lowlands can be attributed to the activities of women faced with considerable constraints on their time and energy. Given the prevalence of short-term camps and logistical use-areas on Black Ledge, we suggest that Coombs must have been occupied year-round.

On the other hand, our presumed age estimates for both the mesa top and lowland sites may be in error. Some of the lowland sites may represent the activities of women during the Archaic, who insisted upon making and using their own tools from local materials, while men and perhaps women also hunted on the nearby mesa tops. Archaic sites may not have been so spatially separated from Formative sites, as we presume from our analysis. Given the limited range of the assemblages and features at all of the sites, we suggest that it is unlikely that these ephemeral settlements can be attributed to adaptive diversity, or in this case—hunter-gatherers living in proximity to farmers (see Simms 1986, Upham 1984, 1988, 1992, 1994, Young 1994 for elaborations upon this alternative).

By testing the features (hearths, ash stains, slab-lined cists, and pits) at sites in both settings we should be able to obtain radiocarbon samples—to resolve chronological questions, bulk soil samples for pollen and flotation analysis—to resolve questions about the utilization of plant resources, faunal remains—to address questions about hunting activities, and tool and debitage samples for microwear and technological studies (See Geib 1996 for an additional example of the advantages of investigating features). Ceramics will be sourced and compared with those from Coombs.

CONCLUSIONS

Our survey of a mesa within close proximity to the Coombs site—the largest pueblo village during the 12th century AD in the area—addresses changes in the organization of technology and sexual division of labor between the much earlier, Late Archaic, and the Late Formative—contemporary with Coombs. Our analysis of the survey data from Black Ledge indicates that indigenous peoples used this area, and most of the sites appear to be contemporary with and attributable to short-term visits by the residents of Coombs. This information indicates that the villagers supplemented their agricultural production through seasonal procurement of plants and animals in the surrounding uplands. The presence of these logistical camps and localities argues for the year-round occupation of Coombs Village, rather than seasonal transhumance to lowland agricultural villages at Glen Canyon. We also propose that many of these sites were created by women using a core technology and local stone that they encountered while harvesting and processing wild plants and gathering firewood, clay (for pottery), and other materials on the northern lowlands, near their village.

Earlier sites, dating from the Archaic, are concentrated at higher elevations, further away from Coombs Village (mostly on top of the mesa). Because projectile points are more prevalent at these sites than at later ones and because some are situated on overlooks, these Archaic sites may be associated with hunting activities. Ground stone is also rarer at the Archaic sites.

Through preliminary analysis of our survey data we have documented the same shift in the organization of lithic technology (from bifaces to cores) observed at many other places around the world. Further research will be directed at evaluating the various alternative explanations for this shift

ACKNOWLEDGMENTS

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Recent High Altitude Archeological Surveys at Cedar Breaks National Monument, Utah

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Abstract. The cultural history of southern Utah's Markagunt Plateau is not well known, but recent archeological surveys have focused on the identification and interpretation of cultural resources within Cedar Breaks National Monument. We conducted survey work in two discrete areas: (1) the lower portions of the monument at elevations ranging from 7,800 to 9,200 feet (2,377 to 2,804 m); and (2) at higher elevations ranging from 10,100 to 10,600 ft (3,078 to 3,230 m). The lower survey areas were found to contain very few archeological resources while the upper portions of the monument were heavily utilized by prehistoric people for at least 3-4,000 years and perhaps longer. Procurement of chert from the Brian Head Formation appears to have been a primary activity. In addition to the archeological investigations, ancillary studies were initiated, including petrographic and trace mineral analysis of the chert source, obsidian sourcing, palynological studies of area peat bogs, and dendroclimatic studies. These ancillary studies will enable a better understanding of prehistoric land use on the Markagunt Plateau, and specifically at Cedar Breaks National Monument.

Key words: cultural resources, Archaic, Late Prehistoric, lithic scatters, chert quarries, paleoenvironment, Cedar Breaks National Monument, Markagunt Plateau

INTRODUCTION

The Markagunt Plateau, oriented southwest-northeast, is the westernmost of the High Plateaus subdivision of the Colorado Plateau physiographic province (Foster 1968), with the Great Basin beginning directly west of the Markagunt Plateau. Cedar Breaks National Monument is a 6,155 acre preserve located along the western margin of the Markagunt Plateau (Fig. 1). In an attempt to learn more about the cultural history of Cedar Breaks , we conducted an archeological survey of the monument.

This project is located along the western edge of the Markagunt Plateau and encompasses both the lower portions of Cedar Breaks National Monument as well as the upper rim (Fig. 2). This project is part of the National Park Service's Systemwide Archeological Inventory Program and was conducted by archeologists from Zion National Park. We are currently in the third year of a four-year project, and have intensively examined nearly all of the monument accessible to pedestrian surveyors. This paper summarizes the results of two years of research at Cedar Breaks and provides a framework for research during the final two years.

Figure 1. Overview of Cedar Breaks National Monument.

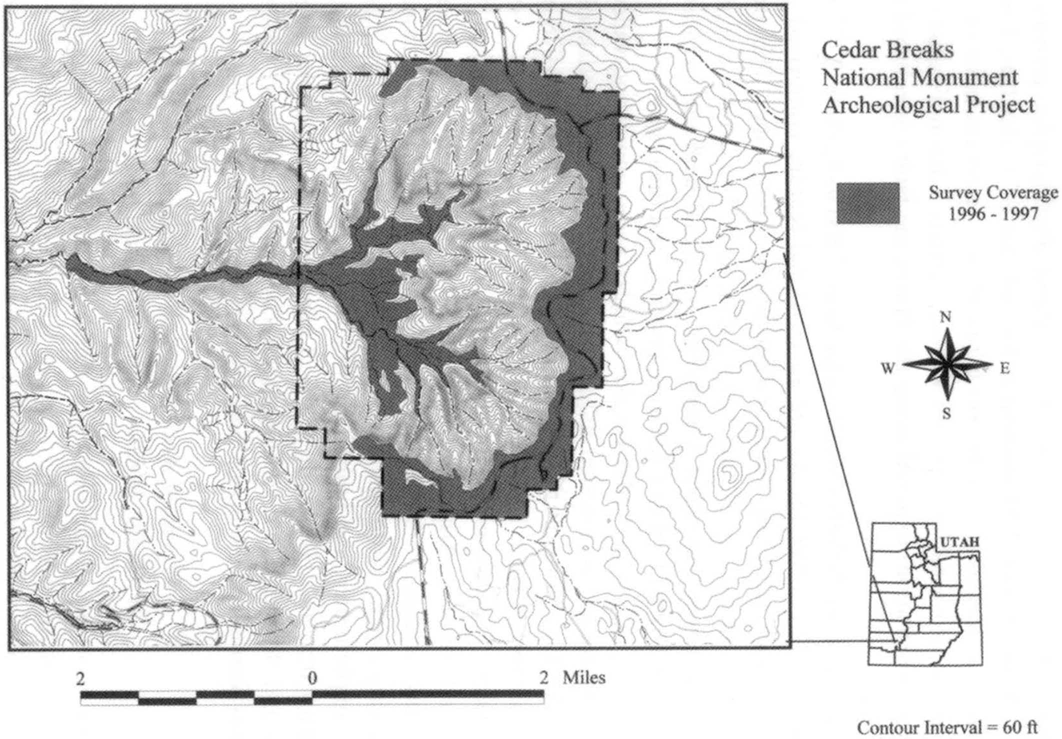

Figure 2. Location of the Cedar Breaks Archeological Project showing survey coverage.

Project Area Description

The Markagunt Plateau is well watered, containing numerous springs, streams and small lakes. Rose and Snedeker (1982) note that several major creeks rising from the Markagunt Plateau form the headwaters of the Sevier River drainage of the Great Basin physiographic province. Cedar Breaks National Monument is located east of Cedar City, Utah and rises to elevations over 10,000 ft (3,048 m). It covers most of a spectacular erosional escarpment of the Tertiary Claron Formation (Wasatch Formation) exposed along the Hurricane fault (Agenbroad et al. 1992).

Elevations in the lower breaks range from 7,800 to 9,200 ft (2,377 to 2,804 m). The lower breaks are an erosional feature comprised of knifelike ridges, steep talus cones and cliff bands of limestone. This area is extremely steep, rugged, and heavily dissected. Due to these topographic extremes, vegetation (commonly associated with the Canadian life zone) is limited to thin ridge tops, benches, and drainages.

The upper rim of Cedar Breaks includes wide, undulating valleys and alpine meadows, forested hillsides and ridges, and exposed knolls and peaks. Elevations on the upper rim range from 10,100 ft (3,078 m) to the summit of Brian Head Peak, 11,278 ft (3,437 m) just north of the monument. Vegetation commonly associated with the Hudsonian life zone predominates. Arno and Hammerly (1984) note that the upper rim supports a subalpine forest of Englemann spruce, subalpine fir, and clones of quaking aspen. Krummholz occasionally descends into the dry limestone amphitheater, and limber and bristlecone pines are present along the rim (Arno and Hammerly 1984). Limestone sink holes, peat bogs, basalt and rhyolite flows, and large areas covered by brecciated rhyolite are also features of the upper rim.

Previous Archeological Research at Cedar Breaks National Monument

An overview of the history of Cedar Breaks National Monument and its environs has been provided by Klein (1991). Two historic era sites within Cedar Breaks (the Visitor Center and the Caretakers Cabin) were nominated to the National Register of Historic Places in 1983. These log structures are set on shaped rock foundations and were constructed in 1937 by members of the Civilian Conservation Corps (CCC). They were added to the National Register because of their relation to the CCC and because they serve as very good examples of the National Park Service (NPS) rustic architectural style.

High altitude areas in the western United States have only recently been the focus of scholars interested in prehistoric land use (e.g., Benedict 1975, 1981, 1985, 1992, 1996, Bettinger 1990, 1991, Bettinger and Oglesby 1985, Canaday 1991, 1992a, 1992b, 1996, 1997, Canaday and Reutebuch 1994, Canaday et al. 1997, Grayson 1988, 1990, 1991, 1993, n.d., Simms 1979, 1993, Thomas 1982, Thomas and Pendleton 1990, Wickstrom 1993, Winter 1983). Prior to the Cedar Breaks Archeological Project, the only prehistoric investigations conducted in the high country of the Markagunt Plateau were related to Cultural Resource Management (CRM) projects (e.g., Craig 1977, Dykman 1976, Rose and Snedeker 1982, Sargent 1979).

