Mexican Spotted Owl Habitat Monitoring
Flagstaff Watershed Protection Project
Mormon Mountain Area

Progress Report

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Introduction

In 2015 the Ecological Restoration Institute (ERI) at Northern Arizona University continued progress on a project to investigate Mexican Spotted Owl (MSO) responses to changes in habitat characteristics associated with the Flagstaff Watershed Protection Project (FWPP) hazardous fuels reduction treatments. This work is being done in collaboration with the US Fish and Wildlife Service (FWS), the US Forest Service (FS), and the Greater Flagstaff Forests Partnership (GFFP). For detailed background information, see Huffman et al. (2015). Progress in summer 2015 included installation of forest structure and vegetation monitoring plots and collection of pre-treatment data in the Mormon Mountain (MM) area of FWPP. The following is a progress report and summary of pretreatment data describing forest conditions in MM Protected Activity Centers (PACs). Funding for this work was provided by a USDA Forest Service grant, awarded to the Southwest Ecological Restoration Institutes (SWERI) under authorization of the Southwest Forest Health and Wildfire Prevention Act.

Methods

Study sites

In summer of 2015 the ERI installed long-term monitoring plots and sampled attributes of forest structure, vegetation, and fuels within three PACs to be treated in the Mormon Mountain area of FWPP as well as three PACs slated to remain untreated ("reference PACs") and located outside of FWPP (Figure 1). The three sampled PACs within FWPP were "De Toros", "Mormon Mountain North", and "Weimer Springs". The three Control PACs outside FWPP were "Dairy Springs", "Moore Well", and "Red Raspberry". PACs were 582-870 acres in size and ranged from 7,269 to 8,397 feet in elevation, with Mormon Mountain North being the lowest in elevation and De Toros the highest (Table 1). Annual precipitation varies from approximately 20 to 28 inches across the six PACs. Soils are derived from primarily mixed igneous parent material

and are classified in the Alfisol and Mollisol soil orders (Table 1). Common forest overstory species include ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.), Gambel oak (*Quercus gambellii* Hutt.), and quaking aspen (*Populus tremuloides* Michx.).

Field sampling

To characterize forest structure, vegetation, and fuels, we established 27-38 long-term monitoring plots in each of the six PACs. We used a stratified random sampling design with an intensity of approximately one plot per 22 acres. Plot stratification was based on treatment type within PACs. Plots were randomly located within treatments using a geographic information system (GIS; ArcView 9.3).

In the field, we navigated to plot locations using handheld geographic positioning system (GPS) units. We used Garmin 12 GPS units that have a nominal accuracy of 15 m (root mean square error). At each location, we drove a small piece (3/4" x 8") of steel rebar into the soil to monument the plot for future relocation. On each piece of rebar, we affixed an aluminum tag, on which the site and plot number was embossed. We also nailed an aluminum reference tag to the base of a large, live tree nearby and embossed the distance and direction to the rebar on this tag. Tree reference information was recorded in an electronic database. Using the rebar as the center point, we sampled forest structure, and vegetation using nested, circular plots (Fig. 2). Within a 0.2-ac plot, we located snags (standing dead trees ≥ 11.8 inches (30 cm) diameter at breast height (dbh; 4.5 feet above the ground surface). Each snag was identified to species and measured for dbh and total height. Within a nested 0.10-ac plot, we located all live trees ≥ 1 inch dbh. Tree species was recorded and all live trees were measured for dbh, total height, and crown base height. Numbered aluminum tags were nailed to all snags and live trees on each plot.

Also within the 0.1-ac plot, we located dead and down logs. Logs were tallied in 3 size classes; *small logs*: 3.3 - 9.7 feet in length and 7.9 - 14.7 inches diameter at large end; *medium logs*: ≥ 9.8 feet in length and 7.9 - 14.7 inches diameter at large end; and, *large logs*: > 9.8 feet in length and > 14.8 inches diameter at large end.

In smaller nested plots (0.025-ac) centered on the rebar, we tallied small trees (< 1 inch dbh) and tree seedlings (< 4.5 feet height) (hereafter "regeneration"). For each individual tallied, we recorded species and condition (live or dead). We also tallied shrubs by species in these plots. We did not assign numbered tags to regeneration or seedlings.

