FINAL REPORT

State: **South Dakota** Grant Number: T-2-R-1

Project Title: Evaluation of timber harvest on nongame bird abundance and diversity in Custer State Park, South Dakota

Period Covered: October 1, 2008 – May 15, 2013

Objective:

By May 15, 2013:

1. Compare nongame bird abundance and diversity before and after timber sale treatments,
2. Determine the affects of timber harvest abundance of sensitive or species of greatest conservation need,
3. Quantify macro- and micro-habitat characteristics used by nongame birds in a ponderosa pine ecosystem.

Accomplishments:

South Dakota Game, Fish and Parks (SDGFP) contracted with South Dakota State University to conduct this project. The completion report is attached.

Report submitted by: Eileen Dowd Stukel, SD Department of Game, Fish and Parks, eileen.dowdstukel@state.sd.us; 605-773-4229.

Evaluation of Timber Harvest on Nongame Bird Abundance and Diversity in Custer State Park, South Dakota

Jessica Panning, Department of Natural Resource Management, South Dakota State University; **Kent C. Jensen**, Department of Natural Resource Management, South Dakota State University; **Chad P. Lehman**, South Dakota Department of Game, Fish, & Parks

Introduction:

Timber harvest changes composition and structural characteristics of the forest and surrounding landscape (Freemark and Merriam 1986, McGarigal and McComb 1995), as well floristic composition of the local plant communities (Franklin and Forman 1987, Ripple et al. 1991, Wiens and Rotenberry 1981, Rotenberry 1985). These habitat manipulations or alterations can influence species composition, diversity, and abundance (Franklin and Forman 1987, James and Wamer 1982, Lord and Norton 1990, Szaro and Balda 1979, Szaro and Balda 1986). Forest bird assemblages are thus likely to change as timber harvest manipulates vegetative structures and plant communities (Freemark and Merriam 1986, James and Wamer 1982, MacArthur and MacArthur 1961, Szaro and Balda 1986). Studies (Wiens and Rotenberry 1981, Robinson and Holmes 1984, and Rotenberry 1985) have also shown strong correlations of bird species with certain plants or plant communities.

In Custer State Park (CSP), timber management occurs on approximately 54% or 38,155 acres. The objectives of this program are to provide species and structural diversity (Custer State Park Resource Management Plan 1995-2010). Timber harvest is important in Custer State Park to control mountain pine beetle outbreaks and to provide a continued revenue stream for the Park.

Not only is timber harvest an important management tool for CSP but also the Black Hills National Forest (U.S. Forest Service). From 2000-2006, about 116,000 acres of forest were harvested (FY2006 Monitoring and Evaluation Report 2007). As mountain pine beetle outbreaks continue to occur, it is expected that timber harvest will persist. Timber harvest is used to minimize the vulnerability of stands that have high likelihoods of infestation (Allen 2008). Little information is available on bird abundance and diversity in relation to timber harvest management. Dykstra et al. (1999) provided some information on songbird species and timber harvest relationships. However, that study lacked a before and after study design to analyze changes in bird assemblages before and after timber harvest. Our goal was to provide more information on the effects timber harvest management has on songbird communities. Our study could be applicable to the entire Black Hills as well as ponderosa pine forests region wide.

The objectives of this study were to (1) compare avian abundance and diversity before and after timber harvest treatments, (2) determine the affects of timber harvest on abundance of sensitive or species of local concern, and (3) quantify macro- and micro-habitat characteristics used by nongame bird in a ponderosa pine ecosystem. We hypothesize that species diversity, abundance, and composition does not differ between treatments.

Study Area:

Custer State Park (28,618 ha) is located in southwestern South Dakota, and within the Black Hills physiographic region (Johnson et al. 1995). Elevations range from 1,146 to 2,042 m above mean sea

level. Northwest to southeast the Park varies considerably in topography and vegetation communities. The northwest is characterized by dense ponderosa pine (*Pinus ponderosa*) /white spruce (*Picea glauca*) forest with steep topography, the central portion is rolling topography dominated by ponderosa pine forest, and the southeastern portion is slightly rolling and dominated by grasslands. The climate is semi-arid with mean annual precipitation of 50.6 cm at the northern end of CSP (National Climatic Data Center 1971–2000) and 46.8 cm at the southern end of the Park (Custer State Park Climate Data 1983–2007). Mean annual temperature is 6.6ºC at the northern end of the Park (National Climatic Data Center 1971–2000). The study area (Figure 1) in the northern and central portion of CSP is mostly coniferous forest dominated by ponderosa pine (55%). Meadows (22%) included dry native prairie and seminatural grasslands. Deciduous communities are rare (2%) and are primarily bur oak (*Quercus macrocarpa*), aspen (*Populus tremuloides*), green ash (*Fraxinus pennsylvanica*), and to a lesser extent cottonwood (*Populus deltoides*) (Hoffman and Alexander 1987). Twenty percent of the study area was burned by wildfires in 1988, 1990, and 2007. Common woodland understory species in the southern end of the Park include bearberry (*Arctostaphylos uva-ursi*), swamp current (*Ribes lacustre*), and common juniper (*Juniperus communis*), while serviceberry (*Amelanchier alnifolia*), and chokecherry (*Prunus virginiana*) occurs less frequently (Larson and Johnson 1999). Common native graminoids in the southern end of the Park include needle-and-thread (*Stipa comata*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), and buffalograss (*Buchloe dactyloides*; Larson and Johnson 1999). Common woodland understory species in the northern end of the Park includes bearberry (*Arctostaphylos uva-ursi*), common juniper (*Juniperus communis*), while western snowberry (*Symphoricarpos occidentalis*), nannyberry (*Viburnum lentago*), and white coralberry (*Symphoricarpos albus*) occurs less frequently. Common native graminoids in the northern end of the Park include carices (Carex spp.), poverty oatgrass (*Danthonia spicata*), and rough-leaved ricegrass (*Oryzopsis asperifolia*; Gibbs 1993, Larson and Johnson 1999).

For our study, we selected 3 study areas, one in the north in a ponderosa pine/spruce mixed vegetation community (Sylvan), and two in the south with ponderosa pine as the climax vegetation community (Flynn Creek and Rimrock) (Figure 1). Within each study area, 6 seral stages were selected for treatment. The 6 ponderosa pine vegetation structural stage categories include pole (2.54-22.9 cm DBH) and mature (>22.9 cm DBH) with 0-40%, 41-70%, and 71-100% overstory canopy cover. Transects for bird monitoring were placed using a stratified random design within a geographic information system (GIS) and the Custer State Park vegetation GIS coverage (Custer State Park Vegetation Database, Cogan et al. 2002). Vegetation descriptions of these macrohabitat polygons were based on sample plots systematically located in polygons as part of the National Vegetation Classification System protocol (Cogan et al. 2002). Transects were placed strategically in each structural stage category so that sampling did not overlap with different structural stages. Transects were monitored for a total of three years, Sylvan and Flynn Creek with one year pre-treatment (2009) and two years post-treatment (2010-11) and Rimrock with two years pre-treatment (2009-10) and one year post treatment (2011). Controls were monitored over the 3-year period as well to determine if natural variability occurs in bird populations (30 transects in at least one pole and one mature structural stage category).

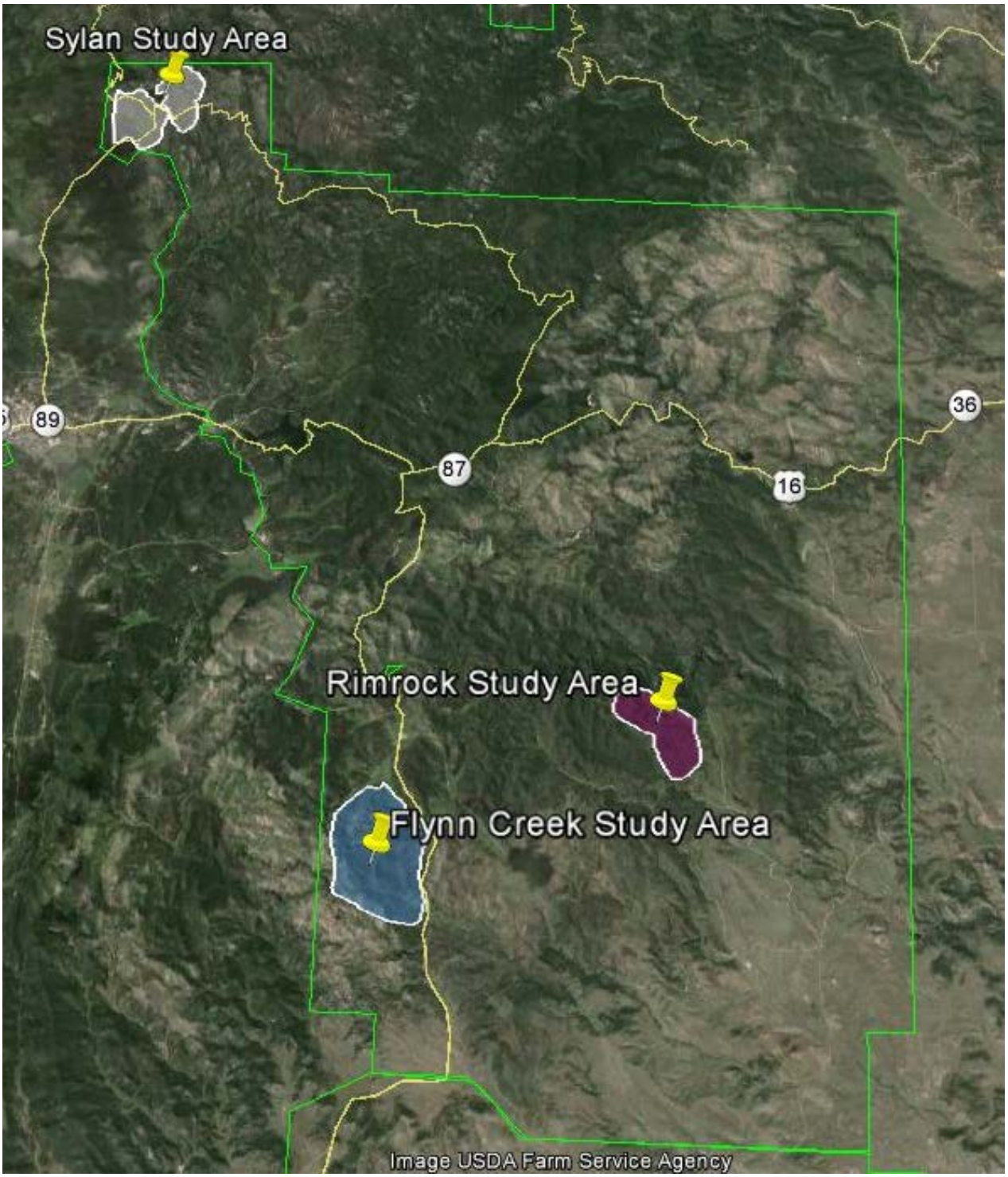

Figure 1. Custer State Park (CSP) (in green outline) with locations of the 3 study sites within the Park. Sylvan in the north, and Flynn Creek and Rimrock in the southern portion of CSP.

