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USING A "FIRE CAGE" TO TEST THE RESPONSE OF *ARABIS JOHNSTONII* TO FIRE

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1. INTRODUCTION

Prescribed fire is increasingly being used to reduce hazardous fuel accumulations on National Forest System and other public lands. Those same lands are often home to rare species for which little or no information on fire response exists. Land managers are stuck with a dilemma – carry out a prescribed fire in rare species habitat with unknown positive or negative effects, or risk having the habitat burn in a wildfire, again with unknown impacts to species that may already be nearing extinction. Most managers and biologists find unacceptable the risk of applying fire to a significant portion of the range of a rare species when nothing is known about how the species will respond. Studies are urgently needed that will yield fire response information without jeopardizing a large part of the remaining population of species in peril.

Figure 1. *Arabis johnstonii* (Johnston's rock cress) in bloom on 5 June 2003 at McGregor Flat in the San Jacinto Mountains, California.

Arabis johnstonii Munz (Johnston's rock cress, Fig. 1) is a small herbaceous perennial plant in the mustard family (Brassicaceae) found in the southern San Jacinto Mountains, California (Rollins 1993, California Native Plant Society 2001), primarily on National Forest System lands within the San Bernardino National Forest (SBNF). It blooms between February and June (California Native Plant Society 2001) and becomes dormant during the dry summer and fall. Considered rare by the California Native Plant Society (2001), *A. johnstonii* has been designated a Regional Forester's Sensitive species by the Pacific Southwest Region, USDA Forest Service (Stephenson and Calcarone 1999). It is distributed in two distinct population centers, one of which is in Garner Valley on the SBNF (California Natural Diversity Database 2001). Populations occur on various soil types (Berg and Krantz 1982, California Natural Diversity Database 2001). Much of its Garner Valley habitat lies within an area that the SBNF plans to treat with prescribed fire to reduce fuel loading for community protection, but nothing is known about the response of *A. johnstonii* to fire.

Before subjecting entire populations of this rare plant to prescribed fire of unknown consequence, SBNF staff worked with us to design a small-scale test of fire effects on a limited number of *A. johnstonii* plants. Study implementation required developing a safe method to conduct burns of small aerial extent, but with realistic fire intensity and severity of effects, in a wildland area suffering from four years of drought. To do this, we developed a cylindrical wire "fire cage" that can be placed over discrete patches of *A. johnstonii* to subject them to controlled fire. The study area, plant sample parameters, and design of the fire cage are described below.

2. STUDY SITES

Three locations containing populations of *A. johnstonii* were identified for use in this study (Fig.2). The sites vary in exposure and topographic position; slopes are less than 10% at all three.

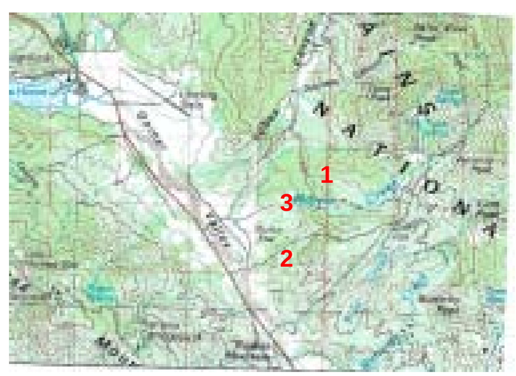

Figure 2. Location of study sites: 1) McGregor Flat, 2) Kenworthy Station, and 3) Quinn Flat. Garner Valley area, San Jacinto Mountains, CA.

Site 1, McGregor Flat, is located on and near the crest of a slope at an elevation of 2200 m. Vegetation at the site is composed of chaparral species, including *Adenostoma fasciculatum, Ceanothus* spp., *Arctostaphylus* spp., and *Quercus* spp. Sizeable inter-shrub spaces have high clay/gravel/rock soil components that support limited herbaceous fuels. *Arabis johnstonii* is found scattered in and around the

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chaparral shrubs, mainly along a dirt access road and near a disturbed area used as a water catchment basin for livestock. Plants grow in full sun and in shade under shrub canopies. Livestock and rabbit grazing activity are high in this area. Fire would burn hot in clusters of chaparral fuels but probably would not carry in inter-shrub spaces because of absence of fuels.

Sites 2 and 3 are located at about 1200 m in elevation. Site 2, Kenworthy Station, faces west while Site 3, Quinn Flat, faces northwest. At both sites *A. johnstonii* grows in rocky areas on slopes under and around mature yellow pines (*Pinus jeffreyi*) with various amounts of herbaceous and pine litter. Site 3 has a mixture of big sagebrush (*Artemisia tridentata*) and chaparral unevenly scattered across the slope (Fig 3). Enough fine fuels are available at both sites to carry fire. Many of the yellow pines formerly shading Site 3 have died and were recently logged to reduce fire hazard.