At each plot location, we sampled dead woody surface fuels on two 50-foot planar transects according to methods described in Brown (1974). The two transects were systematically oriented along south and west cardinal directions radiating outward from the center point rebar. Woody fuels were tallied in the following moisture-lag classes: 1) 1-hour (diameter 0.1-0.25 inches); 2) 10-hour (diameter 0.26-1.0 inches); 3) 100-hour (diameter 1.1-3.0 inches); and 4) 1000-hour (diameter > 3 inches). The largest class (1000-hour) was additionally subdivided into sound and rotten categories.

Planar transects used for surface fuels measurements were also used to estimate canopy cover. Along each transect, canopy cover "hits" (yes/no) were determined at 10 equally spaced points using a sighting tube-type densitometer. Thus, 20 canopy cover points were sampled on each plot.

Lastly, we collected digital photographs at each plot. Photos were taken from two cardinal points (north and east) on the boundary of the nested overstory plot. Photos were taken from

points toward the center rebar. Digital photos and all data described above were archived and stored electronically on a data server maintained by the ERI.

Analysis

For pretreatment summaries, we calculated means and standard deviations of forest structure, vegetation, and fuels variables for individual PACs. Forest structure variables included overstory tree density (trees ac^{-1}), basal area (BA; ft^2 ac^{-1}), snag density (snags ac^{-1}) ($\geq$ 11.8 inches dbh), small, medium, and large logs (no. ac^{-1}), and density of tree regeneration and live shrubs (no. ac^{-1}). We calculated mean relative importance (RI) index values for tree species within PACs following methods adapted from Curtis and McIntosh (1951). This index was calculated for each species as the relative density ((density of each species/total density)*100) plus relative dominance ((species BA/total BA)*100). Thus, importance index values for each species within PACs ranged from 0 (not occurring) to 200 (completely monotypic). To classify composition of PACs based on importance values, we included overstory tree species with importance values > 20. We calculated canopy cover as: ((no. canopy "hits"/20)*100). To provide baseline summaries for monitoring potential fire hazard, we calculated both canopy and surface fuel loading. We used species-specific component biomass equations given in Ter-Mikaelian and Korzukhin (1997) to calculate individual tree foliage mass, then summed these amounts to calculate canopy fuel loading (CFL; lb ft^{-2}) on plots. We used equations in Brown (1974) to calculate woody surface fuel loading (t ac^{-1}) by moisture-lag class. Data were summarized for each PAC in terms of habitat elements described in the MSO Recovery Plan (US Fish and Wildlife 2012).

Results

Stand structure and vegetation

Tree species composition varied across the six PACs sampled (Table 1). Based on relative importance (RI) values, all PACs should be considered warm/dry mixed conifer forests (see Reynolds et al. 2013). For example, ponderosa pine and white fir were common (RI > 20) in all PACs. Ponderosa pine had the highest relative importance in the Moore Well, Mormon Mountain North, Red Raspberry, and Weimer Springs PACs. White fir had the highest importance in Dairy Springs and De Toros PACs. Gambel oak was present in all PACs and showed highest RI values of 58 and 60 in Red Raspberry and Weimer Springs. Douglas-fir was present in all PACs but only showed RI values > 20 in Dairy Springs, De Toros, and Mormon Mountain North PACs. Aspen only occurred in the De Toros PAC. Rocky mountain maple was present (RI < 20) in the De Toros, Mormon Mountain North, and Weimer Springs PACs.

Mean tree density across the six PACs ranged from 247 trees ac^{-1} (Red Raspberry) to 349 trees ac^{-1} (Mormon Mountain North) (Table 2). Smaller trees (< 8 inches dbh) were more abundant than trees in large size classes in all PACs (Fig. 3). Mormon Mountain North and Moore Well PACs had the fewest numbers of large trees (> 16 inches and > 24 inches dbh) (Table 2). Mean basal area (BA) ranged from 126 ft^2 ac^{-1} (Moore Well) to 142 ft^2 ac^{-1} (Red Raspberry). BA was highest in the Red Raspberry PAC while it had the lowest TPA. This was due to Red Raspberry having the highest numbers of large trees (>16 inches and > 24 inches dbh). Among the other four PACs, BA ranged from 127 ft^2 ac^{-1} to 133 ft^2 ac^{-1} (Table 2). De Toros had a higher percentage of total BA comprised of large trees (> 16 inches dbh and > 18 inches dbh) than the other PACs (Table 2.). Dairy Springs had a lower percentage of total BA

comprised of trees in the 12- to 18-inches dbh class than the other PACs (Table 2.). Canopy cover ranged from 49% (Mormon Mountain North) to 57% (De Toros) (Table 2).

