Fuels treatments and ecological values in piñon-juniper woodlands: Vegetation, birds, and modeled fire behavior

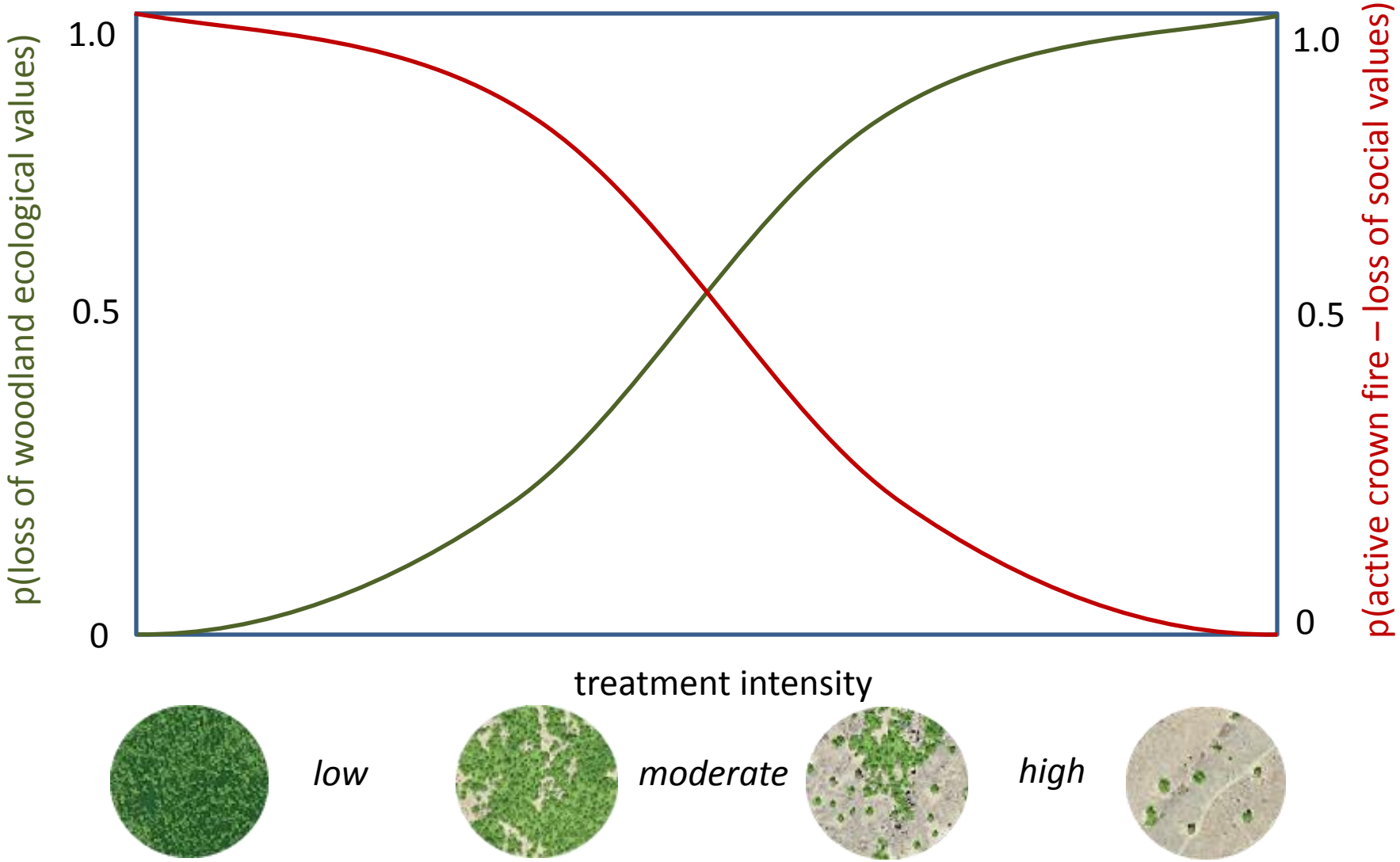
Jonathan Coop and Patrick Magee!
Western State Colorado University, Gunnison, CO
Southwest Fire Science Consortium Monthly Webinar 1 March 2017

How this webinar will work (hopefully):

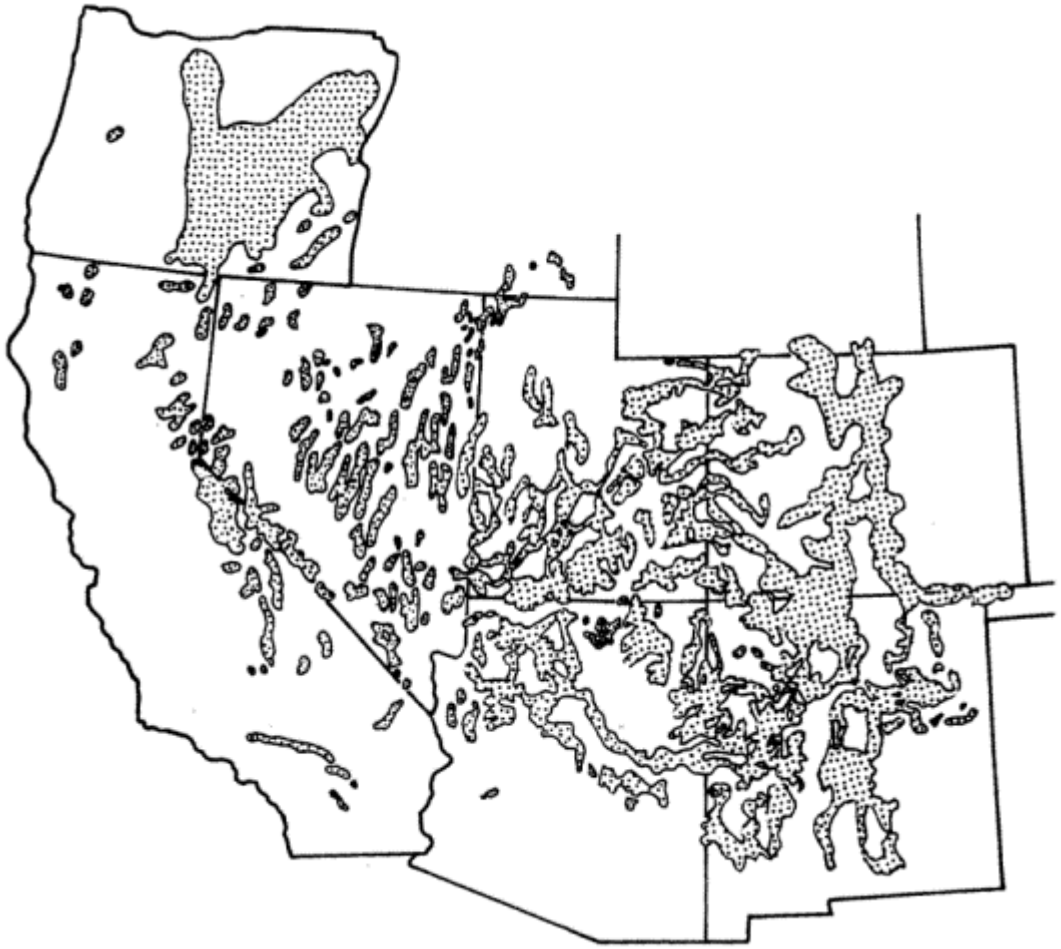
- Introduction – Coop
- Field sampling methods – Magee
- Birds: analysis and findings – Magee
- Vegetation and fuels: analysis and findings – Coop
- Fire behavior models – Coop
- Conclusions/questions – Coop & Magee

Fuels Treatments Objectives

Fuels Treatments
Social-Ecological Tradeoffs



Piñon-Juniper Woodlands



- **Ca. 100 million acres in US (3rd largest veg type)**
- **Largest forest type in Colorado (21%)**
- **Diverse, complex, variable in composition, dynamics.**
- **Uncertainty about effects of human & natural drivers**

Evans, R.A. - Management of Pinyon-Juniper Woodlands. USDA, Forest Service -- Intermountain Research Station, GRT INT-249,
Public Domain, https://commons.wikimedia.org/w/index.php?curid=46708432

Birds of the PJ Ecosystem

Avian/Tree Mutualisms

70+ species of breeding birds

20% are PJ obligates

75% are Neotropical migrants

(Balda and Masters 1980)

State of the Birds (BBS)

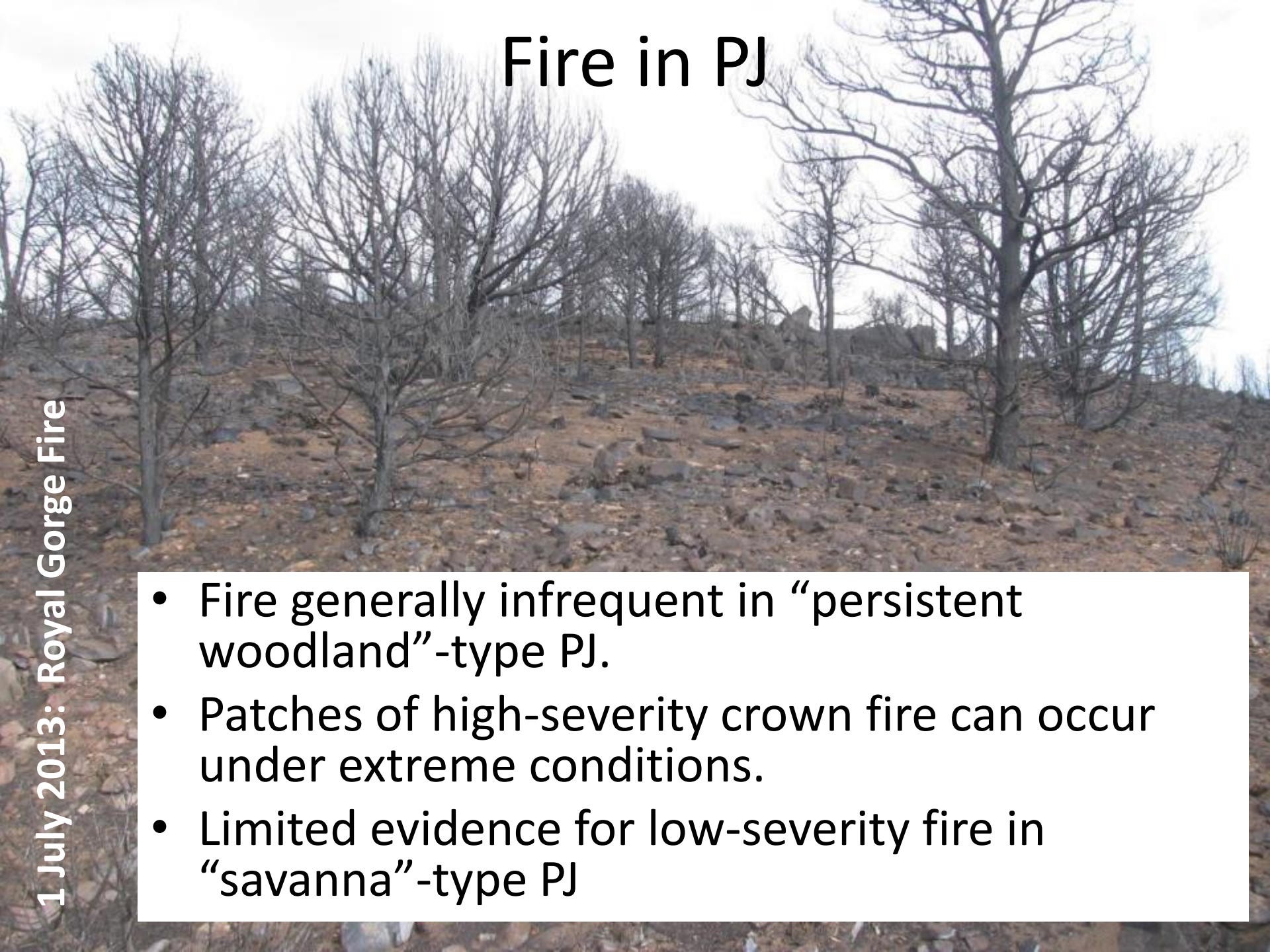
Piñon Jay	-4.26%
Plumbeous Vireo	-2.67%
Black-throated Gray Warbler	-1.45%
Virginia's Warbler	-1.26%
Juniper Titmouse	-0.44%
Gray Flycatcher	+2.73%

Colorado Wildlife Action Plan

Species of Greatest Conservation Need

Juniper Titmouse, Piñon Jay, Virginia's Warbler, Gray Vireo

Fire in PJ



1 July 2013: Royal Gorge Fire

- Fire generally infrequent in “persistent woodland”-type PJ.
- Patches of high-severity crown fire can occur under extreme conditions.
- Limited evidence for low-severity fire in “savanna”-type PJ