Between 1974 and 1982 archeologists from the Dixie National Forest conducted thirteen CRM projects on the Markagunt Plateau. The surveys covered some 2,180 acres and a total of 45 sites were identified (Craig 1977, Dykman 1976, Rose and Snedeker 1982: Table 2). These sites consist of lithic scatters with no apparent subsurface cultural deposits. All seem to share similar characteristics in that hearths, structural features, groundstone and ceramics are absent and the majority of the debitage is thought to be the locally-available Brian Head chert and chalcedony. The only non-chert lithic materials on any of these sites are a few pieces of obsidian (Rose and Snedeker 1982). Obsidian samples analyzed from four Markagunt Plateau sites (42In223, 229, 231, and 232) have been traced to the Mineral Mountains approximately 50 miles (80.5 km) to the north (Nelson and Holmes 1979).

Several sites discovered during these CRM projects suggest that the prehistory of the Markagunt Plateau is both behaviorally and temporally complex. The Long Flat site (42In330), first reported by Dykman (1976), was added to the National Register of Historic Places in 1979. This site ranges in elevation from 10,000 to 10,200 ft (3,048 to 3,109 m), encompasses approximately 750,000 square meters (1,500 x 500 meters in some places), and is thought to date from the Archaic to Ethnohistoric times (Hawkins 1979). It was added to the National Register because of its importance as a chert quarry centered around four chert outcrops, its large size and intra site complexity, and its high elevation (Rose and Snedeker 1982).

The Lowder Creek Bog site (42In461), tested by Sargent (1979), is perhaps more important for its paleoenvironmental potential than for its archeological significance. This site is located at the base of Brian Head Peak, at an elevation of 10,319 ft (3,145 m), approximately two miles (3.2 km) northeast of Cedar Breaks and seems to have served primarily as a quarry and associated tool manufacture. Sargent (1979) suggests that much of the chert/chalcedony debitage recovered at the Lowder Creek Bog site had been heat treated.

The North Point site (42In1210), described by Agenbroad (1992, 1993), contains several deeply buried paleosols eroding from the edge of Cedar Breaks some 6.56 to 13.12 ft (2 to 4 m) below the present ground surface. Dates recovered from these strata were 7,650 +/- 90 years BP (Beta 21121) and 9,005 +/- 175 years BP (GX:11405), respectively. Limited cultural debris is present including utilized flakes, tertiary flakes and a one-hand, sandstone mano/hammer. Unfortunately, the association of the artifacts to the paleosols is not clear and much archeological research remains to be done at this site (Adrienne Anderson pers. com.). Paleoenvironmental research at the North Point site is discussed below.

RESEARCH QUESTIONS

The primary objective of this project was a 100 percent archeological inventory of all portions of Cedar Breaks National Monument that are not too steep for human use. Because of the small size of the park, roughly 9.5 square miles (24.3 km^2), and its position on the Markagunt Plateau, cooperative research with the surrounding Dixie National Forest was built into the overall program.

Because very little archeological research has been conducted in the monument and the surrounding Markagunt Plateau, data collection was designed to provide information for efficient management and interpretation of both historic and prehistoric resources. To that end, each resource is entered into the monument's GIS program. Research questions are tied to a series of domains — including Chronology, Settlement Patterns, Subsistence and Resource Procurement, Material Culture, and Paleoenvironment. The program is expected to address the basic questions of: (1) who used monument lands during the historic and prehistoric period; (2) during what specific time periods did this use occur; (3) what types of activities took place; and, (4) what resources were being utilized.

SURVEY RESULTS IN THE LOWER BREAKS

An intensive pedestrian survey of Cedar Breaks National Monument was conducted during the summers of 1996 and 1997 using transects spaced approximately 49 ft (15 m) apart. A total of 2,218 acres (approximately 36% of the monument) was inspected during the two summer field seasons. Survey during the first field season (Frank 1997) primarily concentrated on the lower portion of the monument, below the rim of the plateau, although a small section of the upper rim was also inspected. Survey areas were determined by percentage of slope, less than 20%, thus omitting large sections of the rough and dissected terrain in the lower part of the breaks. Surprisingly few cultural resources were encountered in the lower breaks despite intensive inspection. Four historic sites dating to the early 20th Century and twenty-one isolated prehistoric occurrences were encountered in the lower breaks during the 1996 field season.

Historic Resources in the Lower Breaks

Three of the four historic sites are located just outside of the monument on Forest Service property, and all are related principally to logging of the Ashdown Meadows (Frank 1997). Two of the sites appear to be historic homesteads containing cabin remnants, corrals and scatters of historic debris. One site is thought to be a logging camp, while the fourth site is a historic road linking several sites along Ashdown Creek.

Prehistoric Resources in the Lower Breaks

All of the isolated occurrences documented in the lower breaks consist of single pieces of debitage (seven occurrences) or small, discrete scatters of debitage, cores or expedient tools (14 occurrences containing between two and eight artifacts). These isolates indicate limited prehistoric use of the lower breaks. No diagnostic, time sensitive prehistoric artifacts were encountered in the lower portions of the monument. The limited prehistoric use of the lower breaks differs greatly from that observed on the upper rim.

SURVEY RESULTS ON THE UPPER RIM

Survey of the upper rim of the monument was completed during the 1997 field season (Canaday 1998). Archeology of the higher monument elevations is in stark contrast to that observed in the lower breaks. Here, extensive lithic scatters and lithic source areas are the norm, most dating to the Middle and Late Archaic, though limited Late Prehistoric and historic use is also evident. A total of 96 sites were recorded, 77 prehistoric, 15 historic and four sites with both historic and prehistoric components. In addition, 11 isolated artifacts (solitary flakes, bifaces and projectile points) were encountered. Eleven high density loci were also identified and recorded within a very large, previously identified prehistoric site (42In1135) located on both the Dixie National Forest and Cedar Breaks National Monument.

Historic Resources in the Upper Breaks

Historic use of the upper rim is present in the form of sheep herding camps, log fences, roads, and recreation related sites. Of the 19 historic sites (including historic components within prehistoric sites), four contain cabin remnants; three are wood pole fences probably associated with the original Cedar Breaks boundary; three contain miscellaneous scatters of historic debris such as bottles (Fig. 3), wood and metal fragments; two appear to be borrow areas associated with the construction

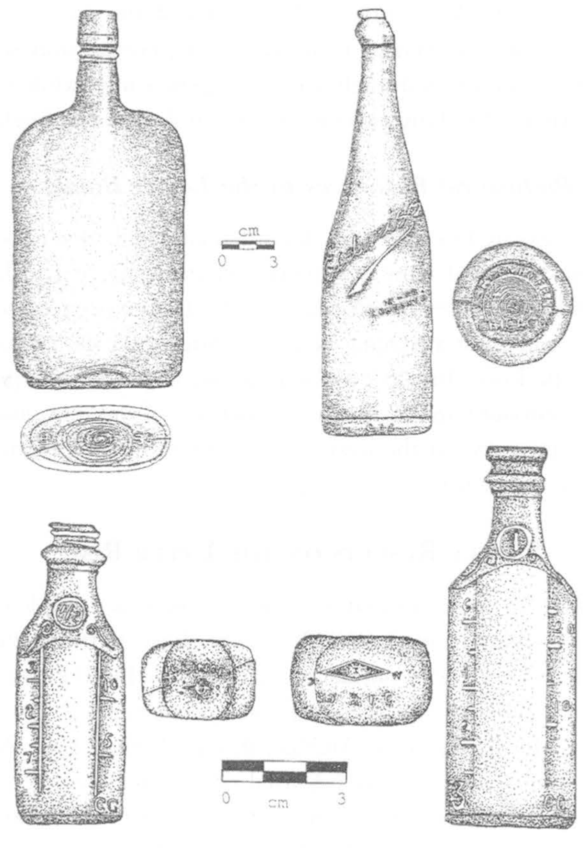

Figure 3. Historic era bottles from Cedar Breaks National Monument. The artifact depicted in the upper left was collected from the lower breaks (42In1424); the remaining artifacts were collected from the upper breaks (42In1543).

of State Route 148 through the monument; two are USGS benchmarks dating to 1936; two are roads; one is a grove of aspen containing historic inscriptions (1909-1946); one is a rock foundation probably constructed by the CCC in the 1930s; and one is the site of the original Cedar Breaks Lodge.

One of the historic cabin remnants is the site of Minnies Mansion, (42In1429) which was built in 1921 and included a dance hall. Minnies Mansion was named for Miriam 'Minnie' Adams Burton, who provided lodging and food for sheep herders operating in the area. Occasionally, rodeos and dances were held at Minnies Mansion for the local inhabitants of 'Little Ireland' (a collection of Irish Morman families who had established ranches near the base of Brian Head Peak), and residents of Parowan (Klein 1991, Frank 1997). With the establishment of Cedar Breaks National Monument in 1933, Minnies Mansion was razed. Frank (1997) notes that milled lumber fragments and a historic debris scatter are still present at this site.

Cedar Breaks Lodge (42In1573) was razed by the National Park Service in 1971. The lodge was established in 1924 by the Union Pacific Company (of railroad fame) who operated a tour business in southwestern Utah and northern Arizona. Lodges were operated at various locations (including Zion, the North Rim of the Grand Canyon, Bryce Canyon and Cedar Breaks) by the Union Pacific Company in order to cater to railroad customers interested in touring the scenic wonders of the area (Klein 1991). All that is left of the lodge today are several foundation remnants, access roads (now revegetated), and a scatter of historic and recent debris.

Prehistoric Resources in the Upper Breaks

Boundaries of historic and prehistoric sites are defined as continuous cultural resources if there is no break in the artifact scatter greater than 98 ft (30 m). Under this definition, some of the prehistoric sites encountered during the Cedar Breaks survey are very large. The largest of these (42In1135) is over three miles (4.8 km) long and nearly a mile (1.6 km) wide. Thousands of pieces of debitage are scattered nearly continuously across this site, broken only by areas of dense concentration where chert and chalcedony nodules of the local Brian Head formation have been tested and reduced. On the main, primary reduction is the focus at this site with final reduction performed elsewhere. Based on diagnostic artifacts collected from the surface, use of the area spans the last three or four thousand years and perhaps longer, because Forest

Service archeologists report a possible fluted point from this site (M. Jacklin pers. com.).