PAC's appeared similar in canopy structure (Fig. 4). Across the six PACs, median tree height ranged between 18 and 26 feet. All PACs showed larger, emergent trees up to 90 feet in height. The Moore Well and Red Raspberry sites tended to have proportionally greater numbers of taller trees as well as greater ranges (interquartile) of tree heights than the other four PACs. The De Toros and Moore Well PACs had the lowest tree height medians (18.7 feet and 19.4 feet, respectively) (Fig. 4). Density of standing dead snags (> 11.8 inches dbh) ranged 4.8-15.5 snags ac^{-1} across all PACs. The Weimer Springs and Red Raspberry PACs had the lowest number of snags at 4.8 and 5.6 snags ac^{-1}, respectively. Density of small logs ranged from 6.2 to 29.0 logs ac^{-1} on average with Dairy Springs having the highest number of small logs (Table 3). Density of medium logs ranged from 15.1 to 41.3 logs ac^{-1} across all PACs (Table 3). Density of large logs ranged from 4.8 to 17.9 logs ac^{-1} across all PACs. The De Toros and Dairy Springs PACs had the highest density of small, medium, and large logs.

Tree regeneration was highest (2810 stems ac^{-1}) in the Weimer Springs PAC and lowest (942 stems ac^{-1}) in the Dairy Springs PAC (Table 3). More than 50% of regeneration in all PACs was Gambel oak (677-2425 stems ac^{-1}). Ponderosa pine (49-124 ac^{-1}), white fir (119-332 ac^{-1}), New Mexico locust (*Robinia neomexicana* A. Gray) (10-454 $ac^{-1)}$, and Douglas-fir (1-17ac^{-1}) regeneration was found in all PACs. Aspen (3-166 ac^{-1}) regeneration was found in all PACs except Mormon Mountain North and Red Raspberry.

Shrub density ranged from 610 individuals ac^{-1} (Red Raspberry) to 7582 ac^{-1} (De Toros) (Table 3). Oregon grape (*Berberis repens* Lindl.) was the most abundant shrub observed (235-7437 ac^{-1}) and was found in all six PACs. Other common shrubs included Woods' rose (*Rosa woodsii* Lindl.), wild raspberry (*Rubus idaeus* L.), and Fendler's ceanothus (*Ceanothus fendleri* A.Gray).

Fuel loading

Mean canopy fuel load across the six PACs ranged from 0.0.176 lb ft^{-2} (Red Raspberry and Moore Well) to 0.229 lb ft^{-2} (Dairy Springs) (Table 4) (for conversion to English units, see Methods *Analysis*). Canopy fuel load of individual species within PACs generally followed patterns of relative importance. Dead woody surface fuels ranged from 12.7 t ac^{-1} (Red Raspberry) to 96.1 t ac^{-1} (De Toros) across the six PACs (Table 5). Mean forest floor depths ranged from 0.9 inches (Weimer Springs) to 1.7 inches (De Toros) across the six PACs (Table 5).

Discussion

PACs to be treated under FWPP in the MM area were similar to one another in terms of tree species composition, stand structure, and fuel loading. For example, all the PACs to be treated are composed primarily of ponderosa pine, Gambel oak, white-fir and Douglas-fir and are considered warm/dry mixed conifer forests. Reference PACs showed similar patterns, with the Moore Well and Red Raspberry PACs being dominated by ponderosa pine. All PACs showed diverse canopy structures.

Tree densities in PACs were similar to those found in the FWPP PACs in the Dry Lake Hills area (see Huffman et al. 2105). However, these structural characteristics are substantially different than those reported in nearby warm/dry mixed conifer forests prior to Euro-American settlement and subsequent fire exclusion in the late 1800s (Cocke et al. 2005). To reduce risk of

stand replacing fire in these forests, contemporary conditions warrant restoration and fuels reduction treatments. Further, site-specific prescriptions will be needed to address variability among PACs. Fuel hazard reduction treatments will need to vary to account for existing variability in tree sizes, canopy structure and cover, and species composition. Continuation of this effort to monitor forest dynamics and MSO responses in both FWPP PACs and untreated reference PACs is of critical importance.