Mechanical Treatments: Fuels mitigation

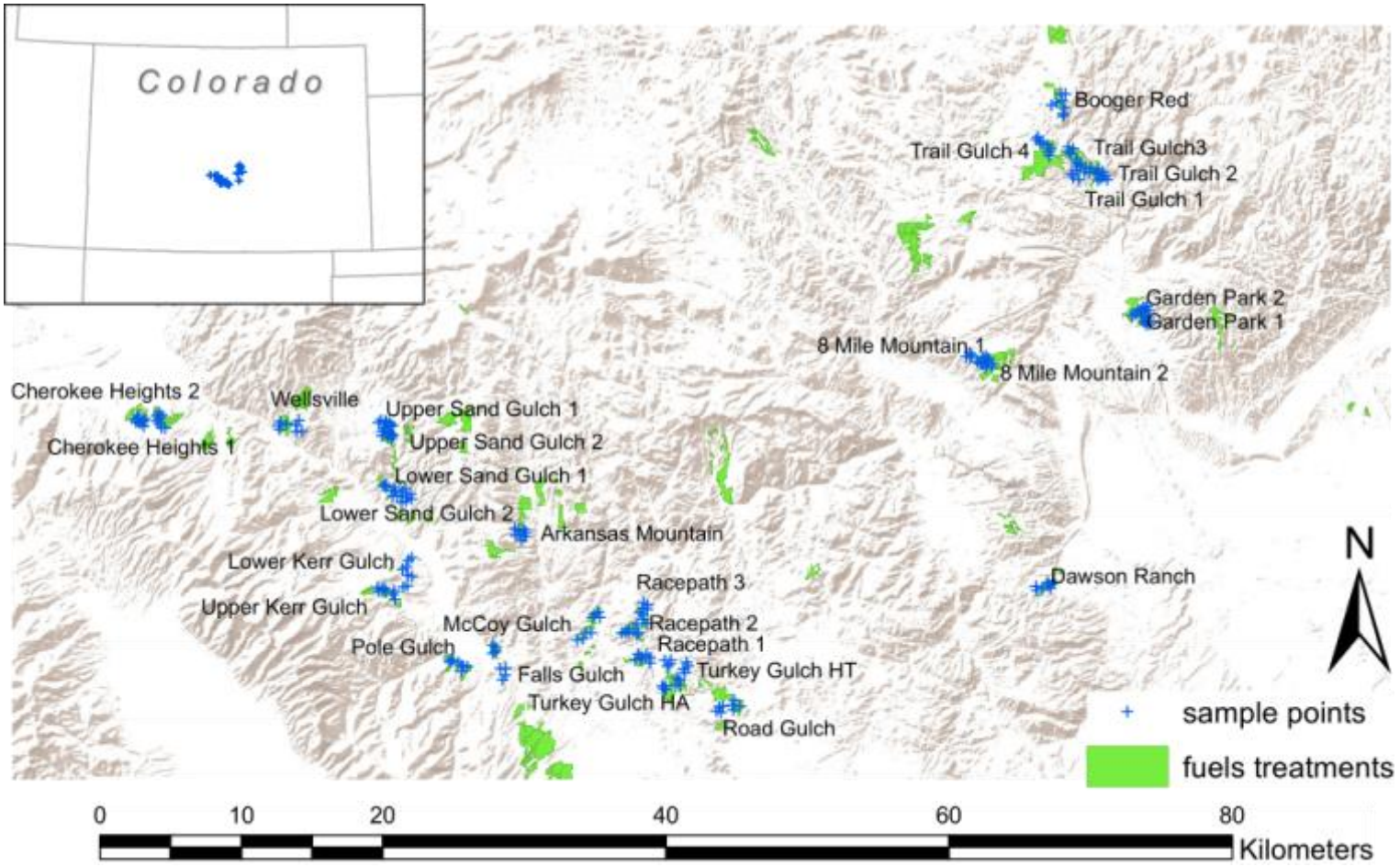
Mastication – hydro-ax
Hand thinning

- Royal Gorge Field Office (BLM) treated >20,000 acres since 1998
- Colorado Parks and Wildlife 95 projects, 31,628 acres since 2001
- In Utah, 40,000 acres annually

- Redistribute fuels from canopy to surface, convert large- to small-diameter fuels.
- Effects on PJ-dependent species and potential fire behavior?

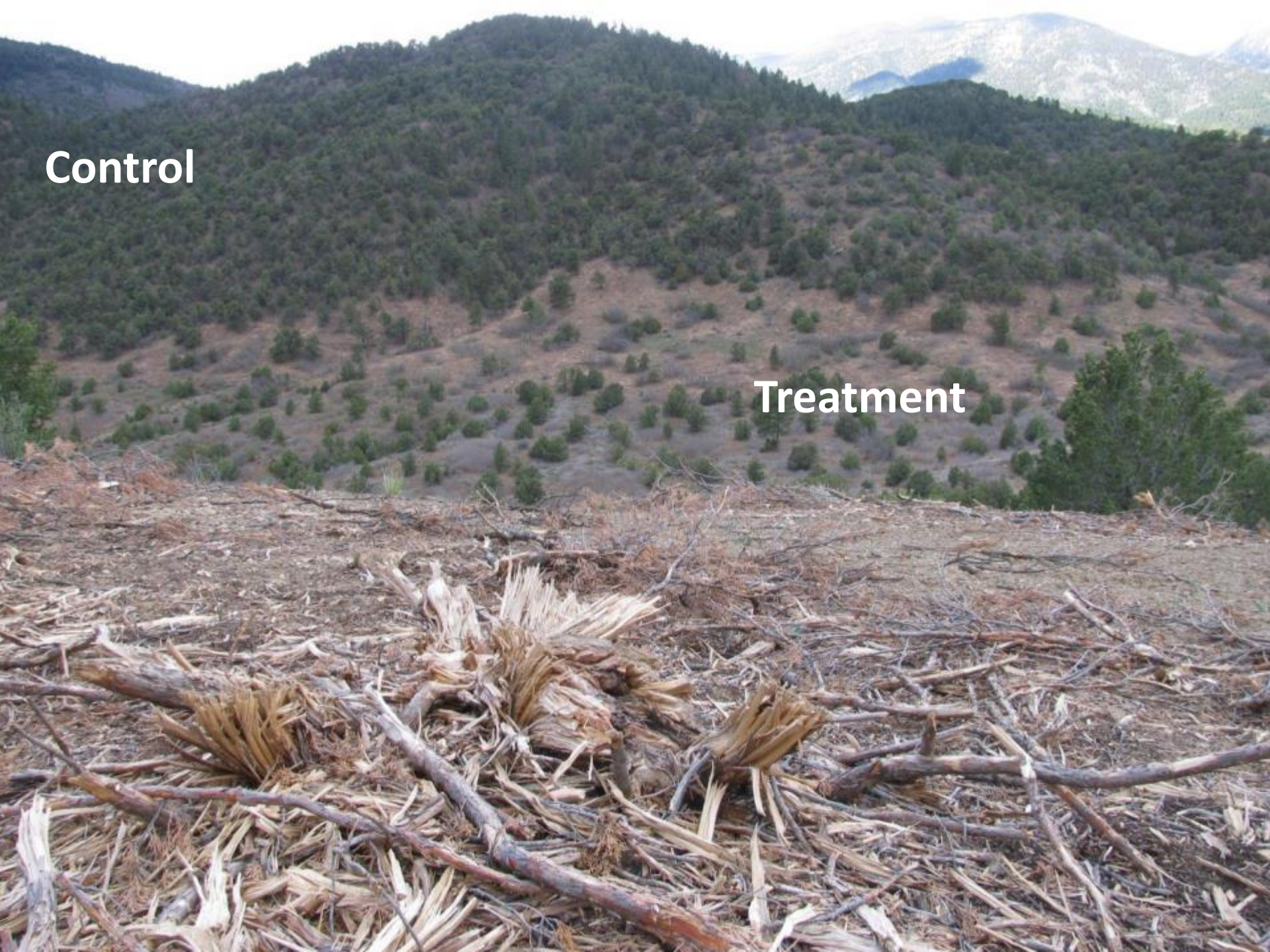
Study Objectives

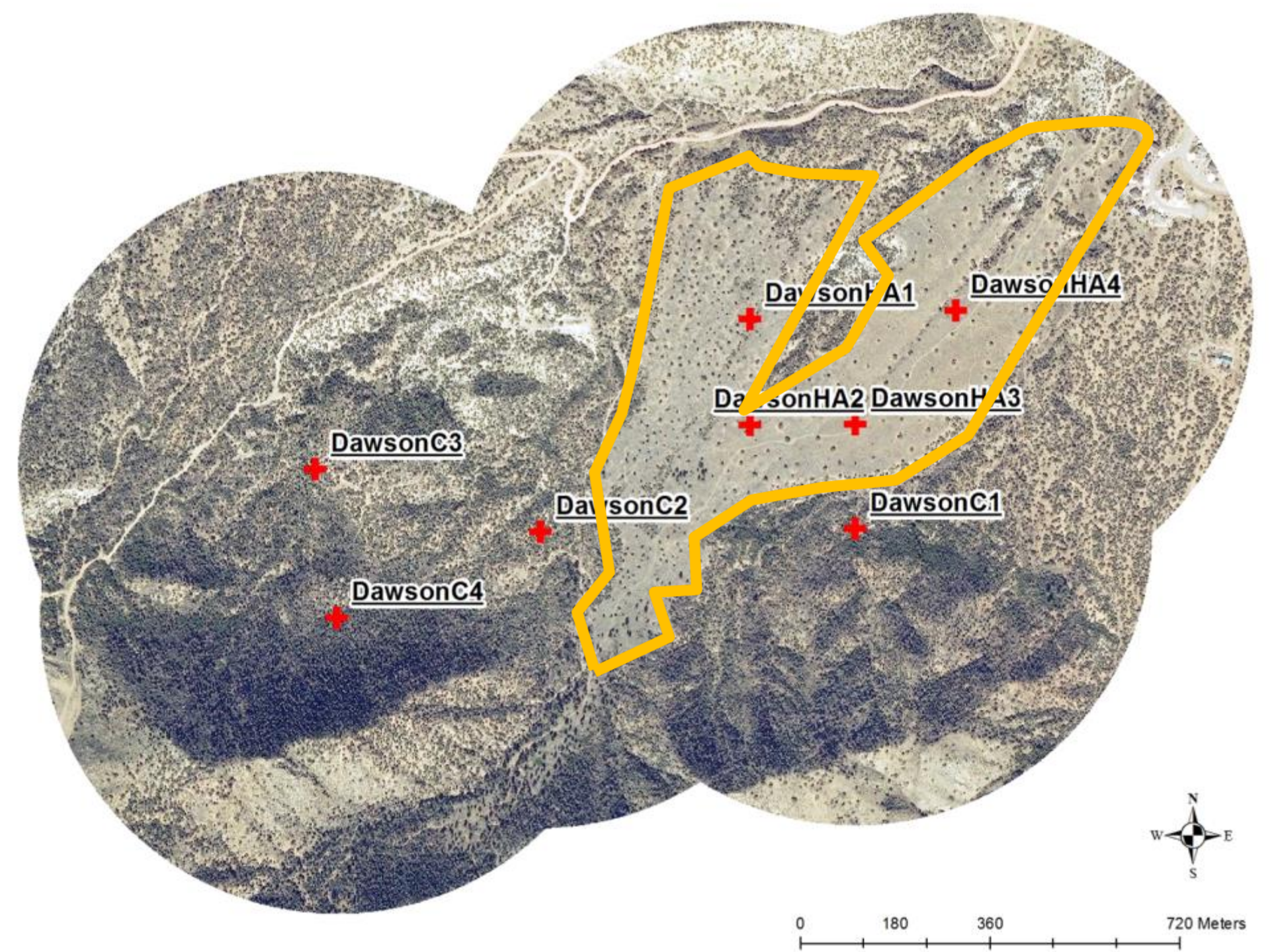
1. Assess impacts of PJ fuels treatments on birds, woodland vegetation and fuels, and modeled fire behavior.
2. Could fuels treatments be optimized to maintain valued ecosystem components and still reduce fire hazard to socially desired levels?



