

Effects of Fuel Management Treatments in Piñon Juniper Vegetation at a Site on the Colorado Plateau

A proposal for the Joint Fire Science Program, AFP 2003-3-Task 2 or Task 3

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Annual Funding Requested:	FY03	\$4,428
(duration: 4 years)	FY04 (post-treatment year 1)	\$109,598
	FY05 (post-treatment year 2)	\$82,940
	FY06 (post-treatment year 3)	\$85,805
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Contributed Funding:		(\$489,370)

Abstract: Piñon-juniper woodlands have expanded beyond their historical range in the western United States, due partly to land management practices such as fire suppression that began with settlement of the region in the late 1880s. This woodland expansion has replaced sagebrush steppe vegetation, leading to decreased wildlife habitat, soil seedbanks, and plant species diversity, and increased potential for soil erosion and high intensity crown fire. In an attempt to restore historical conditions, "post-settlement" trees have been removed to free resources for sagebrush steppe vegetation to become re-established. This was initially done by chaining landscapes to uproot all trees, but this method had many undesirable effects including extreme soil disturbance and the creation of even-aged piñon-juniper stands, and is rarely done now on public lands. More recently, mechanical and chemical thinning methods have replaced chaining, often followed by seeding and/or burning. Unfortunately, the cost-effectiveness and ecological effects of various combinations of thinning, seeding, and burning remain mostly unknown, making it difficult for land managers to develop effective management plans. The need for this information is greater now than ever, because of recent plans to apply large-scale fuel treatments across the western United States, a region dominated by sagebrush-steppe and piñon-juniper vegetation. This proposed project is related to both Tasks 2 and 3 of the Joint Fire Science Program AFP 2003-3 in that it will establish an administrative study that will address scientific knowledge gaps hindering the development and implementation of fuels management plans in piñon-juniper woodlands of the Colorado Plateau, and more generally the western United States.

This proposal is for the first of a two-phase project. Phase 1 will compare the cost effectiveness of two types of mechanical and one type of chemical thinning treatments, alone and when combined with seeding treatments, and evaluate the abilities of these treatments to: (1) reduce densities of post-settlement piñon and juniper trees; (2) increase cover and seedbank density of annual plants and perennial grasses; (3) increase plant species diversity; (4) minimize cover and seedbank density of invasive alien plants; and (5) create a fuelbed that promotes the re-establishment of historic low to moderate intensity ground fires. The second phase, pending additional funding beyond the scope of this proposal, will add fire as a management treatment and compare fire behavior among previous thinning and seeding treatments.

Virtually all previous studies of piñon-juniper fuels treatments have been unreplicated and largely descriptive, comparing adjacent treated and untreated areas. This proposed study would be a replicated, randomized experimental study with quantitative response variables for vegetation seedbanks, and fuels, allowing for the rigorous evaluation of treatment effects needed to develop sound management plans.

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Problem Statement: Thinning, seeding, and burning have been used as fuels management treatments in piñon-juniper woodlands across the western United States, but their effects have been poorly documented and are difficult to predict. Of particular need is an understanding of the cost-effectiveness and ecological effects of different treatments. This need was recently identified as a major impediment to managing piñon-juniper woodlands during a meeting of land managers (BLM, USFS, NPS, Parashant NM,) and scientist working on the western Colorado Plateau (St. George UT, 5-6 Feb, 2002), and at a recent meeting among NPS personnel managing the Colorado river corridor (Lake Mead NRA, Grand Canyon NP, and Glen Canyon NRA)(Sedona, AZ, 5-7 March, 2002). The recent publication of a plan to implement fuels treatments across large areas of the western United States (www.westgov.org/wga/initiatives/fire/implem_plan.pdf) has also highlighted the need for scientifically valid information on the cost-effectiveness and ecological effects of fuels treatments.

During FY02, managers at Lake Mead NRA experienced this problem first hand when they attempted to develop a plan for managing piñon-juniper woodlands in the northeast part of the park. Lake Mead NRA has conducted prescribed burn only treatments in this region with limited success, primarily due to a lack of ground fuels to support the spread of fire within the late-seral piñon-juniper community. It was determined that alternative treatments must be adopted in order to meet restoration goals. They consulted with fire ecologists from Zion NP and the Bureau of Land Management, and with scientists from the US Geological Survey, to choose management treatments that would most effectively achieve the following goals:

- Reduce by 80% stem density of post-settlement Utah juniper *Juniperus osteosperma* and piñon pine (*Pinus edulis* and *Pinus monophylla*).
- Increase cover and seedbank density of annual plants and perennial grasses.
- Increase plant species diversity.
- Minimize cover and seedbank density of invasive alien plants.
- Minimize soil erosion.
- Create a fuelbed that promotes the re-establishment of historic low to moderate intensity ground fires.

Thinning of post-settlement piñon and juniper, seeding with perennial grasses, and burning treatments were all considered, but it was difficult to choose among them because there was very limited information available on their cost-effectiveness or their relative abilities to achieve the management goals. Therefore, it was decided to design this project to allow detailed evaluation of treatment effects for use in an adaptive management framework for future planning in piñon-juniper woodlands at Lake Mead NRA and elsewhere.

Managers at Lake Mead NRA decided that thinning and burning were the two treatments they would most likely use at landscape scales in the future, and committed their limited resources to their implementation in this project. However, they also recognized that soil seedbanks of understory plant species may be depleted at this site, and that thinning alone may not produce enough fine fuel to carry ground fire. It was decided that seeding should be added as an additional experimental variable if funding could be acquired to implement it.

The level of sampling required to effectively document treatment effects, as determined through consultation with agency fire ecologists and USGS scientists using pretreatment vegetation data from the site, far exceeds the typical NPS fire effects monitoring effort. As a result, there was a need to find additional funding to support a higher sampling intensity commensurate with a field experiment.

We plan to implement this project in two phases, pending funding from the Joint Fire Sciences program. This proposal is for funding to support phase 1, which will include application of thinning and seeding treatments, and three years of post-treatment vegetation, seedbank, and fuels sampling. Phase 2 will include the addition of fire treatments (funded by NPS), measurement of fire behavior on thinning and seeding treatment plots, and post-fire fuels and vegetation monitoring. The first phase is designed to be independent of the second phase, should subsequent funding not become available. If we do not receive funding for either phase, then the effects of these replicated management treatments will only be monitored descriptively as NPS funding allows, and this project will not produce the type of information land managers are currently looking for to help develop management plans for piñon-juniper woodlands in the western United States.

Approval signatures for the Joint Fire Sciences proposal titled, "Effects of Fuel Management Treatments in Piñon Juniper Vegetation at a Site on the Colorado Plateau."

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INTRODUCTION

Background

Woodlands dominated by piñon (*Pinus* spp.) and juniper (*Juniperus* spp.) occupy over 30 million ha of the western United States (West 1999). Prior to European settlement of this region during the late 1800s, the range of piñon-juniper woodland was estimated to be only 3 million ha (Miller et al. 1999). This 10-fold expansion of the piñon-juniper range may have only just begun, since it currently occupies less area than climate conditions seem to allow (Miller et al. 2000). Where woodlands are currently established, the type-conversion from shrubland to woodland continues as understory shrub, bunchgrass, and herbaceous species are slowly forced out as the overstory cover of woodland tree species closes in on them. This woodland expansion is a major concern for land managers due to the resulting loss of wildlife habitat associated with sagebrush steppe vegetation, decreased species diversity, loss of soil seedbanks, decreased aquifer recharge, increased soil erosion, and increased chance of high intensity crown fires (Koniak and Everett 1982, Wilcox and Breshears 1994, Davenport et al. 1998, West, 1999, Miller et al. 2000).