Methods:

Songbird Monitoring

Transects 100 meters in length were used to survey bird species during May and June (2009 – 2011), when breeding birds were most active (Emlen 1971 and Burnham et al. 1980). Transects were permanently marked with stakes, plastic flagging, and non-toxic spray paint to maintain the same point for counting birds from year to year. Transects were placed approximately 100 meters or more away from stand boundaries to reduce edge effects and at least 250 meters apart from other transects to avoid double counting birds (Manuwal and Carey 1991 and Ralph et al. 1993). We used the variable circular-plot method, also known as the variable-radius circular plot method (see Reynolds et al. 1980 and Manuwal and Carey 1991 for general description of the method). The transects consisted of 3, 3-minute point counts, one point count occurring on each end and one point count in the middle (Reynolds et al. 1980, Ralph et al. 1993, and Manuwal and Carey 1991). Each transect was visited at least twice per year. Transects were surveyed a half-hour before sunrise and will be completed before 11 am. At each transect, the sex (male, female, or unknown), perpendicular distance from the transect to where the bird was heard or sighted (in meters), method of detection (sighting or hearing of song or call), and transect number was recorded. The order in which transects were surveyed varied to account for hourly variations in species detectability. Transects were surveyed in periods of moderate to heavy rain, in wind conditions > 10 km/hour, in heavy fog, or when temperatures are <7°C or >24°C (Manuwal and Carey 1991).

Vegetation Measurements

We measured the vegetation at transects from 15 June–23 August of each year (2009-2011). Data collected along transects were averaged for each variable of interest. Vegetation was measured at the center point of each transect. Understory visual obstruction readings (VOR) of vegetation was estimated by placing a Robel pole with 2.54-cm increments (Robel et al. 1970, Benkobi et al. 2000) at 5 points along each transect. Measurements were taken starting at the center point. An additional point was placed in each cardinal direction 5 m from the center point (n = 5). At each of the 5 points, 4 VOR's were recorded, one in each cardinal direction. The lowest visible increment on the pole was recorded from a distance of 4 m. Investigators kneeled to a height of 1 m while recording VOR (Robel et al. 1970).

We estimated percent cover of total herbaceous vegetation, graminoids, forbs, shrubs, and dominant plant species using a 0.1 m^2 quadrat (Daubenmire 1959). We estimated percent cover starting at the center point of each transect and measuring out at 2-m intervals in the 4 cardinal directions for the outer 5 measurements (*n* = 20). Tree characteristics were measured in a single plot at the center point. We recorded all trees ≥ 15.24 cm DBH in a variable-radius plot using a 10-factor prism (Sharpe et al. 1976). We recorded data for trees < 15.24 cm DBH in a 5.03-m fixed radius plot. Additionally, using a laser range finder (TruPulse 200, Laser Technology Inc., Centennial Colorado, USA), we estimated proportion tree canopy height and tree canopy width for trees ≥ 15.24 cm DBH. This data allowed us to calculate basal area and tree density. Proportion canopy depth was estimated as the number of meters of tree having canopy divided by total tree height. Canopy width was estimated in meters by placing a stake directly underneath the northern edge of the canopy and investigators would stand and measure from directly underneath the southern edge of the canopy. Aspect was recorded using a compass as the prevailing downhill direction from the site; percent slope was estimated along this same gradient with a clinometer.

Statistical Analyses

Estimates of bird abundance, diversity, and species richness were based on the variable-radius circular plot transects. For bird abundance we used the program DISTANCE (version 6, release 2) to calculate estimated densities (birds/ ha) based on best-fit models chosen by the lowest Akaike's Information Criterion (AIC) values (Buckland et al. 2001, Buckland et al. 2004,Thomas et al. 2003, Thomas et al. 2009) within the DISTANCE program. The DISTANCE program accounts for detectability of birds by calculating density estimates from varying habitats (Rosenstock et al. 2002, Thomas et al. 2010). We pooled all observations for each transect (2 for each transect per year per treatment). Species diversity was calculated using Shannon's Index ($H' = -\sum p_i \log_e p_i$), where p_i was the proportion (p) of the total community represented by each species (Shannon and Weaver 1963, Magurran 1988). We calculated Shannon's Index for all observations pooled at each transect and averaged over each site and treatment. Indices for species diversity (H'), and species evenness (J') were calculated for comparisons between treatments. Species diversity (H') is highly correlated with species richness or as the species richness at a site increases the index value will increase. Species evenness (J') is a value between 0 and 1 and is a measure of how evenly the total bird numbers are distributed among the species present in the surveys; a value of 1 would indicate completely even distribution of numbers among all species present in the sample. Sorenson's index of similarity (Sorenson 1948) was calculated as an indicator of change from the pre- to post-treatment avian diversity. Where appropriate, we used the nonparametric Kruskal-Wallis for comparison of means within each structural stage. Only birds known to breed in the Black Hills were included in the analysis to eliminate diversity biases due to yearly variation in the timing and distribution of migrating birds that use the Black Hills as staging and stopover habitat during the northward spring migration.

Statistical significance for all tests was determined at $\alpha = 0.10$ to reduce the ecological and management implications of failing to reject the null hypothesis when it is false (e.g., Steidl et al. 1997, Hosmer and Lemeshow 2000).

Results

Mean forest structural data (overstory and understory dbh, tree height, crown depth, crown width, and tree density) are shown in Tables 1 – 6 and Figures 2 – 7. Herbaceous and shrub structural cover characteristics (% cover and VOR) and shown in Tables 7 – 10.

Table 1. Mean overstory tree diameter at breast height (cm) (dbh), Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	mean tree dbh (cm)	SE	t-test p-value
Sylvan pre	33.96	2.31	
Sylvan post	31.93	3.12	0.17
Rimrock pre	35.08	4.90	
Rimrock post	34.26	7.92	0.75
Flynn pre	28.09	4.32	
Flynn post	29.21	2.46	0.97

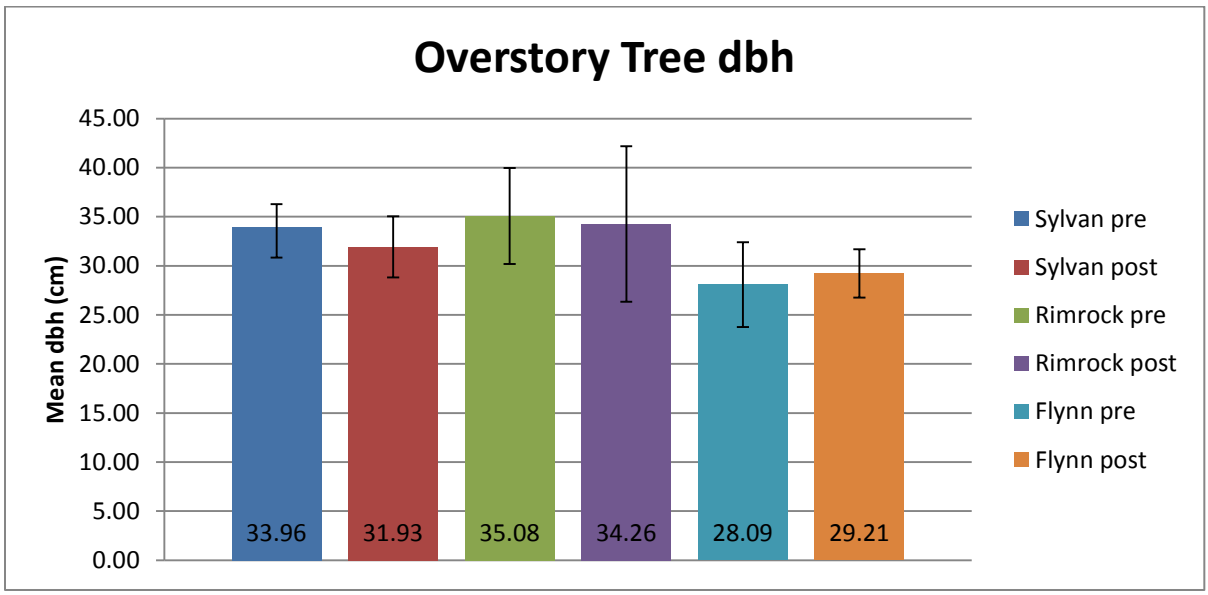

Figure 2. Mean overstory tree diameter at breast height (dbh) and 95 % Confidence Intervals of pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 2. Mean understory tree diameter at breast height (dbh), Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	mean understory dbh	SE	t-test p-value
Sylvan pre	8.06	1.41	
Sylvan post	15.89	3.85	0.00
Rimrock pre	17.67	2.14	
Rimrock post	25.18	3.73	0.03
Flynn pre	8.66	3.10	
Flynn post	7.62	0.00	

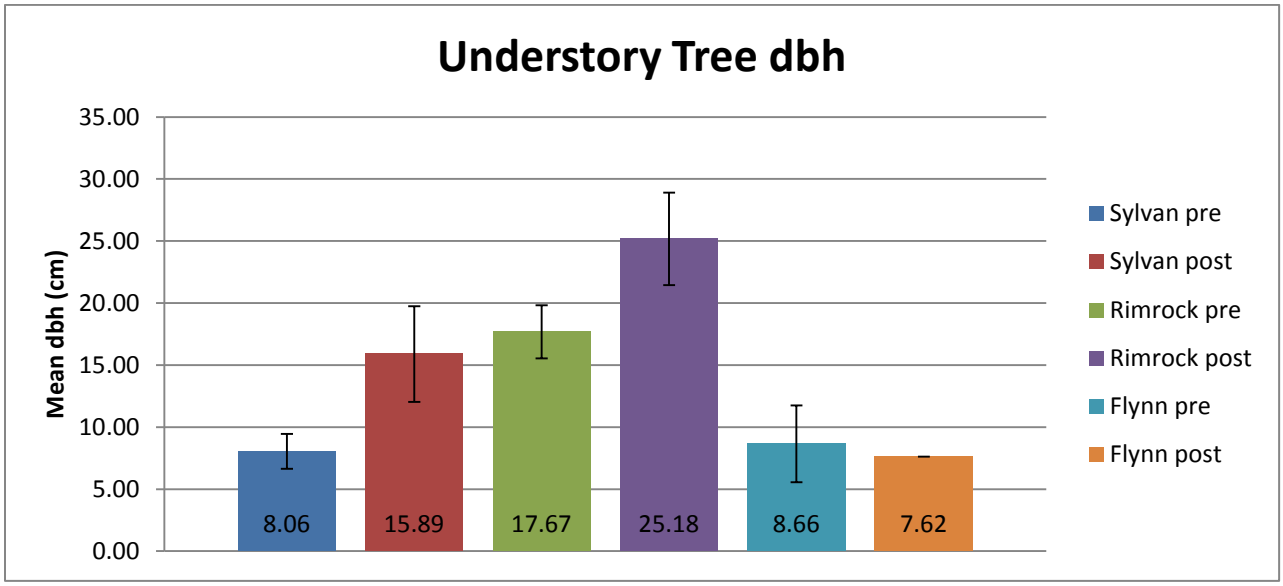

Figure 3. Mean understory tree diameter at breast height (dbh) and 95 % Confidence Intervals of pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 3. Mean tree height (m), Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	mean tree height (m)	SE	t-test p-value
Sylvan pre	17.22	1.04	
Sylvan post	31.93	1.46	0.12
Rimrock pre	25.02	2.30	
Rimrock post	37.21	18.00	0.06
Flynn pre	17.59	1.49	
Flynn post	16.37	1.83	0.47