The 81 sites containing prehistoric components discovered on the upper rim are similar in many ways to 42In1135 and to the other sites previously reported on the Markagunt Plateau (e.g., Rose and Snedeker 1982). The Table below presents data on artifact distributions from sites located on the upper rim of the monument. Projectile point types collected from these sites include Humboldt, Pinto, Gypsum, Elko, Rosegate, Bull Creek, and Parowan Series (Figs. 4 and 5). Artifact distributions and diagnostic projectile point frequencies suggest that most of these sites served as tool stone reduction loci by people visiting the high country during the Middle and Late Archaic Periods. Of all projectile points collected from the surface of the Cedar Breaks sites, 79% are considered to be from the Archaic Period (Fig. 6). Based on the preponderance of debitage and tested chert nodules, procurement and primary reduction

Table. Artifact summary from Cedar Breaks National Monument.

Artifact Type	Dates (B.P.)*	# of Sites	# Of Ob	# of Chert	Artifacts Other	Artifacts Total
Pinto Series	8250 to 6150	4	3	2		5
Humboldt Series	7950 to 5950	1		1		1
Elko Series	7950 to 950	7	3	9		12
Gypsum Series	4450 to 1450	4	1	8		9
Rosegate Series	1650 to 1050	2	1	1		2
Bull Creek Series	1100 to 800	2		2		2
Parowan Series	950 to 750	3	1	2		3
Large Corner Notch		8	4	9		13
Small Corner Notch		1		1		1
Side & Basal Notch		1		1		1
Biface		32	14	74		88
Uniface		4		3	1-Qzt	4
Scraper		7		16		16
Utilized Flake		19		93		93
Hammerstone		4			2-Ryo,2-SS,3-Qtz	7
Edge Grinder		1			1-Qtz	1
Groundstone-Slab		1			1-Ryo	1
Snake Valley B/G	1050 to 750	1			Black-on-gray	1
Unknown Ceramics	1550 to 700	2			Plain Grayware	24

Ob-Obsidian; Qtz-Quartzite; Ryo-Rhyolite; SS-Sandstone

*Ceramic dates based on Fairley et al. (1989) and R. Madsen (1977).

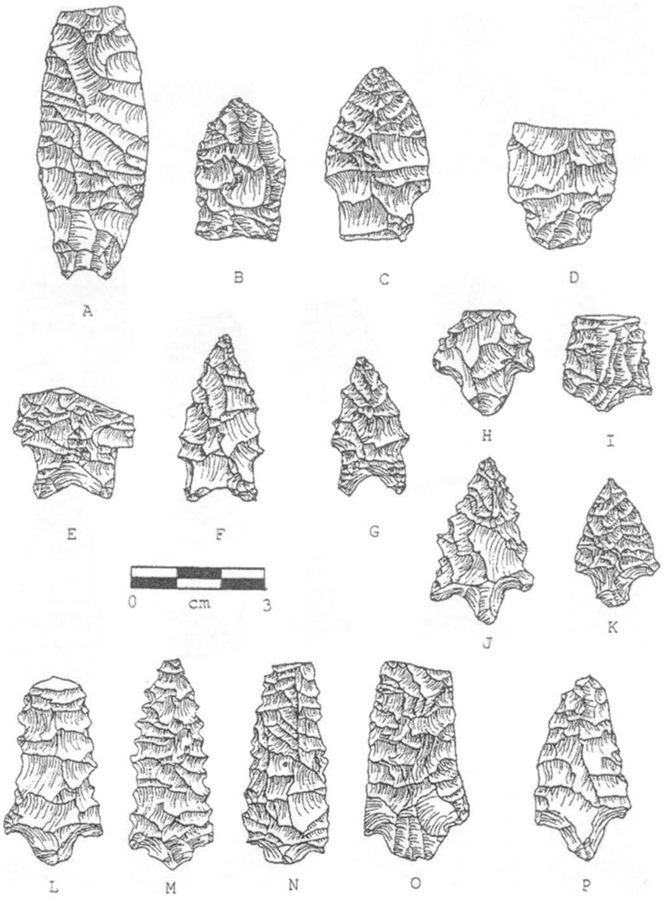

Figure 4. Selected Humboldt (A), Pinto (B - G), and Gypsum Series projectile points from Cedar Breaks National Monument.

of the locally-available Brian Head chert seems to be the main focus of prehistoric land use. Hunting of both large and small mammals undoubtedly occurred, but special game procurement strategies (i.e., using hunting blinds and drivelines) such as those described in similar high altitude settings of the Great Basin (Canaday 1992b, 1996, 1997, Thomas 1982) and Rocky Mountains (Benedict 1975, 1981, 1985, 1987, 1992, 1996), were not encountered at Cedar Breaks. Similarly, sites reported from the Markagunt Plateau lack hunting blinds and drivelines indicative

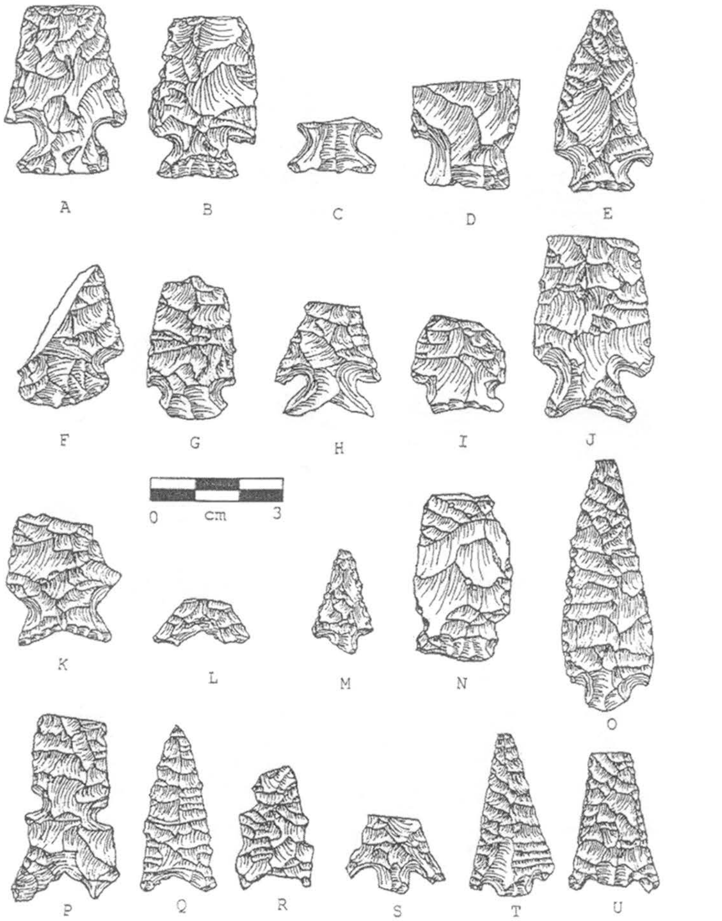

Figure 5. Selected Elko (A - L; N - O), Rosegate (M), Bull Creek (Q - R), and Parowan (S - U) Series projectile points, and an unknown type (P) projectile point from Cedar Breaks National Monument.

of intercept hunting strategies (Binford 1978, Canaday 1997, Pendleton and Thomas 1983).

Late Prehistoric use of the upper rim is indicated at three sites where ceramics and arrow points are present. A Fremont Snake Valley Black-on-gray jar sherd and a Bull Creek projectile point were collected from the surface of site 42In1430. Two other sites (42In1135 and 42In1522) contain plain grayware sherds that are probably attributable to Fremont though the presence of Virgin Anasazi in the area cannot be discounted.

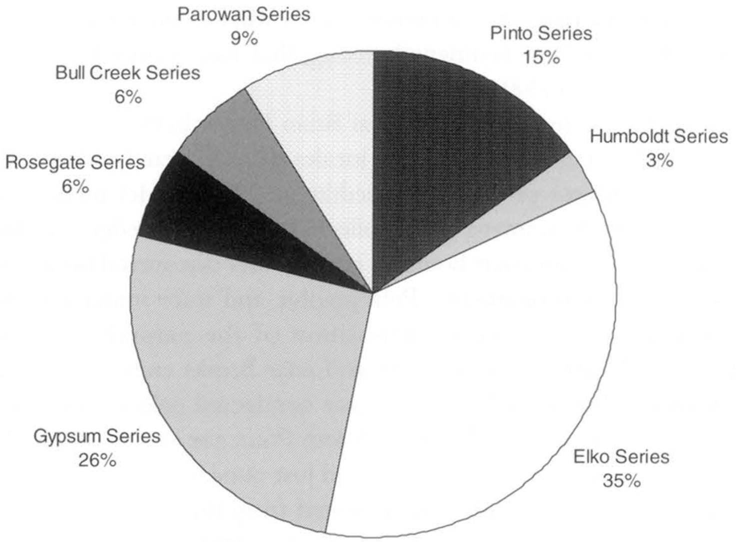

Figure 6. Percentage of projectile point types found at Cedar Breaks National Monument.

Analysis of manufacturing technique, and temper and clay composition, failed to definitively assign these sherds to a specific cultural affiliation. Regardless, the presence of ceramics in these high elevation settings is unique to the Markagunt Plateau. Groundstone, previously identified at only the North Point site, is also present at one of the sites (42In1522) containing ceramics, as is a possible fire hearth. The presence of groundstone, together with ceramics at this site, suggests the possibility of a changing land use strategy during the Late Prehistoric, perhaps one utilizing a different suite of resources.

ANCILLARY INVESTIGATIONS

Ancillary analyses of paleoclimate and resource potential of the Cedar Breaks area have been initiated. These analyses will be used to help interpret the archeological record. Included in these satellite studies will be: (1) additional pollen analyses of area peat bogs; (2) dendroclimatic reconstruction through analysis of bristlecone pine cores; (3) trace element analysis of obsidian artifacts to determine where these exotic materials originated; (5) petrographic analysis of the local Brian Head chert; and, (6) geological studies of the thick colluvial deposits that cover the upper rim in order to determine their origin. In addition, specific investigations into the regional paleoenvironment will be undertaken to ascertain the degree of environmental change that has occurred within the area over the last 10,000 years.

Petrographic analysis of the local Brian Head cherts has been initiated. Samples of chert from several locales were collected and described following guidelines set forth in Luedtke (1992) and McCutcheon and Dunnell (1998). Specimens were collected from chert ledges on Brian Head Peak, and from chert boulders and nodules discovered both within and south of the monument. Petrographic and trace mineral analyses will compare the chemical composition of the naturally occurring toolstone with artifacts collected from Cedar Breaks archeological sites.