The range expansion of piñon and juniper was associated with increased fire return intervals due partly to fire suppression and the reduction of ground fuels caused by the introduction of livestock grazing by European settlers (Miller and Rose 1999). In an attempt to return stands to pre-settlement conditions dominated by sagebrush steppe and lower fire return intervals, and to improve livestock forage and wildlife habitat, land managers have attempted to reintroduce fire and manipulate fuel conditions using mechanical, chemical, and seeding treatments.

Where woodlands are dense, fire does not propagate easily except under extreme fire weather conditions which typically results in intense crown fires that have undesirable effects on soils and plants (Miller et al. 2000). Where woodlands are more open and still possess ground fuels, managers can create low to moderate intensity ground fires with sporadic torching of larger trees, but even in these conditions fire can be hard to propagate. For these reasons, sites have often been prepped before burning, typically by chaining landscapes to uproot trees and provide opportunities for early successional forbs, grasses, and shrubs to re-establish. However, chaining results in removal of both pre- and post-settlement trees and creates significant soil disturbance, which is not compatible with the management goals of many land management agencies, especially the National Park Service. As a result, mechanical thinning or chemical treatment of post-settlement trees is becoming more common, since it creates uneven-aged woodland stands that are more natural and provide better wildlife habitat, and does not create significant soil disturbance. Minimizing soil disturbance is especially important in areas where cultural resources may otherwise be at risk. Follow-up seeding of grasses has also been used to help establish plant cover to minimize soil erosion, and to increase fine fuel loads that are necessary to help re-establish a low intensity ground fire regime.

Although there is some literature on the ecology and management of piñon-juniper woodlands (e.g. annotated bibliography at <http://wsare.usu.edu/pinyon/biblio.htm>), very little is known about the combined effects of thinning, seeding, and burning, and effects are likely variable across its extensive range extending from the Columbia plateau and Great Basin desert to the Colorado plateau in western North America. Possible differences across this geographic range include the presence of different species of piñon, juniper, and understory plant species, and differences in the ratio of summer:winter rainfall (West 1999). This proposal focuses on a site at the interface between these two regions on the north rim of the Grand Canyon in northwestern Arizona.

Objectives and Hypotheses

This proposal is for funding to support the first of two phases:

Phase 1 (current proposal)

- Compare the cost effectiveness of mechanical and chemical thinning treatments for reducing density and cover of piñon and juniper trees
- Evaluate the effects of thinning treatments, alone and when combined with seeding treatments, on cover, soil seedbank densities, and plant species diversity during the first 3 post-treatment years.*

- Compare the effects of thinning treatments, alone and when combined with seeding treatments, on fuelbed characteristics during the first 3 post-treatment years.

Phase 2 (future proposal for additional funding after the third post-treatment year)

- Compare the effects of thinning treatments, alone and when combined with seeding treatments, on fire behavior.
- Evaluate the effects of thinning and seeding treatments followed by fire on cover, soil seedbank densities, and plant species diversity.*

* We do not propose to directly measure effects of treatments on soil erosion, because of the high cost and difficulty in doing this reliably within a single watershed. We will indirectly infer effects of treatments on soil erosion from the response of total plant cover, which is positively correlated with soil stabilization.

Comparisons and Links to Other Related Research

Reported in the Literature

Our proposed project (Phases 1 and 2) is unique in that it will evaluate the effects of all combinations of thinning of post-settlement piñon and juniper trees, seeding of perennial grasses, and burning on fuel conditions, fire behavior, and postfire vegetation composition. It is also unique in replicating these treatment combinations (20 acre treatment plots) within a broad landscape (~1,000 acre site). Although most other studies have been at larger watershed scales, they have been mostly unreplicated, preventing the separation of treatment effects from underlying differences among treatment areas. The variable effects that are reported in the literature for piñon-juniper fuel treatments may be partly due to the preponderance of unreplicated descriptive studies. Detailed descriptions of treatments, site conditions, and vegetation responses will facilitate the application of information generated at Lake Mead NRA to other piñon-juniper woodland sites.

Current Joint Fire Science Projects

Kevin Ryan et al. *Southern Utah Fuels Management Demonstration Project*. Their project focuses on developing fire behavior and effects models for vegetation types in southern Utah. Our proposed project will provide field validation data that will be used to help validate and refine these models.

Jeanne Chambers et al. *A Demonstration Area on Ecosystem Response to Watershed-Scale Burns in Great Basin Pinyon-Juniper Woodlands*. and *Effects of Fire and Rehabilitation Seeding on Sage Grouse Habitat in the Pinyon-Juniper Zone*. The first demonstration project is focused on evaluating fuel load conditions, fire effects, and soil erosion in early, mid, and late seral piñon-juniper woodlands in the western Great Basin. The second project evaluates fire effects, with and without postfire seeding, on soil erosion, and vegetation characteristic important to the sage grouse and other sagebrush obligate bird species. Our proposed project differs by focusing on effects of mechanical and chemical thinning, seeding, and fire, applied in that order, on the western Colorado plateau.

Lisa Floyd-Hanna et al. *Weed Invasions Following Fire in Southwestern Colorado: Long-term Effectiveness of Mitigation Treatments and Future Predictions*. This project evaluates the effects of four postfire mitigation treatments (seeding, mechanical weed removal, biological weed control, and herbicide weed control) to minimize the establishment of two invasive plants, musk thistle and Canada thistle. Our proposed project differs in that it will focus on the relative effects of thinning, seeding, and fire, as fuel management treatments, on post-treatment establishment of two invasive grasses, cheatgrass and red brome, in addition to overall vegetation and seedbank responses.

Other Current Research

Scientists at the USFS, Missoula Fire Lab are working with a consortium of managers on the western Colorado Plateau to help develop plans to evaluate the effects of future large scale fuels management treatments planned for *Pinus edulis*/*Pinus monophylla*/*Juniperus osteosperma* woodlands in the region (K. Ryan, Missoula Fire Lab). Bandelier National Monument is currently evaluating the effects of a mechanical thinning/mulch treatment, and has plans to evaluate future follow-up burn treatments, on *Pinus edulis*/*Juniperus monosperma* woodlands in the southern Colorado Plateau (Brian Jacobs, Bandelier NM, pers. comm.). In addition to providing site-specific information needed by Lake Mead NRA, the project we

propose will provide small scale (20acre) replicated information on various fuels treatments that will complement larger scale unreplicated single management treatments applied elsewhere on the Colorado Plateau.

Commitment of the NPS to This Project

Beyond the timeframe of this proposed project, the Zion NP fire monitoring (NPS-FMH) crew is committed to sample plant density and cover in one FMH brush belt transect/treatment plot (n=32) at the intervals recommended in the FMH handbook (e.g. 5, 10, 15 years, etc)(USDI National Park Service 2001). Managers at Lake Mead NRA will continue to exclude cattle grazing and manage the site to maintain low to moderate intensity ground fire regime at this site indefinitely.

Project Clearances

Environmental and cultural clearances have been completed and the application of treatments and the sampling of vegetation have been approved. An environmental Assessment "Vegetation Treatment and Hazard Fuel Reduction, 2002-2006, Shivwits Plateau Area" January 2002 with a Finding of No Significant Impact (FONSI) was issued in May 2002. The fact that this project has already been approved, and that treatments are partially completed, make this project a very low risk for completion, and should make it highly desirable for funding by the Joint Fire Science Program.

