FINAL REPORT

ASSESS MANAGEMENT-IGNITED FIRE EFFECTS UPON THE VEGETATION OF BONITO PARK

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Summary

We documented plant community and soil conditions in Bonito Park prior to a prescribed burn that occurred on November 6, 2002, and following the burn event. One year after the burn event, we found little change in the species richness or diversity of the plant community in response to burning, however exposed ground was more than twice as abundant in the burned areas relative to controls. The grassland community of Bonito Park is dominated by *Bouteloua gracilis* (blue grama grass), and this species was insensitive to prescribed burning. We documented one ethnobotanically-utilized plant, *Monardella odoratissima*, as relatively resilient to the prescribed burn. Similarly, invasive species showed no measurable response to the burning event. Soil organic matter and soil carbon showed slight declines immediately following the fire, and six months after the prescribed burn, soil moisture was lessened by 1.5%. We conclude that the plant community of Bonito Park showed little response to prescribed burning while some changes in soil properties highlight a need for longer-term monitoring. This study has resulted in baseline data for plant and soil parameters in Bonito Park, and the establishment of a replicated network of permanent plots available for subsequent monitoring.

Objectives

I. Understand the short-term effects of fire on herbaceous and shrub vegetation at Bonito Park

We met and exceeded the goals of this objective. We surveyed plant communities prior to a prescribed burn and one year after the burn had occurred. Burn plots were compared to adjacent control (no burn) plots. Over the course of both survey dates, we documented 50 plant species in six 1000-m^2 plots (Appendices 1 & 2). Burning had no statistically significant effect on average species richness, however species richness showed a trend of slightly more species in 2003 (27 species/1000-m^2) than in 2002 (22 species/1000-m^2) (Appendix 1). We speculate this difference was due to a greater availability of moisture in 2003 relative to 2002, which led to greater germination of annuals (Appendix 5).

We compared the plant community of burn and control plots in 2003 and found no significant differences. We consistently found grasses to comprise slightly more than 50% of the ground cover while shrubs were generally less than 0.01% of the cover

(Appendix 4). Forbs increased in ground coverage between 2002 and 2003 by approximately 12%, but showed little response to the burn (Appendix 4). In all plots, *Bouteloua gracilis* (blue grama) was the dominant species, occupying approximately 50% of the ground cover (Appendix 1). In nearly all cases, the remaining species individually covered less than 10% ground (Appendix 1). The dominance of *B. gracilis* appears greater than other nearby grasslands in Wupatki and Anderson Mesa (M. Loeser, *unpublished data*).

The burn treatment did have a significant effect on the amount of bare ground. In 2003, one year after the prescribed burn had occurred, exposed soil was more than twice as abundant on burn plots (23%) than control plots (9%) (Appendix 3). In part, this difference is due to the greater amount of litter in control plots (26%) than burn plots (20%) following the burn event (Appendix 3). Although these differences in ground cover were marked, the plant diversity responses explained previously indicate little change.

II. Document post-burn changes in ethnobotanically-utilized plant species, including *Monarda pectinata* and *Monardella odoratissima*

We met the goals of this objective. We encountered *M. odoratissima* in all of our plots in 2003, regardless of burning treatment (Appendix 1). This results suggests minimal impacts of the prescribed burn on *M. odoratissima*, however it consistently occurred at less than 0.5% of ground cover which lessens our ability to statistically measure its response to fire (Appendix 1). Prior to treatment the mean ground coverage of *M. odoratissima* across all plots was 0.04%. One year after the treatment, the burned plots had a mean coverage of less than 0.001% while the control plots had a mean coverage of 0.3% (Appendix 1). Longer-term trends require further surveying, and the precision of the measurement would increase if surveys were conducted specifically for *M. odoratissima*.

Our plant surveying efforts did not record *M. pectinata* within our plots.

III. Document post-burn changes in non-native, invasive plant species

We met the goals of this objective. We recorded the following non-native species in our surveys: *Amaranthus powellii*, *Lactuca serriola*, *Linaria dalmatica*, *Tragopogon dubius*, and *Verbascum thapsus* (Appendix 2). No radical, immediate effects of the prescribed burn on these non-native species were observed. All species were observed at less than 0.001% of the ground coverage (Appendices 1 & 6). No statistically significant changes were observed due to the prescribed burn. We did not encounter the non-native species of concern, *Centaurea diffusa* or *Bromus* spp.

Clearly the increase in exposed soil due to the fire increases the risk of invasive plant species establishing or expanding their range. Additional surveying is necessary to determine the long-term effects of fire on these species.

IV. Establish an objective framework for long-term vegetation monitoring at Bonito Park

We met the goals of this objective. This experiment, a product of a collaboration between the Applied Ecology Lab – Northern Arizona University, the Sunset Crater National Monument – National Park Service, and the Coconino National Forest, has created a replicated network of plots treated with prescribed burning adjacent to non-treated controls (Appendix 11). We have collected baseline data on the plant community that will enable future researchers to return to these same plots and document the long-term responses to prescribed burning. The methods are devised to be simple, objective and repeatable (Appendix 11).

We recommend follow-up surveys to be conducted at least once every three years to document plant responses. High-elevation, montane grasslands are likely to exhibit non-linear dynamics in the face of the current stressors of drought and invasive species. Individual, short-duration events, such as the potential widespread germination of *Bromus* spp., can trigger a sweeping change in community composition that may be difficult for resource managers to reverse. Frequent monitoring may provide advance warning of such events and allow for appropriate management action.

