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RESEARCH ARTICLE

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ABSTRACT: Natural area managers in regions of the semi-arid west, particularly on the Colorado Plateau, are presently dealing with expanding pinyon (*Pinus* spp. Engelm.) – juniper (*Juniperus* spp. Engelm.) woodlands on rangelands. Increased equipment costs associated with 'chaining', and dangers associated with prescribed fires, have resulted in more instances where mechanical thinning of woodlands is being used. Our 2005 to 2006 study within Grand Staircase Escalante National Monument, Utah, examined responses of breeding birds to the mechanical reduction of pinyon-juniper woodlands within a randomized 4-block design that incorporated 11 control and nine treatment bird count stations. We surveyed birds within 3.1-ha bird-count stations (n = 20) prior to, and following, pinyon-juniper mechanical reduction treatments. Thinning in April 2006 removed a mean of 92% (+ 6.4% SE) of live trees from treatment blocks. The avian guild most greatly influenced by mechanical thinning included pinyon-juniper obligate species. Species eliminated following mechanical thinning were Gray Vireo (*Vireo vicinior*) and Brown-headed Cowbird (*Molothrus ater*), while Chipping Sparrow (*Spizella passerine*) numbers were significantly reduced. Birds in the shrub-nesting guild, including the sagebrush specialist Brewer's Sparrow (*Spizella breweri*), and habitat generalists such as the Bushtit (*Psaltriparius minimus*), increased in relative abundance following treatment. We conclude that mechanical thinning within the Intermountain West has the potential for natural area managers to design treatments that can influence numbers of both pinyon-juniper and sagebrush (*Artemisia tridentata* Nutt.) steppe avian species.

Index terms: avian community changes, bird surveys, Bureau of Land Management, Colorado Plateau, Intermountain West, mechanical fuels reduction, pinyon-juniper woodlands, Utah

INTRODUCTION

Pinyon (*Pinus* spp. Engelm.) – juniper (*Juniperus* spp. Engelm.) woodlands occur over the Intermountain West on an estimated 24 to 40 million hectares, and exist extensively across the Colorado Plateau (Samuels and Betancourt 1982). The distribution of these woodlands has expanded and contracted throughout history (Tausch 1999), and presently expansion is occurring at some locations (Miller and Wigand 1994; Cole et al. 2008). Potential catalysts to this rapid expansion include historical fire suppression and livestock grazing (Johnsen 1962; West 1984; Miller and Rose 1999; Harris et al. 2003), coupled with influences of recent climate changes (Allen and Breshears 1998; Breshears et al. 2005; Gray et al. 2006).

Land managers of western natural areas are implementing fuel reduction treatments increasingly in pinyon-juniper woodlands with the twin goals of creating a habitat mosaic and reducing fuel hazards. In the past, fire and chaining were the two principal methods used to remove junipers and pinyon pines (Wink and Wright 1973; Scifres 1980). Use of chaining, which removes all standing trees and snags, became sporadic after the 1960s as treatment cost increased (Shindler 2003). Application of prescribed fire, which can be 36 times more efficient than handcutting (deHoop et al. 2006), can sometimes result in devastating crown fires within pinyon-juniper habitats (Allen 2001). Subsequent to the many pinyon pine and juniper reduction efforts over the Colorado Plateau in the 1950 to 60s, numerous trees have reemerged in chained and burned areas, necessitating re-treatment. Currently, natural area managers are using handcutting methods increasingly in place of chaining and prescribed fire. Although it can be costly and slow, handcutting can be applied in a precise manner, leaving particular tree classes or a specific percentage of trees standing (Shindler 2003).

More than 70 bird species breed within pinyon-juniper woodlands, but composition of avian community structure varies considerably among geographic regions (Balda 1987; Sedgwick 1987) and avian communities respond differently to changes in vegetation structure as woodlands encroach or retreat from sagebrush (*Artemisia tridentata* Nutt.) - or grass-dominated vegetation communities (Medin et al. 2000; Rosenstock and van Riper 2001; Knick et al. 2005). Management actions that alter succession in pinyon-juniper woodlands can result in significant changes in avian community structure (Sedgwick 1987). Bird species identified as breeding solely in pinyon-juniper woodlands have been characterized as 'pinyon-juniper specialists' (Pavlacky and Anderson 2001). Because bird species with specialized habitat requirements, or those that use their habitats unevenly, are negatively impacted by loss or changes to habitat (Stauffer and Best 1980), it would be predicted that pinyon-juniper specialists would be negatively impacted by pinyon-juniper reduction.

The objectives of our study were to: (1) describe the vegetation and breeding bird populations within a scattered pinyon-juniper woodland on a sagebrush steppe; (2) assess the effects of mechanical pinyon-juniper reduction on bird abundance, species richness, and avian community composition; and (3) provide information to natural area managers that would balance benefits to avian communities when undertaking mechanical fuel reduction treatments in pinyon-juniper woodlands.