MATERIALS AND METHODS

Study Site

The study site (~1,000 acres) is located within a single watershed on the northern rim of the Grand Canyon in the western Colorado plateau. The administrative boundaries of the project are within the National Park Service portion of the Grand Canyon-Parashant National Monument, an area jointly managed with the Bureau of Land Management, Arizona Strip Field Office. The site is at 6,200 feet, with slopes from 2-15%. Mean annual precipitation is 13 to 17 inches, bimodally distributed in summer monsoons from late June to early September, and winter frontal systems from November through March. Mean annual soil temperature is 49 to 56 degrees F, and the frost-free period is 135 to 150 days.

The Natural Resource Conservation Service conducted an Order Three-Soil Survey for the site in 1999, which indicated the soils are a well-drained, gravelly loam (35-55% clay) with a neutral pH 7.2 from the surface (A1 0 to 1 inch) and a neutral pH of 6.6 from 1 to 6 inches below the surface. The soil parent material is limestone with depth to bedrock ranging from 19 to 60 inches. Chert gravel covers 50 to 70% of the soil surface. The potential plant community composition includes an understory of >50% native perennial grasses, although current perennial grass cover is much lower.

Based on pre-treatment brush belt transects installed in 2002 by the NPS-FMH crew, we are able to describe the current plant community at the study site. Dominant woody perennials include *Juniperus osteosperma* (1,864/ha), *Pinus monophylla* (1,792/ha) *Artemisia tridentata* var. *tridentata* (1,337/ha), *Purshia mexicana* var. *stansburyana* (1,204/ha), *Gutierrezia satrothrae* (432/ha), *Quercus turbinella* (392/ha), and *Pinus edulis* (200/ha). Dominance of herbaceous species was difficult to determine because sampling was done after a few drought years, but species that were observed included in descending order of relative cover were *Eriogonum umbellatum*, *Bromus rubens*, *Elymus elymoides* ssp. *elymoides*, *Bromus tectorum*, and *Bouteloua gracilis*.

European settlement of the site occurred in the mid 1800's including extensive cattle grazing throughout the area until the late 1980's when grazing was ceased on the site and a cattle exclosure fence line was constructed along the boundary line with the Bureau of Land Management just to the north of the project area. Historic evidence of prolific cattle grazing remains in the study region including corrals, drift fences and earthen water tanks. Some of this region was chained in the late 1950's to early 1960's by a local rancher to try and improve range forage conditions. The area was "withdrawn land" by the Bureau of Reclamation in the 1930's and was transferred to the National Park Service in 1964.

Fire suppression has likely occurred concomitantly with European settlement and organized fire

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fighting responsibilities has been shared by the BLM and NPS since the 1950's. A Prescribed Natural Fire Plan was implemented for the area in 1998 and fires are currently being managed as "wildland fire for resource benefits" which is synonymous for allowing naturally caused fires to burn under certain management prescribed conditions.

Lightning storms commonly occur in the area throughout the monsoon season. There is historical evidence of moderate size fires up to 100 acres in area, but in the last 25 years smaller fires less than 1 acre and single tree fires were more common. The NPS has implemented over 6,000 acres of prescribed fires in the area since the program started in 1994. Prescribed burn objectives were only met on approximately 1,500 of those acres, which included the majority of the old-chained areas. Most of the untreated/unchained areas did not carry fire with the use of a helitorch under extreme fire weather conditions. Monitoring has shown that plant diversity has generally increased in burned areas, however native grasses have only increased in small isolated areas, possibly due to a depleted soil seedbank. The need for alternative treatments besides simply re-introducing fire is necessary to meet resource objectives.

Current management goals at this site are to preserve, restore, and maintain naturally functioning ecosystems and cultural resources. Other goals are to maximize native plant and animal diversity within the natural range of variation. Primary management concerns are related to soil preservation and it is believed that current site conditions will not adequately sustain soil resources. The site is ideal to conduct restoration activities since cattle grazing has been excluded, no elk exist in the area, and deer, small mammals and insects are the only remaining grazers. The lack of excessive grazing pressure should facilitate the re-establishment of native grasses and forbs. The Lake Mead Exotic Plant Management Team is available to control invasive plants in the event the treatment sites become sources of exotic plant invasion in the area.

Study Design (Phase 1)

Treatment Units

Each combination of 4 fuel treatments and 2 seeding treatments will be applied to 4 replicate treatment units (n=32 total). Each treatment unit will be 20 acres (200 square chains, 8.1 ha) and configured in a 1320 x 660ft rectangle (20x10 chains, 403 x 201m). Units will be approximately 50ft (18m) apart. This design will allow follow-up in Phase 2 of this project with burning half of the plots, resulting in 2 replicate burns for each unique thinning and seeding treatment combination.

Treatment Prescriptions and Schedule

Table 1. List of Phase 1 treatments.

Fuel Treatments (summer 2002-2003)	Seeding Treatments (fall 2003)
Cut	Hand seeding
Cut, limb, & scatter	Unseeded control
Chemical	
Untreated control	

Thinning Treatments

80% of post-settlement piñon and juniper trees will be treated within each treatment plot, and old growth piñon and juniper trees will be left untreated (age classes described in Table 1). Approximately 50% of the thinning treatment plots were completed in summer 2002. The remainder will be completed in summer 2003.

Cut

- Every 4 post-settlement trees encountered in the treatment plot will be treated, leaving every 5th post-settlement tree.
- Treatment of post-settlement trees will be accomplished by cutting the smallest trees (<1 inch) at ground level using loping shears, and cutting the larger trees at ground level using a chainsaw.
- Trees will be left where they fall.

Cut, Limb, and Scatter

- Every 4 post-settlement trees encountered in the treatment plot will be thinned, leaving every 5th post-settlement tree.
- Treatment of post-settlement trees will be accomplished by cutting the smallest trees (<1 inch) at ground level using loping shears, and cutting the larger trees at ground level using a chainsaw.
- Cut trees will be limbed to manageable lengths then scattered evenly across the site, except under the driplines of uncut trees.

Chemical

- A 15 foot no chemical treatment buffer will be left around old-growth trees due to concerns for chemical soil “drift” within the root zone of untreated trees. This will leave untreated many post-settlement trees that are growing within the canopy drip zone of the old-growth leave trees. We estimate that these untreated post-settlement trees will constitute the 20% of the target trees that are prescribed to leave.
- Every post-settlement piñon and juniper tree located outside of the 15 foot buffer around old-growth trees will be treated, including seedlings and saplings growing within non-target shrubs.
- 15% Tordon 22K will be batch mixed at 3 gallon increments directly into SP-3 backpack sprayers at a rate of 24 ounces of 15% Tordon 22K per gallon of water with 1 ounce of Blaze-on blue dye and 1 milliliter of Kinetic non-ionic surfactant.
- The herbicide mixture will be applied as a streamline basal spray, covering both the base of trees and the soil around them (modified from reference field guide: Max Williamson and Doug Parker; Low-Impact, Selective Herbicide Application for Control of Pinyon/Juniper. www.fs.fed.us/r3).
- Treatment grids will include 6 sprayers spread approximately 30 to 50 feet apart (depending on tree density) along either the north or south perimeter line. The blue dye spray line from the previous application sweep will be followed by the inside applicator while the outside applicator will follow a north-south compass bearing to keep directional alignment. The remaining 4 inside applicators will intersperse between the two outside applicators.