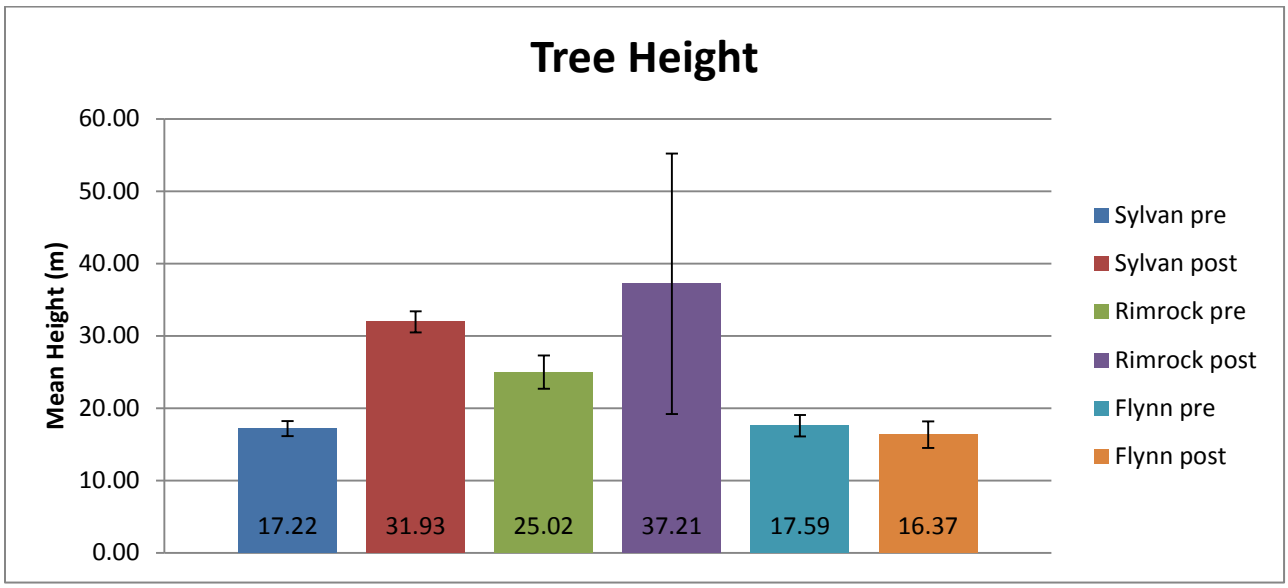

Figure 4. Mean tree height (m) and 95 % Confidence Intervals of pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 4. Mean overstory crown depth (m), Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	mean crown depth (m)	SE	t-test p-value
Sylvan pre	8.67	0.73	
Sylvan post	8.47	0.75	0.90
Rimrock pre	35.08	1.37	
Rimrock post	21.16	10.11	0.03
Flynn pre	7.65	0.23	
Flynn post	7.50	0.36	0.86

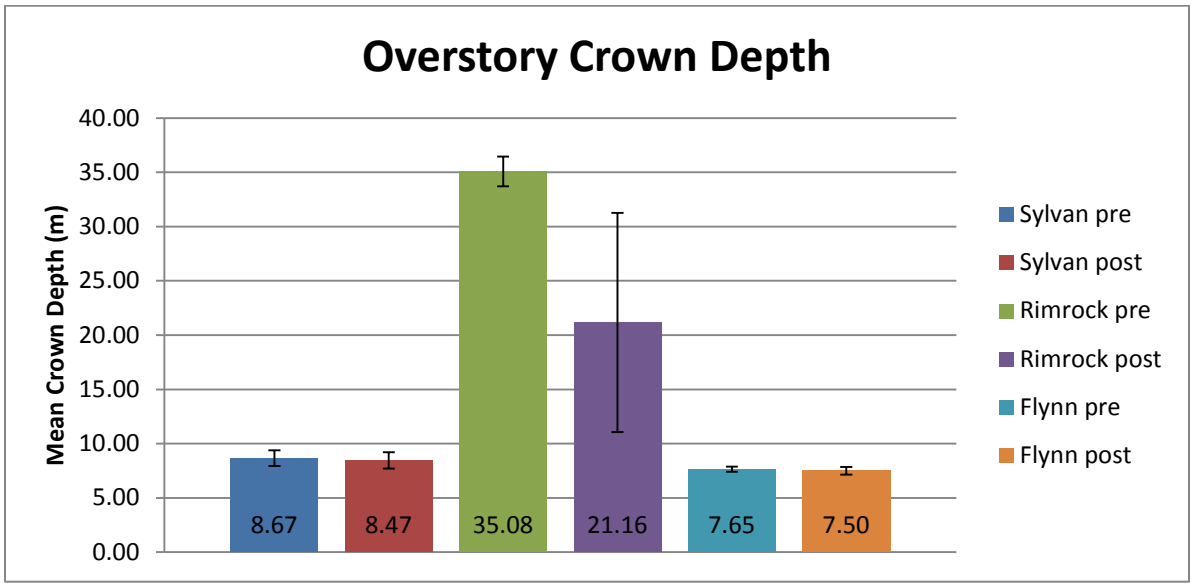

Figure 5. Mean overstory crown depth (m) and 95 % Confidence Intervals of pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 5. Mean overstory crown width (m), Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	mean crown width	SE	t-test p-value
Sylvan pre	4.89	0.60	
Sylvan post	10.92	0.59	0.91
Rimrock pre	20.49	0.79	
Rimrock post	9.66	4.97	0.18
Flynn pre	3.79	0.41	
Flynn post	4.39	0.36	0.31

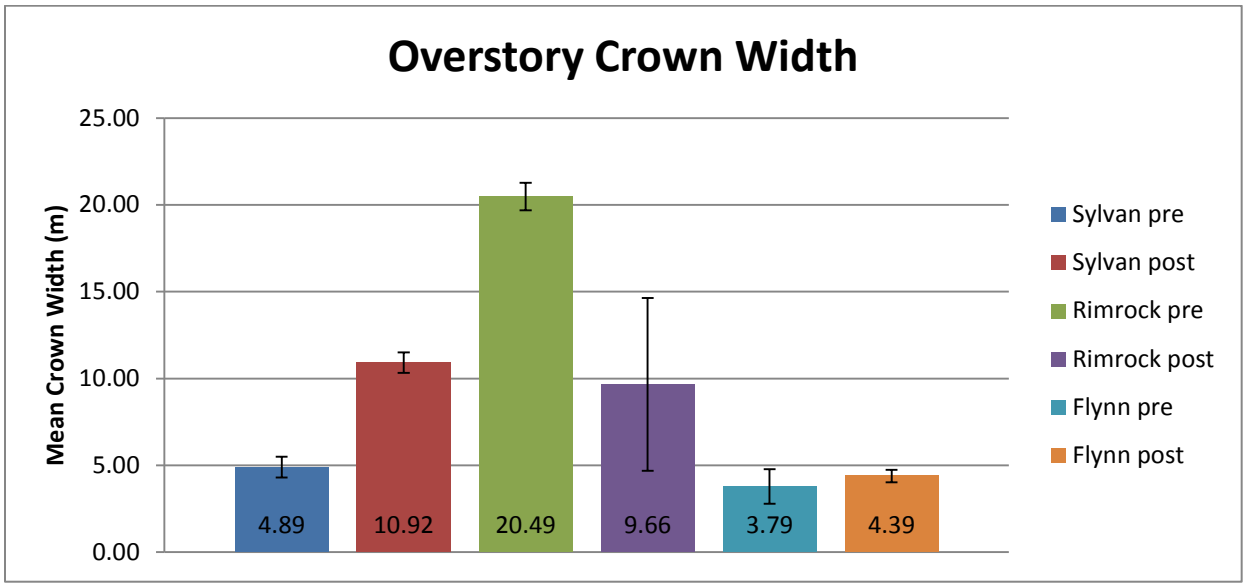

Figure 6. Mean overstory crown width (m) and 95 % Confidence Intervals of pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 6. Mean tree density (trees/ha), Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Tree density (trees/ha)	SE	t-test p-value
Sylvan pre	359.67	3.54	
Sylvan post	125.20	1.85	0.00
Rimrock pre	363.12	11.93	
Rimrock post	262.27	12.06	0.21
Flynn pre	74.20	8.04	
Flynn post	14.27	0.78	0.04

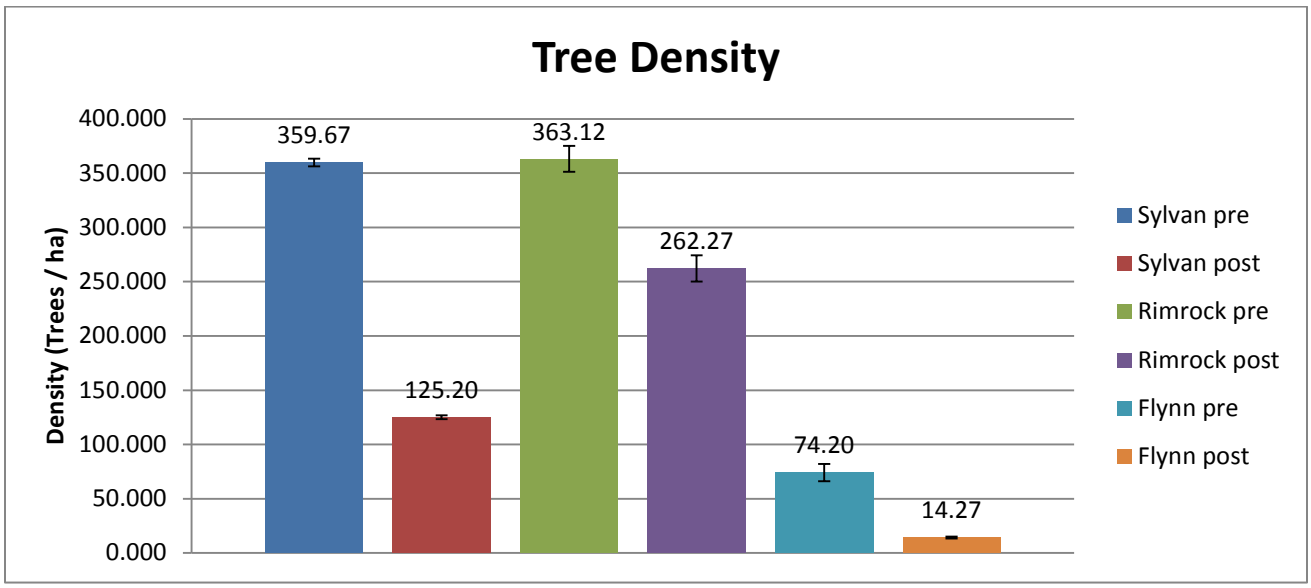

Figure 7. Estimated tree density (trees/ha) and 95 % Confidence Intervals of pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 7. Percent cover of grass, Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	% cover grass	SE	t-test p-value
Sylvan pre	0.51	0.14	
Sylvan post	0.99	0.29	0.00
Rimrock pre	0.99	0.29	
Rimrock post	1.45	0.32	0.04
Flynn pre	17.13	2.41	
Flynn post	8.81	13.61	0.01

Table 8. Percent cover of forbs, Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	% cover forb	SE	t-test p-value
Sylvan pre	0.71	9.66	
Sylvan post	0.80	0.54	0.41
Rimrock pre	0.84	9.89	
Rimrock post	0.46	15.83	0.02
Flynn pre	6.54	6.92	
Flynn post	2.83	6.03	0.24

Table 9. Percent cover of shrubs, Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	% cover shrub	SE	t-test p-value
Sylvan pre	0.58	0.14	
Sylvan post	0.58	0.17	0.99
Rimrock pre	0.80	0.42	
Rimrock post	0.41	0.28	0.10
Flynn pre	7.67	11.24	
Flynn post	7.17	9.97	0.14

Table 10. Mean visual obstruction (VOR), Standard Error (SE), and p-value for t-test comparison of means between pre- and post-treatment at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	mean VOR	SE	t-test p-value
Sylvan pre	4.19	1.06	
Sylvan post	0.46	2.59	0.00
Rimrock pre	5.84	3.88	
Rimrock post	5.81	2.07	0.99
Flynn pre	6.30	7.56	
Flynn post	9.78	8.55	0.99

Avian density data are presented as estimated birds / ha as calculated by Program Distance. Table 11 is a list of all breeding birds encountered and the number of observations across study sites and treatments for surveys conducted from 2009-2011. Table 12 and Figure 8 illustrate mean density, Standard Error, 95% CI, and Effective Detection Radius for all bird species encountered on survey routes (2009-2011). Tables 13 – 20 and Figures 9 – 16 report mean density (birds/ha) and effective detection radius (EDR) data for Brown Creepers, Dark-eyed (White-winged) Juncos, American Robins, Hairy Woodpeckers, Plumbeous Vireos, Red-breasted Nuthatches, Ruby-crowned Kinglets, and Yellow-rumped Warblers, respectively. These species were analyzed individually because either they were listed as species of special concern (Brown Creeper, Dark-eyed [White-winged] Junco), or were representative of the various feeding guilds among forest birds.