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Table 1. Characteristics of Protected Activity Centers (PACs). De Toros, Mormon Mountain North, and Weimer Springs are PACs that will receive Flagstaff Watershed Protection Project (FWPP) treatments. Dairy Springs, Moore Well, and Red Raspberry PACs are planned to remain as untreated reference sites. Precipitation estimates, soil parent material, and soil order information is given in Miller et al. (1995). Overstory classification reflects importance values calculated in this report (see Methods *Analysis*).

PAC	Size (ac)	Elevation (ft)	Precipitation (in)	Parent material	Soil order	Overstory*
De Toros	662	7,510-8,397	20-28	Andesite/basalt/cinders	Alfisol/Mollisol	ABCO/PIPO/QUGA/PSME
Mormon Mtn N.	612	7,269-8,295	20-28	Andesite/basalt/cinders	Alfisol/Mollisol	PIPO/QUGA/ABCO
Weimer Springs	582	7,433-7,927	20-28	Andesite/basalt/cinders	Alfisol/Mollisol	PIPO/QUGA/ABCO
Dairy Springs	698	7,467-8,379	20-28	Andesite/basalt/cinders	Alfisol/Mollisol	ABCO/PIPO/QUGA/PSME
Moore Well	680	7,620-8,321	20-28	Andesite/basalt/cinders	Alfisol/Mollisol	PIPO/ABCO/QUGA
Red Raspberry	870	7,415-7,823	20-28	Andesite/basalt/cinders	Alfisol/Mollisol	PIPO/QUGA/ABCO

* Tree species codes: ABCO (*Abies concolor*); PIPO (*Pinus ponderosa*); QUGA (*Quercus gambellii*); PSME (*Pseudotsuga menziesii*)

Table 2. Attributes (means) of forest structure within Protected Activity Centers (PACs). De Toros, Mormon Mountain North, and Weimer Springs are PACs that will receive Flagstaff Watershed Protection Project (FWPP) treatments. Dairy Springs, Moore Well, and Red Raspberry PACs will remain as untreated reference sites.

	PAC					
Structural Variable	De Toros	Mormon Mtn N.	Weimer Springs	Dairy Springs	Moore Well	Red Raspberry
Density						
Total (trees ac^{-1})	306.2	349.0	286.0	293.5	262.9	247.4
Trees ac^{-1} > 16 in	28.3	20.0	23.0	22.6	21.9	31.3
Trees ac^{-1} > 18 in	17.2	10.0	12.2	17.1	11.6	18.2
Trees ac^{-1} > 24 in	5.5	1.7	1.9	4.2	3.5	3.8
Basal Area						
Total (ft^2 ac^{-1})	133.2	132.6	127.6	133.2	126.0	142.3
Trees 12-18 in (%)*	35.2	36.7	38.2	26.7	43.3	37.5
Trees > 16 in (%)*	51.2	30.9	38.2	41.2	41.0	48.9
Trees > 18 in (%) *	38.6	19.0	25.1	35.1	28.0	34.4
Canopy cover						
Total (%)	57	49	51	50	50	52

* Percentage of total basal area comprised of trees within the size (diameter at breast height) ranges given.

Table 3. Density (mean no. ac^{-1}) of snags, logs (small, medium, large), tree regeneration, and shrubs within Protected Activity Centers (PACs). De Toros, Mormon Mountain North, and Weimer Springs are PACs that will receive Flagstaff Watershed Protection Project (FWPP) treatments. Dairy Springs, Moore Well, and Red Raspberry PACs will remain as untreated reference sites.

PAC	Snags (≥ 11.8 in dbh)	Small Logs*	Medium Logs*	Large Logs*	Tree regeneration	Shrubs
De Toros	15.5	14.1	33.1	17.9	2444	7,582
Mormon Mtn N.	9.1	6.2	31.4	4.8	2208	4,587
Weimer Springs	4.8	11.5	25.6	12.6	2810	1,327
Dairy Springs	13.2	29.0	38.7	14.2	942	3,241
Moore Well	11.9	7.1	41.3	9.4	1900	6,171
Red Raspberry	5.6	8.2	15.1	5.9	2232	610

* *Small logs*: 3.3-9.7 feet length and 7.9-14.7 in. diameter at large end; *medium logs*: ≥ 9.8 feet length and 7.9-14.7 in diameter at large end; and *large logs*: > 9.8 feet length and > 14.8 in. diameter at large end.

Table 4. Canopy fuel loading (means (lb ac^{-2}))* within Protected Activity Centers (PACs). Total canopy fuel loading along with amounts for major overstory species** are shown. Total includes all species occurring on plots (major species, plus others occurring in low abundance).

