

**Award Number:** P13AC00753

**Project Number: Pc-12**

**CFDA Number: 15.945**

**Park/NPS Unit: Mesa Verde National Park**

**Title of Project:** Characteristics of resiliency in *Pinus edulis-Juniperus osteosperma/Purshia tridentata* woodlands of Mesa Verde

**Administered through the:**  Colorado Plateau Cooperative Ecosystem Studies Unit Cooperative Agreement Number H1200-09-0005

**CESU Partner: Prescott College, Arizona**

**PROJECT CONTACTS:**

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**NPS Certified ATR:** George L. San Miguel, Natural Resource Manager, Mesa Verde National Park, PO Box 8, Mesa Verde CO 81330, Tel.: 970-529-5069, Email: george\_san\_miguel@nps.gov

**NPS Technical Expert (if appropriate):**

**FUNDING INFORMATION:**

**Amount Funded: $11,000**

**NPS Account Numbers (amounts in parentheses): PPIMIMRO3B/PPMRSNR1Y.Y00000 ($10,000)**

 **PPIMMEVE6G/PPMRSNR1Z.NI0000 ($ 1,000)**

**Fund Source (e.g., ONPS, FLREA, CRPP, CESU, etc.): CPCESU Regional Base ($10,000)**

[x] NPS Funding

[ ]  Is this funded using a reimbursable account number? If yes, IMR contracting needs a copy of the Interagency Agreement.

**PROJECT DATES:**

**Start Date: June 7, 2013**

**End Date: June 30, 2014**

**NPS Administrative Contacts**

**CESU Coordinator:** Judy Bischoff, CPCESU Research Coordinator, NAU P.O. Box 5765, Flagstaff, AZ 86011, 928-523-6638, Fax: 928-523-2014, judy\_bischoff@nps.gov

**Intermountain Region Administrative Contact:** Kelly Adams, Grants and Agreements Specialist, National Park Service, 12795 West Alameda Pkwy, Lakewood, CO 80228 Phone: 303-969-2392 Fax: 303-969-2992 Email: Kelly\_adams@nps.gov

**FEDERAL FINANCIAL REPORTS SCHEDULE:**

***Federal Financial Reports*** (Check as required for project based on spending plan, period of performance, risk, cooperator history, etc.)

{X} Quarterly { } Semi-annually { } Annually { } Final

**Project SCHEDULE AND TECHNICAL REPORT DEADLINES:**

List all technical reports and products in sequential order as required in the scope (more lines and milestones can be added as needed):

*Project Start Date* – June 7, 2013

*Technical progress reports –* { } Quarterly {X} Semi-annually { } Annually

(Check as needed from PI to monitor progress of specific project. Content should be addressed in the scope.)

*Investigator’s Annual Report (IAR)* – April 1, 2014

*Database, Collections/Specimens, Archives, and Maps provided to the NPS ATR or Technical Expert* – April 1, 2014

*Draft Final Report* – April 1, 2014

*Final Report* – May 31, 2014

*Project End Date* – June 30, 2014

*Final SF425 FFR* must be submitted within 90 days of project end date

**PAYMENTS**

**2 CFR PART 215.22*:*** Cash advance (drawdown) to recipient organization shall be limited to the minimum amounts needed and be timed to be in accordance with the actual immediate cash requirements of the recipient organization in carrying out the purpose of the approved program or project. The timing and amount of cash advances shall be as close as is administratively feasible to the actual disbursements by the recipient organization for direct program or project costs and the proportionate share of any allowable indirect costs.

**2 CFR PART 215.25 (8)(e)(1):** Incur pre-award costs 90 calendar days prior to award or more than 90 calendar days with the prior approval of the Federal awarding agency. All pre-award costs are incurred at the recipient’s risk. (i.e. the Federal awarding agency is under no obligation to reimburse such costs if for any reason the recipient does not receive an award or if the award is less than anticipated and inadequate to cover such costs.)

**CESU REQUIRED PRODUCTS (may be different from those products required by the ATR – See Statement of Work for Products required by the NPS unit):**

The Principal Investigator will prepare a brief report abstract suitable for public distribution and two hard copies and an electronic version (in PDF file format) of the final report and mail all toJudy Bischoff, CPCESU Research Coordinator, NAU P.O. Box 5765, Flagstaff, AZ 86011. Please be sure to include the project number (e.g.; NAU-###, UMT-###, UAZDS-###) and the P number on the cover page of the final report.