Untreated Control

- Do not remove any post-settlement or old-growth juniper and piñon trees.

Seeding Treatments

Seeding will be applied in fall 2003.

Hand Seeded

- Seed mix will consist of *Elymus elymoides* spp. *elymoides* (bottlebrush squirreltail) @ 3 pounds per acre and *Bouteloua gracilis* (blue grama) @ 2 pounds per acre, the two common perennial grasses at the study site. Seed will be biotypes local to southern Utah and northern Arizona.
- Seed will be broadcast using handheld applicator equipment.
- Treatment grids similar to those described for herbicide application will be followed to ensure even seed application.
- No raking or other form of soil scarification will occur to prevent disturbance of cultural resources in the area. Minimizing ground disturbance may also provide less potential habitat for weed species to invade the treatment sites.
- Weed seed germination and percent live seed testing will be conducted by the seed company and the Lake Mead NRA nursery from batch samples provided prior to purchasing the bulk of the seed.

Unseeded Control

- Do not seed.

Sampling Methods

The sampling unit will consist of a 20 x 50m modified Whittaker plot (mod-whit plot) (Stohlgren et al. 1995), centered over a 5 x 30m FMH brush belt transect (Fig. 1)(USDI National Park Service 2001). Each of the 32 treatment plots will have three sampling units randomly located within them, such that the edge of each sampling unit will be >30m from the plot edge.

FMH Brush Belt Transect

Density of woody perennial plants (trees, shrubs, and cacti) will be measured in the 5x30m belt transect centered within each mod-whit plot (Fig. 1). Each individual having >50% of its rooted base within the belt transect will be counted. Data will be recorded by species and age class. Age class of each individual will be identified as either dead, immature-seedling, resprout, or mature-adult (USDI National Park Service 2001).

Cover of woody perennial plants (trees, shrubs, and cacti), and cover of bare mineral soil, will be measured by line intercept, using the two 30m sides of the brush belt transect as subsamples (Fig. 1). Data will be recorded by species and age class (USDI National Park Service 2001).

Density of herbaceous plants will be measured within five 1m² subplots along each of the two 30m sides of the brush belt transect as subsamples (Fig. 1). Herbaceous plants will be counted by species for each frame, separating live and dead individuals (USDI National Park Service 2001).

Cover of herbaceous plants will be measured by the point-intercept method, using the two 30m sides of the brush belt transect as subsamples (Fig. 1). Starting at the end of each transect, a 0.25inch diameter sampling rod (a rigid plumb bob), graduated in decimeters, will be lowered gently so that the sampling rod is plumb to the ground (on slopes this will not be perpendicular to the ground), every 30 cm along the transect line. Since the transect length is 30 m, there will be 100 points from 30 to 3,000 cm. The height at which each species touches the sampling rod will be recorded, tallest to shortest. If the rod fails to intercept any vegetation, the substrate will be recorded (bare soil, rock, forest litter, etc.) (USDI National Park Service 2001).

Seedbank density and diversity will be measured from a single composited soil sample for each of the five 1m² herbaceous plant subplots (described above) by pooling four sub-samples collected just outside each corner of the subplot. All soils will be collected using a 5cm diameter x 5cm deep (volume = 98cm³) core. Soil seedbanks will be assayed by growing them out in a greenhouse and counting the number of seedlings for each species. The methods are adapted from Brenchley and Warington (1939), later modified by Young and Evans (1975).

Mod-Whit Plot

Plant diversity will be calculated at multiples scales within the 20 x 50m mod-whit plot (Fig. 1). The effects of disturbance on plant diversity can vary among spatial scales. For example, the effects on plant community diversity due to fire (Brooks and Matchett 2003) and grazing (Stohlgren et al. 1999) can vary between 1 and 1,000m² scales. It is possible that similar variation will occur among management treatment in pinon-juniper woodland, warranting the use of the spatially nested modified-Whittaker plots in this study. Plant species richness will be measured for all species recorded at 1, 10, 100, and 1,000m² scales. Species evenness will be measured among ten 1-m (0.5 x 2 m) sub-plots within each 1,000m² plot. In addition, seedbank species richness and evenness will be measured from seedbank density assays at the 1m² scale.

Fuelbed Measurements

Representative trees, shrubs, and grasses will be randomly chosen inside each mod-whit plot, to calculate biomass (Means et al. 1994). These data will be augmented using Tausch's allometric model to calculate piñon fuel classes and biomass (Tausch In Prep.). Three fuels transects parallel to the long axis of each mod-whit plot will be established to estimate downed woody debris (Brown et al. 1982).

Sampling Schedule and Responsibilities

Initial pre-treatment sampling was begun by the NPS-FMH crew in 2002, and they will complete the establishment of one brush belt transect/treatment plot, excluding seedbank measurements, in 2003 (n=1

sampling unit/treatment plot). The NPS-FMH crew will also resample these transects during post-treatment year 1, 2, and 3, then at longer time intervals as indicated in the NPS Fire Monitoring Handbook (USDI National Park Service 2001). This sampling effort far exceeds what the NPS-FMH crew initially planned, and exceeds what is typically budgeted for monitoring fuel management treatments. The extra effort and expense was dedicated to this project because the NPS realized the opportunity to generate valuable information because of the replicated, randomized design of the multiple fuel treatments. This decision was also made with the hope that the multi-agency research team would acquire additional funding from the Joint Science Program to expand the sampling effort to the level that preliminary vegetation data indicate are needed to detect differences in plant responses among the experimental treatments (n=3 sampling units/treatment plot).

In order to increase the sample size to the level necessary for this project, a USGS crew will establish two additional brush belt transects/treatment plot (n=2 additional sampling units/treatment plot), and sample these transects during post-treatment years 1, 2, and 3. The USGS crew will also collect soil and analyze soil seedbanks from all three belt transects/treatment plot. In addition, the USGS crew will collect plant diversity data from three mod-whit plots/treatment plot.

USFS crews will collect fuelbed measurements during post-treatment years 1, 2, and 3, within each the 3 vegetation sampling units in each treatment plot.

Pre-Treatment – 2002-2003

- 5 x 30m brush belt transects
 - Density of woody perennial plants (spring-summer)
 - Cover of woody perennial plants (spring-summer)
 - Density of herbaceous plants (spring-summer)
 - Cover of herbaceous plants (spring-summer)

Post-Treatment – 2004-2006

- 5 x 30m brush belt transects
 - Density of woody perennial plants (spring-summer)
 - Cover of woody perennial plants (spring-summer)
 - Density of herbaceous plants (spring-summer)
 - Cover of herbaceous plants (spring-summer)
 - Seedbank density and diversity (late summer)
- 20 x 50m mod-whit plots (spring)
 - Plant diversity
- Fuelbed measurements (summer)

Statistical Analyses

Table 1. ANOVA table for responses of vegetation to fuel and seeding treatments (Phase 1).

Factor	ndf
Fuel Treatment	3
Seeding	1
Fuel x Seeding	3
residual error	24

Data will be analyzed as a fixed factorial, randomized analysis of variance. Response variables will include: (1) stem density and cover of piñon and juniper, perennial grasses, shrubs, alien annuals, and native annuals; (2) alien and native plant diversity at 1, 10, 100, and 1,000m² (richness and evenness); (3) seedbank density and diversity; and (4) fuelbed characteristics. Multiple response variables within each of these four categories will either be analyzed together using multivariate analysis of variance, or separately using analysis of variance with Bonferroni corrected p-values. Post-treatment year will be treated as a repeated-measures variable.