		Species				
PAC	Total	ABCO	PIPO	POTR	PSME	QUGA
De Toros	0.219	0.137	0.053	0.002	0.027	0.002
Mormon Mtn N.	0.217	0.090	0.090	0.000	0.004	0.004
Weimer Springs	0.182	0.061	0.104	0.000	0.006	0.006
Dairy Springs	0.229	0.115	0.084	0.000	0.004	0.004
Moore Well	0.176	0.051	0.117	0.000	0.004	0.004
Red Raspberry	0.176	0.033	0.131	0.000	0.008	0.008

*Canopy fuel loading is commonly given in metric units.

** Tree species codes: ABCO (*Abies concolor*); PIPO (*Pinus ponderosa*); POTR (*Populus tremuloides*); PSME (*Pseudotsuga menziesii*); QUGA (*Quercus gambelii*)

Table 5. Woody surface fuels (means) within Protected Activity Centers (PACs). De Toros, Mormon Mountain North, and Weimer are PACs that will receive Flagstaff Watershed Protection Project (FWPP) treatments. Dairy Springs, Moore Well, and Red Raspberry PACs will remain as untreated reference sites.

PAC	Litter depth (in)	Duff depth (in)	1-hour ($t\ ac^{-1}$)	10-hour ($t\ ac^{-1}$)	100-hour ($t\ ac^{-1}$)	1000-hour sound ($t\ ac^{-1}$)	1000-hour rotten ($t\ ac^{-1}$)
De Toros	0.3	1.3	0.27	0.91	3.93	40.02	49.37
Mormon Mtn N.	0.3	1.0	0.34	0.92	2.88	13.66	12.78
Weimer Springs	0.4	0.5	0.12	0.34	1.21	6.23	5.50
Dairy Springs	0.4	0.9	0.17	0.74	3.33	20.98	33.58
Moore Well	0.5	1.0	0.16	0.71	1.83	28.66	29.32
Red Raspberry	0.4	0.8	0.11	0.39	1.08	5.27	4.67