**PROJECT ABSTRACT:**

Piñon-juniper woodlands are a widespread vegetation type occupying 15 percent of the landscape in New Mexico, Arizona, Colorado, Utah, and Nevada. The understory of “persistent” woodlands is often composed of significant bare-ground within a matrix of grasses, forbs, shrubs, and biotic crusts. The woodlands appear highly resistant to invasion by aggressive exotic plants species*.* This appears to be true despite the availability of ample weed propagules merely a few meters away. However, when the soil is highly disturbed, for example by severe stand replacing fires or grazing, resistance is destroyed. This proposal will investigate, in a pilot study, some of the physical and biological factors that confer resiliency in “persistent” piñon-juniper woodlands at Mesa Verde National Park. The study will address: a) Are native species diversity and intact soil crusts components of resistance to invasion? and b) Do actinorhizal shrubs contribute to ecosystem stability and to resilience? In a related study (Reed et al. 2013); we have gathered data from Mesa Verde that can be used to address, in part, the last questions c) What characteristics of soil nutrients and properties confer resilience? This information will provide information that will aid in the conservation of “persistent” piñon-juniper ecosystems and the biodiversity they support.

**Scope of Work:**

# Objectives

Faced with continuing drought and rising temperatures across the southwestern United States (i.e. Breshears et al. 2005, Hansen and Sato 2011) and severe soil erosion (i.e. Jones 2000), the importance of resilient landscapes dominated by persistent vegetation becomes increasingly critical. Piñon-juniper woodlands cover 15 percent of the southwestern landscape and they are the dominant perennial vegetation covering 40 million hectares. Our pilot research and years of observations suggest these are ecosystems of remarkable stability and resiliency. At least three broad types of piñon-juniper woodlands are recognized by Romme et al. (2009); here we focus on the long-lived “persistent” woodlands which are the prominent type on the Colorado Plateau and much of the southern Rockies. Prehistoric fires were very infrequent; for example intervals in southwestern Colorado’s piñon-juniper woodlands and elsewhere were centuries long (Baker and Shinneman 2004; Floyd et al. 2000, Floyd et al. 2004), hence ecosystem development is slow and biodiversity is significant (Floyd 2003). Across much of this ecosystem is a legacy of chaining/seeding, intense grazing (Fleischner 2010), vehicle use, and recent changes in temporal and spatial patterns of wildfires (Morgan et al. 2001). Yet, in many of the region’s national parks, including Mesa Verde National Park (MEVE) and Dinosaur National Monument (DINO), undisturbed piñon-juniper woodlands are preserved, at least at the present time. Conservation of these remaining persistent ecosystems is critical and underlies this proposed study to investigate mechanisms of resiliency in piñon-juniper woodlands. We will specifically measure resiliency by the woodland’s resistance to exotic plant species. In this proposed pilot study, we will focus on MEVE where a variety of disturbances and intact woodlands occur in close proximity and on similar soils, and where the investigators have related, on-going studies (Floyd et al 2013, Reed et al. 2013 reports to NPS).

Previous data and observations made at MEVE and elsewhere demonstrate that persistent woodlands are highly resistant to invasion by aggressive exotic plant species (e.g. *Bromus tectorum, Carduus nutans, Salsola species, Cirsium arvense* and *Circium vulgare)* when not subjected to severe environmental stressors (Floyd et al. 2006 Tamara Naumann, personal communication, Sherril and Romme, 2013). However, when stress occurs, a threshold appears to be breached and the resistance to invasion is lost. This threshold is highly variable depending on the type of woodland and the type of disturbance. Our study areas have been subjected to both large and small disturbances that mirror those which have occurred throughout the southwest in the past few decades. Large wildfires have occurred throughout the southwest in recent decades, specifically in MEVE 1989, 1996, 2000, 2002 and 2003. Widespread *Ips confusus* bark beetle infestations occurred throughout the southwest in 2001-4, e.g. killing over one third of the piñon pines (Breshears et al. 2005, Floyd et al.2009, Negron and Wilson 2003). Over 11 percent of junipers have died of various causes in MEVE and we recently completed a study of the changes in canopy cover, surface and coarse woody fuels, and potential for changes in fire cycle on the Mesa Verde cuesta (Floyd et al 2012). In the past two years at MEVE, rotted snags are beginning to fall, leaving virtually no disturbance in soils as they “snap” off at ground level (personal observations); therefore soil disturbance is much less severe than that resulting from widespread fires. Gaps in the canopy also have been created by piñon death from *Ophiostoma (=Verticicladiella) wagenerii*, black stain root disease, during the past century (Kearns and Jacobi 2005). Our preliminary data from MEVE suggest that smaller canopy disturbances (beetles and black stain) are protected by as-yet undefined factors of resiliency and exotics do not enter these lightly disturbed systems despite their nearby presence. In contrast, large portions of the post-fire landscape in MEVE have been colonized by *Bromus tectorum* (cheatgrass) and *Carduus nutans* (musk thistle), the presence of which may create unprecedented fuel conditions and may further shorten future fire intervals, especially as drought and rising temperatures continue (Belnap et al. 2003, Floyd et al. 2006, Miller et al. 2001, Hansen and Sato 2011). Burnt landscapes maintain these exotic components for at least three decades (i.e. since the 1972 fires in MEVE). Invasibility may be, in part, due to soil nutrient status and deterioration of soil crusts, but much is unknown about weed resistance and invasibility in these systems (Floyd et al. 2006). Other types of disturbance, such as nitrogen deposition, horse grazing, mechanical thinning of woodlands for fire protection, and visitor impacts occur throughout the piñon-juniper woodlands as well. MEVE is considering expansion of trails for visitor access; therefore additional woodlands may become open to visitor impacts.