Agenbroad et al. (1992, 1993) have conducted paleoenvironmental research within Cedar Breaks at the North Point site and at Alpine Pond as well as at Lowder Creek Bog (located just outside of the monument). Two paleoclimatic signatures are indicated from the analysis of molluscan paleofauna from the North Point site. In addition, the pollen spectra indicates a shift from alpine forest communities at or before 9,005 B.P. to open shrubland at or about 7,650 B.P. (Agenbroad et al. 1992). Environments similar to that observed today were apparently in place by 1,530 ±130 years B.P.

Madsen (1997) has recently completed preliminary analyses of peat bog deposits adjacent to Cedar Breaks as part of a cooperative agreement between the NPS, Dixie National Forest and the Utah Geological Survey. His work has centered on Lowder Creek bog (where he hopes to extend the paleoenvironmental record initiated by Agenbroad et al.) and Red Valley bog. This research was initiated in order to 'provide data on the changing environmental conditions facing prehistoric people in the area.' Evidence of beetle infestations and fire frequency that might have affected regional forest ecosystems was sought at Red Valley bog. At least 14 fire horizons were recognized by Madsen (1997) at Red Valley bog and 'appear to occur at rather constant intervals throughout the deposits.' The bog deposits span the last approximately 11,400 years, and fires appear to re-occur every 700 - 800 years. Additional work is planned at Red Valley bog to determine how consistent the deposition rate is and to directly date fire horizons. Collection and analysis of plant macrofossils is also planned in order to assess the local forest composition. Other paleoenvironmental research planned at Red Valley bog includes pollen analyses and retrieval of fossil beetle assemblages.

Finally, an additional component of the Cedar Breaks Archeological

Project will include ethnographic studies. Ethnographic work is planned with the Southern Paiute of Utah and Arizona, who have cultural affinity to and traditional uses of the Markagunt Plateau. DeBloois (1983) suggests that Southern Paiute groups wintering at Panguich Lake (at the north end of the Markagunt Plateau) followed a seasonal round that started and ended at higher elevations than their Great Basin neighbors. As winter snows melted in the spring and summer, these groups are thought to have ranged upward to the higher elevations. Oral interviews are planned with Paiute elders to gain a better understanding of both historic and contemporary traditional uses of Cedar Breaks.

CONCLUSIONS

The second year of this four year project has just been completed. Thus, the research reported here is still preliminary but does provide guidance for future work as well as the basis for interim conclusions. The lower portions of Cedar Breaks National Monument are characterized by limited prehistoric and historic use. Historic utilization consists mainly of logging related activities. Prehistoric use is present, but on a very limited basis.

The upper portions of Cedar Breaks National Monument, on the other hand, were heavily utilized by prehistoric groups intent on procuring lithic raw material. The majority of sites discovered on the monument's upper rim contain evidence of primary lithic reduction. Tested chert nodules, primary decortication flakes, and secondary percussion flakes are present at nearly all sites. Late-stage biface reduction flakes are present at only a few of the sites but never dominate. Local Brian Head chert and chalcedony artifacts are present at every site that we encountered. Indeed, non-cultural Brian Head chert and chalcedony debris is prevalent throughout the area. Field protocols were developed to distinguish between natural and cultural lithic debris. Thus, it appears that primary reduction of the local Brian Head chert was the focus of Archaic peoples visiting the Cedar Breaks area with later stage reduction occurring elsewhere.

During the Late Prehistoric this pattern probably continued, but at a smaller scale. However, the presence of ceramics, groundstone and a possible hearth at one site may indicate additional activities being carried out. Frank and Betenson (1997) note that Cedar Breaks is near a transitional zone between the Parowan Fremont and the Virgin Anasazi. Both of these distinct, yet contemporary cultures were sedentary horticulturalists, but they may have had a seasonal interest in the monument resources.

Only one of the sherds recovered from the surface of the three ceramic-bearing Cedar Breaks sites could be positively identified as Fremont (a Snake Valley Black-on-gray jar sherd). The other plain grayware sherds could not be assigned to a specific group.

Virgin Anasazi use of high altitude areas has never been identified. Because ceramic typology is the traditional diagnostic indicator for Virgin Anasazi, use of the highlands by task-specific groups carrying an aceramic toolkit may have occurred, but may well be invisible to present day archeologists. This is especially the case for surface assemblages.

One of the goals for the third season of fieldwork will be to recover a larger sample of ceramic artifacts from Cedar Breaks sites. Test excavation of site 42In1522, which contained plain grayware sherds, groundstone and a possible hearth, is planned. Excavations are also planned at a number of other sites on the upper rim that appear to contain buried cultural deposits. Included will be a reexamination of the North Point site in order to determine the association of cultural remains to the deeply buried strata exposed along the edge of the Breaks.

This project will ultimately result in a clearer picture of the cultural history of Cedar Breaks National Monument.

ACKNOWLEDGMENTS

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Cultural Resources and the Glen Canyon Dam–Colorado River Experimental Flow of 1996

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Abstract. The Bureau of Reclamation conducted an experimental flow from Glen Canyon Dam in late March and early April of 1996. The flow reached a maximum of 45,000 cfs and was expected to provide system-wide mitigation to most cultural sites in the river corridor through the accumulation of more sediment. A positive effect was presumed, but not guaranteed. Monitoring in the years prior to the experimental flow determined that a possible negative impact could result at eight archeological sites along the river corridor between Glen Canyon Dam and Lake Mead. On-site mitigation was required at these locations to fulfill federal agency responsibilities for any impacts sustained as a result of the proposed experimental flow. In addition to the required mitigation, monitoring of archeological sites and other kinds of cultural resources, ethnobotanical resources, beaches, and sediment accumulation at the mouths of arroyos was undertaken to assess the results of the experimental flow. Terraces were studied in the Glen Canyon Reach to determine whether terrace erosion in this area occurred as a result of the experimental flow. This paper summarizes the results of the coordinated mitigation and monitoring of cultural resources and sediments in the area of potential effect of the 1996 experimental habitat building flow from Glen Canyon Dam.

Key words: archeology, Glen Canyon Dam, Colorado River, American Indian Tribes, geomorphology, ethnobotany

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The cultural resources of Glen and Grand canyons take many different forms and are viewed from many different perspectives. This paper summarizes the various ways in which cultural resources were handled by federal and tribal researchers attempting to understand the effects of the experimental habitat building flow upon the cultural resources of the canyon. To many scientists, the cultural perspective seems more like philosophy than science. However, the melding of the traditional native American perspective with the western scientific method comes together within the cultural disciplines. Although scientific method was used in evaluating sand deposition, depletion and vegetation impacts, the overall program was guided by overarching principles of preservation and protection of cultural resources. This view is shared by both the federal land managers and the tribal researchers who participated in the studies. This coming together of science and philosophy is a difficult concept for many, but it forms the basis of our perceptions of Grand Canyon and why these resources are so important.

Cultural resources embody the broad view of the landscape, where places and their inherent values have significance. Whether it be the geographical locations, archeological sites, plants and animals, air and water, or rocks and minerals, all things are viewed from both their human perspective and the ways in which humans interact with the natural world. In many ways, the cultural resource approach is the original ecosystem management approach.

The approaches taken to understand the effects of the habitat building flow on cultural resources underscores the opportunities that are presented through the range of natural resource studies and the interdisciplinary nature of cultural resource concerns. Researchers within the cultural disciplines are both users and providers of information with application to other studies.

The notion of what constitutes a "cultural resource" in the 1996 Glen Canyon–Colorado River experimental flow was very different from the typical western view of cultural resources. Usually, cultural resources are thought of quite narrowly, generally encompassing little more than archeological sites and historic properties. However, cultural resources along the Colorado River corridor include not only archeological and historical sites, but also water sources, sediment and mineral deposits, plants and animals, and locations identified as traditional cultural properties. All of these resources have the potential to be affected by Glen Canyon Dam. The ultimate goal of the cultural resource efforts related to Glen Canyon Dam operations is preservation *in situ*, with minimal impact to the integrity of the resources.

The Hopi Tribe conducted research on sediment deposition and depletion. Vegetation transects at significant locations were studied by the Southern Paiute Consortium and the Hualapai Tribe. National Park Service (NPS) archeologists and conservation specialists from the Pueblo of Zuni conducted mitigation of potential impacts to archeological sites. Traditional archeological studies were conducted by the NPS through inundation models, repeat photography, planimetric survey, terrace mapping, drainage cross-sections, aerial photography, and data recovery/excavation. All of these studies applied interdisciplinary approaches, yet all were cultural resource studies. Collectively, these studies evaluated the effects of the habitat building flow upon a wide range of potentially impacted cultural resources.

The following statement, prepared by Joseph Dishta of the Pueblo of Zuni, exemplifies the perspective provided by the Indian tribes of the area:

> "The Grand Canyon, from the indigenous peoples point of view, is a vast 'traditional cultural property' that links traditional lifeways with the present. For example, ancestral archeological sites contain human burials, individuals who are still fulfilling their spiritual life journey. Sacred plants, animals, all living beings and elements, are significant. Birds, waterfowl, and animals of the canyon are important messengers of the spirit world. Minerals, part of the living earth, are also important. Many indigenous groups relate their existence to the Canyon. A place where they emerged from its depths and still reside in today. Traditional lifeways of indigenous people are affected by every aspect of scientific and technical studies that have occurred as a result of the experimental habitat building flow. Elements from the inorganic, vegetation, aquatic, and the animal, to archeological sites are of great importance to the indigenous people of the area. The ultimate concern is for the protection of all cultural resources of the canyon" (Dishta 1997 pers. com.).

METHODS

The studies conducted by researchers representing the cultural discipline followed seven separate lines of inquiry, examining 46 separate locations. The following summarizes the various efforts and conclusions for each of the methodologies employed.

Terrace Mapping

Terrace mapping was completed at five locations in the Glen Canyon Reach (0). Surveyors from the Glen Canyon Environmental Studies (GCES) and archeologists from Glen Canyon National Recreation Area (GLCA) performed the work. Data were collected on planimetric survey areas, cumulative cut and fill volumes, and net sediment gain or loss at the terrace margins. Pre-flow, post-flow, and isopach topographic maps were produced, with cut and fill data based upon 0.25 meter contour intervals (Burchett et al. 1996).

At four of the five sites mapped, the experimental flow had a beneficial effect upon the river terraces, evidenced by the increase in the amount of sediment at the base of the terraces. However, at one location, the experimental flow had an adverse effect, evidenced by the loss of sediment at the terrace margin, even though the beach at the base of the terrace was replenished. Review of the maps and measured volumes suggest that, at this terrace, the experimental habitat building flow increased the beach at the bottom of the terrace at the expense of the terrace deposit itself (Burchett et al. 1996).