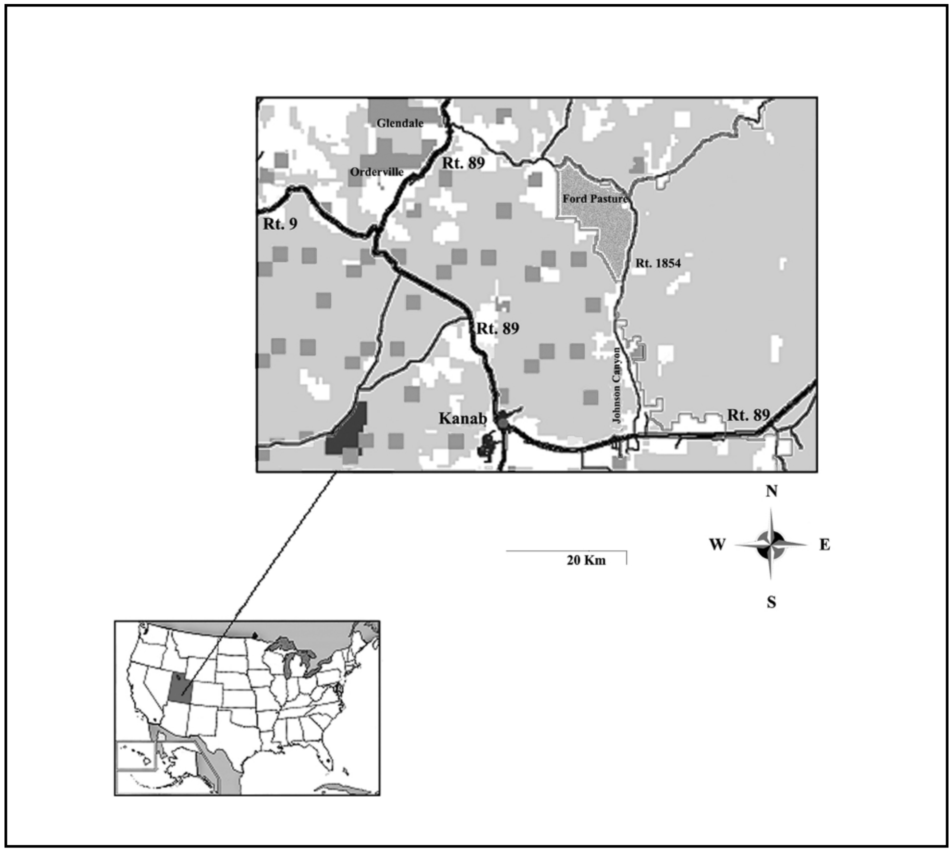

Figure 1. Ford Pasture Fuels Reduction project area, within the Bureau of Land Management, Grand Staircase Escalante National Monument, 30 km northeast of Kanab in southern Utah.

METHODS

Study Area

Grand Staircase Escalante National Monument (GSENM), administered by the Bureau of Land Management (BLM), is a 688,000 ha natural area in southern Utah. The Ford Pasture Fuels Reduction project area (hereafter called 'Ford Pasture') is in the southwest corner of the Monument, about 30 km northeast of Kanab, Utah (Figure 1). The climate in this region is arid, with the ~34 cm of annual precipitation bimodal, with 51% falling between November and March (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?utkana).

Our Ford Pasture study area was at an elevation of 2000 m on a sagebrush steppe, with scattered pinyon-juniper woodlands (Figure 2). Dominant trees were Utah juniper (*Juniperus osteosperma* Torr.) and two-needle pinyon-pine (*Pinus edulis* Engelm.), distributed patchily in the relatively flat sagebrush-dominated area. Tall shrub species included Gambel oak (*Quercus gambelii* Nutt.) and Utah serviceberry (*Amelanchier utahensis* Koehne). Rubber rabbitbrush (*Chrysothamnus nauseosus* Pall.) and occasional patches of sticky-leaved rabbitbrush [*Chrysothamnus viscidifloris* (Hook.) Nutt.] were scattered among Great Basin big sagebrush (*Artemisia tridentata* Nutt.). Herbaceous plants included daisies (*Erigeron* spp.), lupines (*Lupinus* spp.), and globe mallow (*Sphaeralcea ambigua* Gray), with the following grasses: crested wheatgrass [*Agropyron christatum* (L.) Gaertn.], needle-and-thread grass (*Stipa comata* Trin. and Rupra.), Indian ricegrass (*Orhyzopsis hymenoides* Roem. and Schult.), Elymus sp., cheatgrass (*Bromus tectorum* L.), and six-weeks fescue (*Festuca octaflora* Walt.).