Table 11. Total observations of all breeding birds from Custer State Park surveys (2009-2011), at pre- and post-treatment transects at the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Common Name	Scientific Name	Sylvan pre	Sylvan post	Rimrock pre	Rimrock post	Flynn pre	Flynn post
Mourning Dove	*Zenaida macroura*	0	1	0	5	0	0
Common Nighthawk	*Chordeiles minor*	0	1	0	2	0	0
Downy Woodpecker	*Picoides pubescens*	1	0	0	0	1	0
Hairy Woodpecker	*Picoides villosus*	22	41	7	7	1	1
American Three-toed Woodpecker	*Picoides dorsalis*	0	0	0	0	0	2
Black-backed Woodpecker	*Picoides arcticus*	2	0	0	0	0	0
Yellow-bellied Sapsucker	*Sphyrapicus varius*	0	3	0	0	0	0
Red-naped Sapsucker	*Sphyrapicus nuchalis*	13	18	0	0	0	0
Northern Flicker	*Colaptes auratus*	1	2	0	0	0	0
Western Wood-pewee	*Contopus sordidulus*	0	3	1	4	0	7
Dusky Flycatcher	*Empidonax oberholseri*	2	8	0	0	0	0
Cordilleran Flycatcher	*Empidonax occidentalis*	0	4	0	0	0	0
Warbling Vireo	*Vireo gilvus*	16	51	0	0	0	0
Plumbeous Vireo	*Vireo plumbeus*	2	1	12	10	0	9
Blue Jay	*Cyanocitta cristata*	1	0	0	0	0	0
Gray Jay	*Perisoreus canadensis*	5	5	0	1	0	0
Clark's Nutcracker	*Nucifraga columbiana*	0	0	0	0	4	0
Black-capped Chickadee	*Poecile atricapillus*	24	60	18	19	6	4
Red-breasted Nuthatch	*Sitta canadensis*	57	112	53	25	10	14
White-breasted Nuthatch	*Sitta carolinensis*	6	8	3	4	0	10
Brown Creeper	*Certhia americana*	7	10	9	3	1	0
Canyon Wren	*Catherpes mexicanus*	1	0	0	0	0	0
Rock Wren	*Salpinctes obsoletus*	1	0	0	0	0	0
American Robin	*Turdus migratorius*	52	93	7	5	4	5
Swainson's Thrush	*Catharus ustulatus*	2	8	0	0	0	0
Towsend's Solitaire	*Myadestes townsendi*	30	14	1	0	0	1

Table 11. Continued.

Ruby-crowned Kinglet	*Regulus calendula*	55	47	0	0	0	0
Cedar Waxwing	*Bombycilla cedrorum*	0	0	0	0	1	0
Virginia's Warbler	*Oreothlypis virginiae*	4	0	0	0	0	0
Yellow-rumped Warbler	*Setophaga coronata*	49	131	16	12	0	9
Pine Warbler	*Setophaga pinus*	1	0	0	0	0	0
Ovenbird	*Seiurus aurocapilla*	1	0	0	0	0	0
Western Tanager	*Piranga ludoviciana*	3	3	33	18	8	10
Chipping Sparrow	*Spizella passerina*	12	11	9	2	1	5
Dark-eyed Junco	*Junco hyemalis*	59	120	27	19	8	4
Brown-headed Cowbird	*Molothrus ater*	4	6	0	0	0	2
Red Crossbill	*Loxia curvirostra*	25	38	0	0	0	0
Pine Siskin	*Carduelis pinus*	7	7	0	0	0	0
American Goldfinch	*Carduelis tristis*	0	8	1	0	0	0

Table 12. Total bird density estimates, Standard Error (SE), Effective Detection Radius (EDR), and 95% Confidence Interval for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	95% CI
Sylvan pre	21.00	15.244	54.291	52.066
Sylvan post	14.10	11.536	58.686	53.42
Rimrock pre	11.83	6.4152	62.523	46.241
Rimrock post	16.62	9.7034	51.03	46.725
Flynn pre	44.86	13.486	34.731	27.922
Flynn post	32.49	3.1268	52.061	45.551

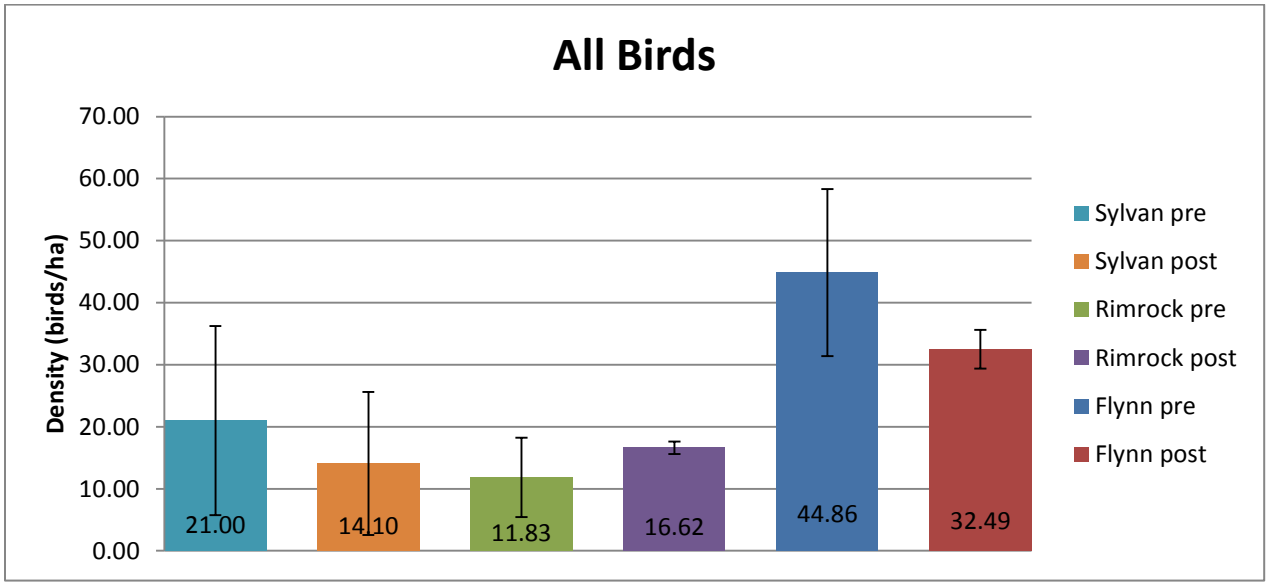

Figure 8. Total bird density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 13. Brown Creeper density estimates, Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	2.47	0.72108	42.496	22.298
Sylvan post	0.99	0.37665	60.042	36.378
Rimrock pre	2.53	0.68662	53.241	27.344
Rimrock post	1.80	0.081935	41.995	7.6682
Flynn pre	0	0		
Flynn post	0	0		

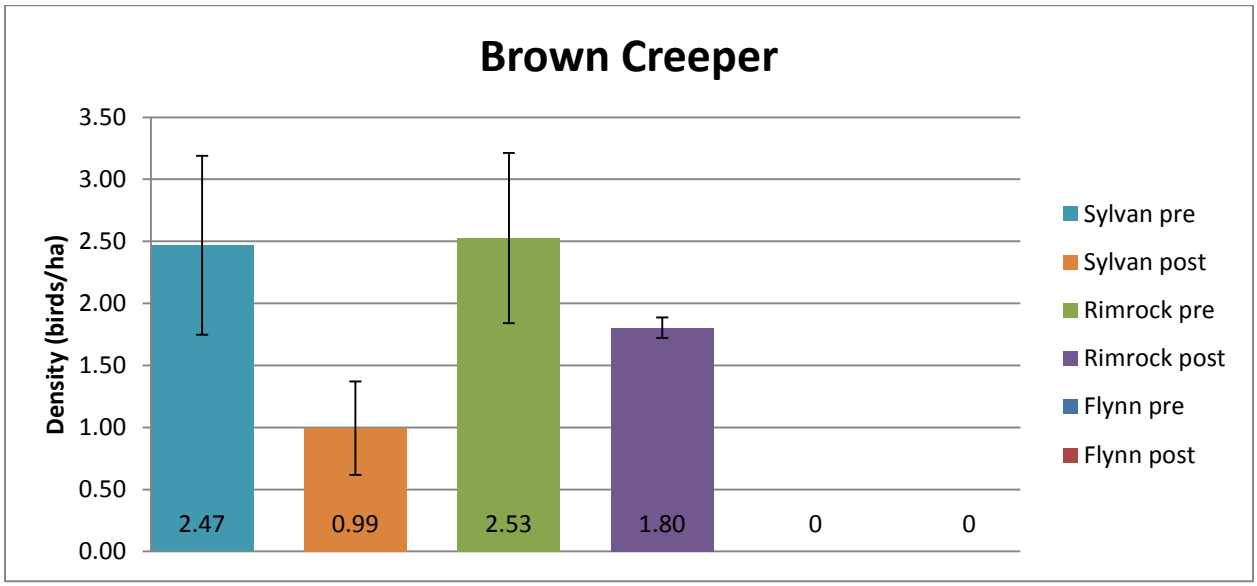

Figure 9. Brown Creeper density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 14. Dark-eyed (White-winged) Junco density estimates, Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	4.48	3.4357	48.271	42.453
Sylvan post	6.33	4.4961	38.846	32.825
Rimrock pre	4.40	2.8868	44.188	35.852
Rimrock post	3.91	2.5163	47.001	37.938
Flynn pre	18.86	8.8971	21.214	14.901
Flynn post	2.29	0.31697	74.493	25.725