V. Understand the short-term effects of fire on soil nutrient cycling within the montane meadow plant community

We met and exceeded the goals of this objective. We collected soil samples 24 hours prior to the prescribed burning treatment and 48 hours after the burning was completed. We analyzed the soil for soil organic matter, total nitrogen, total carbon, and the carbon-to-nitrogen ratio. We found the prescribed burning decreased soil organic matter by absolute percentages of 0.26% and carbon by 0.18% (Appendices 7 & 8). Differences in % nitrogen are difficult to explain because the control plots showed an opposite pattern to the burn plots, thus confounding an explanation of differences in the carbon-to-nitrogen ratios (Appendix 8). We speculate that nitrogen-rich ash from the fire was deposited in the control plots. In total, the biological significance of differences in soil may be small and short-lived, but we suggest repeated sampling to develop the long-term perspective.

We also collected soil in April of 2003 and found the burn treatment to have lower soil moisture by an absolute percentage of 1.5%, but this difference virtually disappeared by June of 2003 (Appendix 9). We speculate that the increased amount of exposed soil led to an increase in evaporation in April, however by June the lack of available water in all plots overrode any treatment effect.

We also note that the pre-existing (pre-burn) soil organic matter and percent nitrogen for the burn plots was higher than for the control plots (Appendix 7 & 8). Although the treatments were randomly assigned, the heterogeneity of the soil in Bonito Park was unexpectedly non-random. We are fortunate to have pre-treatment measurements, which allow us to compare changes within individual plots across time and therefore negate the effects of pre-existing differences among treatment plots.

ACKNOWLEDGMENTS

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APPENDIX 1 – GROUND COVERAGE BY SPECIES FOR EACH TREATMENT IN EACH YEAR (NOTE THAT 2002 WAS PRE-TREATMENT)

YEAR	TREATMENT	SPECIES	MEAN PERCENT COVERAGE		STANDARD ERROR
2002	BURN	*Bouteloua gracilis*	52.59%	±	2.43%
		Artemisia dracunculus	3.24%	±	1.40%
		Aristida purpurea	1.70%	±	1.70%
		Lupinus kingii	1.48%	±	0.01%
		Chamaesyce fendleri	0.40%	±	0.13%
		Oenothera caespitosa	0.32%	±	0.32%
		Elymus elymoides	0.30%	±	0.15%
		Cryptantha jamesii	0.25%	±	0.25%
		Descurainia incana	0.20%	±	0.07%
		Artemisia carruthii	0.19%	±	0.06%
		Aristida purpurea var. longiseta	0.18%	±	0.06%
		Senecio spartioides	0.10%	±	0.06%
		Bahia dissecta	0.07%	±	0.07%
		Brickellia eupatorioides	0.05%	±	0.05%
		Monardella odoratissima	0.05%	±	0.05%
		Erigeron divergens	0.03%	±	0.03%
		Erysimum capitatum	0.03%	±	0.03%
		Amaranthus powellii	< 0.00%	±	< 0.00%
		Artemisia campestris	< 0.00%	±	< 0.00%
		Caesalpinia jamesii	< 0.00%	±	< 0.00%
		Ericameria nauseosa	< 0.00%	±	< 0.00%
		Gaura coccinea	< 0.00%	±	< 0.00%
		Geranium caespitosum	< 0.00%	±	< 0.00%
		Helianthus annuus	< 0.00%	±	< 0.00%
		Hesperostipa comata	< 0.00%	±	< 0.00%
		Ipomopsis multiflora	< 0.00%	±	< 0.00%
		Lappula occidentalis	< 0.00%	±	< 0.00%
		Machaeranthera canescens	< 0.00%	±	< 0.00%
		Penstemon barbatus	< 0.00%	±	< 0.00%
		Pinus ponderosa	< 0.00%	±	< 0.00%
		Schizachyrium scoparium	< 0.00%	±	< 0.00%
		Sphaeralcea sp.	< 0.00%	±	< 0.00%
		Sporobolus airoides	< 0.00%	±	< 0.00%
		Thalictrum fendleri	< 0.00%	±	< 0.00%
		UNK2002-10	< 0.00%	±	< 0.00%

		UNK2002-21	< 0.00%	±	< 0.00%
		Verbascum thapsus	< 0.00%	±	< 0.00%

YEAR	TREATMENT	SPECIES	MEAN PERCENT COVERAGE		STANDARD ERROR
2003	BURN	*Bouteloua gracilis*	45.67%	±	1.18%
		Lupinus kingii	10.03%	±	3.30%
		Elymus elymoides	2.85%	±	0.58%
		Oenothera caespitosa	2.59%	±	0.86%
		Artemisia dracunculus	1.10%	±	0.58%
		Aristida purpurea	0.50%	±	0.50%
		Helianthus annuus	0.46%	±	0.32%
		Lappula occidentalis	0.43%	±	0.43%
		Bahia dissecta	0.27%	±	0.27%
		Aristida purpurea var. longiseta	0.20%	±	0.07%
		Cryptantha jamesii	0.15%	±	0.15%
		Brickellia eupatorioides	0.10%	±	0.10%
		Chamaesyce fendleri	0.10%	±	0.03%
		Senecio spartioides	0.07%	±	0.07%
		Erysimum capitatum	0.03%	±	0.03%
		Artemisia campestris	< 0.00%	±	< 0.00%
		Asclepias subverticillata	< 0.00%	±	< 0.00%
		Caesalpinia jamesii	< 0.00%	±	< 0.00%
		Chenopodium leptophyllum	< 0.00%	±	< 0.00%
		Descurainia incana	< 0.00%	±	< 0.00%
		Ericameria nauseosa	< 0.00%	±	< 0.00%
		Erigeron divergens	< 0.00%	±	< 0.00%
		Gaillardia pinnatifida	< 0.00%	±	< 0.00%
		Gaura coccinea	< 0.00%	±	< 0.00%
		Geranium caespitosum	< 0.00%	±	< 0.00%
		Hesperostipa comata	< 0.00%	±	< 0.00%
		Ipomopsis multiflora	< 0.00%	±	< 0.00%
		Lactuca serriola	< 0.00%	±	< 0.00%
		Linaria dalmatica	< 0.00%	±	< 0.00%
		Linum lewisii	< 0.00%	±	< 0.00%
		Machaeranthera canescens	< 0.00%	±	< 0.00%
		Machaeranthera gracilis	< 0.00%	±	< 0.00%
		Monardella odoratissima	< 0.00%	±	< 0.00%