BUDGET (contributed funds in parentheses)

Fiscal Year Post-treatment year		FY02	FY03	FY04 yr 1	FY05 yr 2	FY06 yr 3
US Geological Survey	Matt Brooks	(3,000)	(15,000)	(15,000)	(15,000)	(15,000)
	Todd Esque	(1,500)	(6,000)	(6,000)	(6,000)	(6,000)
	GS-7 Biol Tech			19,000	19,000	19,000
	GS-5 Biol Techs			24,000	24,000	24,000
	travel	(1,000)	1,000	5,000	5,000	5,000
	supplies			2,000	2,000	2,000
	greenhouse space			5,580	5,580	5,580
	15% of annual costs		150	8,337	8,337	8,337
	USGS subtotal	0	1,150	63,917	63,917	63,917
		(5,500)	(21,000)	(21,000)	(21,000)	(21,000)
National Park Service	Curt Deuser	(12,000)	(12,000)	(6,000)	(6,000)	(6,000)
	Kevin Oliver	(12,000)	(12,000)	(8,000)	(8,000)	(8,000)
	Henry Bastian	(3,400)	(3,400)	(1,200)	(1,200)	(3,400)
	saw crew	(30,000)	(155,000)			
	saw crew-travel	(5,000)	(10,000)			
	saw crew-supplies	(3,000)	(6,000)			
	herbicide	(5,000)	(1,000)			
	spray equipment	(2,000)				
	herbicide treat. supervisor	(1,000)	(1,000)			
	herbicide treat. crew	(15,000)	(2,000)			
	herb. crew-travel	(2,000)	(1,000)			
	seed			12,300		
	seed treat. contract			11,000		
	FMH crew leader	(2,500)	(2,500)	(816)	(816)	(2,500)
	FMH crew	(3,100)	(5,425)	(2,720)	(2,720)	(2,720)
	FMH crew		1,000	360	360	1,000
	overtime pay					
	FMY crew-travel	(750)	750	530	530	1,050
	FMH crew-supplies	(100)	100			
	15% of annual costs		278	3,629	134	308
	NPS subtotal		2,128	27,819	1,024	2,358
		(96,850)	(211,325)	(18,736)	(18,736)	(22,620)
US Forest Service	Kevin Ryan		(4,000)	(7,982)	(8,381)	(9,240)
	GS-9 Ecologist- 3pp		(2,000)	5,778	6,067	6,689
	GS-5 Techs (3)-2 pp			6,118	6,424	7,082
	4% lab maintenance cost			476	500	551
	Supplies			500		
	Travel		1,000	2,660	2,660	2,660
	15% of annual costs		150	2,330	2,348	2,547
	USFS subtotal		1,150	17,862	17,999	19,530
			(6,000)	(7,982)	(8,381)	(9,240)
	Total Funds Requested		4,428	109,598	82,940	85,805
	Total Funds Contributed	(\$102,350)	(\$238,325)	(\$47,718)	(\$48,117)	(\$52,860)
	GRAND TOTAL					\$282,771 (\$489,370)

DELIVERABLES AND TECHNOLOGY TRANSFER

Deliverables

- Annual progress reports delivered at the Joint Fire Science PI workshop.
- Fact sheets.
- Peer-reviewed journal articles.
- Publication briefs for each journal article focused on the management applications of the research (see examples at <http://www.werc.usgs.gov/pubbriefs/>.)
- Website to provide information on the study plan, progress reports, and other deliverables for this project.
- Direct informal information transfer facilitated through close collaboration with management partners.

Data Management

Completed project data sets will be housed in duplicate at the USGS Las Vegas Field Station and at Lake Mead NRA, and archived in the USGS-NBII.

RESEARCH TEAM EXPERTISE AND RESPONSIBILITIES

The combined knowledge and experience of these scientists and land managers will ensure that the products of this project will be scientifically valid and defensible, and directly applicable to land management. Brief CVs are listed in Appendix A. All team members will be involved in each step of the project from inception to completion, and in particular during the production of final products.

Matt Brooks, USGS (fire ecology and management of arid and semi-arid ecosystems, invasive plant ecology)
Develop study plan and treatment methods, coordinate sampling, data analyses, seedbank assays, and development of project products.

Curt Deuser, NPS (restoration planning and implementation, native plant seeding and revegetation, exotic plant management, prescribed fire planning and implementation)
Develop study plan and treatment methods, select treatment site, coordinate project clearances and treatment applications (chemical thinning and seeding treatments), and participate in data analyses and development of project products.

Kevin Oliver, NPS (forest science and wildland fire management)
Develop study plan and treatment methods, select treatment site, coordinate project clearances and treatment applications (mechanical thinning treatments), and participate in data analyses and development of project products.

Henry Bastian, NPS (Intermountain west fire ecology and effects)
Develop study plan and treatment methods, coordinate sampling and data analyses, establish vegetation monitoring plots pre-treatment and measure vegetation plots post treatment (density, cover, and frequency), participate in data analyses and development of project products.

Todd Esque, USGS (seedbank analyses, invasive species ecology, desert fire ecology)
Develop study plan and treatment methods, coordinate soil seedbank assays, and participate in data analyses and development of project products.

Kevin Ryan, USFS (fire effects, fuel and fire behavior modeling)
Develop study plan, collect fuelbed data, and participate in data analyses and development of project products.