Sampling Design

We worked with Grand Staircase Escalante National Monument personnel on this manipulative experiment, following protocols suggested by Hulbert (1984). We developed an experimental study design with interspersion within a randomized block design, in an effort to decrease the probability of chance segregation of treatments. We divided the 323 ha Ford Pasture into a randomized 4-block design, with two (64.6 and 80.75 ha) blocks which were randomly assigned to mechanical thinning by 'lop-and-drop' hand cutting, and two (96.9 and 80.8 ha) for controls. The 'lop-and-drop' mechanical thinning technique entails cutting all selected tree-types and leaving them lie in place where they fell (see Figure 2). In 2005, prior to treatment, we installed 20 bird-count stations (four and five on treatment blocks; five and six within control blocks). In each of the two treatment and two control blocks, we navigated to randomly generated coordinates using handheld GPS receivers and installed rebar to permanently mark the 20 bird-count stations. We discarded coordinates within 100 m of a unit boundary and maintained a minimum 200 m between all of the final 100 m radius circular bird-count stations.

Vegetation Treatment and Sampling

Vegetation was measured during July-August 2005 on all bird count stations prior to treatment. The mechanical-thinning treatment took place 10-16 April 2006.

Figure 2. Post-treatment mechanical thinned Pinyon-Juniper block in the foreground, showing condition of the vegetation following a 'lop-and-drop' treatment in April 2006 at Ford Pasture in Grand Staircase Escalante National Monument, UT. For comparison a control treatment block is on the far, adjacent hill.

Treatment blocks were cut with power saws and downed trees left in place where they fell ("lop and drop"). Snags, any trees with nesting cavities, and shrubs were not cut. We repeated vegetation measurements post-treatment during May and June 2006.

Our vegetation sampling design was based on BBIRD (Martin et al. 1997), and here we discuss departures from that protocol. From each bird count station, we measured the distance to the nearest tree in each of four directions (NE, SE, SW, NW). Four vegetation subplots were located 50 m from the bird count station in each of the cardinal

Table 1. Change in tree numbers and distance characteristics on two randomized treatment blocks (9 bird count stations) due to mechanical-thinning treatment in Ford Pasture, Grand Staircase Escalante National Monument, UT. Pinyon pine and juniper numbers were combined from data collected in 2005 prior to treatment, then in 2006 following the mechanical-thinning treatment.

Vegetation characteristic*	range	mean change	SE	p
Trees removed (%)	49-100	92	6.4	0,0842
Distance to nearest pinyon[a] (m)	0-149	44	18	0.0402
Distance to nearest juniper[a] (m)	0-200	62	28.4	0.0619

[a]increase in distance

* There were no significant changes in numbers of or distance to nearest tree in the two randomized control blocks.

directions. In each subplot, we counted individual trees within a 15 m radius and shrub stems within a 5-m radius. Tree maturity classes were determined following Bradshaw and Reveal (1943). One person estimated canopy cover visually with a gridded ocular for all plots. Gambel oak was treated as a shrub, which is its common form on the study site. Diameter at breast height (dbh) was recorded only for single-stemmed trees, diameter at root crown (drc) for multi-stemmed trees. Diameter at stump height (st) was measured 30.5 cm above the ground (Bradshaw and Reveal 1943). For living junipers whose main trunk lay prone on the ground, we measured height of the tallest "branch".

To verify accuracy of our canopy cover measurements, pre-treatment field estimates of canopy cover were compared to estimates derived from digital orthophoto aerial images (DOQ). An overlay grid of 10 m^2 cells was used to calculate canopy cover of each bird count station (number of cells, to the nearest quarter cell, covered with tree canopy/total number of quarter cells within that bird count station). In each vegetation subplot, we visually estimated percent cover of bare ground, litter, and plants < 50 cm tall within a 1-m^2 quadrat frame. Locations of each 1 m^2 quadrat were randomly selected by taking an azimuth and a distance between 0 and 5 m with a random numbers table (Venables and Ripley 2002).

Vegetation measurements were averaged across the four vegetation subplots to describe vegetation characteristics for each bird count station. Tree and stem counts were converted to density per hectare. At each bird count station, we followed a plotless distance method to determine an index of aggregation ($A1 = ((\Sigma d^2/d'^2)/n) - 0.5$), where d = distance to the nearest tree, d´ = distance to next-nearest tree, n = sample size, and distribution is patchy if $A_1 > 0$, random if $A_1 = 0$, uniform if $A_1 < 0$ (Holgate 1965).

Table 2. Avian species, AOU alpha code, number detected, assigned guild, and residency status of birds counted at 20 bird-count stations. Data are from May-June 2005 and May-June 2006, collected in the Ford Pasture Fuels Reduction project area, Grand Staircase Escalante National Monument, UT. Within the Table Guild column, CA= cavity nester, SH = shrub nester, PJ = pinyon-juniper specialist, TR = tree nester, and GR = ground nester. Within the Table Residency column, SU = summer resident, YR = year around resident, and TR = transient.