BLM, Royal Gorge Field Office

- 29 pairs treated/untreated sites (24 hydro-ax, 5 hand-thin).
- x 4 points each site, **n = 232**
- **chronosequence** of treatments 1-11 years old
- **climate/ecological gradient** from cold, dry woodlands to warmer, wetter savannas
- no pretreatment data


Control
Treatment


DawsonHA1
DawsonHA4
DawsonHA2
DawsonHA3
DawsonC3
DawsonC2
DawsonC1
DawsonC4
N
W
E
S
0
180
360
720 Meters

Field Methods

Birds

- 4 bird points per sample unit (n=232)
- 3 point count periods
- 2014 and 2015

Fuels

- 3 planar intercept fuels transects each point
- 30 samples of fuelbed depth, recorded by type

Vegetation

- 3 point-line-intercept transects each point
- tree ht, BA, canopy and ground cover in 5.64-m radius plot

Birds -- Analysis

Multi-scale Occupancy in Progam Mark

GOAL: produce unbiased estimates of the proportion of sites occupied by a bird species

Landscape Scale (Psi)
Local Scale (Theta)

<u>Three Step Model Selection Process</u>

1. **Detection Probabilities (p)**
2. **Treatment effects models incorporating best detection probability model**
3. **Covariate Analyses**

http://warnercnr.colostate.edu/~gwhite/mark/mark.htm

Covariate Analysis

7 Landscape Variables

Year since treatment
MAT, MAP, HLI, Elevation
Forest Cover (10 ha and 100 ha)

11 Local Scale Variables

Bare ground, herb, shrub
Vegetation height standard deviation
Tree height
Live tree density
Juniper density, piñon density
Live basal area
Juniper basal area, piñon basal area

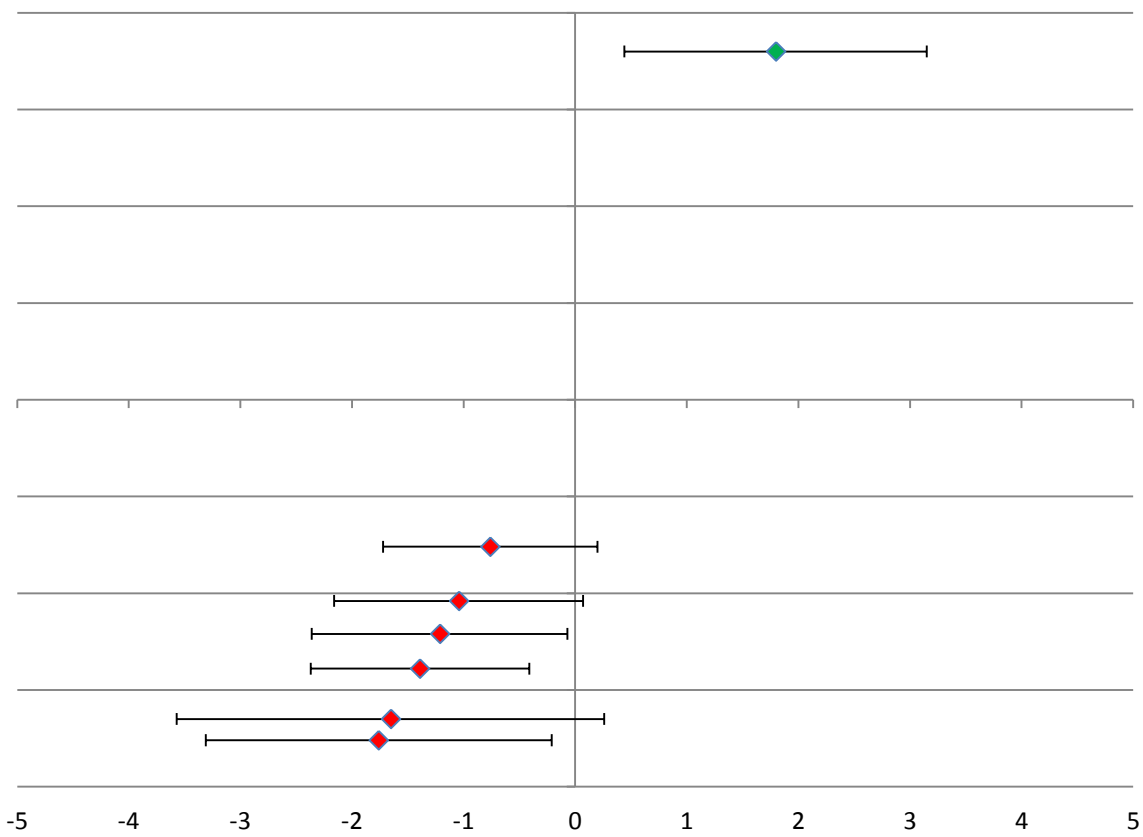
Birds -- Findings

Piñon-Juniper Bird Community	
Spotted Towhee	2,595
Black-throated Gray Warbler	1,022
Western Scrub Jay	834
Chipping Sparrow	806
Broad-tailed Hummingbird	731
Black-headed Grosbeak	703
Plumbeous Vireo	682
Gray Flycatcher	646
Blue-gray Gnatcatcher	545
Ash-throated Flycatcher	491
Mountain Chickadee	446
Mourning Dove	437
Western Tanager	435
Virginia's Warbler	431
Juniper Titmouse	423

Avian Occupancy

Habitat/ Guild	Species	Psi (Landscape Occupancy)			Theta (Local Occupancy)		
		Control	Hydroaxe	Handthin	Control	Hydroaxe	Handthin
Piñon-Juniper Specialists	GRFL	0.956	0.886	0.894	0.903	0.867	0.864
	BTYW	0.998	0.894	0.946	0.934	0.929	0.930
	VIWA	0.862	0.756	0.788	0.861	0.827	0.839
	JUTI	0.806	0.795	0.789	0.924	0.910	0.893
	PIJA	0.576	0.672	0.702	0.842	0.533	0.420
Edge	MOBL	0.654	0.909	0.545	0.771	0.771	0.786
	BHCO	0.648	0.640	0.647	0.885	0.954	0.946
	LASP	0.843	0.825	0.843	0.020	0.622	0.112

Program MARK



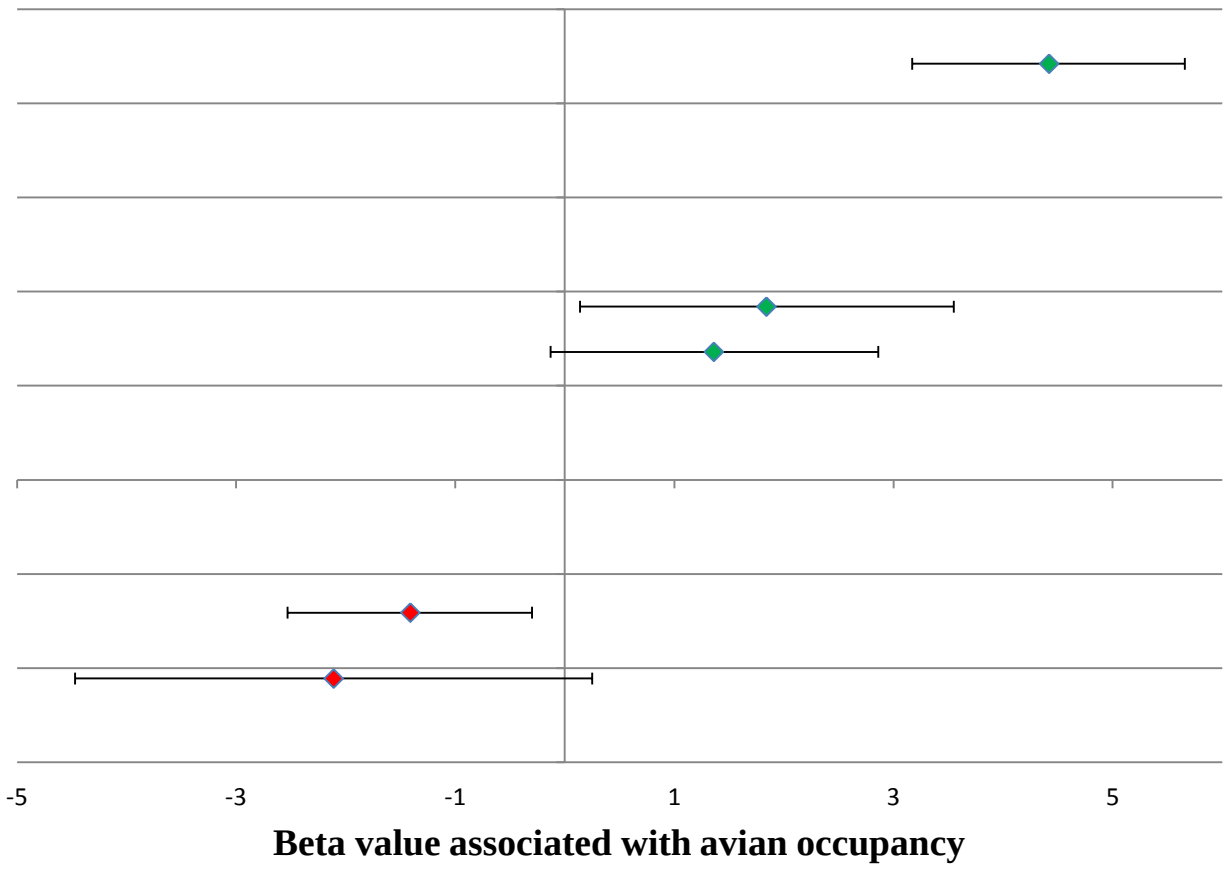
Positive Effect
Mountain Bluebird (M)

Negative Effect

Steller's Jay
Virginia's Warbler
Mountain Chickadee
Clark's Nutcracker
Gray Flycatcher
White-breasted Nuthatch

Beta estimate ± 95% CI

Landscape Occupancy (Ψ) significant treatment effects



Positive Effect

Lark Sparrow (M)

Lark Sparrow (HT)
American Robin

Negative Effect

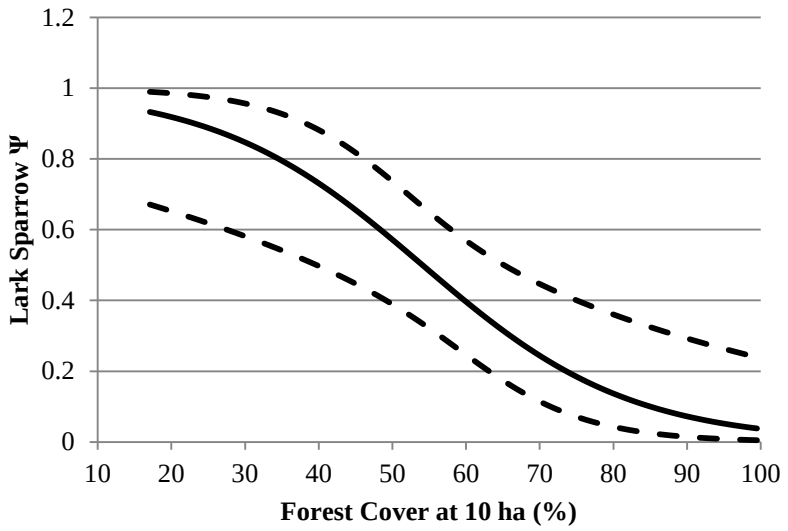
Black-headed Grosbeak (HT)
Piñon Jay

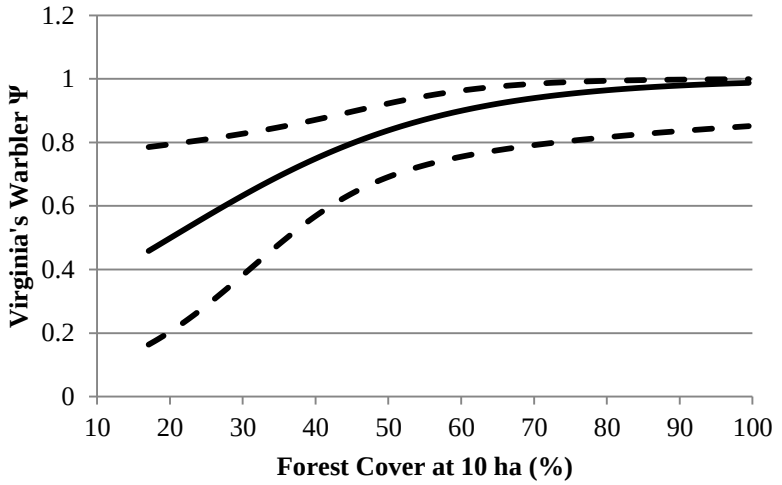
Beta estimate ± 95% CI

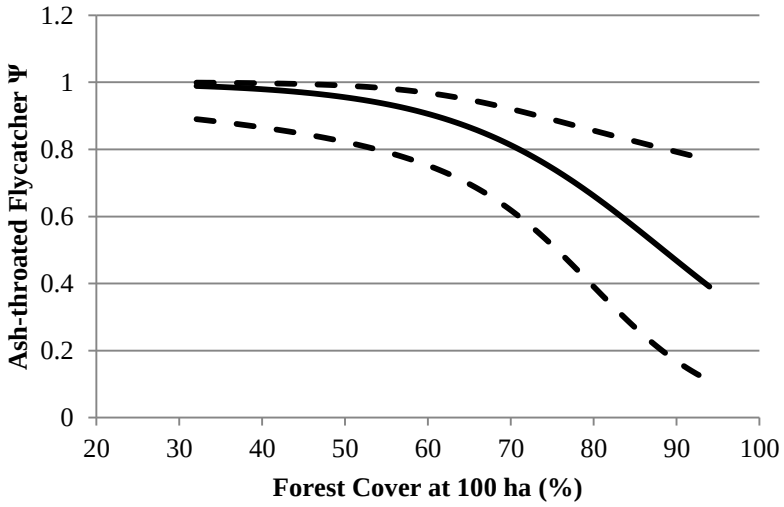
Local Occupancy (θ) significant treatment effects