Peterson et al. (1998) proposed a much-discussed model of the relationship of species diversity to ecosystem function and resiliency. They stated that “ecological resilience is generated by diverse, but overlapping function by apparently redundant species that operate at different scales, thereby reinforcing function across scales. The distribution of functional diversity within and across scales enables regeneration and renewal...” Numerous studies link biodiversity to ecosystem stability and while it is not usually clear which species contribute necessary functions, it is generally thought that the chances of stability increases with the level of species diversity. The authors propose that “redundant species” that serve a similar ecological function may increase ecosystem resilience; when one fails, another may take its place. We hypothesize that a critical part of the stability of Mesa Verde’s piñon-juniper woodlands comes from a balanced soil nutrient status especially involving nitrogen; we test here whether actinorhizal shrubs (*Purshia tridentata*, bitterbrush and *Cercocarpus montanus*, mountain mahogany) and biotic soil crusts alternatively provide resilience by providing a similar ecosystem function, that of nitrogen balance within the biogeochemical pathway.

We are learning much about invaded ecosystems (i.e. Alpert et al. 2000, Choy-ing et al. 2010, D’Antonio and Vitousik 1992, Corbin and D’Antonio 2004, Keeley 2006, Ortega and Pearson 2005, and others listed in the references). But, if we could understand more about the resiliency components and when the threshold is breached beyond which resiliency erodes, it may be possible to conserve such ecosystem stability and emulate specific resiliency characteristics in future restoration of piñon-juniper ecosystems. *The overarching goal of this proposal is to define resiliency in persistent piñon-juniper woodlands*.

We propose to investigate the nature of this resistance through quantitative sampling of species composition, including nitrogen fixing actinorhizal shrubs and biotic soil crusts, and characteristics and numerous physical attributes of paired undisturbed and disturbed locations at Mesa Verde National Park. The study design will take advantage of recently completed soil nutrient profiles conducted by the author and Dr. Sasha Reed, USGS Moab. We compared the levels of NH3, NO2, P, C and C:N in a series of plots on Arabrab Longhorn soils on Wetherill Mesa from old-growth resilient piñon-juniper woodland and nearby fires in 1934, 1989, 1972 and 2000. In order to utilize these biogeochemical tests in the current study, we will return to these precise locations and establish a series of plots in which to measure the variables listed below.

# Methods

We will address the following questions:

What biological and physical attributes confer resiliency in “persistent” piñon-juniper woodlands? Specifically:

* Is native species diversity a component of resistance to invasion?
* Does resiliency vary with light spectra, local ground-level wind condition, and soil moisture?
* Are intact soil crusts, specific soil structures, specific ranges in soil temperatures, and nutrient patterns components of resistance to invasion?
* Do actinorhizal shrubs contribute to ecosystem stability and contribute to resilience in piñon-juniper woodlands?
* Does resiliency vary with level of soil nutrients (using data from Reed et al. 2013)?

Three field experiments will be conducted. In all three cases we will rely on an existing network of sites in which previous data can be utilized. In parts 2 and 3, fertilization plots and soil nutrient testing has been completed and the new study will take advantage of these previously collected data.