		Penstemon jamesii	< 0.00%	±	< 0.00%
		Schizachyrium scoparium	< 0.00%	±	< 0.00%
		Sphaeralcea sp.	< 0.00%	±	< 0.00%
		Sporobolus airoides	< 0.00%	±	< 0.00%
		Thalictrum fendleri	< 0.00%	±	< 0.00%
		Tragopogon dubius	< 0.00%	±	< 0.00%
		Verbascum thapsus	< 0.00%	±	< 0.00%

YEAR	**TREATMENT**	**SPECIES**	**MEAN PERCENT COVERAGE**		**STANDARD ERROR**
2002	NOBURN	*Bouteloua gracilis*	50.59%	±	4.13%
		Hesperostipa comata	3.31%	±	2.04%
		Lupinus kingii	1.52%	±	0.18%
		Artemisia dracunculus	1.29%	±	0.35%
		Oenothera caespitosa	0.65%	±	0.65%
		UNK2002-10	0.60%	±	0.20%
		Artemisia carruthii	0.29%	±	0.10%
		Elymus elymoides	0.20%	±	0.06%
		Erysimum capitatum	0.07%	±	0.03%
		Erigeron divergens	0.07%	±	0.03%
		Monardella odoratissima	0.03%	±	0.03%
		Bahia dissecta	0.03%	±	0.03%
		Amaranthus powellii	< 0.00%	±	< 0.00%
		Aristida purpurea	< 0.00%	±	< 0.00%
		Artemisia campestris	< 0.00%	±	< 0.00%
		Brickellia eupatorioides	< 0.00%	±	< 0.00%
		Chamaesyce fendleri	< 0.00%	±	< 0.00%
		Cirsium arizonicum	< 0.00%	±	< 0.00%
		Cryptantha jamesii	< 0.00%	±	< 0.00%
		Descurainia incana	< 0.00%	±	< 0.00%
		Ericameria nauseosa	< 0.00%	±	< 0.00%
		Geranium caespitosum	< 0.00%	±	< 0.00%
		Helianthus annuus	< 0.00%	±	< 0.00%
		Lappula occidentalis	< 0.00%	±	< 0.00%
		Linum neomexicanum	< 0.00%	±	< 0.00%
		Machaeranthera canescens	< 0.00%	±	< 0.00%
		Muhlenbergia montana	< 0.00%	±	< 0.00%

YEAR	TREATMENT	SPECIES	MEAN PERCENT COVERAGE		STANDARD ERROR
		Oxytropis lambertii	< 0.00%	±	< 0.00%
		Pinus ponderosa	< 0.00%	±	< 0.00%
		Plantago argyraea	< 0.00%	±	< 0.00%
		Senecio spartioides	< 0.00%	±	< 0.00%
		Sporobolus airoides	< 0.00%	±	< 0.00%
		Verbascum thapsus	< 0.00%	±	< 0.00%

YEAR	TREATMENT	SPECIES	MEAN PERCENT COVERAGE		STANDARD ERROR
2003	NOBURN	*Bouteloua gracilis*	47.01%	±	2.95%
		Lupinus kingii	17.33%	±	4.74%
		Hesperostipa comata	5.18%	±	3.46%
		Oenothera caespitosa	1.97%	±	0.66%
		Elymus elymoides	1.52%	±	0.35%
		Artemisia dracunculus	1.19%	±	0.36%
		Artemisia carruthii	0.49%	±	0.10%
		Erigeron divergens	0.26%	±	0.17%
		Monardella odoratissima	0.26%	±	0.14%
		Bahia dissecta	0.20%	±	0.12%
		Erysimum capitatum	0.16%	±	0.09%
		Lappula occidentalis	0.15%	±	0.15%
		Helianthus annuus	0.13%	±	0.13%
		Senecio spartioides	0.10%	±	0.06%
		Machaeranthera canescens	0.06%	±	0.06%
		Cryptantha jamesii	0.05%	±	0.05%
		Ericameria nauseosa	0.05%	±	0.05%
		Amaranthus powellii	< 0.00%	±	< 0.00%
		Aristida purpurea	< 0.00%	±	< 0.00%
		Aristida purpurea var. longiseta	< 0.00%	±	< 0.00%
		Artemisia campestris	< 0.00%	±	< 0.00%
		Brickellia eupatorioides	< 0.00%	±	< 0.00%
		Carex sp.	< 0.00%	±	< 0.00%
		Chamaesyce fendleri	< 0.00%	±	< 0.00%
		Chenopodium leptophyllum	< 0.00%	±	< 0.00%
		Cirsium arizonicum	< 0.00%	±	< 0.00%
		Descurainia incana	< 0.00%	±	< 0.00%
		Gaillardia pinnatifida	< 0.00%	±	< 0.00%

