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A COMPARISON OF BIRD ABUNDANCE AMONG SELECTIVELY LOGGED, OLD-GROWTH, AND MATURE SECOND-GROWTH PONDEROSA PINE/DOUGLAS-FIR STANDS

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A Comparison of Bird Abundance Among Selectively Logged, Old-Growth, and Mature Second-Growth Ponderosa Pine/Douglas-Fir Forest Stands

Director: Richard L. Hutto RLH

I examined breeding bird abundance and habitat characteristics in selectively logged ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) stands in west-central Montana during the 1991 breeding season. I compared my results with the 1991 results from Hejl's study in old-growth and mature second-growth ponderosa pine/Douglas-fir stands of the same geographical region. The abundances of bird species in selectively logged stands more closely resembled old-growth than mature second-growth stands. For example, the pileated woodpecker (*Dryocopus pileatus*), Hammond's flycatcher (*Empidonax hammondi*), Swainson's thrush (*Catharus ustulatus*), and Townsend's warbler (*Dendroica townsendi*) were each more abundant in old-growth and selectively logged stands than in mature second-growth stands. Surprisingly, species that generally benefit from forest thinning and the resultant open understory, e.g., American robin(*Turdus migratorius*) and chipping sparrow (*Spizella passerina*) were not more abundant in selectively logged stands than they were in old-growth stands. This was probably due to the time span between logging and the bird survey. Bird species more abundant in mature second-growth stands generally appear to be selecting for the open understory.

I tested for an association between breeding bird abundance and habitat structure in selectively logged stands that were cut approximately 20-80 years before the study. The relatively open understory had since filled in with shrubs and shade tolerant Douglas-fir. Ecologically interpretable associations included: pileated woodpecker was positively associated with large trees, American robin was negatively associated with shrub cover, and Townsend's warbler was positively associated with tree height.

The selectively logged stands in this study meet minimal old-growth criteria. Because only small remnants of selectively logged and undisturbed ponderosa pine/Douglas-fir old-growth forest remain after a century of logging, I suggest increasing the amount of old-growth with historic levels as a goal.

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INTRODUCTION

Few studies have examined the effects of logging on bird abundance in the ponderosa pine/Douglas-fir forests of the northern Rockies in spite of the fact that many of these forests have been logged. Timber inventories from the 1930s indicate a drastic change in the age structure of the ponderosa pine forests of west-central Montana over the past sixty years (Losensky 1993). In these inventories from the 1930s the mature age class (100-179 years) accounted for a relatively low percentage (18.7%) of total ponderosa pine acres. Potential old-growth (180+years) accounted for more than half (56.4%) of the the acres in the ponderosa pine cover type. Few ponderosa pine/Douglas-fir older selectively logged or old-growth stands remain in western Montana (Yanishevsky 1993). Logging has removed most of the old-growth ponderosa pine/Douglas-fir forests that once covered vast areas of valley floors and lower to mid elevations on mountain slopes in western Montana (Leiberg1899; Losensky 1993). If there are old-growth dependent bird species, the implications are potentially serious.

Selectively logged ponderosa pine/Douglas-fir stands (especially lightly thinned stands) may play an important role in providing habitat for potential old-growth dependent bird species. Whether structural and specific features necessary for potential old-growth dependent bird species still exist after logging is unknown. Future management of the ponderosa pine/Douglas-fir forest type depends, in part, on a comparative analysis of bird abundance in selectively logged and other stand types.

Of the few studies comparing bird species abundance in treated and untreated ponderosa pine/Douglas-fir forest in the northern Rockies, only Medin (1985) and Medin and Booth (1989) compared bird species abundance in selectively logged and unlogged Douglas-fir/ponderosa pine stands. Dobkin (1992), however, criticized their studies in west-central Idaho for their lack of replication. The two other studies comparing bird species abundance in the ponderosa pine/Douglas-fir forest type did not analyze selectively logged older stands. Mannan and Meslow (1984) compared only four old-growth and four thinned mature second-growth stands in Douglas-fir/ponderosa pine habitat of northeastern Oregon. Hejl and Woods (1991) provided the most satisfactory sampling design. They compared bird species abundance in old-growth and mature second-growth ponderosa pine/Douglas-fir stands in west-central Montana and adjacent Idaho. They used a large sample size of sixteen separate stands for each stand condition and sampled them four times per season for three seasons (although the report cited above contained only first year results). Despite methodological problems, several bird species (the pileated woodpecker, brown creeper and Townsend's warbler), when found in large enough numbers for statistical analysis, were consistently associated with unlogged forest in the above studies. In contrast, the dusky flycatcher and chipping sparrow consistently were more abundant in logged stands.