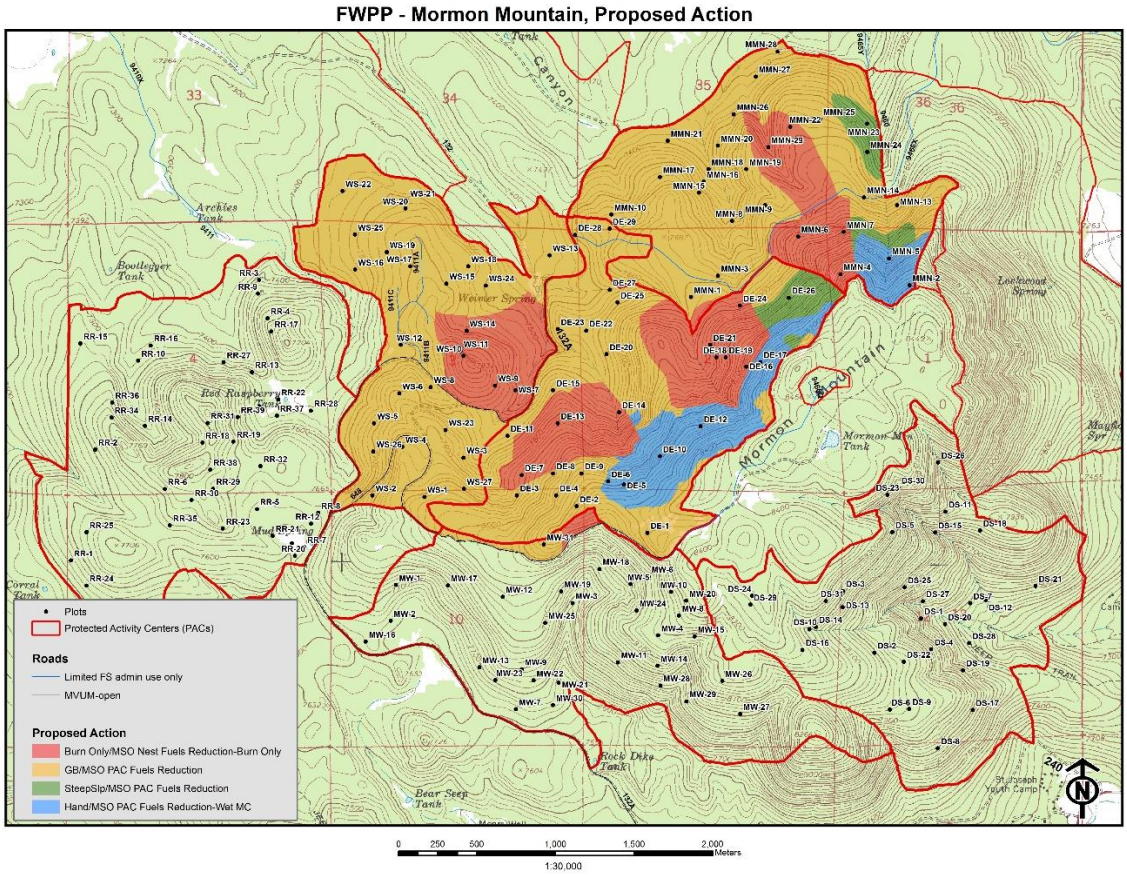

Figure 1. Map showing location of Protected Activity Centers (PACs) and long-term monitoring plots sampled by the Ecological Restoration Institute in 2015. PACs to be treated (filled polygons) in the Mormon Mountain Area as a component of the Flagstaff Watershed Protection Project are shown (FWPP PAC) as well as PACs outside FWPP (open polygons) that will remain as untreated reference sites.

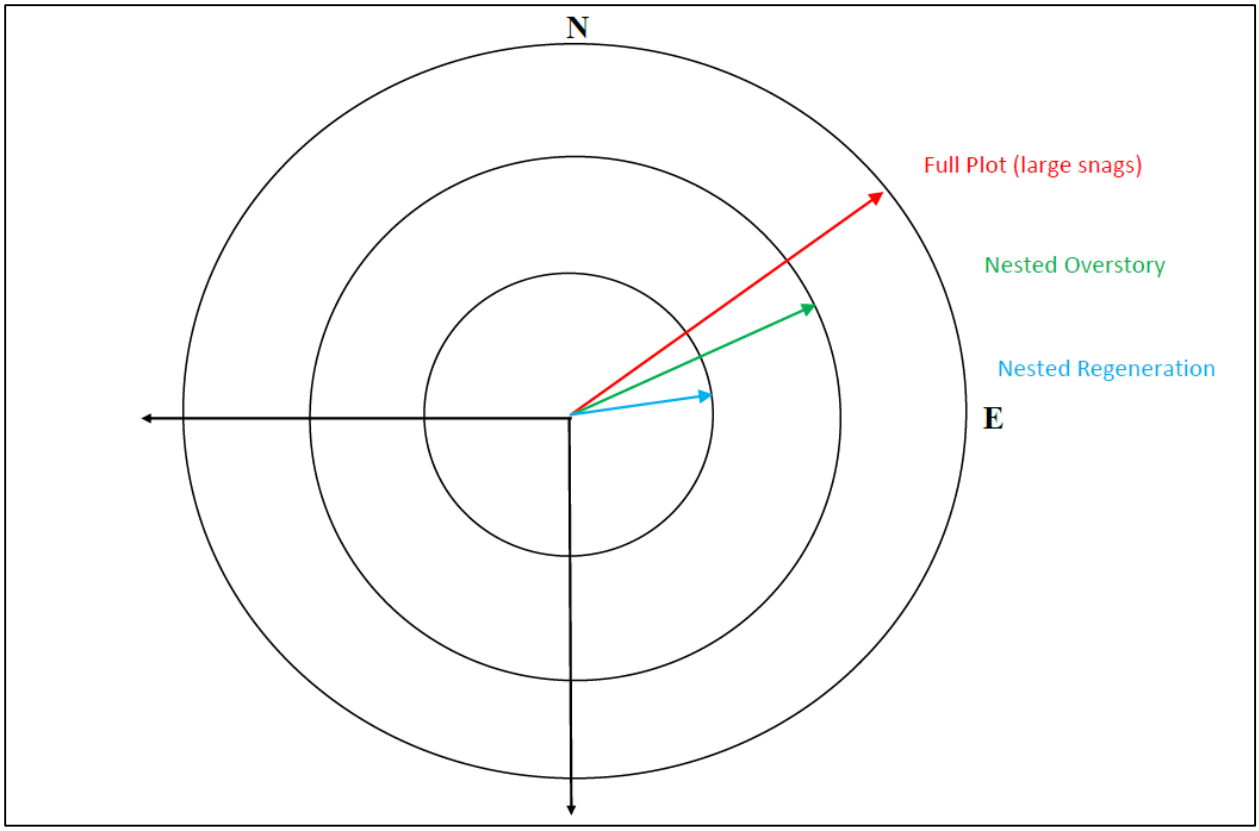

Figure 2. Diagram showing layout of plots used to sample large snags (Full Plot), overstory trees (Nested Overstory), and small trees, tree seedlings, and shrubs (Nested Regeneration). Also shown are two planar transects used to sample woody surface fuels oriented along the south and west cardinal directions (solid black lines with arrows).