1) Gaps vs. intact woodland: Five piñon-juniper woodland sites will be selected from among the sites currently being used in a recently completed study of fuels in Mesa Verde (Floyd et al. 2012). Much of the data needed to characterize the woodlands is available, i.e. existing sites have been characterized by plant species, canopy opening using fisheye with GLA software (Keane et al. 2005), age structure, vertical and horizontal fuel structures (Floyd and Crews, in progress). At each study site, disturbances will be mapped using Arc GIS and sample locations selected randomly (stratified random sampling) such that pairs of plots (disturbed and undisturbed intact woodland) are similar in other physical characteristics and are ideally nearby one another. Small gaps created by tree death from beetles and root fungus will be *paired* with intact woodland plots.

*Independent Variables:* At each site we will collect data on the diversity, density, and cover of each plant species. The cover of *Purshia tridentata*, other actinorhizal shrubs, and black biotic crusts will be recorded to estimate potential nitrogen fixation and tissue samples will be taken and analyzed for amino sugar N, which has been shown to correspond with N inputs from actinorhizal N fixation (Wang et al. 2010, Neff et al. 2006). The cover of biotic crusts and actinorhizal shrubs will be used as indicators of nitrogen fixation. Physical structure of the sites will be measured including wind speeds, soil temperatures, soil depth to bedrock, and light spectra, and depending on funding; a few samples will be analyzed for soil N and C at the USGS lab in Moab. If moisture levels permit exotic species germination, the *dependent variable* “resistance” will be measured by the density of exotic forbs and the cover of exotic grasses. If moisture levels remain low (preventing germination of cheatgrass and other exotic species), comparison will be made between old-growth plots and burned or disturbed adjacent test plots.

2) Fire chronosequence: As described above, we will return to sites where in 2012 we measured soil NH4, NO3, P, C and C:N ratios. We will correlate these available nutrients with the diversity and cover of native and exotic species in plots to be established in 2013 at these locations (old-growth sites and in the fires from 1934, 1972, 1989 and 2000) on Wetherill Mesa.

3) Fertilization plots: In a related study we applied nitrogen fertilizer three times in 2011 and 2012 to 60 plots in the 2002 fire and adjacent unburned piñon-juniper woodlands on Chapin Mesa (Reed et al. 2012). These plots will allow us to determine if excessive nitrogen inputs is a factor in reducing resiliency. The diversity and abundance of exotic and native plant species will be recorded in the current study.

4) Biogeochemistry sampling: At nine sites (3 bitterbrush dominated, 3 biotic crust dominated, 3 lacking both bitterbrush and crust) we will determine the biogeochemical pools of nitrogen (NH4 and NO3), carbon, and phosphorus that might contribute to ecosystem stability and resiliency of the old-growth woodlands. Samples will be collected by Prescott College personnel and transported to Dr. Sasha Reed, USGS, Moab Utah, for analysis under a separate interagency agreement.

Statistical Analysis

Statistical analysis will be carried out using SPSS software (IBM, 2010) after testing all variables for normality and homogeneity of variances. We will run stepwise regression analyses of the dependent variable “density of exotics” with all measured independent variables to determine which variables predict influx of exotics. Logistic regression may be applicable as an alternative. Correlation analyses will be run on exotic density and all continuous variables listed above. Analysis of Variance may be used to determine if the mean density of exotics varies across experimental factors (added N or P, soil crust disturbance).

Spatial treatment

A geodatabase will be created to record the locations of all study plots as well as the extent of significant disturbances within the study areas. This information will be used to refine a spatial model of invasibility, initiated by Floyd et al. (2006), tying weed presence or absence to the measured physical and biological parameters listed above. The model will be applied to existing relevant data layers (e.g. vegetation, soils, and locations of dense weed populations) in other parks. This will be accessible to resource managers in GIS format.

## Final Report

A final report summarizing work completed under this scope of work, will be provided in digital format, including digital photographs, to the NPS key official/ATR (CD-ROM/DVD) George L. San Miguel, Mesa Verde National Park Service, PO Box 8, Mesa Verde, CO 81330. Three hard copies (in color) of the final report will also be provided to the park. Two hard copies and an electronic version of the report on DVD will be sent to the Colorado Plateau Ecosystem Studies Unit.

## Data Development

All digital and tabular data, calculations, graphs, and photographs will be included with the final products. All digital geospatial data will be documented using the Content Standard for Digital Geospatial Metadata (CSDGM), also referred to as the Federal Geographic Data Committee (FGDC) Metadata Standard.