Sand Deposition and Retention (Drainage Cross Sections)

Examination of the effectiveness of the experimental flow to elevate sediment into the mouths of ephemeral arroyos that drain the margin deposits along the Colorado River was undertaken by the Hopi Tribe. Four study locations were chosen, one in Reach 0, and three in Reach 5. These locations were chosen because they contained cultural resources, well within the area of potential effect from the experimental flow, and had arroyos or drainages that would be overtopped at the level of the 45,000 cfs flow. A Glen Canyon Environmental Studies surveyor and a Hopi tribal archeologist conducted fieldwork. Pre- and post flow maps were completed at a 0.25 meter contour interval (Yeatts 1996).

At three of the four study locations, sediments were deposited in the mouths of the arroyos. The fourth site received no deposition and did not experience erosion. One of the Reach 5 locations, consisting of two arroyos, had the highest variability in response. Some areas of the site eroded as much as 0.5 meters, while other portions of the site received nearly 0.8 meters of deposition. A band of sediment was deposited at the 45,000 cfs level. Overall, 202.4 cubic meters of material was deposited in this site while 124.6 cubic meters of material was eroded (Yeatts 1996).

This study illustrated that planned high flows can elevate sediments into the mouths of ephemeral arroyos, which have been implicated as a factor in the erosion of archeological sites. The results substantiate the concept advanced in the Glen Canyon Dam Environmental Impact Statement (GCDEIS) that high flows can be used as a management tool for system-wide stabilization of cultural resources. One of the most critical aspects of the study that needs to be addressed through long-term monitoring is the duration of time that the deposits remain in the arroyos. Ultimately, if these deposits are not retained long enough to slow down the rate of erosion in the arroyo systems, then the goal for these deposits of stabilizing cultural resources sites will not be realized (Yeatts 1996).

Aerial Imaging

Two different types of analysis utilizing aerial imagery were utilized to evaluate the experimental habitat building flow. An archeologist and hydrologist at Glen Canyon in conjunction with Bureau of Reclamation's Remote Sensing and Geographic Information Group utilized one technique. The other method, utilized by Grand Canyon archeologists, employed aerial video documentation taken at the 45,000 cfs level to determine actual distance from the water's edge to the archeological site. The video image was processed on CD-ROM and was analyzed using the Map Image Process System (MIPS) (Burchett et al. 1996).

Five locations within Reach 0 were evaluated using aerial photography. Evaluation of the area pre-flow and post flow suggests that three of the five sites exhibited gains in sediment, while two sites exhibited minor loss (7% and 10%) (Burchett et al. 1996).

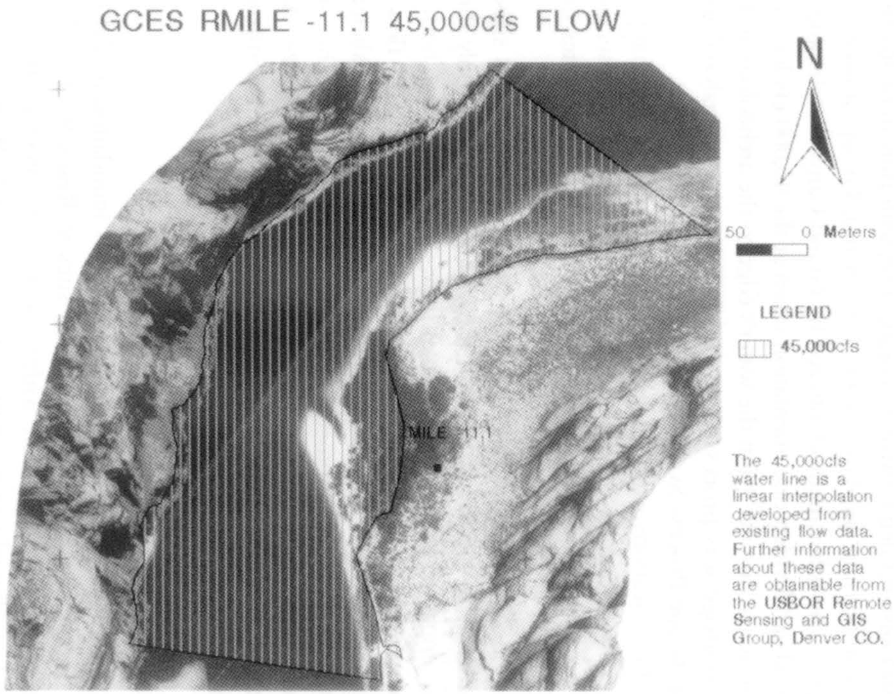
Videography and MIPS analysis was conducted at 18 sites within reaches 1, 2, 4, 5, 6 and 10. Of the 18 sites evaluated, only three sites were impacted by the experimental flow. Two other sites, both historic inscriptions located in reach 2, were underwater during the flow. Reclamation prediction models of flow elevation at one site predicted actual flow to within 15 centimeters. Flow predictions at the other site indicated that the feature was 1.8 meters underwater at 45,000 cfs. Although both sites were affected directly by the flow, no negative impacts were identified (Burchett et al. 1996).

Inundation Model

The accuracy of a predictive 45,000 cfs inundation model supplied by Reclamation was evaluated at six sites in Reach 0. Locations were selected because they were within the area of potential effect and consisted of alluvial terraces with archeological sites. Work was conducted by a Glen Canyon archeologist utilizing Bureau of Reclamation data. The predictive 45,000 cfs water line was a linear interpolation developed from existing flow data available prior to the experimental flow. Photographic images with the interpolated 45,000 cfs flow were produced (Burchett et al. 1996; Fig 1).

The 45,000 cfs inundation model was very accurate at three of the six terraces under study. The model was less accurate at the other three terraces, predicting greater inundation than what actually occurred. The

Figure 1. Linear interpolation of the 45,000 cfs water line that was developed from existing flow data.



linear interpolation model from existing flow data should be used prior to future experimental flows to determine where inundation might occur (Burchett et al. 1996).

Photographic Replication

Photographic replication was employed by NPS archeologists at 24 locations within the river corridor, producing over 200 images. Six locations within Reach 0 were visually evaluated using pre- and post-flow photographs. All but one site appeared to have lost terrace material from the experimental flow (Burchett et al. 1996).

Photographic replication was conducted at 18 sites below Lees Ferry as part of an enhanced monitoring program related directly to the effects of the experimental habitat building flow. Sites were chosen based upon proximity to the river and potential for sediment change as a result of the flow. All analyses were conducted as a time 1 (pre-flood) verses time 2 (post-flood) comparison (Burchett et al. 1996).

Photographic replication documented an immediate overall positive effect on archeological sites located in close proximity to the river below Lees Ferry through the accumulation of sediment. A combination of pre-flow mitigation efforts and replicate photography was undertaken at Palisades. Considerable effort was expended prior to the flow in the construction of erosion control features within arroyos cutting through archeological deposits. Pre- and post flow photographs document the amount of sediment accumulation in these locations and provide good indications that site stabilization efforts, coupled with sediment depositing events may preserve sites *in situ* (Burchett et al. 1996).

Sediment accumulation was documented at five locations, with deposition in eddy complexes adjacent to sites noted at two locations. No sites were adversely affected by the flow, and the information gathered provides considerable insight into the effectiveness of controlled high flows as system-wide mitigation for archeological sites where sediment depletion is the causal factor (Burchett et al. 1996).

Mitigation

Eight sites (four historic and four prehistoric) had the potential for inundation, erosion and/or damage from bank slumpage or direct surface erosion. These sites were chosen for mitigation based upon their relative location within the area of potential effect and the possibility for catastrophic loss, requiring data recovery prior to the experimental flow. The experimental flow was found to have no effect or no adverse effect on seven of the sites. The flow was found to have a beneficial effect on one historic site located in Reach 0 (Andrews et al. 1996).

Three forms of mitigation were conducted consisting of data recovery, medium format photography, and pre-and post-flow underwater dives to determine the extent of impact to the structural integrity of the Charles Spencer steamboat. Photographs and detailed measurements of sediment at various points around the vessel were taken pre and post flow to determine the effect of the flow. Sediment accumulation was documented, indicating a positive effect from the flow (Andrews et al. 1996).

Recovery measures at the four prehistoric sites resulted in mitigation of any adverse impacts due to the experimental flow. Data recovery was the appropriate mitigation strategy because the flow had the potential to adversely affect these resources. Additional information was gained through the data recovery program that allowed expanded information on the geomorphic setting and soil formation processes at these locations. Photographic documentation revealed no adverse impact to the historic inscriptions (Andrews et al. 1996).

Ethnobotany

The Southern Paiute Consortium (SPC) and the Hualapai Tribe undertook ethnobotanical studies. Methods utilized in the studies included both permanent and nonpermanent evaluative techniques. Nonpermanent measures included qualitative assessments of the level of impact due to erosion, flooding, and the presence or absence of river-based streams. Permanent measures included photography, belt transects, line intercept transects, and selected plot monitoring. In general, the impacts were either positive or negligible. For example, the initial scouring and burial of plants, such as willow (*Salix exigi*) that reproduce vegetatively, results in an increase in the abundance of those plants. Nevertheless, the long-term impacts of the increase of introduced species, such as Bermuda grass (*Cynodon dactylon*), are unknown. Also, the effects of the availability of water to plants within the old high water zone are not immediately apparent. Thus, each of these monitoring sites will be visited again in 1997 and reevaluated (Austin and Osife 1996, Phillips and Jackson 1996).

Riparian communities are well adapted to periodic disturbance by flooding. Renewal of eroded sediments along shorelines, scouring out of stagnant return channels, scarification and water-borne dissemination of seeds, and removal of excess dead brush are all potential positive effects of flooding on riparian communities. Most riparian species are well adapted to periodic catastrophic habitat disturbance. The general trend related to the effects of the experimental flow on ethnobotanical resources indicates stabilization of the habitat and recovery of vegetation (Austin and Osife 1996, Phillips and Jackson 1996).

The Gooding Willow at Granite Park, of special concern to the Hualapai Tribe, survived the flood and was observed to be in better health afterwards than it had been in previous years (Austin and Osife 1996, Phillips and Jackson 1996).