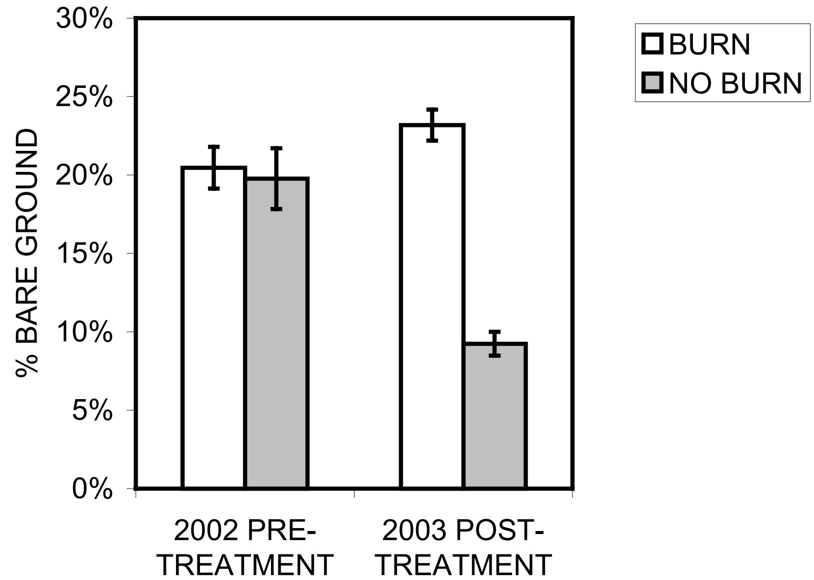
Gaura coccinea	< 0.00%	±	< 0.00%
Geranium caespitosum	< 0.00%	±	< 0.00%
Ipomopsis multiflora	< 0.00%	±	< 0.00%
Lactuca serriola	< 0.00%	±	< 0.00%
Linaria dalmatica	< 0.00%	±	< 0.00%
Linum neomexicanum	< 0.00%	±	< 0.00%
Machaeranthera gracilis	< 0.00%	±	< 0.00%
Muhlenbergia montana	< 0.00%	±	< 0.00%
Oxytropis lambertii	< 0.00%	±	< 0.00%
Pinus ponderosa	< 0.00%	±	< 0.00%
Plantago argyraea	< 0.00%	±	< 0.00%
Sporobolus airoides	< 0.00%	±	< 0.00%
Tragopogon dubius	< 0.00%	±	< 0.00%
Verbascum thapsus	< 0.00%	±	< 0.00%