Figure 3. Site 3, Quinn Flat. Rare plants were flagged prior to selecting plot locations (see Methods section for explanation).

3. METHODS

At each study site we established 12 1-m^2 plots with a minimum of five *A. johnstonii* plants in each plot. Each plot was mapped on a site map, marked with a permanent stake in the northwest corner, and photographed from a south aspect (Fig. 4). Within each plot, all *A. johnstonii* plants were mapped and canopy dimensions recorded (height and two canopy diameters).

Two other rare species were found in many of our Site 3 (Quinn Flat) plots: *Penstemon californicus* (Munz & I.M. Johnston) Keck (California penstemon) and *Calochorus palmeri* S. Watson var. *munzii* F. Ownbey (Munz's mariposa lily). We decided to use this opportunity to examine the effects of fire on these species as well. An extra plot was established at Site 3 to obtain a larger sample of both *P. californicus* and *C. palmeri* var. *munzii*. Prefire data collected for all plants of interest within each plot included density (number per plot), height, cover (two diameters--one north to south, the other east to west), and the number of flowers, flowering stalks and seed pods.

Figure 4. Sample plot at Site 2, Kenworthy Station. Each surveyor pin points to an *Arabis johnstonii* plant.

We constructed the cylindrical "fire cage" (1.2 m diameter x 0.62 m tall) using 8x8 mesh stainless steel woven wire cloth as a firewall (Fig. 5). The cylinder is capped with the same material. In use, the cage is elevated 5 cm above the ground surface by placing it on four equally spaced fire-resistant bricks. Ignition is accomplished using a butane torch that fits under the mesh near the bricks and into the fuel. The fire cage is portable and large enough to include a 10 cm burned buffer zone surrounding each *A. johnstonii* plot.

We intend to examine the impact of different burning seasons on the plants and their seed bank. Field burns were originally planned for August and December 2003 to represent late summer (natural) and winter (typical prescribed fire) burning seasons. However, due to a busy fire season, the summer treatment was postponed until fire crews could be available to assist at the field sites. The first experimental burn is now scheduled for early September 2003.

Fire treatments were randomly assigned to 6 plots per site (3 each for late summer burning and winter burning) and were matched with 3 control plots. For successful combustion on plots, excelsior or on-site fuels may be added if natural fuel is too sparse to carry fire. Prior to ignition, a 5 cm wide scratch line to inorganic soil will be dug around the perimeter of the fire cage. Fire shelters will be placed around the fire cage to serve as an additional 2 m wide fuel break. Fuels will be ignited with a butane torch. A Forest Service fire engine and crew will be present on site during all ignitions.

Weather, fuel conditions, and fire behavior variables will be documented during the burns. Fire temperature will be recorded at the soil surface and at 2 cm depth approximately 0.5 m into the cage using type K thermocouples connected to handheld portable thermometer. Earthenware plates marked with thermal crayons will be placed in several locations within each plot to record maximum surface and subsurface (2 cm depth) temperatures as well. Survival, growth and recruitment of *A. johnstonii, P. californicus and C. palmeri* var. *munzii* will be measured twice a year for up to 3 years beginning 6 months after the test fires.

The fire cage was tested in the burn building at the USDA Forest Service Riverside Fire Lab to determine how well it contained sparks and fire brands.

4. RESULTS

For all 3 sites, a total of 37 plots with 382 *A. johnstonii*, 52 *P. californicus*, and 66 *C. palmeri* var. *munzii* plants were mapped, photographed, and measured (Table 1). The higher elevation Site 1 (McGregor Flat) site had fewer and smaller *A johnstonii* individuals than the other sites (Table 2). Site 3 (Quinn Flat) appeared to have more favorable growing conditions for these perennial herbs, based on the higher population density, greater plant size and increased diversity.

Table 1. Density (plants m^{-2}) observed in 37 plots (1 m^2) for 3 species of rare plants during June 2003 at 3 sites in the Garner Valley area, San Jacinto Mountains, CA.

Site	# Plots	Species	Density min/max		Total
1	12	*A. johnstonii*	5	12	85
2	12	*A. johnstonii*	5	14	112
3	13	*A. johnstonii*	5	23	185
		P. californicus	1	9	52
		C. palmeri	1	16	66

Table 2. Average height and cover for 3 species of rare plants growing in 37 plots (1 m^2), Garner Valley area, San Jacinto Mountains, CA. The great variability in height measurements reflects, in part, a mix of flowering and non-flowering individuals within each plot.

Site	N*	Species	**Height (cm)** Min., Max. Mean	**Cover (cm^2)** Min. Max. Mean
1	12	*A. johnstonii*	0.5 27.0 3.3	0.3 156 12.3
2	12	*A. johnstonii*	0.5 15.5 3.9	0.3 375 34.6
3	13	*A. johnstonii*	0.5 25.5 5.5	0.1 621 52.7
		P. californicus	5.0 98.0 66.9	32.5 783 235
		C. palmeri	9.0 46.5 23.7	0.9 108 18.1

*N=number of plots

During trials conducted in the Riverside Fire Lab burn building using excelsior, dried chaparral branches packed to 0.5 m depth, and a 7 mph wind, the fire cage successfully contained all fire brands and sparks (Fig. 5).