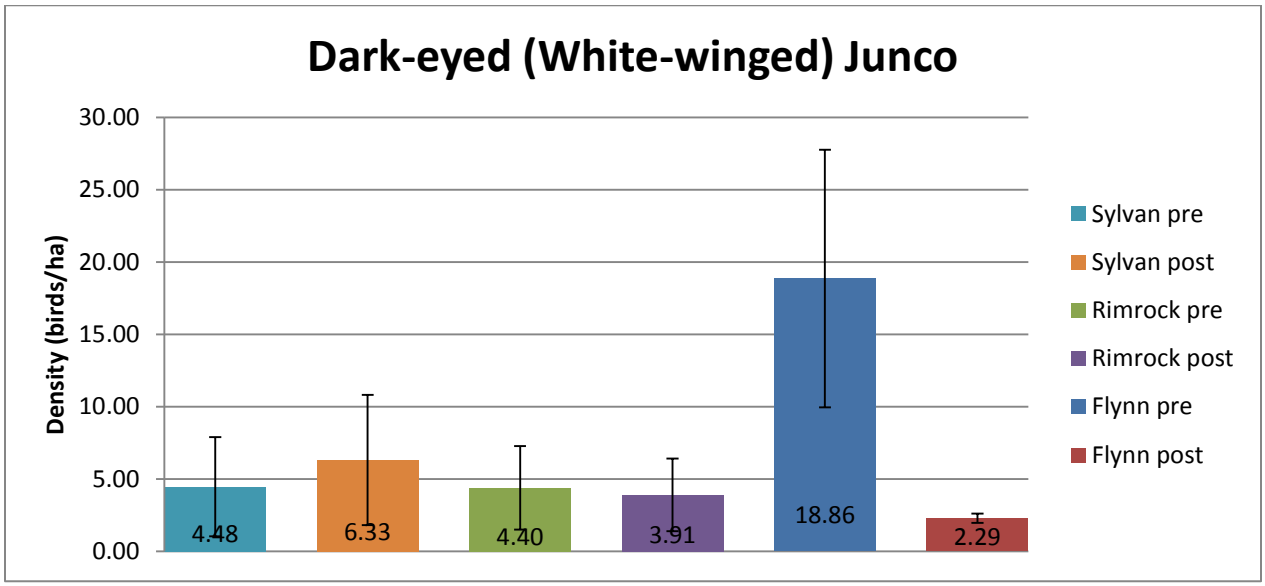

Figure 10. Dark-eyed (White-winged) Junco density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 15. American Robin density estimates Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	2.11	1.6095	58.45	51.353
Sylvan post	1.90	0.72978	62.35	37.804
Rimrock pre	1.91	0.38152	53.99	22.525
Rimrock post	0.66	0.15165	77.55	35.603
Flynn pre	0.88	0.08468	69.49	18.886
Flynn post	2.54	0.05806	56.00	24.574

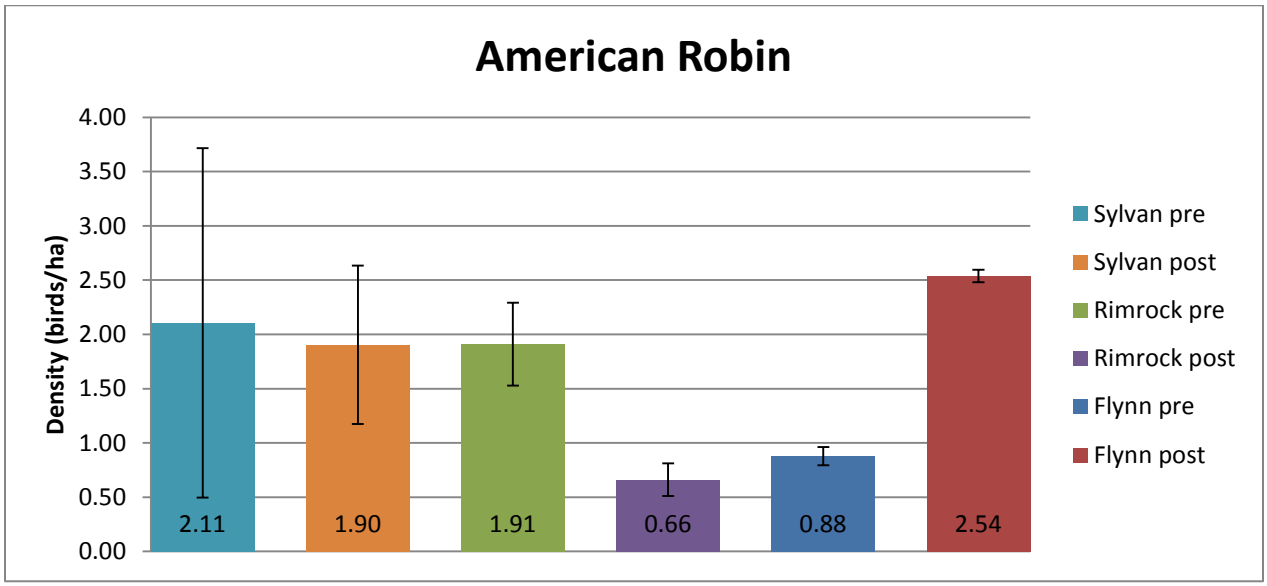

Figure 11. American Robin density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 16. Hairy Woodpecker density estimates, Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	1.25	0.69988	68.35	51.115
Sylvan post	1.31	0.93109	59.65	50.253
Rimrock pre	0.58	0.2544	74.13	48.703
Rimrock post	0.71	0.29817	79.41	51.06
Flynn pre	0	0		
Flynn post	0	0		

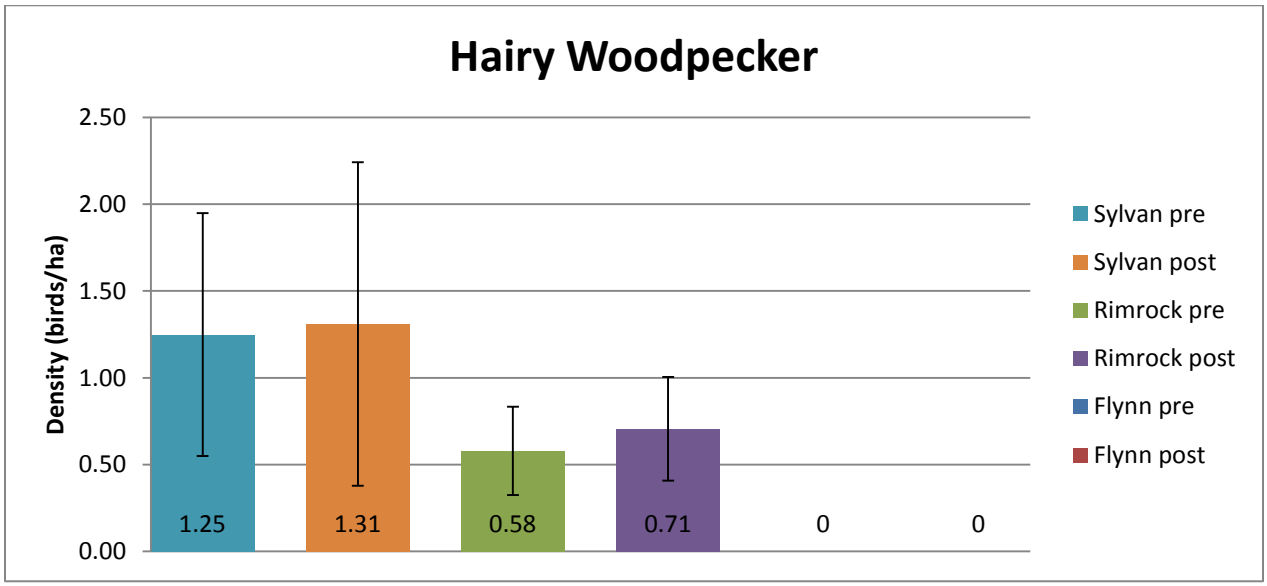

Figure 12. Hairy Woodpecker density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 17. Plumbeous Vireo density estimates, Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	0	0		
Sylvan post	5.93	9.71E-04	40.14	23.068
Rimrock pre	0.86	0.27871	79.80	44.304
Rimrock post	0.82	0.25258	74.49	40.351
Flynn pre	0	0		
Flynn post	3.12	0.97588	55.32	33.973

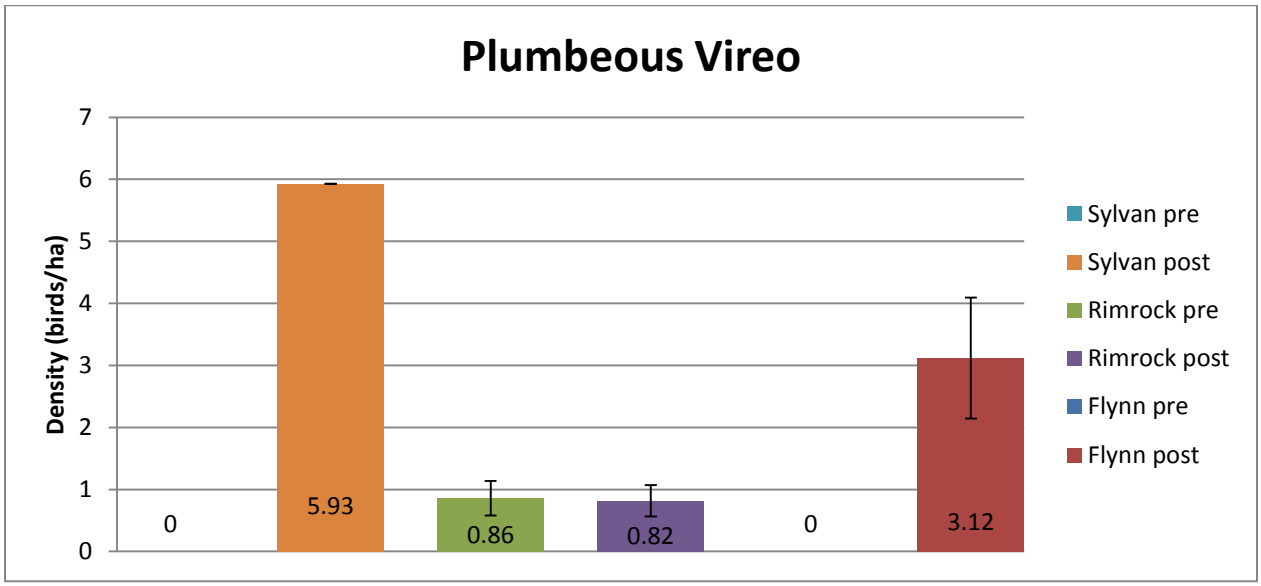

Figure 13. Plumbeous Vireo density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 18. Red-breasted Nuthatch density estimates, Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	2.45	1.6909	59.36	49.494
Sylvan post	3.25	2.5123	46.86	41.225
Rimrock pre	3.62	2.2629	55.71	44.218
Rimrock post	3.36	1.8291	48.67	35.836
Flynn pre	2.01	0.66971	72.69	40.967
Flynn post	10.56	5.4608	37.51	28.282