Studies of bird abundance in partially cut and untreated ponderosa pine sites in Arizona (Franzreb and Ohmart 1978; Scott and Gottfried 1983; Szaro and Balda1986; Mannan and Siegel 1988) and in treated and untreated sites in the higher elevation forests of the northern Rockies (Moore 1992; Tobalske et al. 1991; Petersen 1982) are of limited value in determining management for bird species found in the ponderosa pine/ Douglas-fir forest type of the northern Rockies. Nonetheless, study results from Arizona's ponderosa pine forests did correspond roughly with those from the ponderosa pine/Douglas-fir forests of the northern Rockies. In both regions cavity nesting species were more abundant on unlogged sites and ground gleaning species were more abundant on treated sites. In the higher elevation forests of the northern Rockies, however, western tanagers, yellow-rumped warblers, ruby-crowned kinglets, red-breasted nuthatches and even chipping sparrows demonstrated different responses to similiar site conditions. Across these three studies from the northern Rockies, no bird species exhibited a consistent positive or negative response to logging or undisturbed conditions.

At present, many management recommendations for potential old-growth dependent bird species in the northern Rockies are based on studies from other regions. Data from different forest types may not be valid due to structural and species differences; applying results between forest types and/or regions should be approached with caution. The management recommendations that have been developed from information available from the northern Rockies (Harger 1978; Christiansen and Kuennen 1984; Warren 1990) do not specifically address statistical differences in bird abundance between habitats. For instance, McClelland (1977) provided compelling evidence for pileated woodpecker use of old-growth forest habitat components, particularly large broken-top trees and snags for nest cavities. His study, however, did not include a comparison of relative species abundance in different forest successional stages or treatment types. Large sample sizes encompassing sites from all successional stages and treatment types, combined with a landscape analysis, would more adequately describe bird species-habitat associations.

Despite some convergence of results for studies of bird abundance in treated and untreated sites across regions and forest types in the western United States no substitute exists for directly testing the regional forest type in question. The low number of comparative studies indicates a need for further investigation of bird abundance in the ponderosa pine/Douglas-fir forests of the northern Rockies. With this in mind I chose to complement Hejl's ongoing study (1991) of ponderosa pine/Douglas fir old-growth and mature second-growth sites by assessing bird abundance in selectively logged stands of the same forest type.