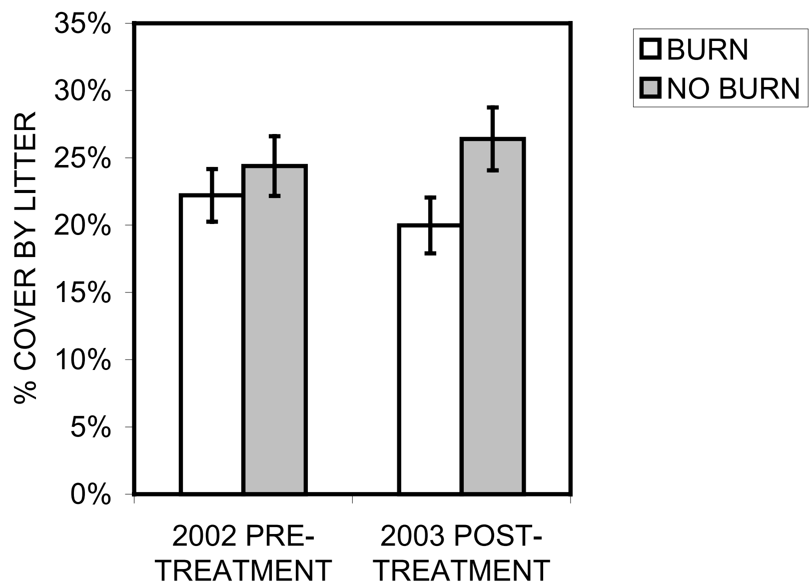
APPENDIX 2 – THE COMPLETE PLANT SPECIES LIST FOR ALL PLOTS AT BONITO PARK

COMPLETE SPECIES NAME	FAMILY	COMMON NAME	HABIT	DURATION	ORIGIN
Amaranthus powellii S. Wats.	Amaranthaceae	powell's amaranth,	forb	annual	exotic
Aristida purpurea Nutt.	Poaceae	purple threeawn	grass	perennial	native
Aristida purpurea Nutt. var. *longiseta* (Steud.) Vasey	Poaceae	fendler threeawn	grass	perennial	native
Artemisia campestris L.	Asteraceae	field sagewort	forb	perennial	native
Artemisia carruthii Wood ex Carruth.	Asteraceae	carruth's sagewort	forb	perennial	native
Artemisia dracunculus L. tarragon	Asteraceae	tarragon	forb	perennial	native
Asclepias subverticillata (Gray) Vail	Asclepiadaceae	horsetail milkweed	forb	perennial	native
Bahia dissecta (Gray) Britt.	Asteraceae	wild chrysanthemum	forb	annual	native
Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	Poaceae	blue grama	grass	perennial	native
Brickellia eupatorioides (L.) Shinners	Asteraceae	false boneset	forb	perennial	native
Caesalpinia jamesii (Torr. & Gray) Fisher	Fabaceae	james holdback	forb	perennial	native
Carex sp.	Cyperaceae	sedge	forb		
Chamaesyce fendleri (Torr. & Gray) Small	Euphorbiaceae	fendler's sandmat	forb	perennial	native
Chenopodium leptophyllum (Moq.) Nutt. ex S. Wats.	Chenopodiaceae	narrowleaf goosefoot	forb	annual	native
Cirsium arizonicum (Gray) Petrak	Asteraceae	arizona thistle	forb	perennial	native
Cryptantha jamesii (Torr.) Payson	Boraginaceae	james' cryptantha	forb	perennial	native
Descurainia incana (Bernh. ex Fisch. & C.A. Mey.) Dorn	Brassicaceae	mountain tansymustard	forb	annual	native
Elymus elymoides (Raf.) Swezey	Poaceae	squirrel tail	grass	perennial	native
Ericameria nauseosa (Pallas ex Pursh) Nesom & Baird	Asteraceae	rubber rabbitbrush	shrub	perennial	native
Erigeron divergens Torr. & Gray	Asteraceae	spreading fleabane	forb	annual	native
Erysimum capitatum (Dougl. ex Hook.) Greene	Brassicaceae	sanddune wallflower	forb	annual	native
Gaillardia pinnatifida Torr.	Asteraceae	red dome blanketflower	forb	perennial	native
Gaura coccinea Nutt. ex Pursh	Onagraceae	scarlet beeblossom	forb	perennial	native
Geranium caespitosum James	Geraniaceae	pineywoods geranium	forb	perennial	native
Helianthus annuus L.	Asteraceae	common sunflower	forb	annual	native
Hesperostipa comata (Trin. & Rupr.)	Poaceae	barkworth needle and thread	grass	perennial	native
Ipomopsis multiflora (Nutt.) V. Grant	Polemoniaceae	manyflowered ipomopsis	forb	perennial	native
Lactuca serriola L.	Asteraceae	prickly lettuce	forb	annual	exotic

Lappula occidentalis (S. Wats.) Greene var. *cupulata* (Gray) Higgins	Boraginaceae	flatspine stickseed	forb	annual	native
Linaria dalmatica (L.) P. Mill.	Scrophulariaceae	dalmatian toadflax	forb	perennial	exotic
Linum lewisii Pursh	Linaceae	prairie flax	forb	perennial	native
Linum neomexicanum Greene	Linaceae	new mexico yellow flax	forb	annual	native
Lupinus kingii S. Wats.	Fabaceae	king's lupine	forb	annual	native
Machaeranthera canescens (Pursh) Gray	Asteraceae	hoary tansyaster	forb	perennial	native
Machaeranthera gracilis (Nutt.) Shinners	Asteraceae	slender goldenweed	forb	annual	native
Monardella odoratissima Benth.	Lamiaceae	moutain monardella	forb	perennial	native
Muhlenbergia montana (Nutt.) A.S. Hitchc.	Poaceae	mountain muhly	grass	perennial	native
Oenothera caespitosa Nutt.	Onagraceae	tufted evening-primrose	forb	perennial	native
Oxytropis lambertii Pursh.	Fabaceae	purple locoweed	forb	perennial	native
Penstemon barbatus (Cav.) Roth	Scrophulariaceae	beardlip penstemon	forb	perennial	native
Penstemon jamesii Benth.	Scrophulariaceae	james' beardtongue	forb	perennial	native
Pinus ponderosa P.& C. Lawson	Pinaceae	ponderosa pine	tree	evergreen	native
Plantago argyraea Morris	Plantaginaceae	saltmeadow plantain	forb	annual	native
Schizachyrium scoparium (Michx.) Nash	Poaceae	little bluestem	grass	perennial	native
Senecio spartioides Torr. & Gray	Asteraceae	broomlike ragwort	forb	perennial	native
Sphaeralcea sp.	Malvaceae	globemallow	forb	perennial	native
Sporobolus airoides (Torr.) Torr.	Poaceae	alkali sacaton	grass	perennial	native
Thalictrum fendleri Engelm. ex Gray	Ranunculaceae	fendler's meadow-rue	forb	perennial	native
Tragopogon dubius Scop.	Asteraceae	yellow salsify	forb	annual	exotic
Verbascum thapsus L.	Scrophulariaceae	common mullein	forb	annual	exotic

APPENDIX 3 – COVERAGES BY EXPOSED SOIL AND LITTER PRIOR TO THE TREATMENT AND FOLLOWING THE TREATMENT





APPENDIX 4 – GROUND COVERAGE BY PLANT HABIT (FORB, GRASS, OR SHRUB)

PLANT HABIT	YEAR	BURN TREATMENT		NO BURN TREATMENT	
		MEAN	STD.ERR.	MEAN	STD.ERR.
FORB	2002	5.77%	1.24%	3.63%	0.24%
	2003	13.45%	3.85%	20.81%	5.10%
GRASS	2002	54.08%	1.87%	54.10%	3.04%
	2003	49.09%	1.89%	53.71%	3.06%
SHRUB	2002	0.00%	0.00%	0.00%	0.00%
	2003	0.00%	0.00%	0.05%	0.05%

APPENDIX 5 – GROUND COVERAGE BY PLANT DURATION (ANNUAL OR PERENNIAL)

DURATION	YEAR	BURN TREATMENT		NO BURN TREATMENT	
		MEAN	STD.ERR.	MEAN	STD.ERR.
ANNUAL	2002	1.68%	0.10%	1.68%	0.21%
	2003	11.22%	3.68%	18.18%	4.60%
PERENNIAL	2002	58.17%	2.95%	56.05%	3.38%
	2003	51.31%	1.89%	56.37%	3.46%

APPENDIX 6 – GROUND COVERAGE BY ORIGIN (NATIVE OR EXOTIC)