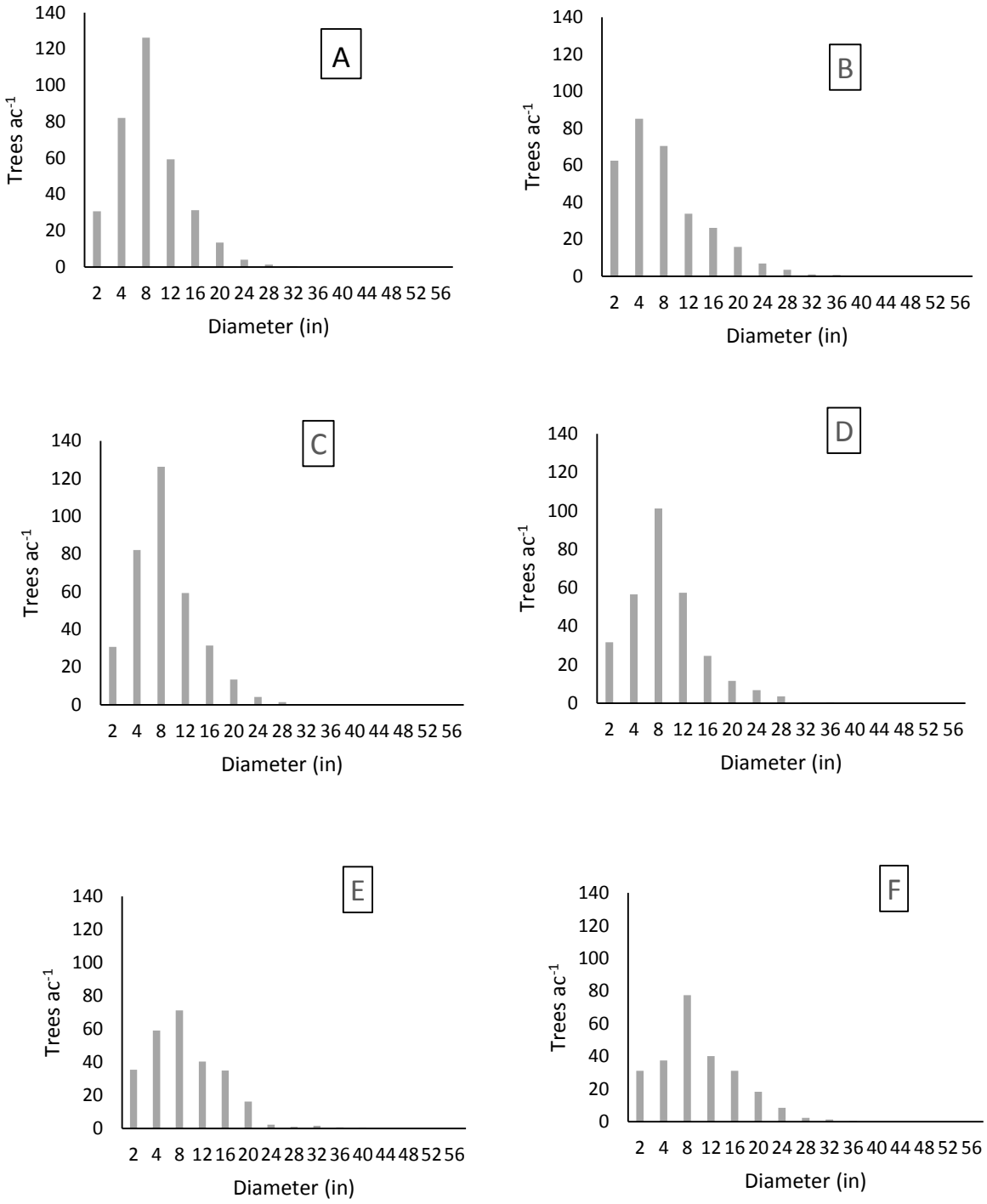

Figure 3. Tree diameter (diameter at breast height (dbh)) distribution within Protected Activity Centers (PACs). De Toros (A), Mormon Mountain North (B), and Weimer Springs (C) are PACs that will receive Flagstaff Watershed Protection Project (FWPP) treatments. Dairy Springs (D), Moore Well (E), and Red Raspberry (F) PACs will remain as untreated reference.