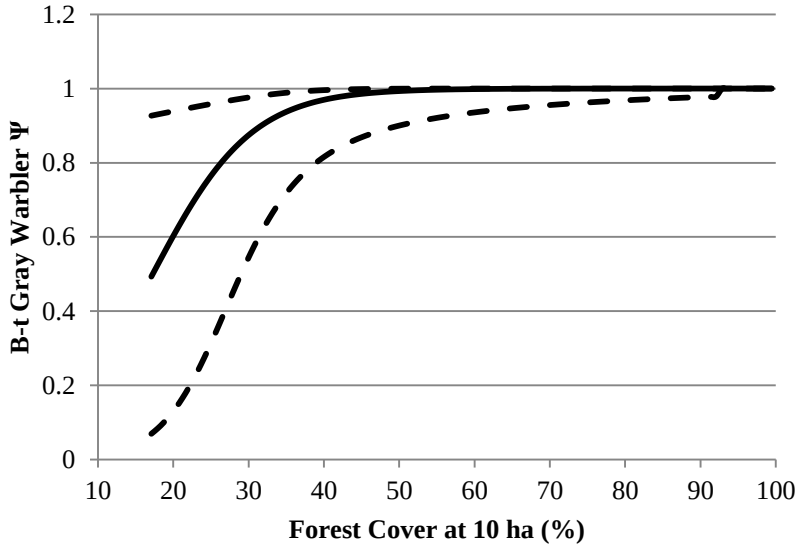
Niche	Species	Local Scale Covariates										
		Bare Ground	Herb Cover	Shrub Cover	Tree Height	StD Height	Live Count	Juniper Count	Piñon Count	Live Basal Area	Juniper Basal Area	Piñon Basal Area
Piñon-Juniper Specialist	BTYW	0.04	0.08	0.04	0.04	0.05	0.06	0.27	0.05	0.06	0.10	0.18
	VIWA Ψ	0.08	0.05	0.58	0.06	0.04	0.08	0.02	0.06	0.03	0.02	0.06
	JUTI Ψ	0.05	0.69	0.05	0.02	0.03	0.04	0.08	0.04	0.10	0.63	0.04
	PIJA θ (Ψ)	0.01	0.02	0.98	0.01	0.58	0.12	0.13	0.98	0.02	0.01	0.02
	GRFL Ψ	0.01	0.16	0.01	0.01	0.01	0.02	0.01	0.01	0.70	0.25	0.02
Mature Conifer	**WBNU Ψ**	0.05	0.53	0.04	0.17	0.03	0.11	0.10	0.07	0.15	0.09	0.10
	MOCH Ψ	0.04	0.08	0.05	0.12	0.08	0.05	0.04	0.06	0.07	0.08	0.37
	PLVI Ψ	0.38	0.06	0.07	0.05	0.75	0.03	0.29	0.05	0.67	0.14	0.20
	YRWA Ψ	0.08	0.13	0.05	0.05	0.06	0.24	0.57	0.39	0.06	0.06	0.11
Open Conifer	**CLNU Ψ**	0.12	0.12	0.03	0.21	0.13	0.02	0.02	0.02	0.03	0.04	0.05
	WETA Ψ	0.09	0.31	0.11	0.18	0.23	0.17	0.10	0.10	0.24	0.11	0.13
	CHSP	0.16	0.12	0.08	0.09	0.11	0.15	0.15	0.23	0.20	0.33	0.17
	AMRO θ	0.00	0.99	0.00	0.01	0.98	0.01	0.01	0.99	0.00	0.00	0.00
	ATFL θ	0.06	0.07	0.05	0.05	0.05	0.05	0.07	0.05	0.05	0.12	0.05
Open Woodland/ Shrubland	**BGGN θ**	0.02	0.02	1.00	0.12	0.10	0.02	0.02	0.03	0.02	0.02	0.02
	BUSH θ	0.22	0.02	0.26	0.01	0.16	0.09	0.03	0.09	0.42	0.40	0.05
	SPTO	0.00	1.00	0.00	0.67	0.33	0.00	0.33	0.00	0.17	0.17	0.33
	CONI	0.04	0.08	0.03	0.06	0.05	0.02	0.05	0.04	0.06	0.04	0.42
	WEBL θ	0.10	0.54	0.20	0.12	0.07	0.06	0.15	0.09	0.07	0.44	0.07
	WEWP θ	0.08	0.15	0.04	0.29	0.05	0.10	0.04	0.38	0.05	0.04	0.04
Forest Edge	**MOBL Ψ**	0.03	0.03	0.09	0.03	0.27	0.03	0.05	0.09	0.07	0.08	0.14
	BHCO	0.05	0.04	0.94	0.17	0.26	0.04	0.33	0.05	0.06	0.56	0.06
	LASP θ	0.09	0.10	0.01	0.04	0.14	0.04	0.01	0.17	0.70	0.23	0.05
Gener-alist	BTLH θ	0.08	0.48	0.19	0.07	0.06	0.07	0.54	0.08	0.06	0.54	0.06
	BHGR θ	0.01	0.01	0.01	0.06	0.03	0.11	0.88	0.16	0.77	0.06	0.79
	NOFL Ψ	0.06	0.31	0.07	0.17	0.33	0.04	0.10	0.25	0.07	0.26	0.06

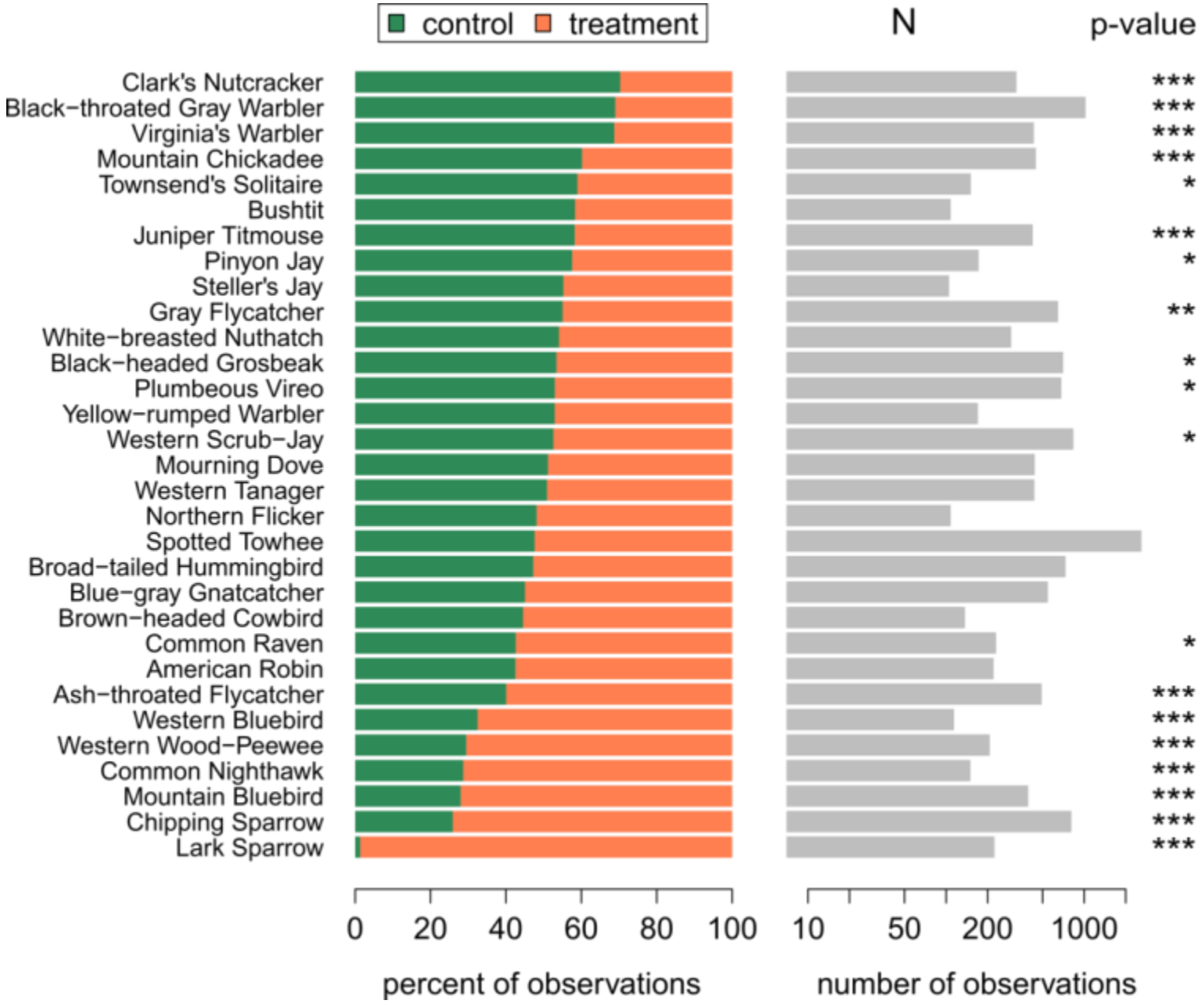
Habitat/Guild	Species	Landscape Scale Covariates						
		Year Since Treatment	Mean Annual Temperature	Mean Annual Precipitation	Elevation	Heat Load Index	Forest Cover 10 ha	Forest Cover 100 ha
Piñon-Juniper Specialist	BTYW	0.27	0.12	0.13	0.10	0.14	0.86	0.29
	VIWA Ψ	0.03	0.05	0.05	0.08	0.83	0.29	0.52
	JUTI Ψ	0.02	0.55	0.02	0.46	0.04	0.04	0.03
	PIJA θ (Ψ)	0.01	0.01	0.03	0.01	0.02	0.01	0.01
	GRFL Ψ	0.14	0.32	0.81	0.47	0.01	0.01	0.01
Mature Conifer	**WBNU Ψ**	0.16	0.18	0.11	0.85	0.14	0.02	0.03
	MOCH Ψ	0.17	0.33	0.05	0.96	0.10	0.15	0.06
	PLVI Ψ	0.01	0.02	0.03	0.04	0.12	0.02	0.02
	YRWA Ψ	0.05	0.15	0.36	0.16	0.06	0.07	0.18
Open Conifer	**CLNU Ψ**	0.14	0.27	0.16	0.75	0.60	0.16	0.06
	WETA Ψ	0.20	0.07	0.07	0.07	0.08	0.37	0.09
	CHSP	0.43	0.12	0.08	0.11	0.07	0.07	0.07
	AMRO θ	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ATFL θ	0.23	0.54	0.04	0.48	0.08	0.14	0.63
Open woodland/ shrubland	**BGGN θ**	0.02	0.07	0.01	0.97	0.03	0.03	0.03
	BUSH θ	0.16	0.14	0.37	0.10	0.36	0.07	0.05
	SPTO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CONI	0.42	0.03	0.06	0.04	0.45	0.91	0.12
	WEBL θ	0.08	0.19	0.11	0.30	0.07	0.09	0.07
	WEWP θ	0.42	0.04	0.04	0.04	0.09	0.47	0.51
Edge	**MOBL Ψ**	0.13	0.44	0.06	0.53	0.09	0.31	0.45
	BHCO	0.03	0.03	0.03	0.03	0.17	0.04	0.04
	LASP θ	0.37	0.01	0.00	0.01	0.01	0.93	0.08
Gener-alist	BTLH θ	0.06	0.09	0.11	0.09	0.06	0.09	0.06
	BHGR θ	0.01	0.01	0.01	0.01	0.05	0.01	0.02
	NOFL Ψ	0.11	0.31	0.05	0.48	0.06	0.04	0.11


Lark Sparrow Ψ
1.2
1
0.8
0.6
0.4
0.2
0
10 20 30 40 50 60 70 80 90 100
Forest Cover at 10 ha (%)


Virginia's Warbler Ψ
1.2
1
0.8
0.6
0.4
0.2
0
10 20 30 40 50 60 70 80 90 100
Forest Cover at 10 ha (%)


Ash-throated Flycatcher Ψ
1.2
1
0.8
0.6
0.4
0.2
0
20 30 40 50 60 70 80 90 100
Forest Cover at 100 ha (%)

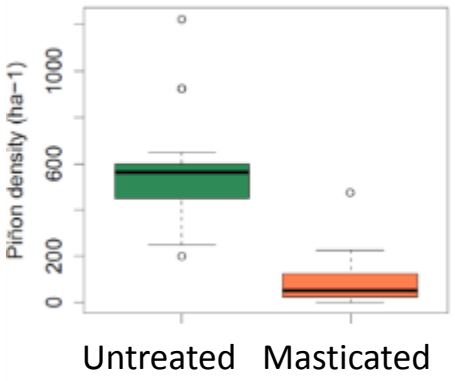

B-t Gray Warbler Ψ
1.2
1
0.8
0.6
0.4
0.2
0
10 20 30 40 50 60 70 80 90 100
Forest Cover at 10 ha (%)