Archilochus alexandri	BCHU	4	-	SU
Spizella atrogularis	BCSP	1	-	SU
Pheucticus melanocephalus	BHGR	45	SH	SU
Dendroica nigrescens	BTYW	26	PJ	SU
Amphispiza bilineata	BTSP	8	-	SU
Polioptila caerulea	BGGN	105	PJ	SU
Spizella breweri	BRSP	160	SH	SU
Molothrus ater	BHCO	7	-	SU
Psaltriparus minimus	BUSH	36	TR	YR
Tyrannus vociferans	CAKI	2	-	SU
Spizella passerina	CHSP	119	TR	SU
Cordeiles minor	CONI	2	-	SU
Junco hyemalis	DEJU	2	-	YR
Empidonax wrightii	GRFL	7	-	SU
Vireo vicinior	GRVI	11	PJ	SU
Pipilo chlorurus	GTTO	1	-	SU
Picoides villosus	HAWO	1	-	YR
Carpodacus mexicanus	HOFI	9	TR	YR
Chondestes grammacus	LASP	22	GR	SU
Passerina amoena	LAZB	2	SH	SU
Numenius americanus	LBCU	1	-	TR
Melospiza lincolnii	LISP	2	-	SU
Sialia currucoides	MOBL	14	CA	SU
Poecile gambeli	MOCH	1	-	TR
Zenaida macroura	MODO	37		SU
Colaptes auratus	NOFL	4	-	YR
Circus cyaneus	NOHA	1	-	TR

Second portion of Table 2 continued on the following page.

Bird Sampling

We conducted counts (after Ralph and Scott 1981) at each bird count station during five separate sampling periods in May and June of 2005 (pre-treatment) and five additional sampling periods in 2006 (post-treatment). Utilizing 3.1-ha variable circular plots (Reynolds et al. 1980), observers waited for one minute upon arriving at each count station for birds to acclimate before recording detections. We truncated detections at 100 m radius, yielding an effective survey area of 31,000 m^2 for each bird count station. Species identification and distance were recorded over a period of 5 min for all detected birds (visually or aurally) within the 100 m radius. Visits to each bird count station were one week apart, with counts occurring only between sunrise and 1000 hr MT. In the pre-treatment surveys, two observers alternated visits to minimize observer bias. One observer (C. Crow) conducted all post-treatment surveys. Observers were trained and tested in local

Table 2. (Cont'd) Avian species, AOU alpha code, number detected, assigned guild, and residency status of birds counted at 20 bird-count stations. Data are from May-June 2005 and May-June 2006, collected in the Ford Pasture Fuels Reduction project area, Grand Staircase Escalante National Monument, UT. Within the Table Guild column, CA= cavity nester, SH = shrub nester, PJ = pinyon-juniper specialist, TR = tree nester, and GR = ground nester. Within the Table Residency column, SU = summer resident, YR = year around resident, and TR = transient.

Table 2 (Cont'd). Avian species, USGS alpha code, and number detected on 20 bird count stations in Ford Pasture fuels reduction project area, May-June 2005 and May-June 2006.

Common Name	Scientific Name	Code	No. on plots	Guild*	Residency+
Northern Mockingbird	*Mimus polyglottos*	NOMO	7	TR	SU
Red-tailed Hawk	*Buteo jamaicensis*	RTHA	2	-	YR
Sage Sparrow	*Amphispiza belli*	SAGS	3	-	YR
Say's Phoebe	*Sayornis saya*	SAPH	5	-	SU
Spotted Towhee	*Pipilo maculatus*	SPTO	311	GR	YR
Townsend's Solitaire	*Myadestes townsendi*	TOSO	5	-	YR
Vesper Sparrow	*Pooecetes graminius*	VESP	101	GR	SU
Violet-green Swallow	*Tachycineta thalassina*	VGSW	2	-	SU
Virginia's Warbler	*Vermivora virginiae*	VIWA	4	-	SU
Western Bluebird	*Sialia mexicana*	WEBL	59	TR	YR
Western Meadowlark	*Sturnella neglecta*	WEME	29	GR	YR
Western Tanager	*Piranga ludoviciana*	WETA	3	-	SU
Western Scrub Jay	*Aphelocoma californica*	WSJA	16	PJ	YR
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	4	-	SU

* Within the 'Guild' column: CA= cavity nester, SH = shrub nester, PJ = pinyon-juniper specialist, TR = tree nester, and GR = ground nester.

+Within the 'Residency' column: SU = summer resident, YR = year around resident, and TR = transient.

bird identification and distance estimation at the beginning of each season. No counts were conducted during rain or high winds, and we varied sampling order of bird count station to minimize temporal bias.