CONCLUSIONS

The overall findings of the cultural resources studies done in conjunction with the 1996 Glen Canyon Dam–Colorado River experimental flow strongly suggest that this event had either no effect, no adverse effect, or a beneficial effect on cultural resources. These findings support the original contention that habitat-building flows can offer a system-wide mitigation for cultural resources. Some locations, especially in the Glen Canyon Reach, did experience loss of sediments or redeposition of sediments in a way that, in the long run, could be detrimental to cultural resources.

Specific results include:

1. At four of the five sites mapped, the flow had a beneficial effect upon the river terraces as evidenced by the increase in the amount of sediment at the base of the terrace.
2. The inundation model was very accurate at three of the six terraces under study; however, at three sites, the model predicted greater inundation than what actually occurred.
3. The flow had an immediate overall positive effect on the cultural resources proximal to the river; however, this gain may be of short duration without additional maintenance flows of equal or greater volume.
4. At three of the four study locations, sediments were elevated in the mouths of ephemeral arroyos that may slow erosion of sediments containing archeological materials.
5. The flow did impact culturally important plants, however the impacts were either positive or negligible as scouring resulted in an increase in the abundance of those plants.
6. The Gooding Willow at Granite Park appeared healthier than it had been for several years during the 1996 growing season. Stabilization efforts prior to the flood release slowed erosion and the

tree was not adversely affected. However, possible loss of stabilization materials and erosion of the underwater bank at the shoreline during high releases are potential causes for concern.

One caution that should be heeded in the planning of future experimental flows is that flows higher than 45,000 cfs will impact other cultural resources than those monitored and mitigated for this experimental flow. Additional monitoring will be necessary to determine the duration of the beneficial effects of sediment deposition on sediment deposits which protect cultural resources by slowing the erosion of the terraces on which they are located. However, if the newly deposited sediments are shown to slow erosion significantly, the system-wide benefits from the experimental flow will be well worth repeating for the perspective of cultural resource preservation.

Continued monitoring will be necessary to determine the duration of the beneficial effects of sediment deposition on beaches, which protect cultural resources by slowing the erosion of the terraces on which they are located. The relatively high steady flows which have been released from Glen Canyon Dam since the spring 1996 experimental flow have caused significant erosion to the newly built alluvial terraces. Although most cultural resources appear more stable than prior to the experimental flow, the need for additional sediment deposition remains.

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Southern Utah Wilderness and the Meaning of the West

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Abstract: The debate over Southern Utah wilderness and the more recent Grand Staircase-Escalante National Monument designation transcends issues of environmental protection to include a host of regional-specific themes and concerns. Cultural contours and cleavages such as a rural Western economy and federal versus de jure wilderness, have framed the Utah wilderness debate. These cultural contours and their significance are discussed in the larger context of a western political culture and stem from a series of in-depth qualitative interviews. It is only once the full range of cultural issues are considered that conflict can be minimized and the true meaning of the West better understood.

Key words: policy, Grand Staircase-Escalante National Monument, economics

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In September 1996, using the 1906 Antiquities Act, President Bill Clinton proclaimed 1.7 million acres of Southern Utah as the Grand Staircase-Escalante National Monument. Even today, said the president, "This unspoiled natural area remains a frontier ... it is a place where one can see how nature shapes human endeavors in the American West" (USDI 1997). Presidential proclamation 6920 is but one part of a long contemptuous battle over public lands in Utah. The Utah wilderness debate provides an excellent case in which to understand how political culture may affect environmental politics in the American West. This case study is chosen because of its timeliness, relevancy, the cultural and sometimes contrasting values it involves, its environmental impact, and the number and diversity of political players involved. Within the battle for additional Utah wilderness, cultural values are at play, and divergent ones are often pitted against one another for the meaning of the West.

The debate in southern Utah involves more than just wilderness or monument designation. The contours of the debate, real or imaginary, are central in many respects and invariably frame its discourse. There are five such contours discussed herein: (1) the Utah economy; (2) federal versus local control of public lands; (3) the lack of incorporating local knowledge and gathering community input into environmental decision making; (4) the perceived influence of non-Western and urban interests; and, (5) the differences between de facto and de jure wilderness. At times, in fact, the question of wilderness seems a peripheral issue. But whatever the importance of Utah wilderness may be, it has proven to be an excellent means to further understand some of this study's earlier findings. An in-depth examination of this particular case, using personal narratives to help illustrate, shows just how unmistakable a Western political culture can be, and the environmental ramifications it inevitably presents.

BACKGROUND

Henry David Thoreau once mused that "in wilderness is the preservation of the world," thus staking an importance on wilderness that would reverberate in the years to come. It is not surprising, therefore, that the designation of wilderness often elicits the most passion and controversy among those concerned with public land issues. Much of this is due to the language of the 1964 Wilderness Act that defines wilderness as an area "...where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." An area may be determined suitable for wilderness designation if it has the following characteristics:

> [It is] an area of undeveloped land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the impact of man's works substantially unnoticeable; (2) has outstanding opportunities for solitude or primitive and unconfined type of recreation; (3) has at least 5, 000 acres of land or is of sufficient size as to make practicable its preservation in use and in an unimpaired condition; and, (4) may also contain ecological, or other features of scientific, educational , scenic, or historic value (Public Law 88-571 1964).

Congress has the authority to designate areas as wilderness and uses its power to do so under the act. The intent is to make designations permanent and to add new lands as Congress sees fit.

The 1964 act established the National Wilderness Preservation System and set aside 9.14 million acres of wilderness in 54 areas, all on national forests. The system now protects more than 99 million acres of wilderness in national forests, wildlife refuges, parks, and BLM lands, and is managed by a host of agencies including the Forest Service, Bureau of Land Management, National Park Service, and the Fish and Wildlife Service. As the Table below shows, more than 95% of designated wilderness is located in these 12 western states.

Although protected to preserve its natural conditions, a number of non-motorized activities such as horseback riding, hiking, camping, fishing, and hunting are allowed in wilderness areas. Preexisting and valid extractive uses are also allowed to continue until permits granted for such activities expire, are abandoned, or are purchased by the government. Preexisting grazing is also allowed to continue as long as it is found consistent with sound resource management practices. Activities that are not allowed in wilderness areas include mining (new claims),

Table. Western state wilderness areas, 1995.

State	Acreage
Alaska	57,408,589
Arizona	4,537,864
California	13,851,936
Colorado	3,257,398
Idaho	4,005,545
Montana	3,442,305
Nevada	792,525
New Mexico	1,613,263
Oregon	2,087,072
Utah	800,958
Washington	4,320,308
Wyoming	3,080,358
Western Total	99,198,121
National Total	103,596,244

Source: Bureau of Land Management, Washington, D.C., 1995.
Note: This is federal wilderness acreage in the states, managed by the Bureau of Land Management, the US Forest Service, the US Fish and Wildlife Service, and the National Park Service.

timber harvesting, chaining, water development, mountain biking, and use of any motorized equipment such as snowmobiles. These allowances in the 1964 wilderness bill can be seen as a compromise between preservationists and those resource interests concerned with grazing, mining, timber harvesting, water development, and motorized recreation.

In 1976, the Federal Land Policy and Management Act (FLPMA) required the BLM to inventory all roadless areas suitable for wilderness classification. Completed on a state by state basis, Utah's wilderness inventory was completed in 1980. Although a highly controversial and contested issue, the BLM ended up recommending 1.8 million acres as possible wilderness in the state.

The debate over wilderness designation has a long and notable ancestry, and has been ongoing since preservation calls were made by John Muir and foresters such as Aldo Leopold, Arthur Carhart, and Bob Marshall during the 1920s (Hendee et al. 1990, Zaslowsky and Watkins 1994). The dialogue between what political scientist Christopher McGrory Klyza calls 'preservationists" and "technocratic utilitarians" has a rich historical context showing just how little the debate over wilderness has changed since its institutional inception (Klyza 1996).

Environmental historian Roderick Nash believes the historic conception of wilderness, especially the frontier movement from east to west, provides a glimpse into the American mind (Nash 1967). Those such as Leopold also recognized the importance of the frontier in how the concept of wilderness was first constructed: "To the laborer in the sweat of his labor, the raw stuff on his anvil is an adversary to be conquered. So was wilderness an adversary to the pioneer" (Leopold 1966). Yet, Leopold also contends that it is the philosophical "laborer in repose" that sees "...that same raw stuff is something to be loved and cherished, because it gives definition and meaning to his life" (Leopold 1966).

THE DEBATE: THE BIRDWATCHERS AND ROUGHRIDERS

The battle over the federal designation of additional wilderness areas in southern Utah involves up to 5.7 million acres of Utah's 22 million acres of public land. The contested area abuts six national parks and recreation areas—Zion, Capitol Reef, Arches, Canyonlands, Bryce Canyon, and Glen Canyon, and includes several geological systems including the Upper Paria Canyon, the White and Vermillion Cliffs, and the Kaiparowits Plateau. The area also includes coveted archeological sites and findings from native peoples such as the early Anasazi, Fremont, Southern Paiute, and Navajo cultures. Given the varied terrain, the region is also home to a multitude of various flora and fauna.

For these reasons, wilderness advocates such as the Southern Utah Wilderness Alliance, the Grand Canyon Trust, the Utah Wilderness Coalition, and thousands of Utah and non-Utah residents believe the area should be forever preserved in its most natural and primitive state. The region, the last to be mapped in the continental U.S., remains the most primitive and wild place in the lower forty-eight states. Its proximity to national parks, amount of surrounding public lands, and distance from any major urban areas, some observers say, makes southern Utah the prime candidate for future American wilderness designation.

There are a number of recommendations made by organizations concerning the amount of land that should be set aside as wilderness in the state (as of 1997). One million acres or less has been recommended by Utah's county governments, 1.2 million acres by Utah representatives Bill Orton and Jim Hansen, 1.9 million acres by the BLM, 2.8 million acres by the Utah Wilderness Association, and 5.7 million acres by the Utah Wilderness Coalition. Despite these acreage variations, predictably, the debate has focused on the two extreme proposals pitting the county position, interpreted as the local or rural response, against the 5.7 million acre plan championed by groups such as the Southern Utah Wilderness Alliance.

The Utah Wilderness Coalition represents 115 citizen groups that support the designation of 5.7 million acres of Utah BLM land as wilderness—approximately 15 percent of all land in the state. The group formed in 1985 as a response to the perceived failure of the BLM Utah lands inventory—not enough wilderness. The "Citizen's Wilderness Proposal" was first introduced by then Utah Congressmember Wayne Owens as H.R. 1500, and then reintroduced as "America's Redrock Wilderness Protection Act" by Maurice Hinchey of New York. It is the largest acreage proposal and adopts the strictest interpretation of the 1964 Act.