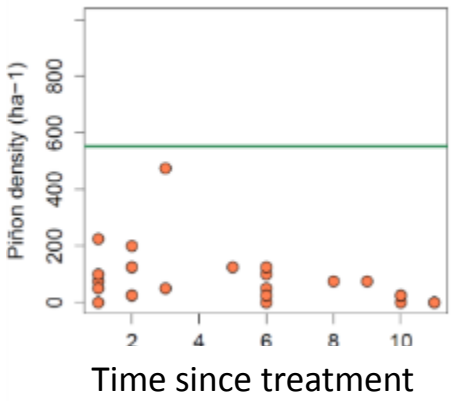

control
treatment
N
p-value
Clark's Nutcracker ***
Black−throated Gray Warbler ***
Virginia's Warbler ***
Mountain Chickadee ***
Townsend's Solitaire *
Bushtit
Juniper Titmouse ***
Pinyon Jay *
Steller's Jay
Gray Flycatcher **
White−breasted Nuthatch
Black−headed Grosbeak *
Plumbeous Vireo *
Yellow−rumped Warbler
Western Scrub−Jay *
Mourning Dove
Western Tanager
Northern Flicker
Spotted Towhee
Broad−tailed Hummingbird
Blue−gray Gnatcatcher
Brown−headed Cowbird
Common Raven *
American Robin
Ash−throated Flycatcher ***
Western Bluebird ***
Western Wood−Peewee ***
Common Nighthawk ***
Mountain Bluebird ***
Chipping Sparrow ***
Lark Sparrow ***
0 20 40 60 80 100
percent of observations
10 50 200 1000
number of observations

control vs. mastication

Vegetation

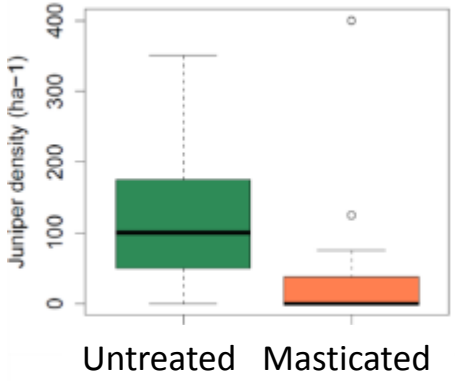
piñon density

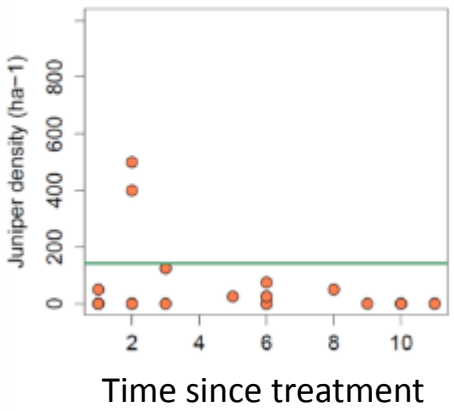




sustained decreases in piñon density, BA

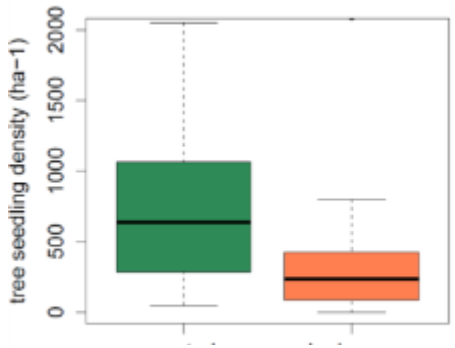
juniper density

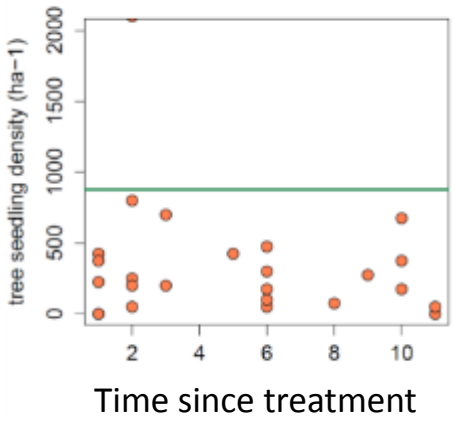




sustained decreases in juniper density, BA

tree seedlings



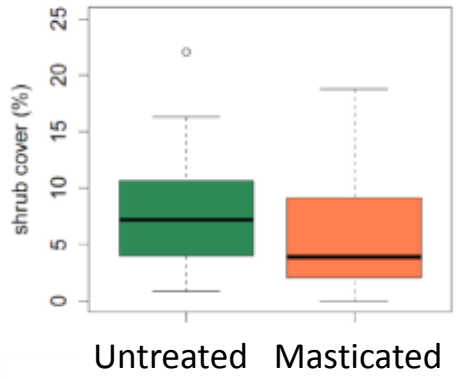


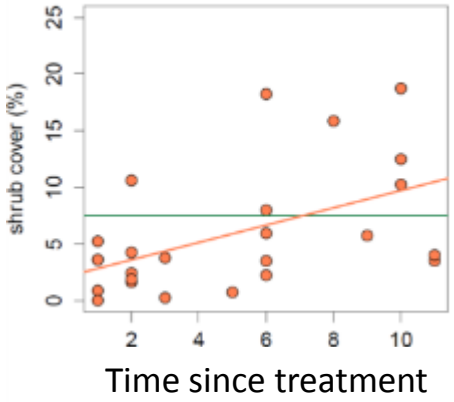
sustained decreases in woodland tree seedling density

control vs. mastication

Vegetation

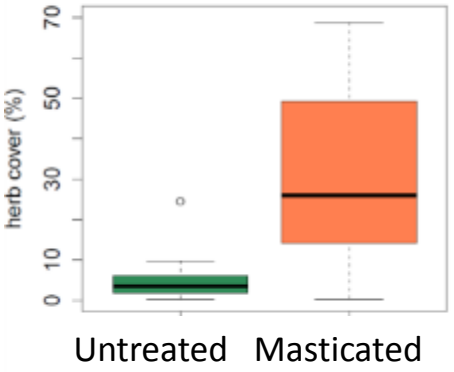
shrubs

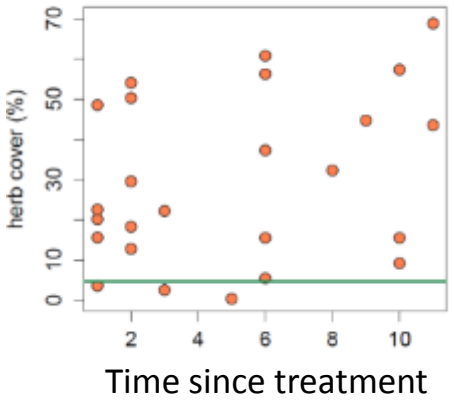




initial decrease in shrubs, but increases to > pre-treatment levels within a decade

herbs

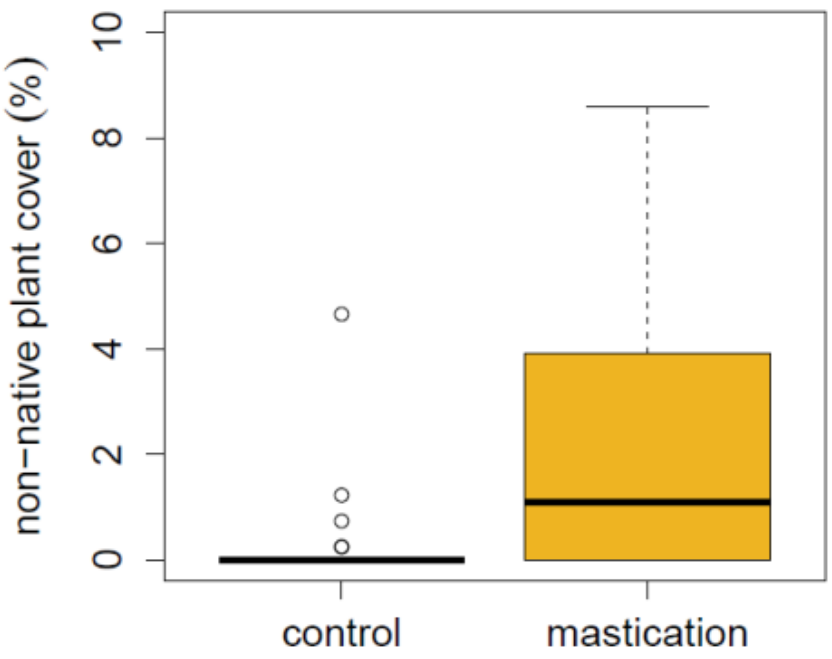




sustained increases in grasses and forbs

control vs. mastication

Non-native Species



- Significant, persistent increases in occurrence, richness, and cover by exotic plant species in treatments
- Richness of non-natives > doubled in treatments
- 20 spp. of non-natives encountered in treatments, including cheatgrass (*Bromus tectorum*), Canada thistle (*Cirsium arvense*), tumbleweed (*Salsola kali*), Jim Hill mustard (*Sisymbrium altissimum*), mullein (*Verbascum thapsus*)

Non-native Species

Relative effects of disturbance, changes in light environment, changes in surface cover?

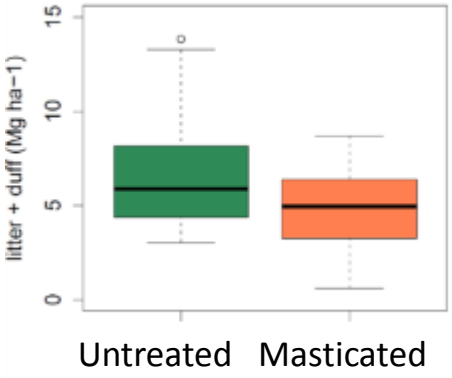
variable	treatment	canopy	on woodchip pile	next to woodchip pile
cheatgrass		**- ***	**- ****	**+ ****
other invasives	**+ ***			
all invasives	**+ ***		**- ****	**+ ***

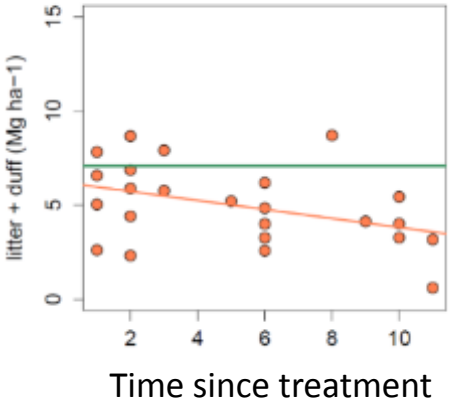
* $P<0.05$
** $P<0.01$

control vs. mastication

Dead & Down Woody Fuels

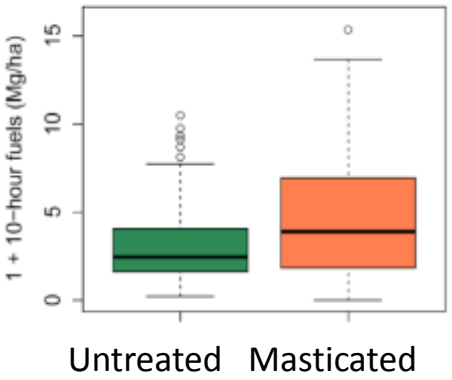
litter + duff

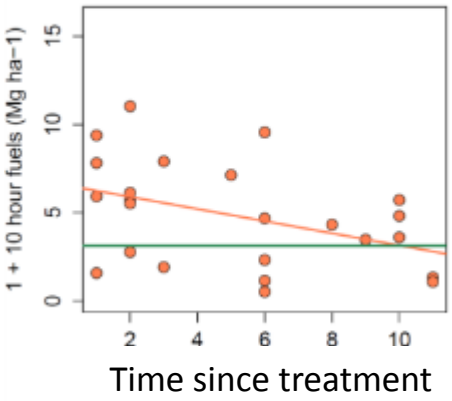




initially no change in litter and duff, but then decreases over time.

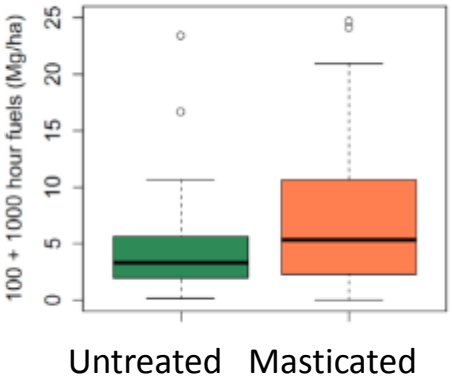
1 + 10 hour

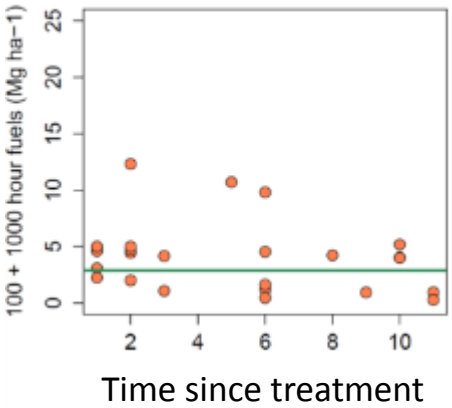




mastication increases 1 + 10 hour fuels, gradual declines toward pre-treatment levels (8-12 years)