Other Cooperators

Claire Crow, Lead Fire Effects Monitor, Zion National Park

Tim Duck, Ecologist, BLM, Grand Canyon-Parashant National Monument

Paul Reeberg, Regional Fire Ecologist (Monitoring), NPS Pacific West Region

Robin Wills, Regional Fire Ecologist (Research), NPS Pacific West Region

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- Miller, R.F. and J.A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management. 52:550-559.
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- Miller, R.F., R.J. Tausch, and W. Waichler. 1999. Old-growth juniper and pinyon woodlands. Pg. 101-146 in S.B. Monsen and R. Stevens (compilers). Proceedings: ecology and management of pinyon-juniper communities within the Interior West. RMRS-P-9, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.
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- Stohlgren, T.J., L.D. Schell, and B. Vanden Heuvel. 1999. How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. Ecological Applications 9:45–64.
- Tausch, R.J. In Prep. An allometric model for determining biomass and fuel loads for singleleaf pinyon. Ecological Monographs.
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- Wilcox, B.P. and D.D. Breshears. 1994. Hydrology and ecology of piñon-juniper woodlands: conceptual framework and field studies. Pp. 109-119 on D.W. Shaw, E.F. Aldon, and C. LoSapiro (eds.) Proceedings: desired future conditions for piñon-juniper ecosystems. GTR-RM-258, US Department of Agriculture, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.
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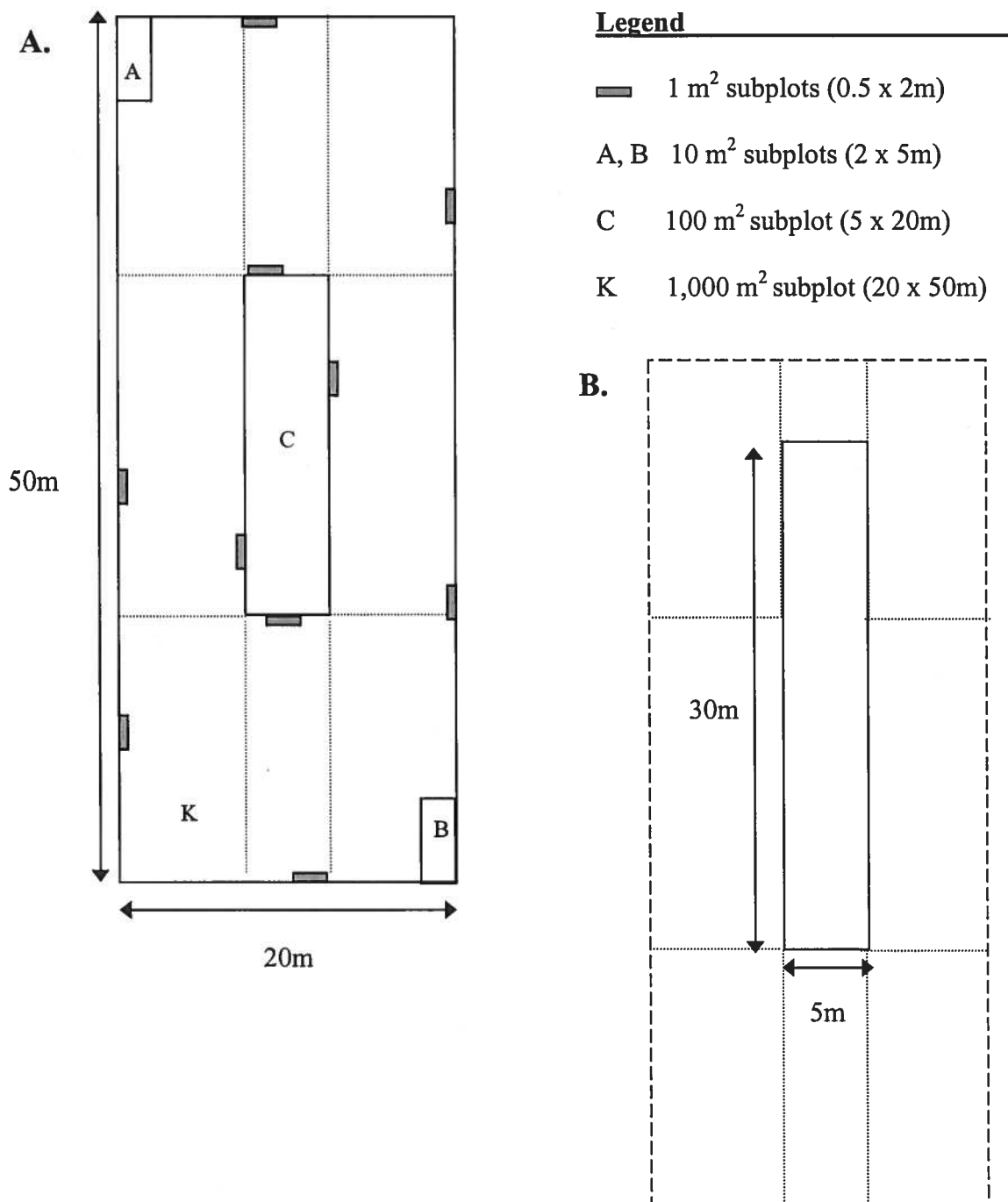


Figure 1. Diagram of the sampling unit, which consists of a (A.) 20 x 50m modified Whittaker (mod-whit) plot positioned around a (B.) 5 x 30m FMH brush belt transect.

Table 1. Range of variables describing post-settlement (Class 1-3) and old-growth (Class 4) piñon and juniper trees (*sensu* Bradshaw and Reveal, unknown date). Variation within categories reflects the range among growth forms within each species along environmental gradients.

Age-class Descriptors	<i>Pinus monopylla</i> / <i>P. edulis</i>	<i>Juniperus osteosperma</i>
<u>Post-settlement Trees</u>		
age (years)	< 100-175	<200
height (feet)	<10-30	<14-20
d.b.h. (inches)	<6-16	<3-12
stump diameter (inches)	not listed	<8-16
other characteristics	Crown dense to sparse, rounded, and regular. Foliage to the ground and concealing trunk. Bark thin to moderately thick, with shallow fissures and little plate formation.	Crown dense to sparse, rounded, and regular. Foliage dense, concealing trunk. Branches straight to somewhat gnarled, diverging from trunk at acute angles.
<u>Old-growth Trees</u>		
age (years)	>175	>200
height (feet)	>12	>14
d.b.h. (inches)	>10	>6
stump diameter (inches)	not listed	>12
other characteristics	Crown very sparse, flat-topped, and irregular. Little foliage near the ground or center of tree. Bark thick, corky, with definite plates.	Crown very sparse, flat-topped, and irregular. Foliage more sparse. Branches heavy and gnarled, diverging from trunk or base at near horizontal angles. Many dead branches as twigs.

APPENDIX A

RESEARCH TEAM QUALIFICATIONS

MATT BROOKS

Research Botanist, United States Department of the Interior, United States Geological Survey, Western Ecological Research Center, Las Vegas Field Station, 160 N. Stephanie, Henderson, NV 89074. phone: 702-564-4615; email: matt_brooks@usgs.gov

Education

Ph.D. Biology	University of California, Riverside	1998
M.A. Biology	California State University Fresno	1992
Secondary Teaching Credential	California State University Fresno	1990
B.S. Biology	University of California, Irvine	1987

Experience

Research Botanist, USGS, Western Ecological Research Center, 1998-present
Adjunct Professor of Biology, University of Nevada, Las Vegas, 2002-present
Board of Directors, Association for Fire Ecology, 2002-present
Editorial board of Fire Ecology, the journal of the Association for Fire Ecology, 2002-present
Board of Directors, California Exotic Pest Plant Council, 2000-present
Graduate Student Researcher/Prin. Investigator, University of California Riverside, 1995-1998
Adjunct Professor, Department of Biology, California State University, Northridge. 1997
Scientific Aid, California Department of Fish and Game, 1989-1990
Science Teacher at the high school, community college, and university levels, 1988-1998

Selected Peer-Reviewed Publications Related to the Proposed Research (since 1998)

- Brooks, M.L. 2003. Effects of increased soil nitrogen on the dominance of alien annual plants in the Mojave Desert. *Journal of Applied Ecology*. In press.
- Brooks, M.L. 2002. Peak fire temperatures and effects on annual plants in the Mojave Desert. *Ecological Applications* 12:1088-1102.
- Brooks, M.L. 2000. *Bromus madritensis* subsp. *rubens* (L.) Husnot. Pp. 72-76. In C. Bossard, M. Hoshovsky, and J. Randall (eds.). *Invasive Plants of California's Wildlands*. University of California Press. Berkeley, CA.
- Brooks, M.L. 2000. *Schismus arabicus* Nees, *Schismus barbatus* (L.) Thell. Pp. 287-291. In C. Bossard, M. Hoshovsky, and J. Randall (eds.), *Invasive Plants of California's Wildlands*. University of California Press. Berkeley, CA. Brooks, M.L. 2000. Competition between alien annual grasses and native annual plants in the Mojave Desert. *American Midland Naturalist* 144:92-108.
- Brooks, M.L. 1999. Habitat invasibility and dominance by alien annual plants in the western Mojave Desert. *Biological Invasions* 1:325-337.
- Brooks, M.L. 1999. Alien annual grasses and fire in the Mojave Desert. *Madroño* 46:13-19.
- Brooks, M.L. 1998. Ecology of a Biological Invasion: Alien Annual Plants in the Mojave Desert. Dissertation, University of California, Riverside. 186 pp.
- Brooks, M.L., and T.C. Esque. 2003. Alien annual plants and wildfire in desert tortoise habitat: status, ecological effects, and management. *Chelonian Conservation and Biology*. In Press.
- Brooks, M.L. and J.R. Matchett. 2003. Plant community patterns in unburned and burned blackbrush (*Coleogyne ramosissima*) shrublands in the Mojave Desert. *Western North American Naturalist*. In Press.