Similar to earlier wilderness disputes, the Coalition and its former spokesperson Wallace Stegner see the conflict on the Colorado Plateau as not only one between the material and the spiritual, but also one of disparate cultures.

According to Stegner:

> Utahns were, and some still are, frontiersmen. They share states' rights assumptions and biases. Away from Wasatch Front, the population is so thin and the wild land so extensive that they cannot conceive of its being damaged.... No more than other Westerners do they like dictation or interference from outsiders,

> and they are as susceptible as other frontier Westerners to the temptation of violence. Many consider the wilderness inventory, and indeed all federal regulation, an unwarranted intrusion into land use decisions that should properly be made by the people who live there (Stegner 1989).

Stegner saw the conflicting parties as consisting of the "...Birdwatchers and the Roughriders, the responsible stewards of the earth and those galvanized by the spirit that 'won the West'" (Stegner 1989). Although Stegner, a Utah native, remained sympathetic to many rural Utah concerns and understood the roots of their intransigence, many of which stem from historic religious persecution, he believed they have failed to read their own history. Southern Utahns, said Stegner, are willing to sacrifice what makes their place so special in return for marginal economic and material rewards.

Many wilderness advocates appeal to the emotional and soulful importance of this redrock environment. T. H. Watkins, editor of Wilderness, the magazine of the Wilderness Society, points to the "...usual suspects [that] include mining, grazing, timber extraction, oil and gas development, industrial-strength tourism, and unfettered urban growth and the water projects that will be necessary to sustain it" as the primary threats to the southern Utah environment (Watkins 1996).

Those who live in wilderness areas, on the other hand, often feel under siege by those who live outside, but nevertheless want to "lock up" the area's natural resources. It is southern Utah counties, says the Utah Wilderness Education Project, an advocate for the county position, that together have the most collective expertise about the area's wilderness, e.g., proper boundaries, micro-economic impacts, travel corridors. Therefore, it is largely believed that the people closest to the land should have more decision-making power over how that land is managed.

Southern Utahns are often portrayed as being against additional wilderness or monument designation—sometimes out of principle and sometimes for economic factors (Kluger 1997). While those like Stegner and Watkins direct criticism at the "usual suspects," many southern Utahns see extractive industries, on a limited scale, as being the only means of recovering a lost rural economy, keeping a distinct culture intact, and providing the incentives to keep young adults in the area.

An important component in the wilderness debate has been the use and contesting nature of public opinion polling. As a whole, Utah residents are in favor of additional wilderness area designations in the southern part of their state. Studies show there are pockets of "anti-environmentalism" in the West and southern Utah is used as one such example. The Utah wilderness surveys cited, however, were taken before the acrimony became more pronounced and the sides more clearly visible (1986 and 1990). Since these surveys, there have been a number of competing polls and other information used by various parties in the debate to strengthen their positions. Surveys and other information that confirms support are embraced while those that question are eschewed.

Other measures of public opinion show state residents to be supportive of the 5.7 million acre plan. Utah governor Mike Leavitt, asking for public comment on the contesting bills, received 22,000 letters and petitions, 65 % of which supported the largest acreage set aside (Kriz 1996). County hearings were also scheduled by the state to elicit additional input, and while many of these hearings were held in the most rural parts of the state, hundreds of miles away from the central Utah population—an intentional strategy according to wilderness advocates—citizens in favor of H. R. 1500 outnumbered opponents by a reported ratio of six, seven, and nine to one. According to wilderness advocate Dave Foreman, the Utah Sierra Club and SUWA effectively mobilized wilderness sentiment and "...took that lie away from the Utah congressional delegation that the people of Utah are against wilderness" (Kriz 1996).

Despite this apparent success, however, those who support additional wilderness designation report the public hearing process to be anything but the hearing of the public. Despite wilderness proponents outnumbering their opposition, former Utah congressmember Karen Shepherd reports that "never in my memory have so many had so little influence on their own elected representatives" (Glick 1995).

A more representative way to measure Utah wilderness opinion, state public opinion polls show state residents to be in favor of additional wilderness, with how much wilderness to designate still in question. A Desert News poll finds only 4% of the state wanting no more additional land set aside as wilderness, while 26 % support the 1.8 million acre proposal, and 36 % supporting the 5.7 million acre plan (Satchell 1995). There is no consensus on how much wilderness Utahns favor. Surveys done by Utah State University, Desert News, Salt Lake Tribune, and other interested parties, uncovers no consistent majority favoring a certain proposal.

THE GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT

Encompassed within the debate over southern Utah wilderness designation is President Clinton's executive order creating the Grand Staircase-Escalante National Monument. Although monument status is not as restrictive as is wilderness designation, lands within the Monument are withdrawn from entry, location, selection, sale, leasing, or other disposition under public land laws (USDI 1997). Thus, no new mineral leases can be issued within monument boundaries. Despite these restrictions, several valid existing rights in the monument are recognized, meaning that such preexisting activities as grazing can continue.

Since the Antiquities Act of 1906, more than 100 national monuments have been established by presidential proclamation, including those in the southwest such as Grand and Bryce Canyons and Zion. Although there are differences between wilderness and monument status, Congress does have the ability to create wilderness areas within a monument's boundaries, and the Grand Staircase-Escalante contains approximately 900,000 acres of existing BLM wilderness study areas (WSAs).

Many people in Utah believe that the Grand Staircase-Escalante National Monument's designation was politically motivated. Made during the 1996 presidential campaign, with Ralph Nader's Green Party threatening to take environmental votes away from the Democrats, Clinton was ensured positive environmental coverage while knowing that winning Utah was already improbable. Clinton's strategy appears to have gone as planned. For example, whereas Utah Senator Bob Bennett said Clinton's pronouncement "...shows blatant disregard for existing process in exchange for a campaign photo-op at the Grand Canyon," executive director of the National Resources Defense Council, John Adams, said the president "...deserves tremendous credit for his leadership and vision in preserving this portion of Utah's magnificent and unique red rock wilderness" (Siegel 1996).

Western Cultural Contours

Within the debate over wilderness and monument designation in southern Utah are a number of important and repeating themes that have set the terms of its discussion. Taken together, these cultural contours and cleavages show how Western political culture can shape and inform its environmental politics.

Economics: Southern Utah as Playground or Paycheck

The Grand Staircase-Escalante National Monument and other southern Utah wilderness proposals include areas that have the potential for increased economic development. The Kaiparowits Plateau includes 650,000 acres of coal-rich lands that the Dutch-owned Andalex company wants to extract. Coal-mining the Kaiparowits has drawn interest since 1965 from such companies as Southern California Edison, San Diego Gas and Electric, and Arizona Public Services of Phoenix (the Kaiparowits energy consortium) (Bishop 1996). The proposed production of 2.5 million tons of coal, and its accompanying sales taxes, property taxes, royalty payments, and potential source of employment, is seen by several government and business leaders in the state as a way to resuscitate a fragile southern Utah economy (Utah Energy Office 1989).

Andalex's proposed Smokey Hollow coal mine has been challenged on economic grounds by those wishing to preserve the area. The Flagstaff-based Grand Canyon Trust argues that the mine is comparatively uneconomical due to higher transportation costs and lower coal quality than central Utah mining operations (Duffield 1995). Expecting to sell its coal to the California industrial and Pacific Rim steam coal markets, Andalex has asked the state to commit resources to build and maintain new roads along the coal haul route. The Trust sees the mine as not only environmentally deleterious, but also views these government subsidies as being economically unsound.

The economic value and opportunity costs associated with wilderness and monument designation is a central theme in the public lands controversy. Larger wilderness designation bills are opposed by most rural county officials because they are seen as a loss of revenue either from lost payments-in-lieu of taxes or mineral leases. Although some cite this as a red herring, the loss of possible revenue produced by school and institutional trust lands—acreage owned by Utah for the purpose of generating revenue for education—is another reason put forth by Utah counties not to support a larger wilderness bill.

Some southern Utah counties believe wilderness will jeopardize the economic and social stability of the region, while preservationists believe it will spur economic growth in wilderness related service sectors while also protecting the environment. County representatives point to the small percent of privately owned land in Utah and the economic ramifications of this federal presence. It is private property, not federal land, they say, that generates revenue to pay for such services as education, infrastructure, law enforcement, emergency services, fire protection, and ironically, a host of tourist needs and services.

The assumption that the wilderness-related service sector provides an economically and environmentally sound alternative is also suspect by many in the region. For example, one comprehensive study done by

Utah State University in 1995 finds that the economic benefits from added wilderness recreation appear to be inconsequential (Snyder et al. 1995).

The economic arguments made by the countries and others who favor less wilderness are doubted by such organizations as the Southern Utah Wilderness Alliance. The supposed economic opportunity costs associated with increased wilderness is fallacious according to the Alliance. Executive director Mike Matz contends that wilderness opponents are "...clinging to this historic notion that they have to exploit the land in order to make a living" (Glick 1995 *in litt.*). Not only are several existing uses respected by the Wilderness Act, but the Alliance contends that global economic trends, changing energy markets, increased automation, and the increasing importance of the service sector, among other factors, are changing national as well as rural Utah employment patterns. Wilderness, contends the Alliance using logic supported by Thomas Michael Power and other economists, provides the possibility of abandoning the boom and bust economy symbolic of the West in favor of a more sustainable and ecologically sensitive economy.

These differences of interpretation regarding the southern Utah economy are ubiquitous across the West and are perhaps best illustrated by a bumper sticker asking, "Are you an environmentalist or do you work for a living?" In other words, environmentalists, including those in Utah, are being perceived as condemning all work in nature, or sentimentalizing certain archaic forms of work. The environmentalists are viewed as being unaware of the nature that supports them, whether it be the wood that heats their homes, the dammed water they drink, or the electricity that runs their computers. As environmental historian Richard White notes, environmentalists are seen as being part of a privileged leisure class that identifies nature as a place to play and visit, and not a place to work, stay, or live (White 1996).

Federal Versus Local Control

A predominant theme in this debate is the amount of land in the area that is already owned and operated by the federal government. Simply put, preservationists believe that this federal presence is necessary to ensure that these public lands can be enjoyed by a public that goes beyond southern Utah. The canyons of Utah, says writer and wilderness supporter Stephen Trimble, belong not to an elite cadre of backpackers, not to the cattle-raising families of Escalante and Kanab, not to the Utah state legislature, not to the Bureau of Land Management, but belong to all citizens of the United States. In truth, they belong to no one (Trimble 1996 *in litt.*).