PLANT ORIGIN	YEAR	BURN TREATMENT		NO BURN TREATMENT	
		MEAN	STD.ERR.	MEAN	STD.ERR.
NATIVE	2002	59.85%	3.05%	57.73%	3.19%
	2003	62.54%	2.68%	74.55%	5.03%
EXOTIC	2002	< 0.00%	< 0.00%	< 0.00%	< 0.00%
	2003	< 0.00%	< 0.00%	< 0.00%	< 0.00%

APPENDIX 7 – SOIL ORGANIC MATTER AT DEPTHS OF 0-5 cm AND 5-10 cm

SAMPLE DEPTH	SAMPLE COLLECTION DATE	BURN TREATMENT		NO BURN TREATMENT	
		MEAN	STD.ERR.	MEAN	STD.ERR.
% SOIL ORGANIC MATTER 0-5 cm DEPTH	pre-treatment	3.95	0.11	3.59	0.13
	post-treatment	3.69	0.10	3.48	0.07
% SOIL ORGANIC MATTER 5-10 cm DEPTH	pre-treatment	3.28	0.13	3.06	0.13
	post-treatment	3.37	0.17	3.03	0.07

APPENDIX 8 – PERCENTAGE OF CARBON AND NITROGEN, AND CARBON-TO-NITROGEN RATIOS IN TOP 5 cm OF SOIL

SOIL PROPERTY	SAMPLE COLLECTION DATE	BURN TREATMENT		NO BURN TREATMENT	
		MEAN	STD.ERR.	MEAN	STD.ERR.
% CARBON	pre-treatment	1.370	0.144	1.247	0.107
	post-treatment	1.197	0.184	1.240	0.101
% NITROGEN	pre-treatment	0.103	0.007	0.083	0.009
	post-treatment	0.093	0.013	0.090	0.006
CARBON : NITROGEN	pre-treatment	12.943	0.704	14.530	0.122
	post-treatment	12.887	0.522	13.720	0.486

APPENDIX 9 – PERCENTAGE OF SOIL MOISTURE IN TOP 5 cm OF SOIL FOLLOWING THE PRESCRIBED BURN (6 MONTHS AND 8 MONTHS AFTER BURN EVENT)

SAMPLE COLLECTION DATE	BURN TREATMENT		NO BURN TREATMENT	
	MEAN	STD.ERR.	MEAN	STD.ERR.
APRIL 2003	4.78%	0.14%	6.27%	0.27%
JUNE 2003	0.42%	0.01%	0.44%	0.04%

APPENDIX 10 – SURVEY METHODS

Vegetation survey methods

Surveys were conducted at the peak of vegetation productivity in 2002 and 2003. In 2002, we surveyed vegetation between September 23 and September 28. In 2003, we surveyed vegetation between October 3 and October 8. Survey plots were permanently marked modified-Whittaker plots (Stohlgren et al. 1995). Modified-Whittaker plots are 20 x 50 m with 13 nested subplots. Species richness and ground cover will be measured with a 1 m x 0.5 m frequency frame (Mueller-Dombois and Ellenberg 1974).

Protocol

1. Run a 100 m tape from the origin (0 m) clockwise to the 90 m corner. Run a 50 m tape counter-clockwise to the 90 m corner. Walk into the inner-plot and run a 50 m tape clockwise beginning at the inner-plot origin.

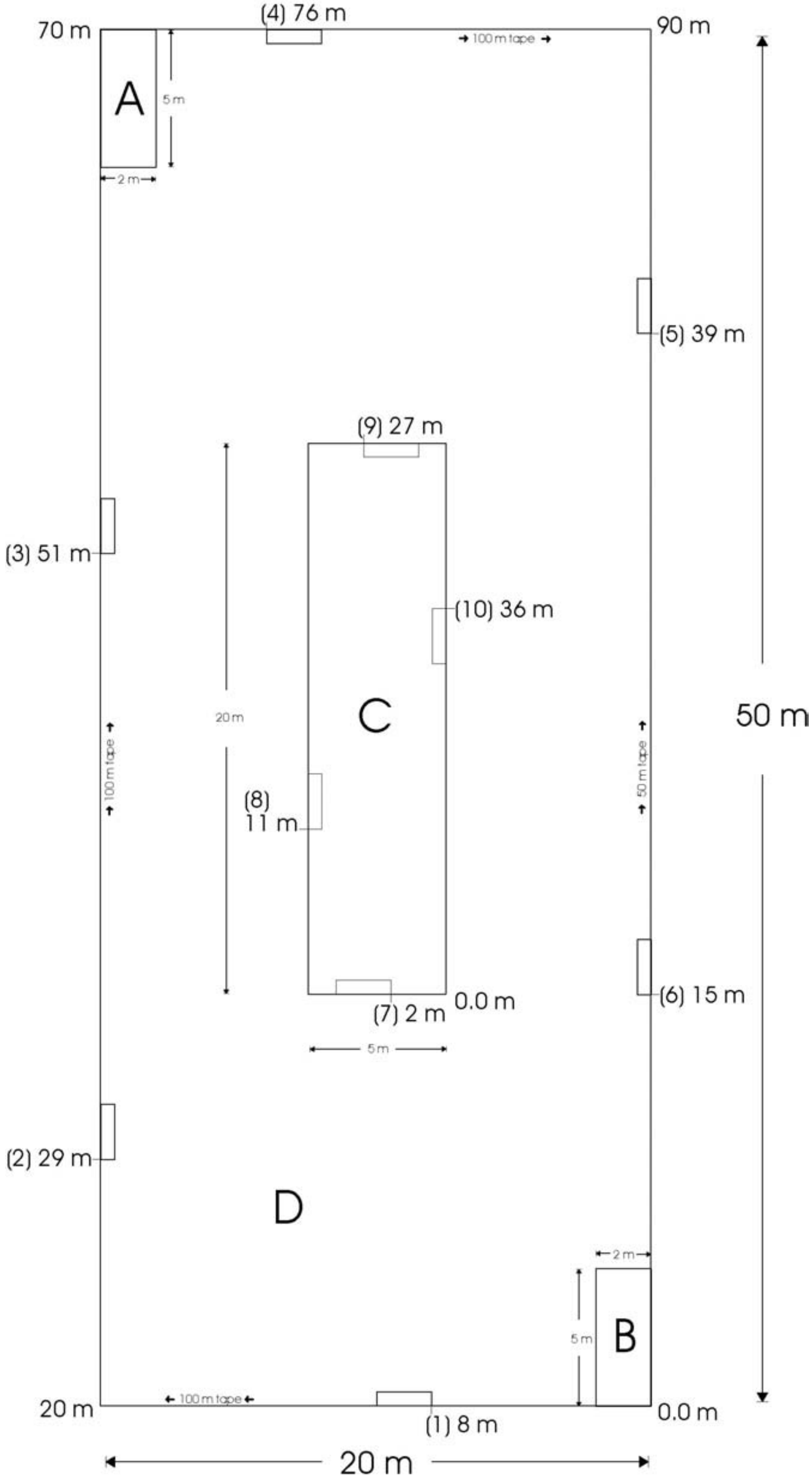
2. Refer to the modified-Whittaker plot map to determine where the frequency frame should be placed.