- Brooks, M.L. and D. Pyke. 2001. Invasive plants and fire in the deserts of North America. Pp.1-14 *In* K. Galley and T. Wilson (eds.), Fire Conference 2000: The First National Congress on Fire, Ecology, Prevention and Management. Invasive Species Workshop: The Role of Fire In the Control and Spread of Invasive Species. Tallahassee: Tall Timbers Research Station.
- Kemp, P. and M.L. Brooks. 1998. Exotic species of California deserts. *Fremontia* 26:30-34.

CURT DEUSER

Supervisory Restoration Biologist, National Park Service, Biological Resource Management Division, Lake Mead Exotic Plant Management Team, 601 Nevada HWY., Boulder City, NV. 89005. phone: 702-293-8979; email: curt_deuser@nps.gov

Education

Colorado State University, B.S. Natural Resources Management, 1988.

Experience

14 Years experience with the NPS (Mt. Rainier NP, Sequoia Kings Canyon NP, Glacier NP, and Lake Mead NRA)

Restoration Coordinator: 1993- Current, NPS portion of the Parashant NM, conducts soil erosion control projects, meadow restoration, ponderosa pine forest restoration, implemented pinyon juniper rangeland improvement projects including burning, seeding and monitoring on more than 6,000 acres.

Native Plant Restoration: revegetation of native species, native plant propagation, seed dispersal, native plant restoration and monitoring following exotic plant removal.

Exotic Plant Management: developed successful salt cedar (*Tamarix spp*) control methods, developed the Exotic Plant Management Team (EPMT) concept for the NPS, coordinated the prototype EPMT program for the NPS, coordinates the Lake Mead EPMT.

Fire Management: prescribed fire planning and operations, prescribed fire burn boss.

KEVIN OLIVER

Assistant Fire Management Officer, National Park Service, Lake Mead National Recreation Area, 601 Nevada Hwy, Boulder City, NV 89005. phone: 702-293-8434; email: kevin_oliver@nps.gov

Education

B.S. Forest Science

Pennsylvania State University 1989

Experience

Assistant Fire Management Officer – Lake Mead NRA, 2001-present

Assistant Fire Warden, Idaho Department of Lands, 1995-2001

Senior Forester, Idaho Department of Lands, 1993-1995

Forester, Idaho Department of Lands, 1991-1993

Forestry Technician, Idaho Department of Lands, 1989-1991

Forestry Technician, USDA-Forest Service 1988

Lake Mead National Recreation Area

Responsible for prescribed fire, hazard fuels and fire suppression operations within the National Recreation Area. Interagency wildland fire operations liaison. Prescribed Fire Burn Boss II, Incident Commander Type 3.

HENRY BASTIAN

Fire Effects Ecologist, United States Department of the Interior, National Park Service, Intermountain Region, Zion National Park, Fire Management, Springdale, UT 84767. phone: 435-772-0193;
email:henry_bastian@nps.gov

Education

B.S. Fish and Wildlife Biology Utah State University, Logan, UT 1994

Experience

Fire Effects Ecologist, DOI-NPS, IMR, Zion National Park 2000-present.
Fire Effects Specialist, DOI-NPS, IMR, Zion National Park 1998 – 2000.
Field Crew Lead, DOI-NPS, IMR, Zion National Park 1997-1998.
Biological Science Tech., DOI-NPS, IMR, Bryce Canyon National Park 1995 – 1997.
College of Natural Resources Aid, Utah State University, 1992 – 1994.
Exotic Weed Specialist, Sevier County, State of Utah, 1989 – 1994.
Intermountain Nursery, Sigurd, UT, 1985 – 1987.

Current Publications

- Bastian, H.V. 2000. Effects of Low Intensity Prescribed Fires on Ponderosa Pine Forests in Wilderness Areas of Zion National Park, Utah. . *In*: Vance, Regina K.; Edminster, Carleton B.; Covington, W. Wallace; Blake, Julie A., comps. 2001. Ponderosa pine ecosystems restoration and conservation: steps toward stewardship; 2000 April 25-27; Flagstaff, AZ. Proceedings RMRS-P-22. Ogden, UT: U.S. Department of Agriculture, Forest Service. Rocky Mountain Research Station. 43p.
- Bastian, H. V. 2000. The Effects of a Low Intensity Fire on a Mixed Conifer Forest in Bryce Canyon National Park, Utah. *In*: Vance, Regina K.; Edminster, Carleton B.; Covington, W. Wallace; Blake, Julie A., comps. 2001. Ponderosa pine ecosystems restoration and conservation: steps toward stewardship; 2000 April 25-27; Flagstaff, AZ. Proceedings RMRS-P-22. Ogden, UT: U.S. Department of Agriculture, Forest Service. Rocky Mountain Research Station. 49p.
- Bastian, H.V. 2001. The Effects of Prescribed Fire in Mixed Conifer Forests of Bryce Canyon National Park, Utah. In press. Fire Conference 2000: The First National Congress on Fire Ecology, Prevention and Management.
- Bastian, H.V. 2001. Prescribed Fires in Ponderosa Pine Wilderness Areas of Zion National Park, UT. In press. Fire Conference 2000: The First National Congress on Fire Ecology, Prevention and Management.

TODD ESQUE

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email:todd_esque@usgs.gov.

University of Nevada, Reno, Dept. of Biology MS/314, Reno, Nevada 89557. phone:(775)784-1703;
email:esque@unr.edu

Education

Ph.D. Candidate, Ecology Evolution, and Conservation Biology, University of Nevada, Reno. Present.
Dissertation: "*The role of fire, rodents and ants in changing plant communities in the Mojave Desert*".
M.S. Zoology, Colorado State University. 1994. Thesis: "*Diet and diet selection of the desert tortoise (Gopherus agassizii) in the northeast Mojave Desert*".
B.A. Biology, Prescott College, Arizona. 1982.

Experience

Ecologist, US Geological Survey, Western Ecological Research Center, Las Vegas Field Station, 1993-Present
Principal investigator of integrative research projects on desert ecology and conservation biology. Quantifying the interactions between ants, rodents, fire, alien invasive plants and community change and biodiversity in the Mojave, Sonoran, and Great Basin deserts through experimental field studies. Conducting research to determine the mechanisms of plant invasions and methods of control. Established long-term monitoring plots to ascertain the effects of wildfire on long-lived species such as the giant saguaro cactus (*Carnegie gigantea*) and Joshua tree (*Yucca brevifolia*). Conducted research on foraging ecology, forage nutrition, habitat selection, hibernation, health, and biophysical ecology of the desert tortoise (*Gopherus agassizii*). Provide technical consultations on research projects, Habitat Conservation Plans, and management activities for Bureau of Land Management, US Fish and Wildlife Service and National Park Service. Supervision of employees, additional student volunteers and interns.