100 + 1000 hour





increases in 100 and 1000 hour fuels in treatments

Potential Fire Behavior

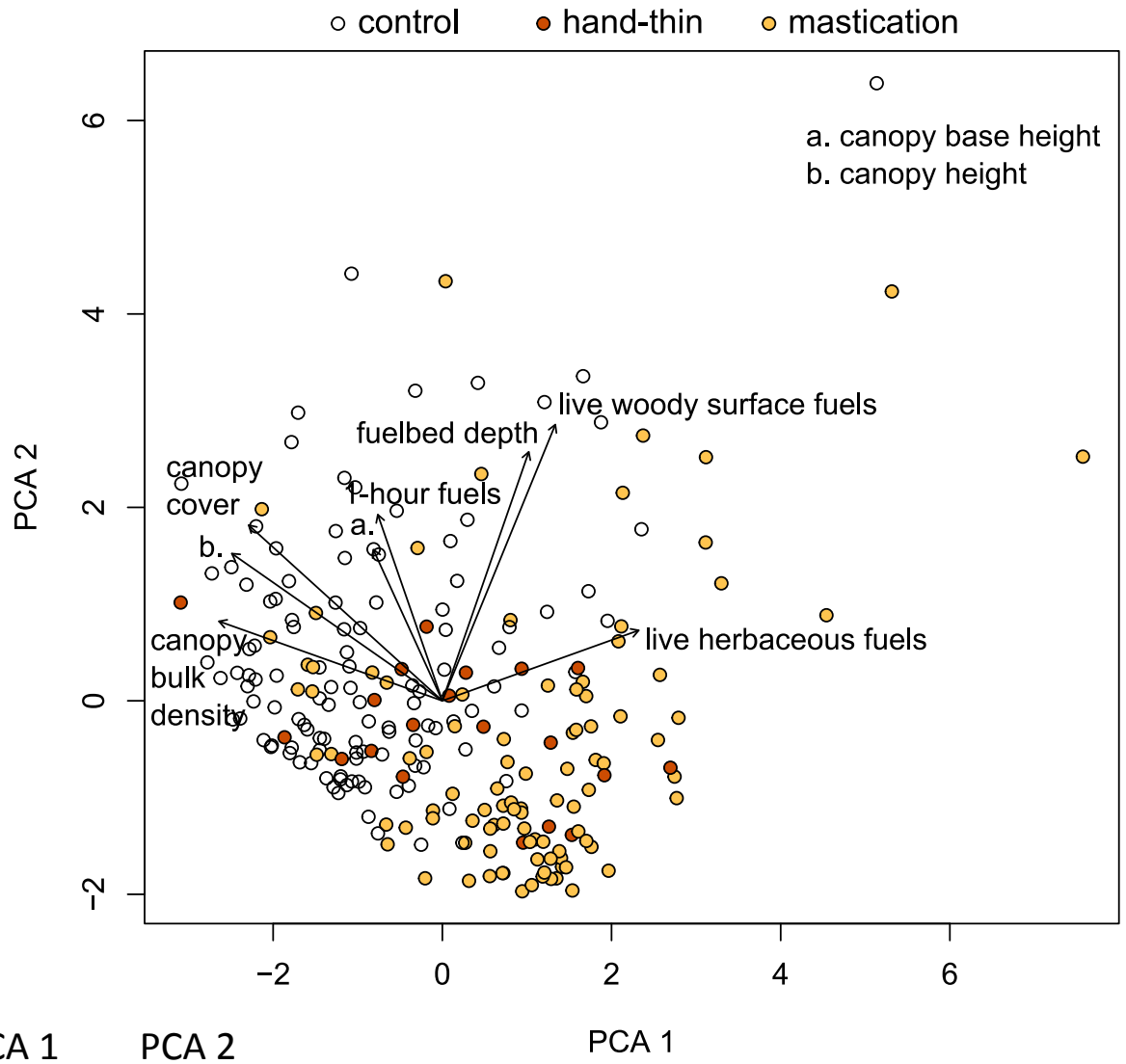
- Model fire behavior across fuels gradients under different moisture scenarios – how effective are they?
- Model fire behavior with two simulated changes to treatments: 1) **pruning** -- elevated canopy base height and 2) **surface fuel reduction**-- reduced surface fuel loads (e.g., Rx fire, pile-and-burn).

10 fuel parameters

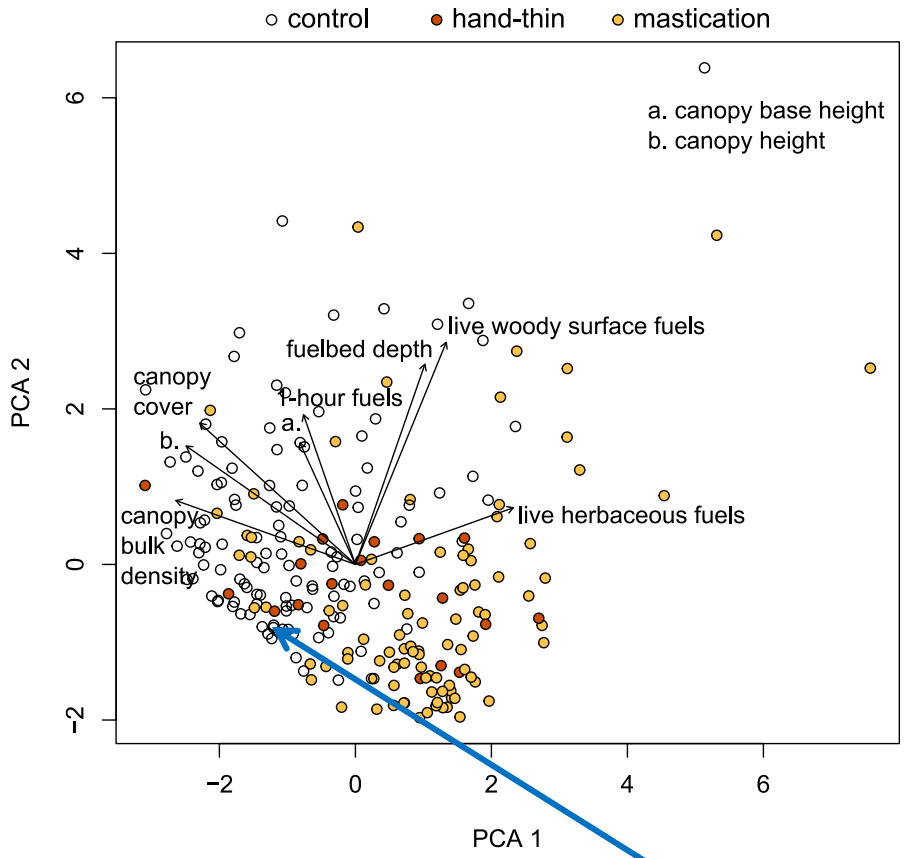
Fuel parameter	Control	Treatment	Significance
1-hour surface fuels (Mg ha^{-1})	5.2 ± 2.9	4.5 ± 2.8	*
10-hr surface fuels (Mg ha^{-1})	2.7 ± 2.5	3.8 ± 3.6	**
100-hour surface fuels (Mg ha^{-1})	2.0 ± 2.7	2.9 ± 3.0	*
Live herbaceous surface fuels (Mg ha^{-1})	0.12 ± 0.17	0.32 ± 0.43	***
Live woody surface fuels (Mg ha^{-1})	0.67 ± 1.07	0.49 ± 0.90	NS
Fuelbed depth (m)	0.14 ± 0.07	0.11 ± 0.06	**
Canopy cover (%)	**28.7 ± 24.2**	**6.2 ± 14.0**	***
Canopy height (m)	5.9 ± 3.2	2.4 ± 2.0	***
Max. canopy bulk density (kg m^{-3})	**0.34 ± 0.21**	**0.09 ± 0.15**	***
Canopy base height (m)	0.54 ± 0.41	0.38 ± 0.55	*

Principle Component Analysis of Fuel Parameters

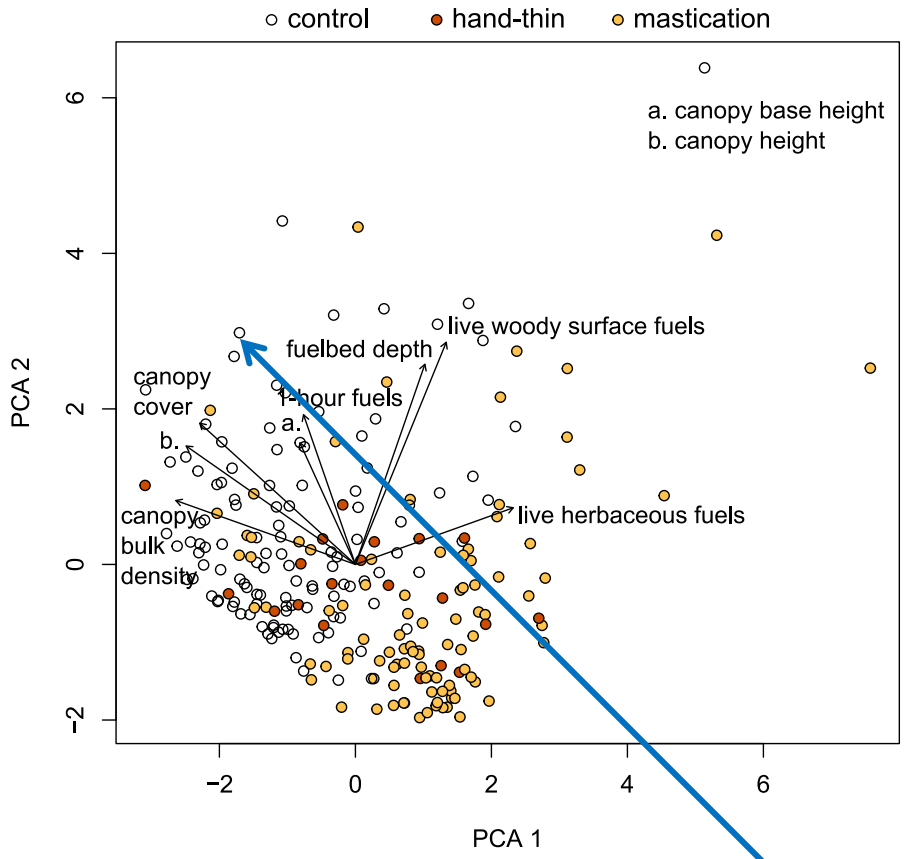
- Controls vs. treatments segregate along PCA 1 & 2
- PCA 1: corresponds with decreasing canopy bulk density, increasing grass.
- PCA 2 increases with increasing live & dead woody surface fuel loads.



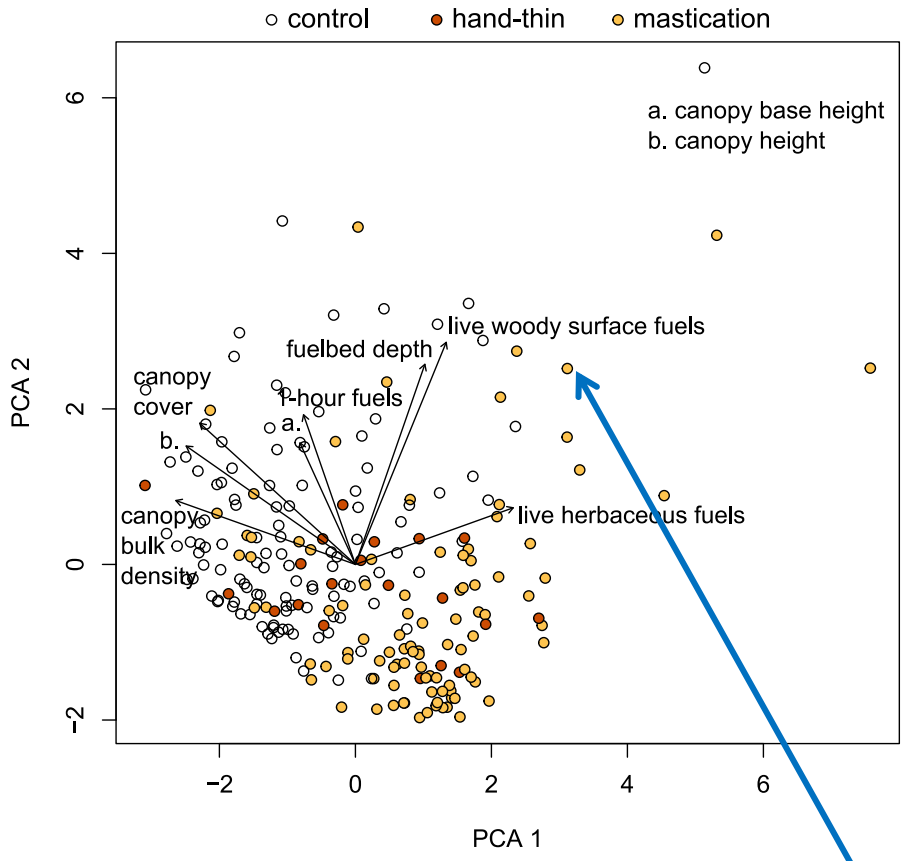
	PCA 1	PCA 2
variance explained	0.27	0.18