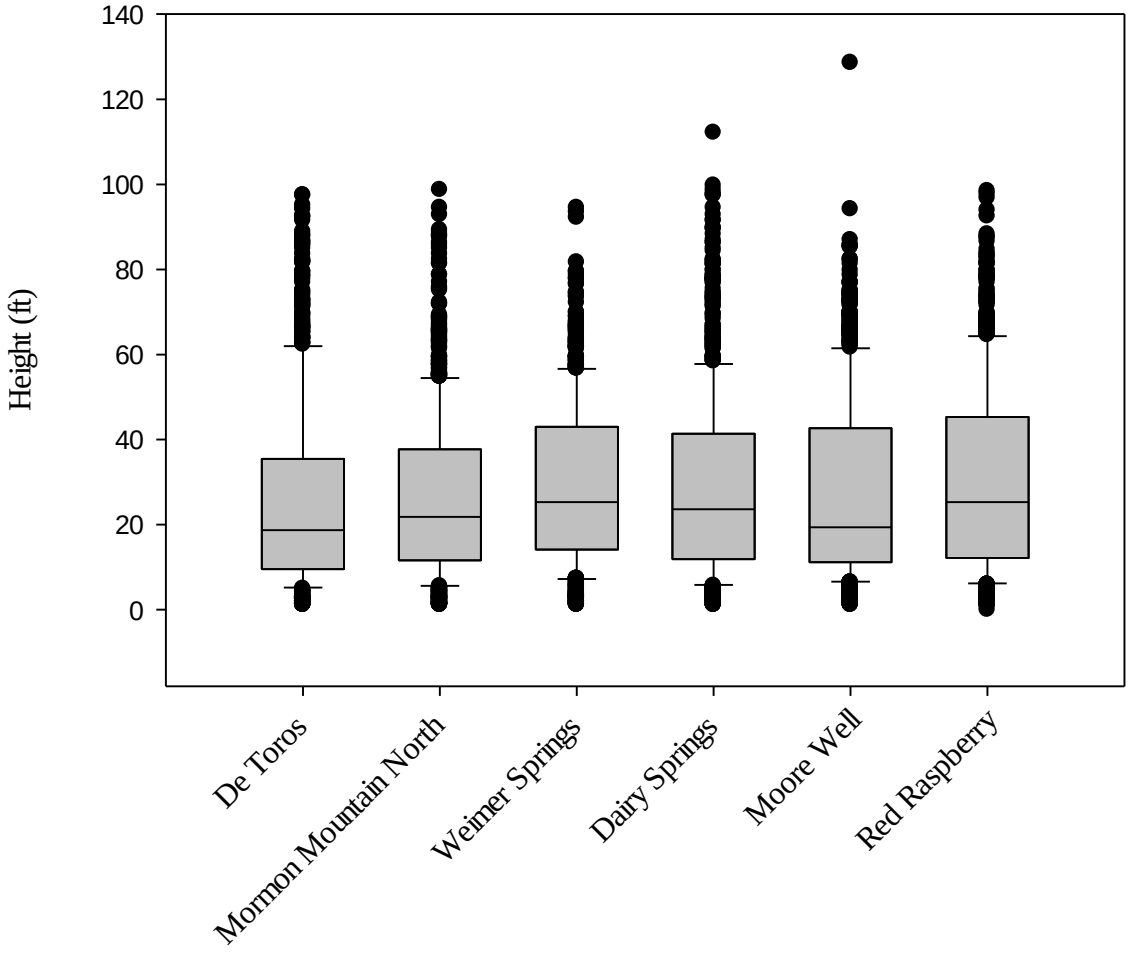

Figure 4. Distribution of tree heights (feet) within Protected Activity Centers (PACs). Box plots show median (horizontal line), data quartiles (box outline and bars), and outliers (filled circles). De Toros, Mormon Mountain North, and Weimer Springs are PACs that will receive Flagstaff Watershed Protection Project (FWPP) treatments. Dairy Springs, Moore Well, and Red Raspberry PACs will remain as untreated reference sites.