Relevant Funded Research

- 2001-2003 *Evaluating Methods for Eliminating Buffelgrass (Cenchrus ciliare, formerly Pennisetum) in the Arizona Upland of the Sonoran Desert*. Funding Source: US Geological Survey/National Park Service. Collaborators: C. Schwalbe, W. Halvorson - USGS, M. Holden- NPS.
- 2001-2002 *The impact of buffelgrass (Cenchrus ciliaris L.) invasion on biodiversity in the Sonoran and Chihuahuan Desert*. Funding Source: World Wildlife Fund. Collaborators: B.T. Bestelmeyer - USDA-ARS Jornada Experimental Range, and A. Búrquez -Estación Regional Noroeste, Departamento de Ecología Funcional y Aplicada, Instituto de Ecología, Universidad Nacional Autónoma de México (UNAM).
- 2001 *Changes in vegetation and small rodent composition within the Mojave and Great Basin Deserts on the Nevada Test Site*. Funding Source: US Geological Survey. Collaborators: R.H. Webb, K. Thomas, and L.A. DeFalco - USGS, P. Medica - USFWS.
- 2000-2002 *Evaluating post-fire restoration treatments in pinyon-juniper vegetation associations*. Funding Source: Bureau of Land Management. Collaborator: L.A. DeFalco - USGS.

Current Publications

- Esque, T.C., A. Búrquez M., C.R. Schwalbe, T.R. Van Devender, Michelle J. M. Nijhuis, P. Anning. *In Press*. Fire ecology of the Sonoran desert tortoise. Chapter 10. *In The Sonoran Desert Tortoise: Natural History, Biology and Conservation*. T.R. Van Devender, *ed*. Arizona-Sonora Desert Museum. The University of Arizona Press. Tucson.
- Esque, T.C., and C.R. Schwalbe. *In Press*. Alien annual plants and their relationships to fire and biotic change in Sonoran Desertscrub. *In Invasive exotic species in the Sonoran region*. Tellman, B., *ed*. Arizona-Sonora Desert Museum. The University of Arizona Press. Tucson. Ch. 10.
- Esque, T.C., C.R. Schwalbe, L.A. DeFalco, T.J. Hughes and R.B. Duncan. *In Review*. Effects of wildfire on small desert vertebrates, especially desert tortoises (*Gopherus agassizii*). Submitted to *The Southwestern Naturalist*.
- Brooks, M.L., and T.C. Esque. 2003. Alien annual plants and wildfire in desert tortoise habitat: status, ecological effects, and management. *Chelonian Conservation and Biology*. *In Press*.
- Nussear, K.E., T.C. Esque, and C.R. Tracy. *In Press*. The Efficacy of using miniature temperature sensing data-loggers to estimate body temperatures in desert tortoises (*Gopherus agassizii*). *Herpetological Review*.
- Webb., R.H. T. C. Esque, P.A. Medica, L A. DeFalco, M. Murov. 2001. Monitoring of ecosystem dynamics in the Mojave Desert: the Beatley permanent plots. U. S. Geological Survey Fact Sheet FS-040-01 April 2001.

KEVIN C. RYAN

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Fire Sciences Lab
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Missoula, MT 59807

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Education

1993 Ph.D. Forest Ecophysiology, U. of Montana, Missoula, MT
1976 M.S. Forest Ecology, Colorado State U., Ft. Collins, CO
1973 B.S. Forest Biology, Colorado State U., Ft. Collins, CO

Experience

1970-1976: Fire Suppression USFS R-5 & R-2 (Type 1 Firefighter, Patrolman and Crew Boss for District Crew) and graduate studies in fire science at Colorado State University
1976 - 1979: Research Forester/Fire, Forest Residues and Energy Program, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Seattle, WA
1979 - 1992: Research Forester, U.S.D.A. Forest Service, Fire Effects Project, Intermountain Fire Sciences Laboratory, Missoula, MT
1992 - 1995: Supervisory Research Forester, Team Leader, Fire and Ecosystem Processes, U.S.D.A. Forest Service, Fire Sciences Laboratory, Missoula, MT
October 1995 - Present: Project Leader, Fire Effects: Prescribed Fire and Wildfire, U.S.D.A. Forest Service, Intermountain Fire Sciences Laboratory, Missoula, MT
Society of American Foresters: Student Mentor, Fire and Forest Ecology Working Groups

Society Affiliations

International Association of Wildland Fire: Associate Editor, Int. J. Wildland Fire; Association for Fire Ecology

Reviewer

European Economic Commission's Fire Research Program; Science; Forest Science; Canadian Journal of Forest Research; International Journal of Wildland Fire; Western Journal of Applied Forestry; U.S.D.A.'s Competitive Grants and Forest Service; McIntyre-Stennis; Joint Fire Sciences Program

Publications (68 publications, 26 refereed and 42 non-refereed including)

- White, J.D., S.W. Running, P.E. Thornton, R.E. Keane, K.C. Ryan, D.B. Fagre, and C.H. Key. 1998. Assessing simulated ecosystem processes for climate variability research at Glacier National Park, USA. *Ecological Applications* 8(3):805-823.
- Keane, R.E., C. Hardy, K.C. Ryan, and M.A. Finney. 1997. Simulating effects of fire on gaseous emissions and atmospheric carbon fluxes from coniferous forest landscapes. *World Resources Review* 9(2):177-204.
- White, J.D., S.W. Running, R. Nemani, R.E. Keane, and K.C. Ryan. 1997. Measurement and remote sensing of LAI in Rocky Mountain ecosystems. *Can. J. For. Res.* 27:1714-1727.
- White, J.D., K.C. Ryan, C.C. Key, S.W. Running. 1996. Remote sensing of forest fire severity and vegetation recovery. *Int. J. of Wildland Fire* 6 (3): 125-136.
- Ryan, K.C., G.D. Amman. 1996. Bark beetle activity and delayed tree mortality in the Greater Yellowstone Area following the 1988 Fires. In: *Ecological Implications of Fire in Greater Yellowstone, 1996*, Int. Assoc. Wildland Fire, Fairfield, WA:151-158.

- Keane, R.E., K.C. Ryan, S.W. Running. 1996. Simulating effects of fire on northern Rocky Mountain landscapes with the ecological process model FIRE-BGC. *Tree Physiology* 16:319-331.
- Ryan, K.C. 1991. Vegetation and Wildland Fire: Implications of global climate change. *Environment International* 17:169-178.
- Ryan, K. C., and W. H. Frandsen. 1991. Basal injury from smoldering fires in Mature *Pinus ponderosa* Laws. *International. Journal of. Wildland Fire* 1(2):107-118.
- Keane, R, E., J. K. Brown, E. D. Reinhardt, and K. C. Ryan. 1990. Predicting first order fire effects in the United States. *Compiler* 8(4):11-15.
- Ryan, K. C., and E. D. Reinhardt. 1988. Predicting postfire mortality of seven western conifers. *Canadian Journal of Forest Research* 18:1291-1297.
- Ryan, K. C., D. L. Peterson, and E.D. Reinhardt. 1988. Modeling long-term fire-caused mortality of Douglas-fir. *Forest Science* 34(1):190-199.

Honors and Awards

Certificate of Merit, U.S. Forest Service, 1997, 2000, 2002; George M. Bright Memorial Fellowship, University of Montana, 1986; Sigma Xi, 1974; Xi Sigma Pi Forestry Honor Society, 1972