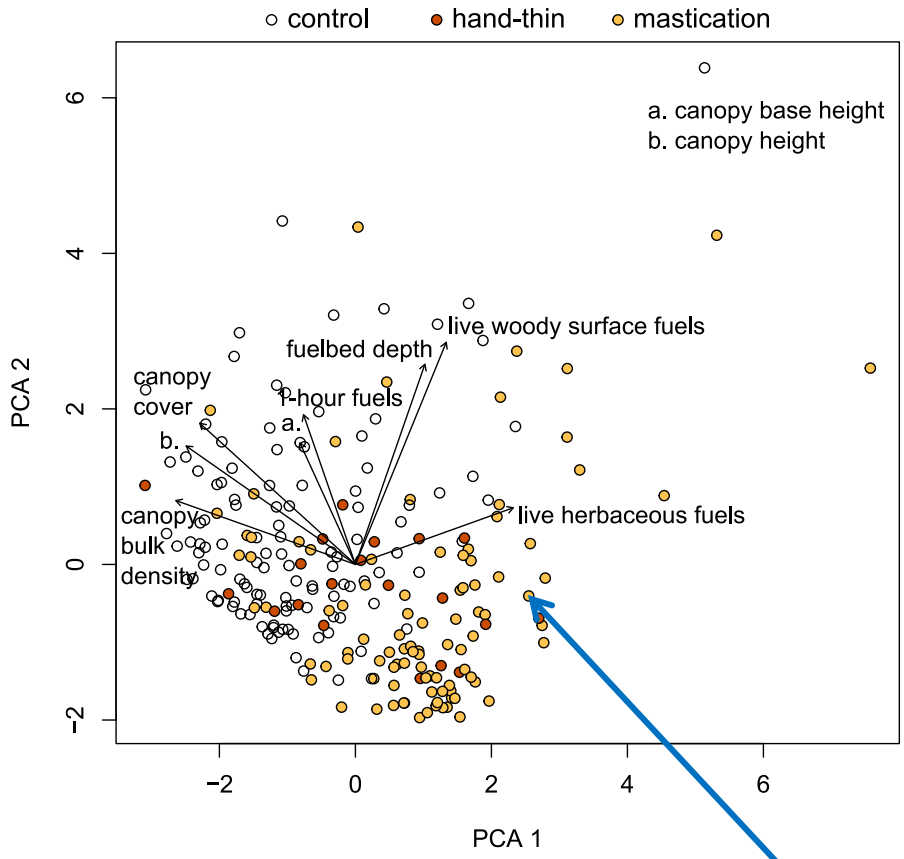
Lower Sand2 C4 (-1, -0.8)



Dawson C1 (-1.8, 2.7)



Upper Kerr HA3 (3.1, 2.5)



8 Mile Mountain HA2(2.5, -0.4)

Fire Behavior Fuel Moisture Scenarios (from nearby RAWS stations, 2011-2015)

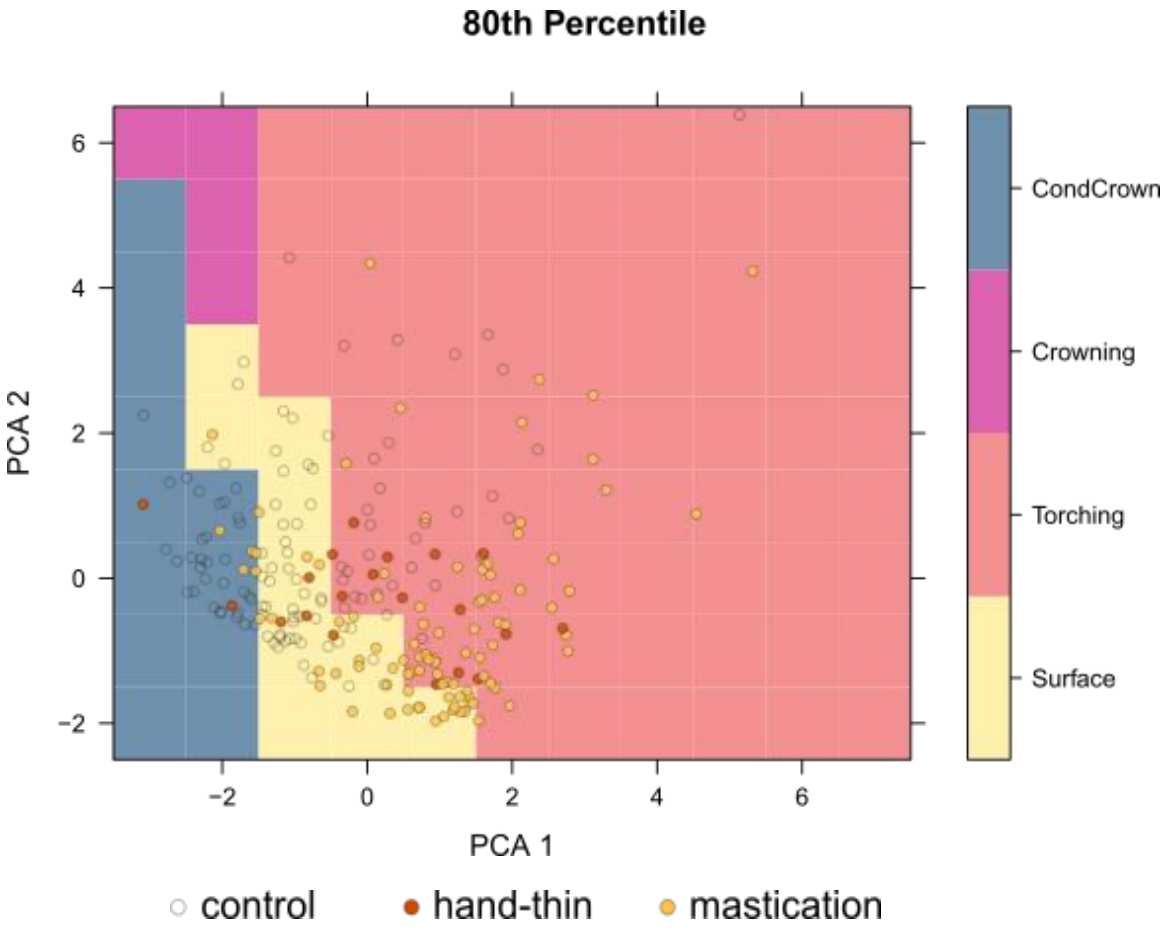
FireFamilyPlus 4.1	Percentile Conditions		
	80th	**90th**	**97th**
1-Hour Fuel Moisture	3.4	2.9	2.5
10-Hour Fuel Moisture	4.4	3.9	3.4
100-Hour Fuel Moisture	8.8	7.9	7.0
Live Herbaceous Fuel Moisture	29.2	28.2	27.3
Live Woody Fuel Moisture	73.1	69.3	64.8
20' Wind Speed (km/h)	12.2	13.2	15.3
1000-Hour Fuel Moisture	11.0	10.7	10.3

Calculated Spread Comp.	11.0	13.0	16.3
Calculated ERC	63.5	66.5	69.5

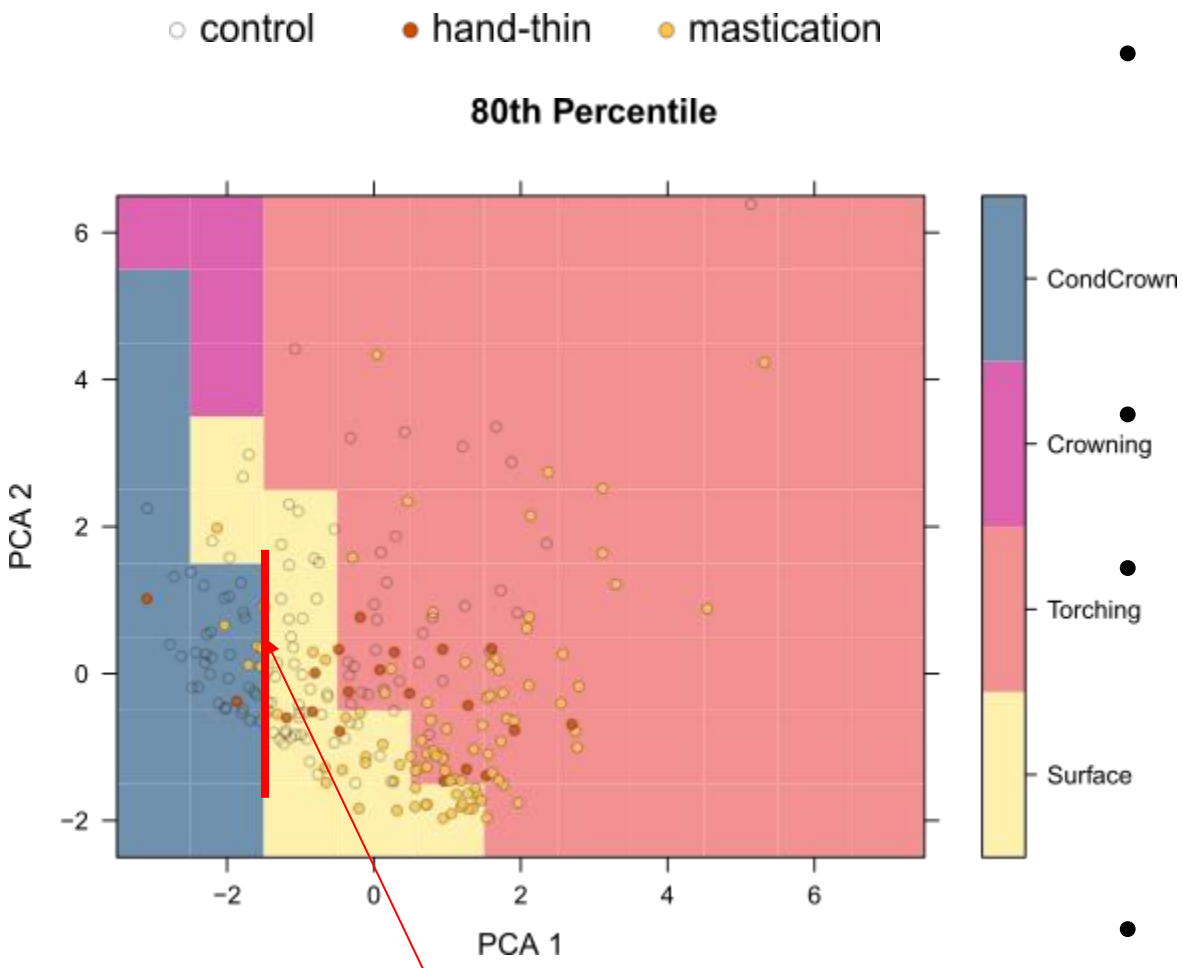
Expected Fire Behavior

Four Fire Types

1. **Surface**: fire consumes grass, down wood, but not trees
2. **Torching:** surface fire that transitions into trees, but does not spread tree-to-tree
3. **Crowning**: fire transitions into canopy and spreads tree-to-tree
4. **CondCrown**: fire cannot transition into canopy, but if it did, would spread tree-to-tree



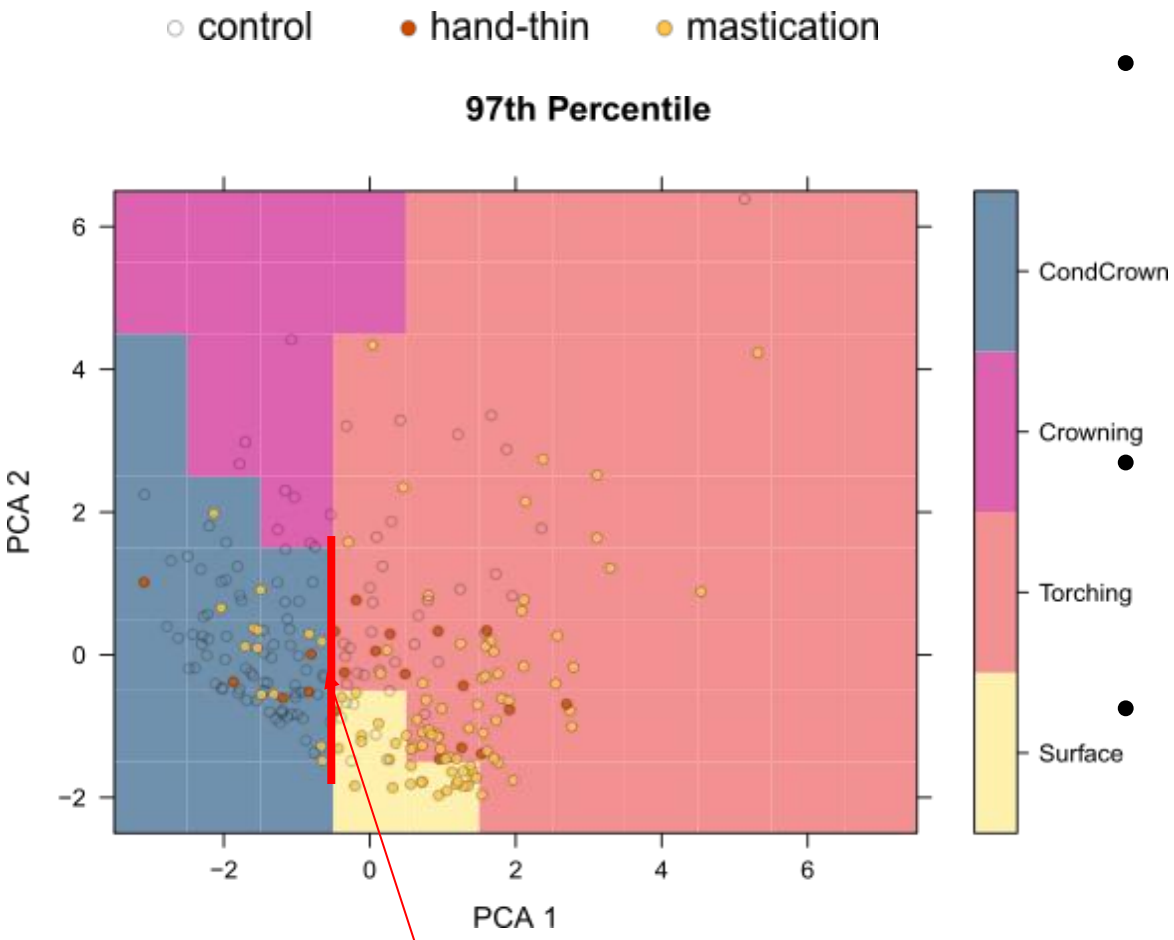
Expected Fire Behavior



Canopy bulk density > 0.4 kg m^{-3}
Canopy cover > 30-50%

- Across most burning conditions (80th percentile), treatments effectively reduced crown fire risk, but
- most untreated stands were not at risk,
- treatments reduced far more trees than needed to reduce risk--reduction to 30-50% canopy cover sufficient, and
- most remaining trees in treatments are still at high risk of torching.