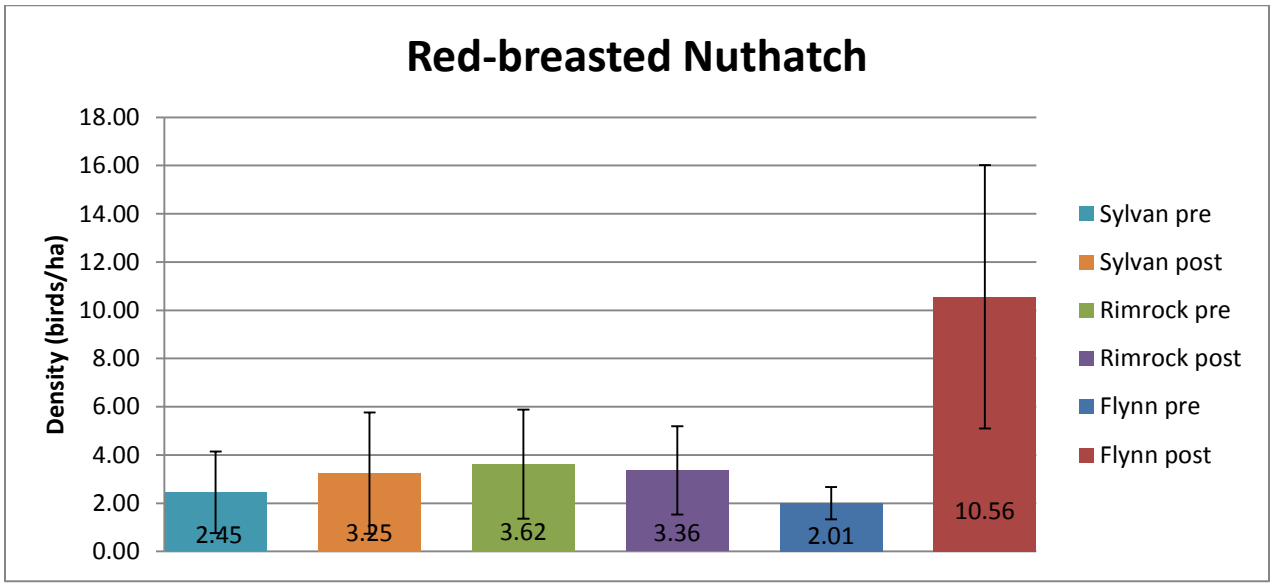

Figure 14. Red-breasted Nuthatch density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 19. Ruby-crowned Kinglet density estimates, Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	1.90	1.2689	68.96	56.482
Sylvan post	0.94	0.19876	78.29	32.946
Rimrock pre	0	0		
Rimrock post	0	0		
Flynn pre	0	0		
Flynn post	0	0		

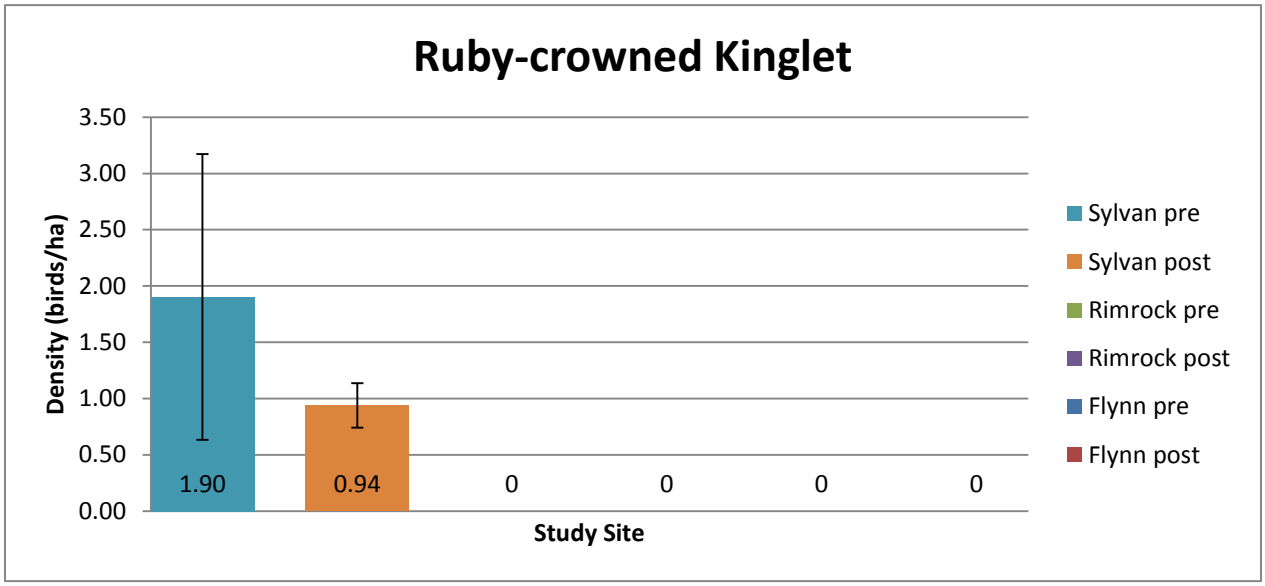

Figure 15. Ruby-crowned Kinglet density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Table 20. Yellow-rumped Warbler density estimates, Standard Error (SE), Effective Detection Radius (EDR), and SE for the EDR as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Density (birds/ha)	SE	EDR (m)	SE
Sylvan pre	5.24	3.0721	41.80	31.994
Sylvan post	2.15	0.73132	62.31	35.268
Rimrock pre	1.08	0.4811	82.02	54.815
Rimrock post	0.97	0.39198	74.89	46.848
Flynn pre	0	0		
Flynn post	1.93	0.47048	70.43	40.963

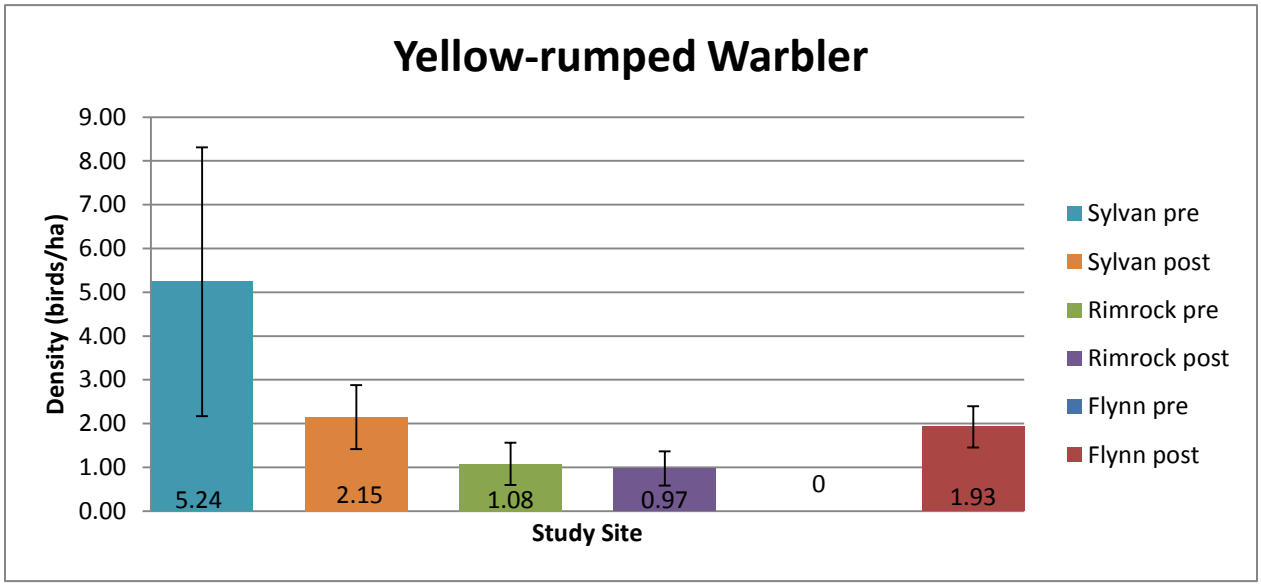

Figure 16. Yellow-rumped Warbler density estimates and 95 % Confidence Interval as calculated by best-fit model within program DISTANCE from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Avian diversity measures (Shannon H' (diversity), Shannon J' (evenness), and Sorenson's Similarity Index) are presented in Table 19. Figure 17 illustrates the Shannon H' diversity index (species richness) with the accompanying 95% confidence interval around the estimate.

Table 19. Shannon diversity (H') and evenness (J') indices, total species present, total numbers, and Sorenson's index of similarity for avian presence and abundance data from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Site	Shannon Index (H')	SE	Shannon Evenness (J')	Total Species	Total Individuals	Index of Similarity*
Sylvan pre	2.7137	0.076	0.833	26	466	
Sylvan post	2.6060	0.065	0.782	28	818	0.7931
Rimrock pre	2.1812	0.109	0.826	14	197	
Rimrock post	2.3825	0.113	0.879	15	136	0.8276
Flynn pre	2.0708	0.175	0.863	11	45	
Flynn post	2.4173	0.109	0.916	14	83	0.56

* Index of Similarity = Sorenson's Beta Diversity (Sorenson 1948)

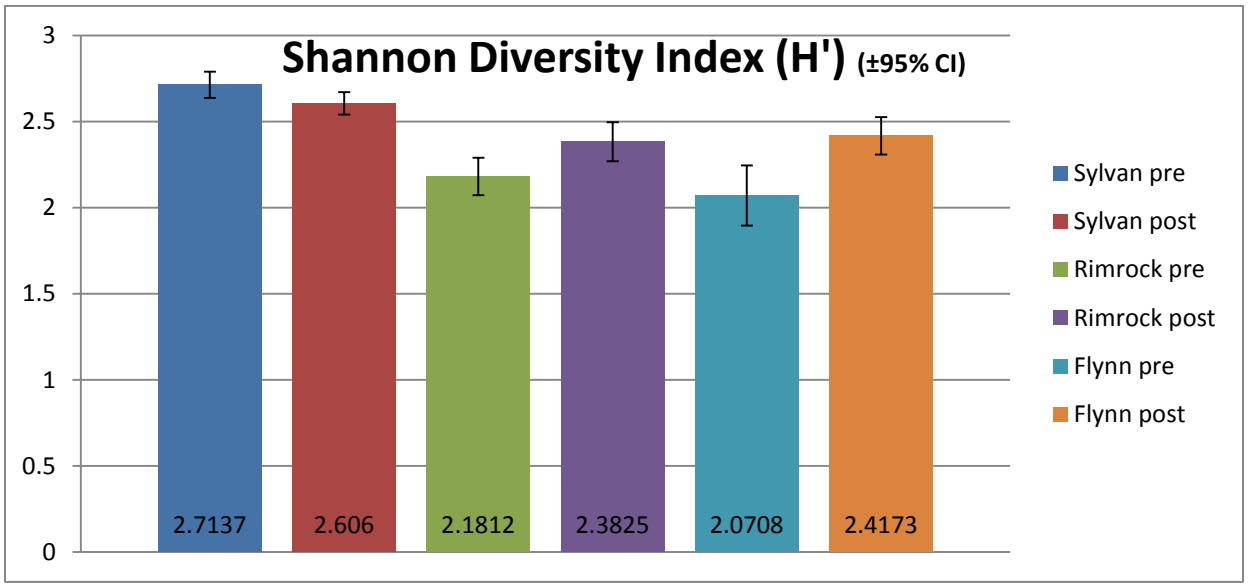

Figure 17. Shannon species diversity indices (H') and 95 % Confidence Interval for avian composition and abundance from the Sylvan Lake, Rimrock, and Flynn Creek study sites.

Discussion

Vegetation Structure – Thinning out dense stands of small size class trees functions to open the stand and allows more resources (light and moisture) for the remaining trees those results in more vigorous growth. Thinning is the reduction of stand density, thereby reallocate growing space for remaining trees, thereby increasing tree vigor (Oliver and Larson 1990). Trees with low vigor often have greater risk of bark beetle attack resulting in mortality (Sartwell 1971; Larsson et al. 1983). Research has shown that thinning ponderosa pine can reduce competition leading to immediate decreases in water stress that can last from 8 to 16 years and contribute to increases in phloem thickness, net photosynthetic rates, and annual or periodic basal area increment growth rates (Kolb et al. 1998; Zausen et al. 2005).