3. Run the rod down to the ground at every other corner made by the string. Record the ground cover. Rules:

If the pranger hits 2 plant species, then place a tick mark for both and a tick mark under double (triple for 3 plant species, etc.). If a plant and litter is touched at the same time, only the plant species is recorded.

4. After conducting 50 hits with the pranger, record a ‘P’ for any plant species present in the 1 m^2 sub-plot that wasn’t hit with the pranger.

Map of Modified-Whittaker plot



Soil survey methods

Soil was collected on the day prior to the burn (05Nov02) and following the burn on November 8, 2002 in subplots 1 through 6, following the Modified-Whittaker map. Six soil cores (2.5 cm diameter x 10 cm depth) were collected from each plot during the plant surveys. Soil cores were divided into the 0-5 cm depth and the 5-10 cm depth. Soils were analyzed for soil organic matter following standard loss-on-ignition techniques (see protocol below). Percent carbon and nitrogen, as well as the carbon-to-nitrogen ratio were measured by the Colorado Plateau Isotope Laboratory.

Soil organic matter – ashing protocol

Contact person for analytical lab: Tom Huntsberger, 523-7265, Thomas.Huntsberger@nau.edu

1. Pour entire sample through a 12.7 mm sieve and remove rocks. Place all dirt clods larger than 12.7 mm in a Ziploc bag and hammer with a rubber mallet until the clods are small enough to fit through the 12.7 mm sieve.

2. Pour the entire sample on to a clean flat surface and mix thoroughly. Follow the "halve & mix" method to create a sub-sample that is approximately 200g. Pour this sample into a Ziploc bag and label. Pour the remaining sample material into a Ziploc bag and label.

3. From the 200g sub-sample, weigh out three 20g sub-samples of soil into a metal drying tin. Each 20g sample should be a representative sub-sample of the entire sample so use the "halve & mix" method to get samples. (We can only do 20 samples at a time because there are 2 ovens and each oven can hold 10 crucibles.)

4. Label the drying tin with an aluminum foil tag.

5. Dry for 24 hours at 105 ºC.

6. While samples are still warm they need to be transferred to crucibles. Put on latex gloves to handle crucibles and wash each crucible. Dry crucibles thoroughly before use.

7. For each sample, record the weight of a crucible, then add the sample to the crucible and weigh again (use a balance that measures to 0.01g). Set the aluminum foil tag in the crucible (although it will be removed prior to ashing). Repeat this process for all samples.

8. Fill each muffle furnace with 10 crucibles. Map the locations of each crucible in your logbook.

9. Set the muffle furnace for 550 ºC or 450 ºC or 430 ºC depending on soil type. If the soil has a high concentration of Calcium Carbonate ($CaCO_2$) the temperature as to be lower then 550 ºC, it has to be between 450 and 430 ºC records the starting time.

10. 24 hours later turn off the muffle furnace and let cool for 30 minutes before opening the door.

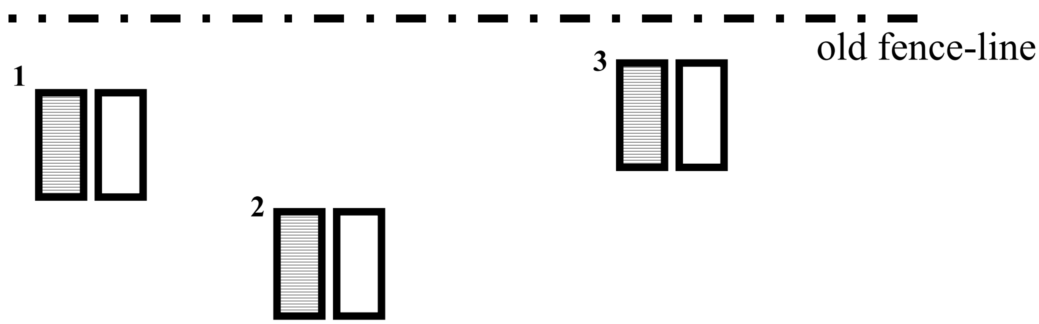
11. Put on heat protectant gloves, and remove crucibles from furnace and set the aluminum foil tag in the crucible. Set crucibles in the dessicator prior to weighing.