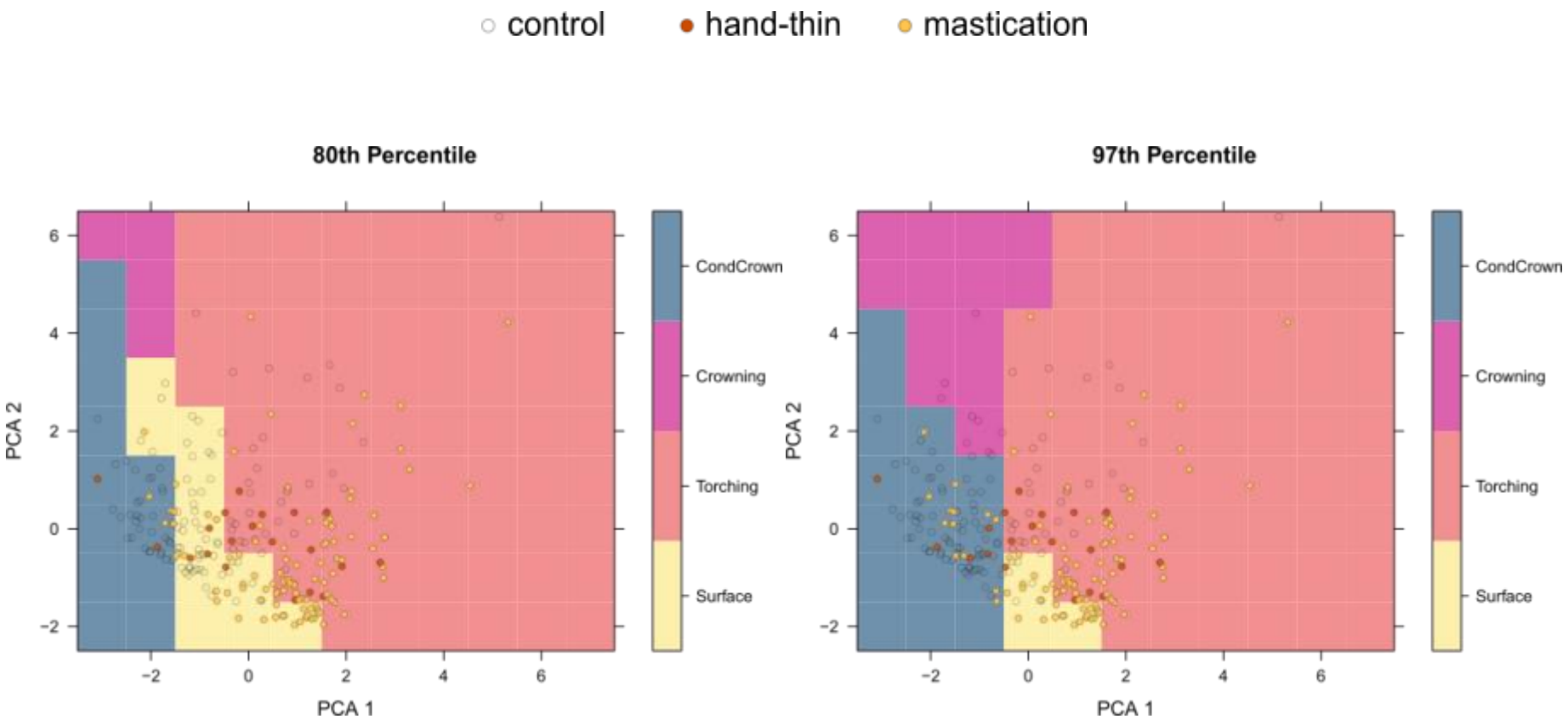
Expected Fire Behavior



Canopy bulk density > 0.3 kg m^{-3}
Canopy cover > 15-35%

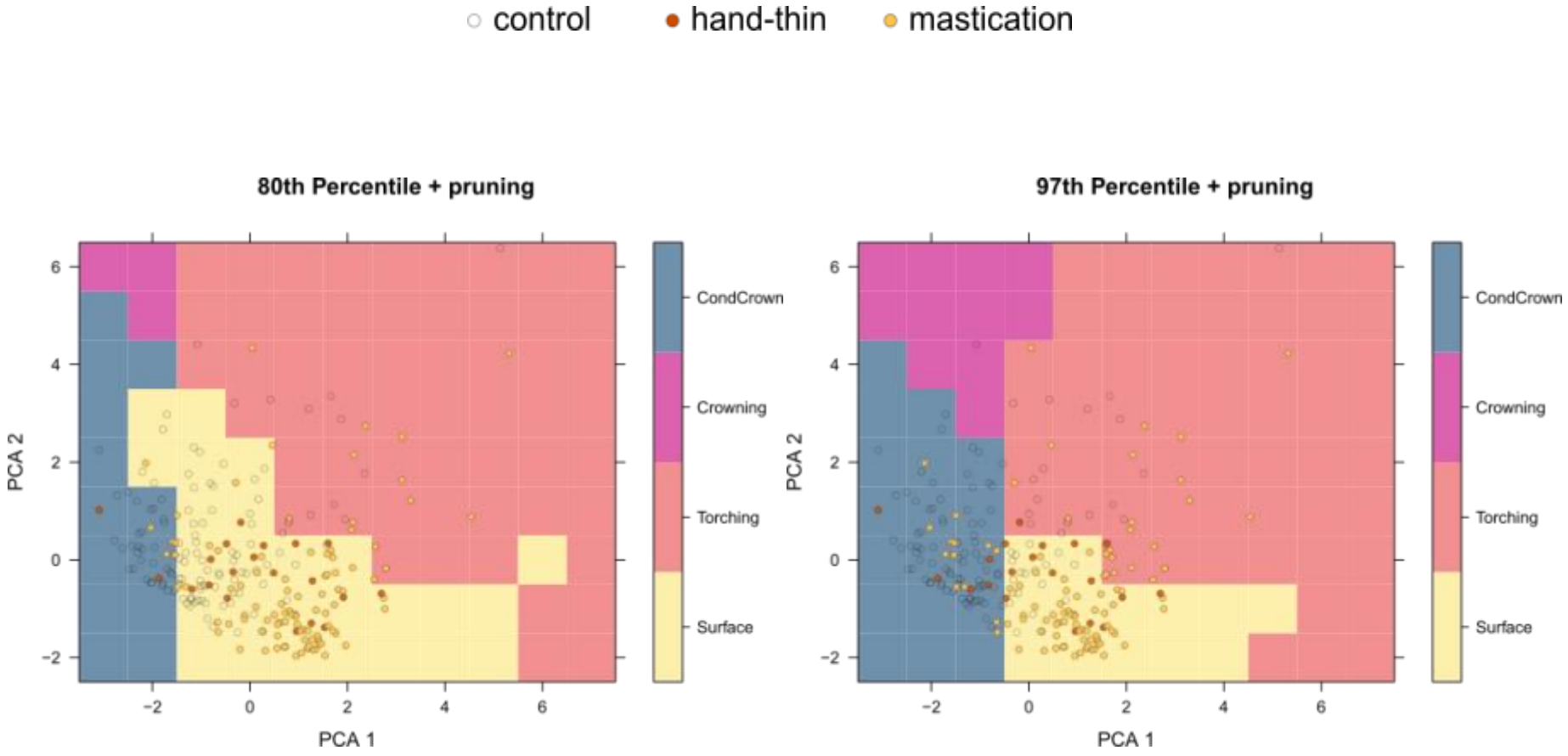
- At 97th percentile conditions, reduction between 15-35% canopy cover sufficient to reduce crown fire risk.
- Untreated stands showed higher risk of crown fire, but
- conditional crown fire in much of these stands suggest crown fire is contingent on transition to crown fire elsewhere.
- Lots of torching.

What about treatment modifications that might decrease risk of transition from surface to crown fire?



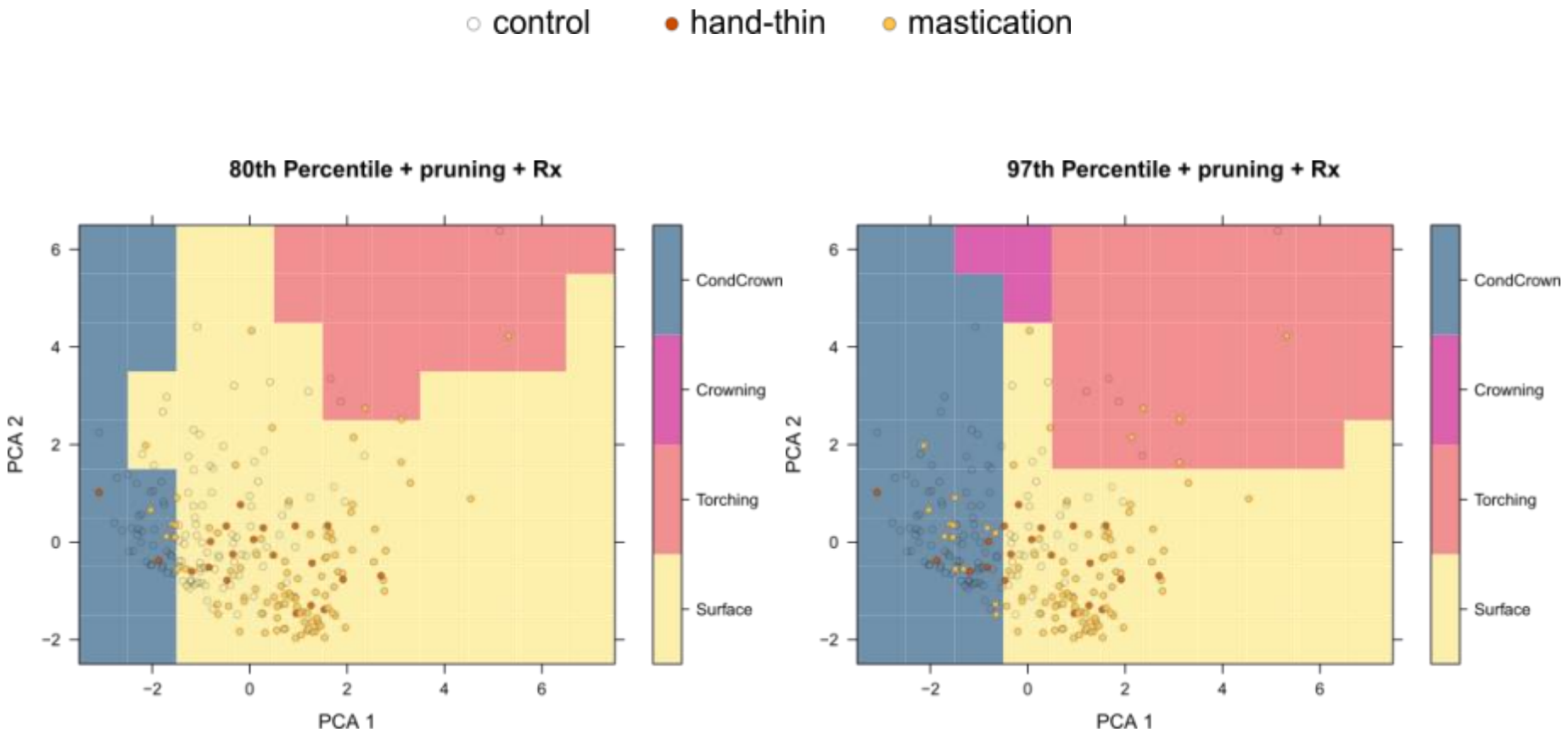
- Raising canopy base height (pruning)
- Reducing surface fuel loads (Rx fire or pile burns)
- Can’t do this with a hydro-ax.

Pruning crown bases to 1.5-m height



- Pruning sufficient to reduce torching in most cases, especially under moderate 80th percentile conditions.

Pruning + surface fuel reduction (e.g., Rx fire).



- Pruning + Rx fire highly effective under both 80th and 97th percentile conditions.

Conclusions/Management Implications

- PJ fuel treatments can reduce active crown fire hazard, but may impart undesirable effects on native species and ecological communities.
- 13 of 26 bird species respond negatively to treatments, including high conservation priority PJ and conifer forest obligate species.
- Non-native species increases in treatments suggest need for proactive and reactive strategies.
- Across a wide range of sites and moisture scenarios, treatments may not be needed (especially given likely future drought-caused dieback). Focus treatments on WUI.
- For more ecologically friendly (and fire resistant) stands:
  1. Retain more trees (canopy cover ca. 15-50% probably sufficient, depending on objectives)
  2. Raise canopy base height
  3. Reduce surface fuels in treatments

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Thoughts/questions?

jcoop@western.edu
pmagee@western.edu