Thinning may also alter the structure of habitats that provide the vegetative components of the community that largely influence the bird community structure by providing nesting, roosting, and feeding habitats for the various guilds of forest birds ((Wiens and Rotenberry 1981; Robinson and Holmes 1984; Rotenberry 1985). In forest systems, structure is provides within the framework of tree density, size (diameter and height), and the density of the forest canopy, which is a function of both the depth and width of tree crowns within each forest stand. Both horizontal and vertical cover at or near the forest floor is provided by herbaceous vegetation (forms and grasses), and shrubs. The structure of these components largely dictates avian species assemblages; and altering these structural components by thinning trees may also in turn alter the avian community.

Forest treatment (thinning) in the threes study sites within CSP did not significantly alter the mean dbh of the overstory within the forest stand. This indicates that in most cases, the thinning process did not target certain size classes (by diameter) of larger trees. In the pre-treatment sites the overstory trees ranged from a mean of 28 – 35 cm (11.0 – 13.8 in), and in the post-treatment sites the trees ranged from means of 29.2 – 34.2 cm (11.5 – 13.5 in) across the three study sites. Within the understory component of the forest stands (trees <25 cm, [10 in}), thinning appeared to be directed at removing the smaller trees within the Sylvan and Rimrock study sites because the mean dbh of smaller size class trees was greater in both of those areas. There was no difference in pre- and post-treatment mean dbh of understory trees within the Flynn Creek site.

Tree heights averaged 12 – 14 m taller on the post treatment sites at both Sylvan and Rimrock. They did not significantly change at Flynn Creek. Harvest of trees at the Sylvan and Rimrock sites focused on sub-dominant trees within the stand, and thereby opened the stand but also retained the larger, dominant stand trees. Removal of the sub-dominant trees has the potential to remove or reduce habitat availability within the stand for birds that are mid-story specialists.

Crown depth and width of trees functions as canopy cover and acts to shade the ground and block light that in turn inhibits the growth of herbaceous and shrub layers on or near the forest floor. The treatments applied at the Sylvan and Flynn Creek sites did not alter mean crown width or depth (Tables 3 and 4), but significantly reduced both crown depth and width at the Rimrock site. Opening the crown structure at the Rimrock site has the potential to increase the available habitat for birds preferring more open stands with less crown canopy.

Tree density was reduced significantly at all three study sites. Density reduction varied from 28% at Rimrock, 76% at Sylvan, and 83% reduction of trees/ha at the Flynn Creek site. The reduction in tree density significantly opened up the stands in terms of habitat structure; potentially providing adequate habitat resources for bird species that prefer larger trees in more open stands. The reduction in tree density should also potentially allow more light to penetrate to the forest floor and thereby facilitate a more robust herbaceous community.

The grass and forb components of the vegetative community were negligible at all three sites, it ranged from 0.5% to 17%. The Flynn Creek site had the most robust grass and forb component and both were reduced by the thinning treatments. This may be a result of the soil disturbance caused by the machinery and harvesting activities, but may recover over time. Later monitoring may indicate recovery of the herbaceous cover. Shrub cover was only present in large part at the Flynn Creek site and the shrub community was remained largely intact after the thinning treatments. Shrub cover at both Sylvan and Rimrock was less than 1%. Sylvan and Rimrock probably do not provide adequate habitat resources for birds that prefer the shrub and herbaceous layers of the vegetative community.

The mean VOR was reduced at the Sylvan study site but remained unchanged at both the Rimrock and Flynn Creek sites. At both the Sylvan and Rimrock sites the ground vegetation provided visual obstructions to a height of approximately 14cm at the maximum. The Flynn Creek site provided slightly more ground visual obstruction but still only ranged from 16 to 24 cm pre and post treatment, respectively.

Avian Communities- Based on the overlap of the 95% CI, there was no change in total bird density between the pre and post treatments on any of the sites. The largest difference in pre and post treatment density was at Flynn Creek, where the mean density was reduced by approximately 20%. But due to the high variability, it was not statistically significant. Flynn Creek (pre-treatment) also contained the highest density of breeding birds even though the total number detected there during surveys was less than others. This was because the Effective Detection Radius was much smaller in that particular habitat condition of high density of smaller-sized trees and a robust shrub component within the forest stand.

Brown Creepers were not detected at the Flynn Creek study site. However, they were present at both the Sylvan and Rimrock sites that were composed of larger sized (dbh) trees that are preferred by creepers. Several studies have found that Brown Creepers are found in highest abundance in mature to old-growth forests with high canopy coverage (Verner and Boss 1980; Hejl and Verner 1988; Mannan and Siegel 1988). Our findings are consistent with those previously published. As thinning activities reduced the density of larger-sized trees within the Sylvan and Rimrock study sites, the Brown Creeper densities decreased accordingly (60% decrease at Sylvan and 29% at Rimrock). Although thinning treatments reduced the density of brown creepers, it did not eliminate them since adequate numbers of appropriate sized trees were retained in those sites.

Dark-eyed (white-winged) juncos are endemic to the Black Hills and adjacent areas of South Dakota, Wyoming, Nebraska and Montana (Nolan et al. 2002). Due to their endemic status, they are a

species of particular concern to state and federal management agencies. Juncos were not present in high densities in either the Sylvan or Rimrock sites, and the thinning activities at these sites had little to no impact on junco density. However, junco densities were highest (18.8 birds/ha) at the pre-treatment Flynn Creek site and their densities were reduced by 88% after the thinning treatment. The thinning of the smaller tree sizes of the understory may be directly related to the reduction in junco densities at Flynn Creek. Since the shrub component of the Flynn Creek site remained largely intact after the thinning process, it seems likely that juncos were utilizing the dense stand of smaller size-class Ponderosa pine to meet their resource needs. Tree density was reduced by 81% at the Flynn Creek site, which correlated nearly directly with an 88% decrease in junco density.

American robin densities remained relatively unchanged at the Sylvan site from pre- to post-treatment. However, at the Rimrock site, robin density decreased by 66% after the thinning treatment. At the Flynn Creek site, the density of robins increased from 0.88 birds/ha to 2.54 birds/ha, an increase of 2.88%. Robins are fairly plastic and have the ability to utilize habitats ranging from open suburban gardens to native forest stands. (Sallabanks and James 1999). American Robins do tend to avoid very dense, young stands of small trees or shrubs (Sallabanks and James 1999), so opening dense, early age stands of Ponderosa pine should increase their attractiveness for robins, as we observed at the Flynn Creek study site. However, American Robins were not in high densities in any of the three sites.

Hairy Woodpeckers were not found at the Flynn Creek study site. They were present at both the Sylvan and Rimrock sites. The density of Hairy Woodpeckers increased slightly at both the Sylvan and Rimrock sites following the thinning treatment, indicating that thinning had no negative impact, and perhaps benefitted the species. In previous descriptions of preferred habitats of Hairy Woodpeckers in California, it was found that they preferred old-growth trees, but were most common in old-growth pines (Robertson 1993), or in mixed conifer-oak stands, or in nearly unmixed open conifer forest stands (Small 1994).

The Plumbeous Vireo generally favors coniferous woodlands of open structure with some deciduous understory (Balda 1969, Johnsgard 1979). We detected no change in Plumbeous Vireo density at the Rimrock site (0.86 – 0.82 birds/ha). However, Plumbeous Vireos responded positively to the thinning treatments at both the Sylvan and Flynn Creek sites. The thinning and opening of these stands certainly benefited the Plumbeous Vireos. Plumbeous Vireos were absent from both the Sylvan and Flynn Creek sites prior to stand treatments. Vireo densities increased dramatically at both sites to 5.93 birds/ha at Sylvan, and 3.12 birds/ha at Flynn Creek. Thinning treatments in dense conifer stands within the Black Hills should certainly improve habitat conditions for Plumbeous Vireos.

Red-breasted nuthatch densities did not change from pre- to post treatment at either the Sylvan or Rimrock sites. They did, however, respond positively to the thinning treatment at the Flynn Creek site (525% increase). Raphael and White (1984) found that Red-breasted Nuthatches in California were coniferous forest specialists, and preferred open, high canopies and larger-sized trees. They avoided areas that had been burned (Raphael and White 1984). It appears that as the tree density at Flynn Creek decreased, it opened the stand to allow nuthatches access to the remaining trees.

Ruby-crowned Kinglets were observed only in the higher elevations (Sylvan site) where there is a white spruce component to the forest. They were not observed in either the Flynn Creek or Rimrock sites, where the stand is purely ponderosa pine. Beason et al. (2006) found the highest densities of breeding Ruby-crowned kinglets in the white spruce forests of the northern Black Hills, but also found them in mixed Ponderosa pine and riparian habitats. Other studies have found that Ruby-crowned Kinglets prefer relatively dense forest stands, and that kinglet abundance decreased in spruce forests that experienced heavy spruce mortality due to beetle infestations relative to lightly infested forests. These studies also showed that kinglets were lower in abundance in salvage-logged spruce forest, and absent from both young and old burns (Lance and Howell 2000, Matsuoka et al. 2001, Schwab et al. 2001). Our findings are consistent with these previously published studies. The Ruby-crowned Kinglet breeding density at Sylvan decreased by approximately 50% after the thinning treatment that reduced the stand density by 65%.

The highest densities of Yellow-rumped Warblers were at the pre-treatment Sylvan site. The thinning treatment reduced densities at Sylvan by approximately 60%. However, the variability of breeding densities was high at Sylvan. There was no observed effect on Yellow-rumped Warblers at the Rimrock site. However, Yellow-rumped warbler density increased from no warblers detected pre-treatment, to 1.93 birds/ha following the thinning operations. Parker et al. (1994) found that Yellow-rumped Warblers were largely absent in early successional stage coniferous forests in eastern Canada. Other studies have shown variable responses to logging operations from decreases of 75-86% in an Arizona study (Franzeb 1978), to no significant change in density (Webb et al. 1977). In our study it appears that decreasing tree density at the Flynn Creek site allowed the warblers to utilize that stand. Conversely, thinning the more mature and diverse stand at Sylvan apparently decreased the suitability of that site to sustain high densities of Yellow-rumped Warblers.

Two other species of special concern, American Three-toed Woodpecker and Black-backed Woodpecker were also detected during our surveys. The American Three-toed Woodpecker was detected in the post-treatment transect on the Flynn Creek site, and the Black-backed Woodpecker was detected at the pre-treatment Sylvan site. In both cases, the encounters were during only one of the two surveys conducted on each transect each year, and continued searching failed to detect these species of concern.

Diversity Indices- Overall we detected no change in species diversity (Shannon H') across all three study sites from the pre- to post-treatment. In all sites there were more species detected following treatment than were detected previous to the thinning operations. Diversity increased the most (16.7%) at the Flynn Creek site following the stand treatment. However, the bird community at Flynn Creek was the least diverse in both the pre- (11 species) and post-treatment (14 species). The Sylvan site was the most diverse overall in terms of the number of species present and the total number of birds detected. The similarity index (Sorenson 1948) indicated that the species composition was most different pre- to post treatment at the Flynn Creek site (0.56) and most similar at the Rimrock site (0.83). Thinning the dense stand of smaller trees at Flynn Creek allowed species that were previously absent or rarely encountered at the site to colonize the area. These include species such as Plumbeous Vireos, Yellow-rumped Warblers, Red-breasted Nuthatches, and American Robins. Thinning treatment in the more mature

stands had little impact on most species, and either slightly increased or decreased specific bird densities based on species preferences for open vs. dense forest stands. In a meta-analysis of studies investigating impacts of forest thinning on biodiversity of all species, Verschuyl et al. (2011) determined that forest thinning treatments had generally positive or neutral effects on diversity and abundance across all taxa, although thinning intensity and the type of thinning conducted may at least partially drive the magnitude of responses. Our findings during this study support this as well. Thinning had definite positive effects on bird species that preferred more open forest stands (eg. Plumbeous Vireo), but also showed negative impacts on breeding densities of other species such as Brown Creepers that prefer dense, old-growth conditions with large trees. Overall species richness and evenness remained largely unchanged by thinning treatments.