According to SUMA's Mike Matz, public ownership is necessary to ensure that non-Westerners – those who have long subsidized Western growth and development – are taken into account when land use decisions are being made. Underlying this support of federal control is a distrust among preservationists of what southern Utah communities would do to the land if given the opportunity. Matz maintains that "this land is owned by you and me. But if special interests and local politicians have their way, it is a land that could be lost to us forever" (Matz 1997 pers. com.).

The local response to this extensive federal presence is an angry and culturally-based one. According to Garfield county commissioner, Louise Liston, whose county is comprised of less than 2 percent of private land:

> The truth is, massive federal ownership of lands in Utah and the West with its accompanying laws, regulations, and policies, is destroying the custom, culture and economic stability of rural America [and] wilderness is perceived as yet one more nail in the coffin (Liston 1995 pers. com.).

The ubiquitous federal presence is cause for concern for many in southern Utah. Clinton's use of the Antiquities Act, without meaningful state consultation, and proclaiming the south rim of the Grand Canyon in Arizona but not Utah, angered Utah political representatives and provides an example for some of just how out of touch the federal government has become with some Western communities. According to Utah Senator Orrin Hatch, this "mother of all land grabs" is a clear example of "the arrogance of federal power" (Siegel 1996).

This antipathy towards the federal government may stem from the belief that those closest to the area's natural resources know best how to manage those resources. For example, in one survey of 602 respondents in southwestern Utah, a largely rural area including the cities of St. George, Hurricane, La Verkin, Toquerville, and Virgin, residents express the most satisfaction with the job state (65%) and local (66%) governments are doing to manage the area's natural resources, while they express the lowest satisfaction for federal government management (48%) (pers. obs.).

Ken Sizemore, a community and economic development director for the Utah Association of Governments and a member of the Grand Staircase-Escalante Monument planning team, believes that Mormon history provides a partial but important explanation for hostility towards the federal government (Sizemore 1997 pers. com.). Historically persecuted and driven out of such states as Illinois and Missouri, the federal government refused to defend Mormon religious rights, as well as the legitimacy of the Desert state. The federal government, according to Sizemore, is perceived by Mormon culture as being historically hostile, or at least unsympathetic, to Mormonism, and this history's legacy still endures.

It is also worthwhile to note that while southern Utahns remain disdainful of a far-away and overbearing government, they do not seem to show the same degree of enmity towards out-of-region corporations such as the Dutch-owned Andalex company.

Local Knowledge and Community Input

Closely related to this federal antagonism is the feeling among many in the region that they are continually slighted by an overcentralized, technocratic, and out-of-touch federal government. The President's proclamation, made without meaningful Utah consultation, angered those who believe they have the most at stake in protecting the area's natural resources and amenities. These sorts of feelings are pervasive in southern Utah, and while most are comfortable with the status quo of BLM multiple use management, most express a desire for greater consultation and community collaboration.

Jim Matson, a one-time Kaibab Industries employee (one of the last regional timber companies to close), and now a "biopolitics" consultant in southern Utah, believes that federal administrative agencies "...cannot hide behind palace walls," but must become more entrenched and integrated into local communities (Matson 1997 pers. com.). Matson cites the Soil Conservation Service and BLM as examples of successful integrating efforts (Foss 1960, Culhane 1981).

Scott Truman, executive director of the Utah Rural Development Council, and vice chair of the Southwestern Utah Planning Authorities Council, concurs with Matson and believes the outside expert is bound to be more successful as a "local." Accordingly, says Truman, "The BLM Resource Manager, the area Forester, the District Ranger, the FWS, and the environmentalists need to be a part of the community. They need to coach Little League, be on community committees, be involved with the PTA, rope with ropers, drink coffee at the local café, etc. ...As 'locals' we can better resolve our differences amongst ourselves" (Truman 1997 pers. com.). Truman also contends that as a local, one gets better feel for the area's land, politics, and attached values. Truman, however, is adamant about expanding the traditional definition of "local" to encompass a variety of stakeholders, including preservationists (Truman 1997 pers. com.).

Although many in southern Utah are disappointed by being left out of such important federal decision making as the Grand Staircase-Escalante National Monument designation, they now do not want to be left out of its operations. Gerry Rankin, mayor of Big Water, Utah, the likely southern gateway community to the newly established monument, believes a hearing of community concerns is absolutely essential if local support is to be galvanized (Rankin 1997 pers. com.). Although Rankin is disappointed at being left out of the initial monument planning process, she hopes her town can heretofore play a role in its management, such as having a BLM Monument substation in Big Water.

Many in the region believe they are vilified by those outside southern Utah and receive no credit for keeping the beauty of the area intact. Karla Johnson, a rancher in Kanab, Utah, likens the situation to a neighbor who after admiring another neighbor's home and upkeep, demands to take over its management, while they have never put any work of effort into its maintenance (Johnson 1997 pers. com.). Thus, there is a feeling among many of those in the region, many of whose families have lived in the area for generations, that local knowledges are not appreciated nor taken into account by environmental decision makers.

Urban and Non-Western Influence

Several in southern Utah believe that increased wilderness designation and Grand Staircase-Escalante National Monument support comes from those outside the area who are either completely unfamiliar with the region, or use it solely on a playground basis. Much of this criticism is directed towards Eastern and California political representatives who want to dictate how land, that they are not responsible or accountable for, is managed.

Those outside the region, on the other hand, due to such instances as the hanging of the Interior Secretary Bruce Babbitt in effigy, and "Black Wednesday" in which some Utah residents wore black ribbons and released black balloons to commemorate Clinton's Monument Proclamation, are apt to see locals as being environmentally hostile and thus untrustworthy caretakers.

Non-Western support for H. R. 1500 is indeed strong. For example, there are 82 co-sponsors of the bill as of 30 March 1997, and excluding California, only five are from the West. This Eastern support, especially from those such as original sponsor Maurice Hinchey of New York and former Senator Bill Bradley of New Jersey, is resented by some Western congressional representatives. According to Utah Senator Orrin Hatch, "They don't even know what wilderness is. We do [and] we've got plenty in Utah" (anonymous 1996a).

Another example of non-Western animosity is provided by Utah representative Jim Hansen, who steered his House Resources Subcommittee on National Parks, Forests and Land, to approve funding for protection of New Jersey's 17,500 acre Sterling Forest, but only if it was first declared as wilderness. Arguing that 5.7 million acres of wilderness does not fit southern Utah, just as 17,500 acres may not fit New Jersey, Hansen asserted that "roads in New York are the same as in Utah [and] power lines in Utah are the same as power lines in New York" (anonymous 1996b).

The debate over southern Utah wilderness has been framed in national terms, so a national strategy has been adopted. Because three-quarters of SUWA's members are from outside Utah, including 23 of the 36 members on its board of directors and advisory committee, and the acreage in question is federal and not state-owned land, the approach seems logical. Full-page ads in the New York Times and USA Today are meant to target a more sympathetic American audience.

Tom Robinson, director of conservation policy for the Grand Canyon Trust, notices a backlash in rural Utah because of this outsider strategy (Robinson 1997 pers. com.). Yet, Robinson, like other concerned preservationists, notes that these are national lands with certain national values attached to them; thus, the stakeholder community goes beyond southern Utah. But as Craig Sorenson, a BLM outdoor recreation planner in Escalante recognizes, "These are very fiercely independent people [and] they don't want to be told what to do. They perceive it as their land, yet it's public land. It belongs to all of us" (Ryckman 1996).

A rural-urban dichotomy is also evident in the debate, with those living in such cities as Salt Lake City perceived as being more pro-wilderness than those in rural Utah. Recognizing where pro-wilderness support is strongest, groups such as the SUWA are headquartered in Salt Lake City, and not in the more rural parts of the state.

Many in the area feel indignant about this vocal urban and non-Western wilderness support. The outside strategy has polarized much of the state, with preservationist concerns and beliefs being equated with non-rural beliefs and values. There is a sense that urbanites interpret southern Utah as a place where wilderness should be championed, while human occupation discouraged—even though it is the preserved records of early human occupation that makes the area such a valued anthropological and archeologic place of study.

Wilderness Versus wilderness

One of the most consistent themes in the southern Utah wilderness debate is the difference between de jure and de facto wilderness, that is, whether or not officially recognized wilderness will be beneficial or detrimental to the land. According to Sizemore, preservationists want officially recognized and managed wilderness (wilderness with a capital W), while locals believe that it is this official designation, or the newly established Grand Staircase-Escalante National Monument designation, that will ruin and not preserve the area. According to Steve Crosby, commissioner of Kane County, "Environmentalists need to know that it does not have to have a wilderness stamp on it to be wilderness" (Crosby 1997 pers. com.). Hence, while one side emphasizes human restrictions, the other side focuses on human impact.

Some feel wilderness or monument status, as does national park status, poses a greater environmental threat than does the status quo. Boulder, Utah Mayor Julee Lyman sees the newly created monument as potentially harmful: "Now it's going to become more destroyed, because people destroy the land faster than animals do" (Ryckman 1996). The specter of another Moab, the epitome to many of a new recreation-based West that benefits those owning hotels, restaurants, and trinket shops, but not providing enough stability to keep young people from leaving the area, are feared by many in the region. Some also worry that wilderness or monument designation, as was the case with the former Capitol Reef National Monument, is a prelude to adding yet another national park in the region, and thus, more visitors and more impact.

Several residents of southern Utah also believe that wilderness in the area will *ipso facto* always remain wilderness, with or without official recognition. Crosby believes the land in question is self-preserving and will not be developed because of its rugged terrain and notorious lack of rainfall (Crosby 1997 pers. com.). Many believe that the fear among preservationists like SUWA's Matz (that if the area is not officially set aside, it will be developed) is unfounded given the area's past conservation record.

CONCLUSION

The debate over wilderness in southern Utah transcends questions of acreage and management. At its roots are different interpretations of culture and place. Although many of these differences go beyond a Western framework, and are more central to environmental values, some are particularity regional in orientation and are better understood using a

Western political cultural framework. Placing the debate in cultural terms also shows how the usual way of framing this debate—more or less wilderness—is overly simplistic. Arguing over 1.8 or 5.7 million acres misses the point. It is only once these dimensions of the debate are fully explored that the true meaning and importance of wilderness and the West can be better understood and conflict diminished.

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