Reconnaissance of the Garner Valley study sites in late August revealed that late summer rains had created high fuel moisture conditions, such that the test plots were unlikely to burn without added fuel. Tests using various mixes of excelsior and dried chamise branches in the Riverside Fire Lab burn building produced the highest temperatures with a combination of 0.5 kg of excelsior and 0.5 kg of dried chamise (Table 3). The fuel was packed to a depth of approximately 0.3 m. If the field burns are conducted as currently scheduled (early September), a mix of excelsior and dried chamise branches will be added to each plot to ensure combustion occurs.

Figure 5. Fire cage test trial burning dry chaparral fuel with a 7 mph wind in the burn building, USDA Forest Service Riverside Fire Lab.

5. DISCUSSION

Land managers in southern California and elsewhere often face a quandary when planning prescribed fires in habitat containing rare plant species. Should they risk reducing an already small population by burning it? Or should they install firebreaks or use complicated burn plans to protect a species that may actually benefit from the effects of fire? By burning small numbers of plants under controlled conditions in our fire cage, we hope to acquire information that will help managers of the San Bernardino National Forest plan prescribed burns in habitat for *Arabis johnstonii*.

At our Garner Valley study sites, *A. johnstonii* grows under chaparral shrubs and in intershrub spaces, suggesting that individual plants within a location would be subject to a range of fire effects should the sites burn in a prescribed fire or wildfire. Due to lack of surface fuels, some plants may escape burning altogether, though they could be subject to heat effects. Other plants would experience complete burn-over. Our fire cage experimental burns, utilizing added fuels, are designed to imitate the latter situation, which would presumably create the most adverse conditions for plant survival. Population density and plant size were highly variable within and among plots for *A. johnstonii*, *Penstemon californicus*, and *Calochortus palmeri* var. *munzii*. Because each plant was mapped and measured, we will be able to relate postfire survival and growth to initial plant size and reproductive status.

Most prescribed burns are carried out during winter or early spring, when air temperatures are cooler and fires are less likely to escape control. Considerable concern exists over the impacts of out-of-season burning in chaparral, however (reviewed in Beyers and Wakeman 2000). Winter burning over moist, cool soils may not generate sufficient heat to stimulate seed germination in some species, while the seeds of other species may suffer adversely from being heated while wet. The seed germination requirements of the three species examined in this study are unknown. Our test burns are planned for late summer and during winter to compare the effects of a more or less natural season fire to a typical prescribed burn. By monitoring the plant occurrences after these tests for survival, growth, and seedling recruitment, we will generate data that should begin to predict how these species would respond to a typical prescribed fire in their habitat.

Many areas of the western United States have been subject to over 100 years of fire suppression, and efforts to reintroduce fire to these ecosystems are complicated by multiple factors, including the presence of rare plants. Results of our test burns will indicate whether the fire cage technique could be useful for examining the fire response of other plant species of concern that grow in habitat proposed for prescribed fire. Results from studies similar to ours could help land managers anticipate the impacts of prescribed fire and plan its implementation in a way that will minimize negative impacts to rare plant species.

6. LITERATURE CITED

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Table 3. Surface temperatures measured with type K thermocouples in various fuel mixes during test burns conducted at the Riverside Fire Lab burn building. Air temperature at the time of the burns ranged from 35.2 to 36.4 ^{o}C. Relative humidity was 26 to 30 percent. Fuels were packed to about 0.3 m deep. Flame lengths shown in the table are maximum recorded for each trial.

	Fuel Type and Weight							
	Excelsior 1 kg		**Excelsior 0.5 kg**		**Excelsior 0.5 kg +Chamise 0.5 kg**		**Chamise 1 kg**	
Thermocouple	**T1 ^{o}C**	**T2 ^{o}C**	**T1 ^{o}C**	**T2 ^{o}C**	**T1 ^{o}C**	**T2 ^{o}C**	**T1 ^{o}C**	**T2 ^{o}C**
Temperature at:								
0 min	35	35	36	36	36	36	36	36
1 min	109	202	214	165	96	236	---	---
2 min	279	266	199	155	273	264	63	90
4 min	2 55	251	--	--	385	181	180	248
5 min	160	151	105	105	449	140	371	224
10 min	88	95	80	70	297	95	195	126
15 min	66	73	63	56	186	71	129	81
20 min	54	54	55	50	134	61	85	56
30 min	49	50	--	--	--	--	--	--
Ignition time	13 sec		24 sec		30 sec.		83 sec	
Flame length	2.5 m		1.0 m		2.0 m		2.7 m	