Acknowledgements

This study was funded in part by the South Dakota Department of Game, Fish and Parks and in part by federal funding through State Wildlife Grant T-2-R-1, Study #2442, administered through the U.S. Fish and Wildlife Service.

Literature Cited

Allen, K. K. 2008. Evaluation of mountain pine beetle activity in the Norbeck Area, Black Hills National Forest. Forest Health Evaluation RCSC 08-03, US Forest Service, Rocky Mountain Region, Golden CO.

Balda, R. P. 1969. Foliage use by birds of the oak-juniper woodland and ponderosa pine forest in southeastern Arizona. Condor 71:399-412.

Benkobi, L., D. W. Uresk, G. Schenbeck, and R. M. King. 2000. Protocol for monitoring standing crop in grasslands using visual obstruction. Journal of Range Management 53:627–633.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling. Oxford University Press, London.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas (eds). 2004. Advanced distance sampling. Oxford University Press, Oxford.

Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs 72: 202 pp.

Cogan, D., H. Marriott, and M. Pucherelli. 2002. Custer State Park South Dakota Vegetation Mapping Project. U.S. Bureau of Reclamation, Technical Services Center, Federal Center Building 56, Denver, Colorado, USA.

Custer State Park Climate Data. 1983–2007. Climate Data, Custer State Park, South Dakota, Annual Summary. Custer State Park Weather Station, Custer, South Dakota, USA.

Custer State Park Resource Management Plan. 1995-2010. South Dakota Department of Game, Fish, and Parks. Parks Division, Custer State Park, Custer, SD, USA.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43-64.

Dykstra, B. L., M. A. Rumble, and L. D. Flake. 1999. Effects of timber harvesting on birds in the Black Hills of South Dakota and Wyoming, USA. In: Cook, J. E. and B. P. Oswald, compilers. First Biennial North American Forest Ecology Workshop; 1997 June 24-26; Raleigh, NC; 16-26.

Emlen, J. T. 1971. Population densities of birds derived from transect counts. Auk 88:323-342.

Franklin, J. F., and R. T.T. Forman. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles. Landscape Ecology 1:5-18.

Franzreb, K. E. 1978. Tree species used by birds in logged and unlogged mixed-coniferous forests. Wilson Bull. 90:221-238.

Freemark, K. E., and H. G. Merriam. 1986. Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biology Conservation 36:115-141.

FY2006 Monitoring and Evaluation Report. 2007. United States Department of Agriculture, U.S. Forest Service, Supervisor's Office, Black Hills National Forest, 1019 North Fifth St., Custer, SD.

Gibbs, M.C. 1993. Big game habitat utilization in noncommercially thinned ponderosa pine in Custer State Park. M.S. thesis. South Dakota State University, Brookings, South Dakota, USA.

Hejl, S. J. and J. Verner. 1988. Evaluating avian-habitat relationships in red fir forests of the Sierra Nevada. Trans. West. Sect. Wildl. Soc. 24:121-134.

Hoffman, G. R., and R. R. Alexander. 1987. Forest vegetation of the Black Hills National Forest of South Dakota and Wyoming: a habitat type classification. USDA, For. Serv. Res. Paper RM-276. Rocky Mtn. For. And Range. Exp. Stn., Fort Collins, CO.

Hosmer, D. W., and S. Lemeshow. 2000. Applied Logistic Regression. Second edition. John Wiley and Sons Incorporated Publication, New York, New York, USA.

James, F. C., and N. O. Wamer. 1982. Relationships between temperate forest bird communities and vegetation structure. Ecology 63:159-171.

Johnsgard, P. A. 1979. Birds of the Great Plains. Univ. of Nebraska Press, Lincoln, NE.

Johnson, R. R., K. F. Higgins, and D. E. Hubbard. 1995. Using soils to delineate South Dakota physiographic regions. Great Plains Research 5:309–322.

Kolb, T.E., K.M. Holmberg, M.R. Wagner, and J.E. Stone. 1998. Regulation of ponderosa pine foliar physiology and insect resistance mechanisms by basal area treatments. Tree Physiology. 18: 375–381.

Lance, E. W. and S. Howell. 2000. Survey of songbirds during a spruce beetle (*Dendroctonus rufipennis*) outbreak on the Kenai Peninsula, Alaska. Northwestern Naturalist 81(1):1-10.

Larson, G. E and J. R. Johnson. 1999. Plants of the Black Hills and Bear Lodge Mountains. South Dakota State University, Brookings, South Dakota, USA.

Larsson, S., R. Oren, R. H. Waring, and J.W. Barrett. 1983. Attacks of mountain pine beetle as related to tree vigor of ponderosa pine. Forest Science. 29: 395–402.

Lord, J. M., and D. A. Norton. 1990. Scale and the spatial concept of fragmentation. Conservation Biology 4:197-202.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey, USA.

Mannan, R. W. and J. J. Siegel. 1988. Bird populations and vegetation characteristics in immature and old-growth ponderosa pine forests, northern Arizona. Unpubl. rep. to U.S. For. Serv. #G500016. Dep. Wildl. Fish. Univ. of Arizona, Tucson.

Manuwal, D. A., and A. B. Carey. 1991. Methods for measuring populations of small diurnal forest birds. USDA, For. Serv. Gen. Tech. Rep. PNW-GTR-278. Pacific Northwest Res. Stn., Portland, OR.

Matsuoka, S. M., C. M. Handel, and D. R. Ruthrauff. 2001. Densities of breeding birds and changes in vegetation in an Alaskan boreal forest following a massive disturbance by spruce beetles. Canadian Journal of Zoology. 79:1678-1690.

McGarigal, K., and W. C. McComb. 1995. Relationships between landscape structure and breeding birds in the Oregon Coast Range. Ecological Monographs 63:235-260.

National Climatic Data Center. 1971–2000. Climatological Data, South Dakota, Annual Summary. National Oceanic and Atmospheric Administration, Asheville, North Carolina, USA.

Nolan, Jr., V., E. D. Ketterson, D. A. Cristol, C. M. Rogers, E. D. Clotfelter, R. C. Titus, S. J. Schoech and E.Snajdr. 2002. Dark-eyed Junco (Junco hyemalis), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/716 doi:10.2173/bna.716

Oliver, C.D., and Larson, B.C., 1990. Forest Stand Dynamics. McGraw-Hill Inc.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. USDA, For. Serv. Gen. Tech. Rep. PSW-GTR-144. Albany, CA.

Raphael, M. G. and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildlife Monographs. 86:1-66.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82: 309-313.

Ripple, W. J., G. A. Bradshaw, and T. A. Spies. 1991. Measuring forest landscape patterns in the Cascade Range of Oregon, USA. Biology Conservation 57:73-88.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weights of grassland vegetation. Journal of Range Management 23: 295-297.

Robertson, D. 1993. Hairy Woodpecker *Picoides villosus*. Pages 200-201 in Atlas of breeding birds of Monterey County. (Robertson, D. and C. Tenney, eds.). Monterey Peninsula Audubon Society, Pacific Grove, CA.

Robinson, S. K., and R. T. Holmes. 1984. Effects of plant species and foliage structure on the foraging behavior of forest birds. Auk 101:672-684.

Rosenstock, S.S., D. R. Anderson, K. M. Geisen, T. Leukering, and M. E. Carter. 2002. Landbird counting techniques: current practices and an alternative. Auk 119:46-53.

Rotenberry, J. T. 1985. The role of habitat in avian community composition: physiognomy or floristics? Oecologia 67:213-217.

Sallabanks, R. and F.C. James. 1999. American Robin (*Turdus migratorius*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/462 doi:10.2173/bna.462

Sartwell, C., 1971. Thinning ponderosa pine to prevent outbreaks of mountain pine beetle. In: Baumgartner, D.M. (Ed.), Proceedings of the Precommercial Thinning of Coastal and Intermountain Forests in the Pacific Northwest, February, Pullman, WA. Coop. Ext. Serv., Dep. For. Range Manage. Washington State Univ., Pullman, WA, pp. 41–52, 109 pp.

Schwab, F. E., N. P. P. Simon, and C. G. Carroll. 2001. Breeding songbird abundance related to secondary succession in the subarctic forests of western Labrador. Ecoscience 8:1-7.

Shannon, C. E., and W. Weaver. 1963. The mathematical theory of communication. University of Illinois Press, Urbana, USA.

Sharpe, G. W., C. W. Hendee, and S. W. Allen. 1976. Introduction to forestry. McGraw-Hill Company, New York, New York, USA. 544 pp.

Small, A. 1994. California birds: their status and distribution. Ibis Publishing Co., Vista, CA.

Sørensen, T.A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analyses of the vegetation on Danish commons. Kongelige Danske Videnskabernes Selskabs Biologiske Skrifter. 5: 1–34.

Steidl, R. J., J. P. Hayes, and E. Schauber. 1997. Statistical power analysis in wildlife research. Journal of Wildlife Management 61:270-279.

Stumpf, K. A. 1993. The estimation of forest vegetation cover descriptions using a vertical densitometer. Joint Inventory and Biometrics Working Groups Session. Indianapolis, Indiana, USA.

Szaro, R. C., and R. P. Balda 1979. Bird community dynamics in a ponderosa pine forest. Studies in avian biology no. 3. Cooper Ornithological Society.

Szaro, R. C., and R. P. Balda. 1986. Relationships among weather, habitat structure, and ponderosa pine forest birds. Journal of Wildlife Management 50:253-260.

Thomas, L., J. L. Laake, S. Strindberg, E. E. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, and J. R. B. Bishop. 2003. Distance 4.1 Release 1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK

Thomas, L., J.L. Laake, E.A. Rexstad, S. Strindberg, F.F.C . Marques, S. T. Buckland, D.L. Borchers, D.R. Anderson, K. P. Burnham, M. L. Burt, S. L. Hedley, J. H. Pollard, J.R.B. Bishop and T. A. Marques 2009. Distance 6.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J.R.B. Bishop, T.A. Marques, and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

Verner, J. and A. S. Boss. 1980. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. U.S. For. Serv.

Verschuyl, J. S. Riffell, D. Miller, and T. Bently Wigley. 2011. Biodiversity response to intensive biomass production from forest thinning in North American forests – A meta-analysis, Forest Ecology and Management. 261: 221-232.

Webb, W. L., D. F. Behrend, and B. Saisorn. 1977. Effect of logging on songbird populations in a northern hardwood forest. Wildlife Monographs. 55:6-35.

Weins, J. A., and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecology Monogram 51:21-41.

Zausen, G.L., T.E. Kolb, J.D. Bailey, and M.R. Wagner. 2005. Long-term impacts of stand management on ponderosa pine physiology and bark beetle abundance in Northern Arizona: a replicated landscape study. Forest Ecology and Management. 218, 291–305.