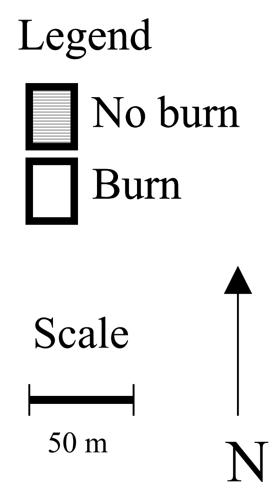
12. Once crucibles have cooled sufficiently (but are still warm), weigh each crucible (WITHOUT TAG) and record. Set crucible aside.

13. Once all crucibles have been weighed, pour sample contents into a garbage can and rinse crucibles thoroughly. Dry and return to cabinet.

APPENDIX 11 – GPS COORDINATES & MAP

BONITO PARK
FIRE EFFECTS STUDY DESIGN





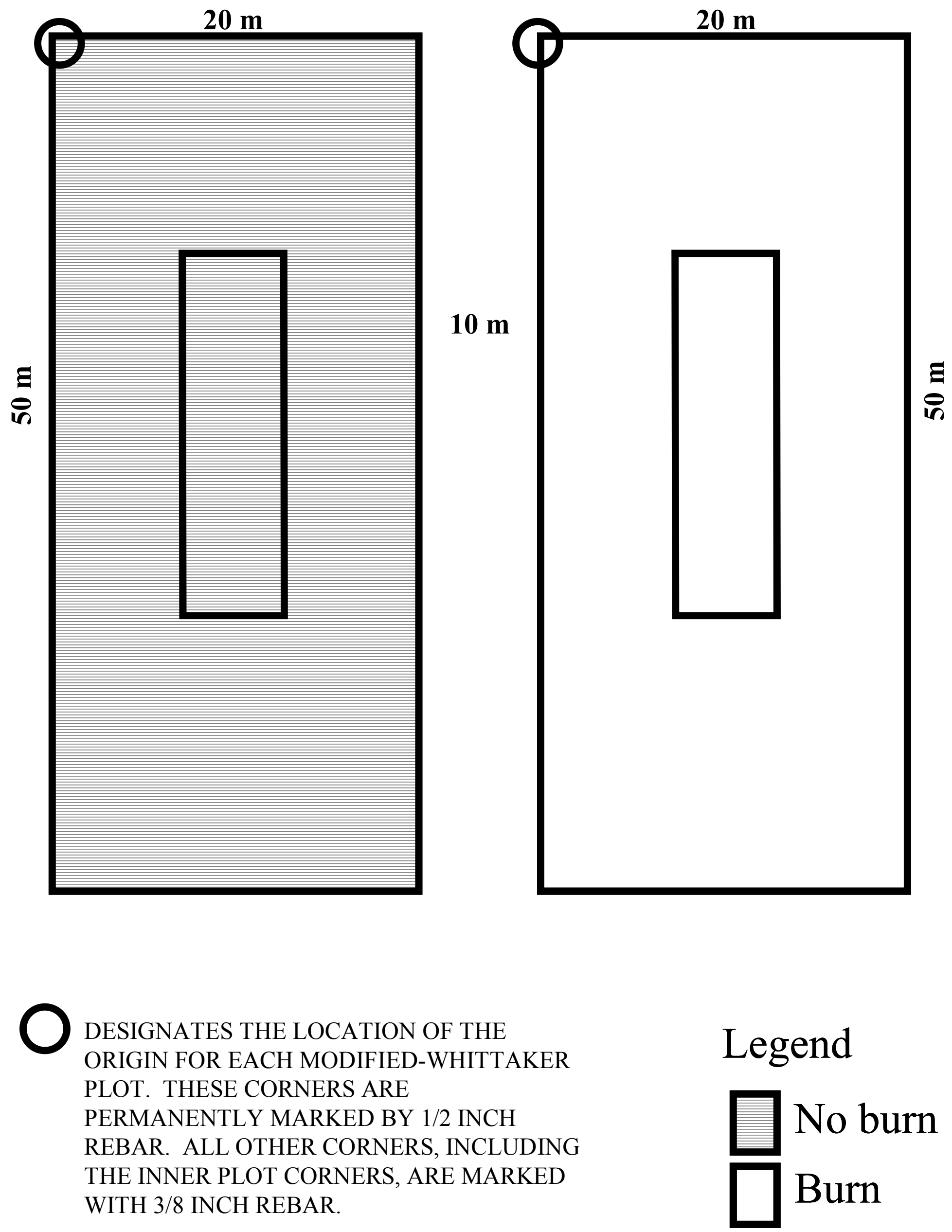
LAT./LONG. COORDINATES FOR ORIGIN OF NO BURN PLOTS

REPLICATE 1
LATITUDE: 35º 21´ 52.68965"N
LONGITUDE: 111º 33´ 31.44035"W

REPLICATE 2
LATITUDE: 35º 21´ 50.81035"N
LONGITUDE: 111º 33´ 26.45188"W

REPLICATE 3
LATITUDE: 35º 21´ 53.10827"N
LONGITUDE: 111º 33´ 19.52334"W

PAIRED-PLOT DESIGN



Note: Corners of each outer plot are labeled with the following information: Replicate number, treatment, corner location, and the PI (e.g. 2 Burn 20m NAU-Sisk).

MAP OF BONITO PARK MARKED WITH REPLICATE LOCATIONS