Data Analyses

We tested for differences in vegetation between years with a matched pair t-test. Avian species richness was estimated by summing the number of species detected on each bird count station over each year. We then estimated the mean difference between years by treatment type (mechanical-thinned or control), and tested for treatment effect with a two-sample t-test.

We chose to exclude from analysis bird species that comprised less than 1% of our total observations or that were observed only one time in either year. Mean relative abundance was calculated for each bird species at each bird count station (total number detections/effort) for each year, because there were not sufficient observations to determine detection functions (Buckland et al. 2001). Recognizing that relative abundance assumes equal probability of detection, we analyzed relative abundance of bird species by guilds (pinyon-juniper specialists, and the four nesting guilds of tree, cavity, shrub, and ground nester). A power analysis was conducted *a priori* on all statistical tests that we employed within this study (Cohen 1988). We then determined treatment effect against the control site for each bird species and guild, using two-sample t-tests on the mean difference in relative abundance between years.

Occupancy was modeled before and after treatment for each bird species detected during this study. To identify variation in the probability of occupancy (Ψ) at any given block due to mechanical thinning, we modeled occupancy for each species with the following covariates: year, mechanical-thinning or control, and the interaction of year and treatment assignment. Akaike's information criterion (AIC) was used for model selection (Burnham and Anderson 2002). If the model with the lowest AIC rating (top model), or competing models (Δ AIC ≤ 2), included occupancy probability values dependent on the interaction covariate, and if the otherwise identical model without the interaction covariate was not a competing model, we inferred an effect of thinning on occupancy for that species. To identify variation in detection probability due to treatment (p), we followed Mackenzie et al. (2006) in summing AIC weights from all models that included a covariate to determine the most influential covariate(s) on Ψ and p.

Table 3. Difference in mean relative abundance and outcomes of two-sample t-tests for treatment effect on the average difference in relative abundance on control blocks (Δ Control) vs. the mean difference in relative abundance on treatment blocks (Δ Treatment). Data were collected within Ford Pasture in Grand Staircase Escalante National Monument, UT, during 2005-2006. Bird species within table are listed by guild, with the average 'Guild' value followed by specific species values. The 'PJ' category denotes bird species that we considered pinyon-juniper specialists. Table subcategories labels of: y = mean response, SE = standard error, df = degrees freedom, t = t-test value, p = probability value with * =P < -0.10, ** = P < - 0.05.

		Effect of Mechanical-Thinning (Δ Treatment) - (Δ Control)				
Guild	Species[a]	y	SE	df	t	p
PJ	**Group**	0.1	0.07	71	1.69	0.0949 *
PJ	BGGN	0.1	0.19	17	1.48	0.6387
PJ	BTYW	-0.1	0.10	11	1.01	0.3355
PJ	GRVI	-0.2	0.07	18	3.14	0.0057 **
PJ	WSJA	-0.3	0.15	17	1.55	0.1400
Shrub	**Group**	0.4	0.19	28	-1.94	0.0618 *
Shrub	BHGR	0.0	0.11	17	1.23	0.8173
Shrub	BRSP	0.7	0.36	10	-2.04	0.0686 *
Tree	**Group**	-0.3	0.16	37	1.17	0.2500
Tree	CHSP	-0.5	0.27	18	1.89	0.0753 *
Tree	MODO	0.1	0.13	18	-1.05	0.3063
Cavity	ATFL	-0.2	0.14	16	-1.54	0.1443
Ground	**Group**	0.2	0.14	55	-1.10	0.2773
Ground	SPTO	0.4	0.21	13	-1.66	0.1201
Ground	VESP	-0.1	0.18	18	0.76	0.4589

[a]See Table 2 for species codes and names

RESULTS

Vegetation Changes

Mechanical thinning removed the majority of trees from all treated blocks (Figure 2). Tree canopy cover decreased from 57% to 100% while stem density decreased between 49% and 100% (92 ± 6) on treated blocks. Field visual estimates of canopy cover were only 2% lower (-4.3% to 0.0%, t = -2.30, P = 0.0503) than the DOQ estimates. We found that by combining both canopy cover techniques, average cover decreased after treatment between 57% and 100% (92 ± 5). Mean distance from bird count station to the nearest juniper increased 64 (± 28.4) m, while distance to nearest pinyon increased 44 (± 18.0) m (Table 1). Tree dispersion post treatment tended towards increased patchiness as our index of aggregation increased from 3.2 to 9.3 (after Holgate 1965). Mean sagebrush density increased by 18 stems/ha, rubber rabbitbrush by 3 stems/ha, while Gambel oak decreased by 2 stems/ha. Mean densities of Utah serviceberry and sticky-leaved rabbitbrush did not change significantly following treatment.