## Voucher Specimens and Curatorial Data

Plant specimens collected during surveys, if any, will be delivered to MEVE staff. If so, the investigators will provide a spreadsheet of required specimen information for entry into the Automated National Catalog System software (ANCS+). Photographs and original data forms will be provided to the NPS in a format to be discussed and agreed upon after project initiation.

**COOPERATIVE AGREEMENTS OR TASK AGREEMENTS INVOLVING COOPERATORS WORKING ON-SITE**

**Background**

In cooperative agreements or task agreements with universities where the university utilizes interns, student employees, research associates (RAs) or cooperators on-site (hereafter called “cooperator personnel”), these cooperator personnel sometimes work on government sites in close proximity to federal employees. It is illegal (without specific statutory authority) for federal employees to directly supervise the cooperator personnel or any university employees or for the students or other university employees to supervise federal employees. When cooperator personnel are working on an NPS site, it is important that there is a clear distinction between students and federal employees.

**Office Environment and Vehicles**

* The office space of the cooperator personnel and NPS personnel should be clearly labeled (Name and NPS or University affiliation on office or cubicle space).
* Cooperator personnel should be listed separately from NPS personnel in telephone lists, other identification or organizational rosters, and publication credits.
* Cooperator personnel should not receive “all-employee” e-mail or other communications intended for NPS personnel (unless it relates directly to the work the cooperator is doing for the NPS). When the e-mail does relate to the work being done, a copy of the same e-mail message should be sent to the University or cooperator’s supervisor.
* Cooperator personnel may use NPS e-mail systems when the communication relates directly to the work the cooperator is doing for the NPS. The e-mail addresses of the cooperator personnel must include a label associated with their NPS e-mail address that identifies the cooperator’s status (i.e., “Linda Webb, Cooperator” would be the label associated with the e-mail address, linda\_webb@contractor.nps.gov). Doing so clearly identifies this individual each time they send an e-mail message using the NPS system, and it identifies their status as a research associate, student intern or student employee in the e-mail directory.
* Unless stipulated in the agreement, cooperator personnel should not drive government vehicles.
* Unless stipulated in the agreement, cooperator personnel should not ride as a passenger in a government vehicle. When this is planned as part of the agreement, an appropriate amount of liability insurance should be negotiated.
* Prior written approval by the Park Superintendent or Center Manager must be obtained in order for a task to allow cooperator personnel to drive or ride in government vehicles.

**Supervision and Scheduling**

* Each task must specify the university’s/cooperator’s supervisor for the cooperator personnel.
* Unless stipulated in the agreement, NPS staff should not set hours for cooperator personnel, specify where the work should be done, or conduct performance appraisals. National Park Service staff may give performance feedback to the cooperator personnel supervisor.
* Cooperator personnel should report leave, scheduling, and other related issues to the university or cooperator’s supervisor, not to NPS employees. The supervisor of the cooperator personnel should then communicate with the NPS. National Park Service employees cannot directly supervise cooperator personnel on a day-to-day basis. Work should be given to the cooperator personnel (via the cooperator’s supervisor) on a “task basis.” Cooperators should work without NPS supervision to accomplish each task, although technical consultations and cooperation is permissible.
* The Cooperator will be responsible for any disciplinary action needed to correct student employee conduct or performance problems. The NPS agreements technical representative will inform the university/cooperator’s supervisor of any conduct or performance problems.
* The Cooperator will remove student employees from their positions if they fail to improve performance or address conduct issues.
* The NPS will review and provide feedback to students or interns regarding work assignments.
* The NPS will inform the cooperator of conduct or performance problems with cooperator personnel so that the university can counsel employees and correct the performance problems.
* The NPS will recommend to the cooperator dismissal of cooperator personnel based on conduct or performance issues.
* The Cooperator will hire students, interns or RAs to work on NPS tasks identified in the agreement. Hiring will be conducted in consultation with the NPS Agreements Technical Representative (ATR).
* The Cooperator will: pay students, interns or RAs for hours they have worked in support of the agreement.

**Representation and Communication**

* Cooperator personnel cannot in any way represent themselves to the public as NPS employees.
* Cooperator personnel are required to wear visible identification at all times.

**Other Issues**

* Cooperator personnel should not list an NPS affiliation on publications, but rather should list the cooperative agreement under which the work was performed.
* Cooperator personnel should not be invited to official NPS “social” events.
* Cooperator personnel will follow the local policy of the facility when federal facilities are closed due to early release for holidays, snow days, etc.

**PRODUCTS:**

* Progress report, IAR, draft report, and final report.
* Voucher specimens and curatorial data, if any.
* Digital and tabular data, including GIS files.