Table 4. Percent of all individual birds, of the five most greatly affected species, on control and treatment blocks. These percentages were derived from the total number of birds detected before and after mechanical thinning of pinyon-juniper woodlands. Data were collected on the Ford Experimental Pasture during 2005-2006, in Grand Staircase Escalante National Monument, UT.

	Control Blocks		Treatment Blocks	
Species[a(n)]	Pre % Occupancy	Post % Occupancy	Pre % Occupancy	Post % Occupancy
BTYW (26)	55	64	0	11
GRVI (11)	0	45	33	0
BHCO (7)	0	36	11	0
BUSH (36)	18	18	0	56
NOMO (7)	0	22	0	11

[a]See Table 2 for species codes and names

Table 5. Site occupancy: percent of variation in detections explained by summed AIC weights of occupancy probability (Ψ) and detection probability (p) covariates for avian species. In the table subtitles trt = treatment assignment (treat or control), yr = year.*

Species[a]	Site Occupancy			Detectability		
	Ψ(trt*yr)	Ψ(trt)	Ψ(yr)	p(trt*yr)	p(trt)	p(yr)
BGGN	0%	26%	0%	0%	71%	18%
BTYW	0%	0%	0%	23%	82%	76%
GRVI	**top model**	N/A	N/A	N/A	N/A	N/A
WSJA	0%	36%	30%	15%	33%	36%
BHGR	27%	46%	46%	58%	77%	76%
BRSP	0%	0%	0%	59%	0%	0%
CHSP	0%	25%	0%	27%	96%	46%
MODO	0%	0%	0%	19%	43%	80%
ATFL	0%	25%	0%	20%	75%	41%
SPTO	0%	0%	0%	42%	59%	75%
VESP	0%	0%	0%	32%	100%	98%
BHCO	**competing model**	N/A	N/A	N/A	N/A	N/A
BUSH	0%	33%	0%	0%	42%	23%
NOMO	0%	18%	48%	0%	17%	47%

[a]See Table 2.for species codes and names.

*Weights were not summed for Gray Vireo and Brown-headed Cowbird, for which effect of mechanical thinning on occupancy, denoted by the interaction covariate (trt*yr), was an element of the model with the lowest and second-lowest AIC values, respectively.

Power analyses

The many rare bird species and their low densities within our study area greatly reduced the power of our experimental design and subsequent analyses. This was further compounded by the very low effect size (ES) between our treatment and control blocks. Since we were much more concerned with violating a Type II (β) error than a Type I (α) error (Toft and Shea 1983), we selected a probability rejection level of our null hypothesis at $P \leq 0.10$. This meant that we were more concerned in failing to reject a false H_o, because of the ramifications of not identifying any influence to birds with mechanical thinning, when in fact an effect did exist. When concerned about Type II error, a standard convention is $\beta \leq 0.20$; however, there are practical arguments for minimizing the probability of β well below 0.2 (Di Stefano 2003), and we thus chose to set the probability of significance at ≤ 0.10 (Cohen 1988). This choice of maximizing β is particularly compelling when rare and endangered species are involved (O'Brien et al. 2009).

Bird Changes

Over two breeding seasons, we detected 829 individual birds of 48 bird species, of which 13% (n = 6) were transient. Of the 42 remaining species, 60% (n = 29) were summer and 27% (n = 13) year-round residents (Table 2). Bird species with relatively high numbers of detections included Spotted Towhee (*Pipilo maculatus*) (SPTO), Brewer's Sparrow (*Spizella breweri*) (BRSP), Chipping Sparrow (*Spizella passerine*) (CHSP), Vesper Sparrow (*Pooecetes gramineus*) (VESP), and Blue-gray Gnatcatcher (*Polioptila caerulea*) (BGGN). Some species, usually characterized as pinyon-juniper specialists (e.g., Juniper titmouse – *Baeolophus griseus*), were absent and are probably not residents of our particular study area.

We found that avian community composition changed significantly in response to treatment, with species and numbers of detected birds either increasing or decreasing following mechanical thinning (Table 3). After accounting for all possible non-treatment factors (e.g., year of study, detection probability), there was evidence of a significant influence of mechanical thinning on two avian guilds and four bird species. One guild (pinyon-juniper specialists) decreased in numbers while a second guild (shrub nesters) increased. Three species, the Gray Vireo (*Vireo vicinior*), Brown-headed Cowbird (*Molothrus ater*), and Chipping Sparrow, significantly decreased following treatment, while the Brewer's Sparrow significantly increased on treatment blocks (Table 4). The Gray Vireo and Brown-headed Cowbird were no longer detected on treatment blocks after mechanical thinning, but their numbers did increase on control blocks. Site occupancy of all other bird species (n = 38) that we analyzed was not influenced by mechanical thinning.

Table 6. Species richness (measured as total number of bird species) from pre- and post-treatment bird surveys on mechanical-thinned and control blocks. Data were collected during 2005-2006 on the Ford Experimental Pasture in Grand Staircase Escalante National Monument, UT.

	Pre-treatment		Post-treatment	
Treatment assignment	Mean	SE	Mean	SE
Mechanical-thinning	9.6	1.9	9.8	1.3
Control	9.7	1.5	10.0	1.8

For some avian species, however, it was difficult to assign reasons for changes in numbers between treatment and control blocks. Gray Flycatchers (*Empidonax wrightii*) were detected only on control blocks; thus, we were unable to assess for effects of thinning treatment. The Northern Mockingbird (*Mimus polyglottos*) was not detected on treatment or control blocks prior to treatment, but was found on both treatment and control blocks after thinning (Table 4). The Black-throated Gray Warbler (*Dendroica nigrescens*) and Bushtit (*Psaltriparius minimus*), were detected on treatment blocks only after mechanical thinning occurred, but this difference may be the result of variations in detection probability rather than variation in occupancy (Table 5). We found that differences in pre- and post-treatment site occupancy in Black-headed Grosbeak (*Pheucticus melanocephalus*) was explained by variation in occupancy between years (46%) and between thinning and control blocks (46%), rather than by the influence of the mechanical thinning (27%). Although avian community composition changed during our study, species losses were balanced by species gains; thus, overall bird species richness did not change in response to vegetation treatment (t_{15} = 0.11, P = 0.9129; Table 6).

DISCUSSION

Over western North American, as pinyon-juniper woodlands establish in shrub steppe and grasslands, land managers are faced with the need to achieve a delicate balance between ecological restoration of shrub steppe, while avoiding negative impacts on woodland-dependent species. We found that, within 323 ha following mechanical thinning, avian community composition did change in response to treatment. Bird species richness did not differ because the loss of species was balanced by the addition of new species. We also demonstrated that whole avian guilds, as well as their individual species, can rapidly be added or eliminated from pinyon-juniper habitat through select mechanical thinning of trees.

As a group, there was evidence that the relative abundance of pinyon-juniper specialists decreased in response to mechanical thinning treatment. The Gray Vireo was eliminated from treated blocks. This is consistent with previous studies that have found that this pinyon-juniper obligate, which breeds in open, mature pinyon-juniper, juniper-oak, and juniper-dominated woodlands (Balda and Masters 1980; Latta et al. 1999), requires shrubs or junipers for nesting (Ehrlich et al. 1988; Parrish et al. 2002). Positive associations have also been found between density of Gray Vireo and ratio of junipers to pinyon pines (Schlossberg 2006). Previous research has shown that the Gray Vireo was absent in pinyon-juniper woodlands where trees had been killed by fire, but present in adjacent unburned pinyon-juniper woodlands (Schlossberg 2006). Clearly, trees in pinyon-juniper woodlands are important to this species, although the exact nature of the relationship is not known, as there is little detailed knowledge about the life history and habitat requirements of the Gray Vireo, possibly due to sparse distribution and the species secretive behavior (Parrish et al. 2002).

The Brown-headed Cowbird, which prefers wooded areas near the interface with fields or shrubs (Gates and Evans 1998), was also eliminated from treatment blocks as a result of mechanical thinning. This was an unexpected finding in that removal of trees and creation of 'edge' through management activities have been previously implicated, along with cattle grazing, in the spread of Brown-headed Cowbird distribution throughout the United States (Lowther 1993; Rothstein and Robinson 1998). In our study, the Brown-headed Cowbird was found post-treatment only in untreated areas bounding the mechanically-thinned units. Female cowbirds require perches from which to observe other avian species in order to find nests to parasitize (Lowther 1993). Additionally, a positive association has been found between the number of tall perches available and the frequency of cowbird parasitism of Black-throated Sparrows (*Amphispiza bilineata*) in central Arizona (Johnson and van Riper 2004). Removal of 49% to 100% of the trees in the mechanically-thinned units at Ford Pasture might have rendered treated areas less desirable to female cowbirds. Additionally, changes in the distribution of hosts might also have contributed to the elimination of Brown-headed Cowbird, which is known to heavily parasitize Gray Vireo nests (Ellison 1992; Latta et al. 1999).

Relative abundance of the Chipping Sparrow, a species associated with pinyon-juniper woodland edges and other moderately open areas in mature woodlands (Sedgwick 1987; Pavlacky and Anderson 2004), decreased in response to mechanical thinning. In previous research, this species foraged and nested in chained blocks three to four years after treatment, but did not venture further than 100 m from the treatment boundary into chained areas (O'Meara et al. 1981; Sedgwick and Ryder 1987). Because Chipping Sparrow nests in conifers and deciduous trees (Middleton 1998), treatments that significantly reduce the number of trees available for nesting are likely to have negative impacts on this species.

Relative abundance of shrub nesting birds increased following mechanical thinning. The group response was largely driven by Brewer's Sparrow, a species which prefers relatively open areas with large shrubs and low tree density within early successional pinyon-juniper woodlands (Sedgwick 1987; Pavlacky and Anderson 2004). In several different vegetation communities throughout western North America, Brewer's Sparrow increased following mechanical thinning (Rotenberry and Wiens 1980; Wiens 1985). The Brewer's Sparrow has been identified as a shrub steppe obligate that nests nearly exclusively in sagebrush openings within pinyon-juniper habitat (Rotenberry et al. 1999; Parrish et al. 2002). The species used chained areas at the interior of one treatment (Sedgwick 1987), and was found exclusively on chained blocks in another study (O'Meara et al. 1981). Mechanical thinning within Ford Pasture appears to have increased breeding habitat quality, so that during our post-treatment surveys the area supported a larger number of nesting Brewer's Sparrows.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

In our study, mechanical thinning of live trees within pinyon-juniper woodlands resulted in elimination of the Gray Vireo. Similar mechanical-thinning projects on a scale larger than 323 ha could, therefore, have greater consequences for this bird species. The Gray Vireo is already uncommon within GSENM, and has been identified as a 'Species of Conservation Concern' over the Colorado Plateau and at the national level (USFWS 2002). Because the Gray Vireo has been found in higher densities in southern Utah and on the Colorado Plateau than elsewhere (Parrish et al. 2002), it is important that these pinyon-juniper woodlands be managed with an awareness of conserving this avian species.

Although it was beyond the scope of our study to compare hand cutting to other fuel reduction methods, hand cutting does allow increased precision in application of treatments. For example, in areas where the Gray Vireo is known to be present, thinning could be limited to a proportion of young juniper and pinyon trees, leaving numbers of standing mature live trees. This treatment strategy would reduce fire risk by removing ladder fuels, without reducing breeding habitat for Gary Vireo. We thus argue that hand cutting of pinyon pines and junipers for sagebrush restoration projects, in areas like Ford Pasture, is a viable alternative to prescribed fire and chaining.

As a group, shrub nesters increased in relative abundance in response to the mechanical-thinning treatment. Brewer's Sparrow, a species of concern in the Mountain-Prairie region (USFWS 2002) and Partners in Flight priority population in Utah (Parrish et al. 2002), quickly increased within our treated areas. This provides evidence that mechanical thinning can produce positive changes over time for avian sagebrush species. However, in every case thinning trees will not always immediately improve conditions for Brewer's Sparrow. Our study site was a sagebrush steppe with scattered pinyon-juniper woodlands and already had a strong shrub component dominated by sagebrush (Figure 2). Brewer's Sparrow populations within pinyon-juniper woodlands without existing brushy openings might not benefit as quickly from mechanical thinning, needing to wait until the shrub component has had time to respond.

We have demonstrated that small-scale tree removal in pinyon-juniper woodlands can contribute to sagebrush restoration objectives. Repeated small-scale projects require a lower financial commitment in a single year and are more likely to fit legal compliance requirements than would a single large-scale restoration project. Thus, the small-scale approach that we examined may be useful where management goals are to minimize detrimental effects of sagebrush restoration on Gray Vireos and other pinyon-juniper specialists.

Natural area managers should recognize that multiple, small-scale fuel reduction projects will produce more "edge" than a single large-scale mechanically-thinned treatment, thus fragmenting pinyon-juniper woodlands into a number of artificially defined units (see Lovejoy 1980). This could result in an increase in nest parasitism by Brown-headed Cowbirds (Johnson and van Riper 2004). In our study, Brown-headed Cowbirds were eliminated from treated areas but increased within the control areas adjoining the mechanically-thinned sites. If minimizing negative impacts of Brown-headed Cowbirds to woodland species is an objective for land managers, it is important to consider the possible implications of increasing levels of nest parasitism.

Pinyon pine and juniper are both slow-growing trees (Samuels and Betancourt 1982) – some exceeding 100 years of age before reaching mature size (Bradshaw and Reveal 1943). Because avian community composition varies along a successional gradient of pinyon-juniper woodlands (Pavlacky and Anderson 2001; Rosenstock and van Riper 2001), a series of small-scale mechanical-thinning projects performed over time could effectively rotate treatment units through successional stages, thus maximizing the number of habitat stages available for avian species.

Further studies addressing long-term effects in abundance, occupancy, and nesting success should be conducted to ensure that the adaptive management policies of agencies are based on an understanding of the true implications of mechanically thinning pinyon-juniper woodlands. In the interim, our study suggests that small-scale mechanical thinning fuels-reduction projects in pinyon-juniper vegetation communities can influence both pinyon-juniper and sagebrush steppe avian communities.

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