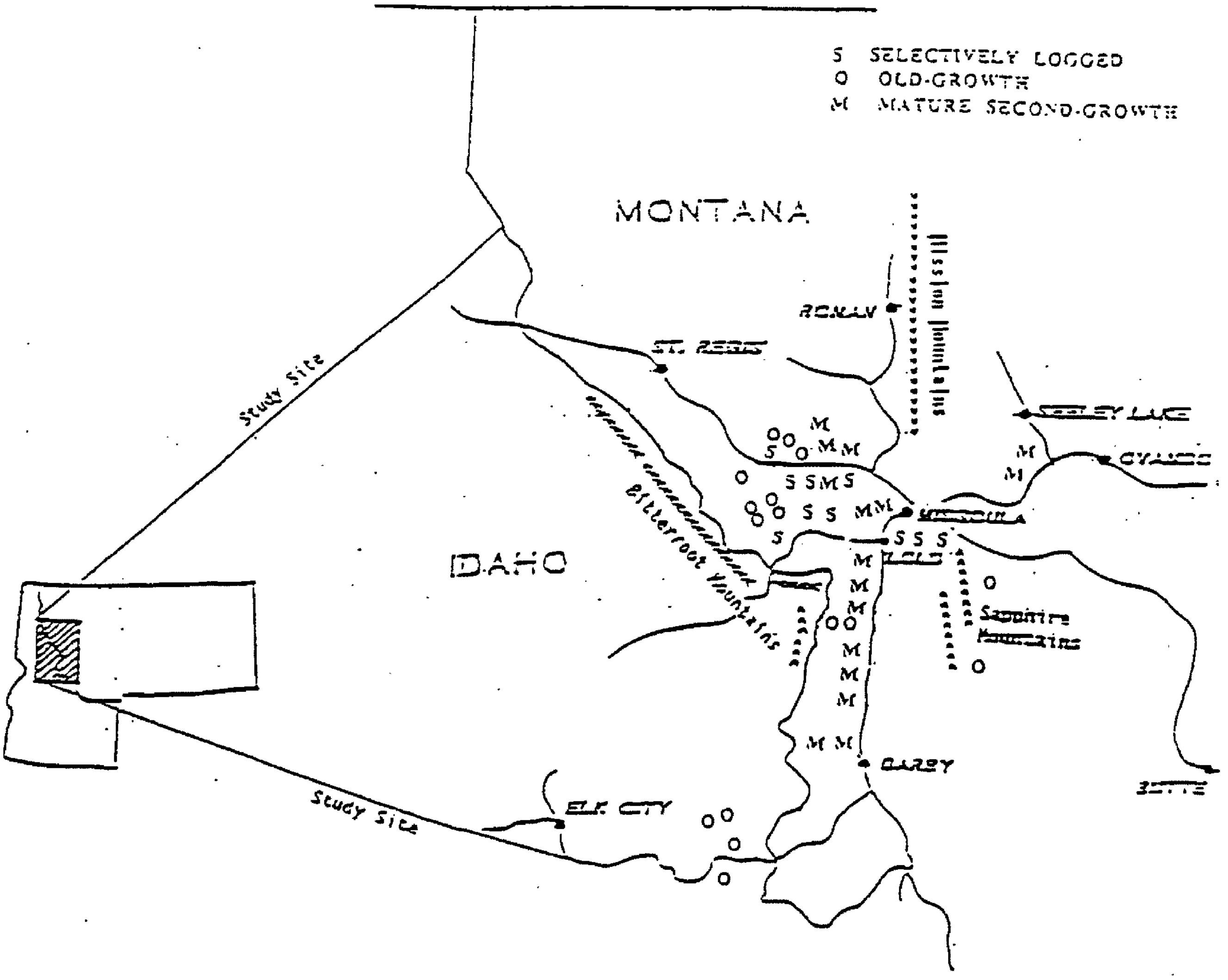
My study objectives were (1) to quantify bird species abundance in selectively logged ponderosa pine/Douglas-fir stands; (2) to analyze the association of bird abundance with habitat variables on selectively logged sites; and (3) to statistically compare bird abundance in selectively logged ponderosa pine/Douglas fir stands to the old-growth and mature second-growth ponderosa pine/Douglas-fir stands of Hejl (unpub. data) for the 1991 field season.

STUDY AREAS

Ponderosa pine/Douglas-fir forest types occur primarily on south and west aspects of well-drained, low elevation sites in USFS Region One (Green 1992).

I chose selectively logged stands located within a 40-mile radius of Missoula, Montana (Figure 1). Nine stands were on the Lolo National Forest and one selectively logged stand was a Bureau of Land Management site 20 miles east of Missoula. I compared my results to those from Hejl's 16 old-growth and 16 mature second-growth stands, located in western Montana on the Bitterroot and Lolo National Forests, Lubrecht Experimental Forest, and on adjacent areas of eastern Idaho (Figure 1).

Figure 1. Location of study areas in western Montana and eastern Idaho.



Methods

Stand Selection

I chose selectively logged stands based on Hejl and Woods' (1991) criteria for old-growth stands with the exception of significant disturbance on my sites caused by past selection logging. In Hejl and Woods' and my study: (1) each site was homogeneous in vegetative structure and composition, (2) each site was at least 8 ha in size and at least 200 m wide, (3) the dominant species on each site was ponderosa pine, (4) the dominant trees were near maximal for the species in this geographic area and had old-age characteristics, and (5) stands were at least 0.8 km apart.

Based on U.S. Forest Service records and discussions with Forest Service employees, logging occurred on selectively logged stands approximately 20 to 80 years prior to this study. Almost all selective logging was "high-grading", or the cutting of the largest trees on the site, and varied in intensity among the sites. On average, "high-grading" left a stand with approximately 29 trees and 15 stumps greater than 50 cm dbh/ha (Table 1). Selectively logged stands ranged in size from 11.7 to 93.9 ha and were primarily on steep, south-facing slopes. Although these old-aged sites were distinct in structure from the surrounding landscape, all were situated in a forested matrix predominated by stands at the stem exclusion stage (Oliver and Larson 1990) or older.

Criteria for Hejl and Woods' mature second-growth stands were the same as for their old-growth stands except that the dominant trees were approximately rotation-age for Douglas-fir and ponderosa pine in Forest Service Region One (80 to 120 years), and obvious large scale human disturbance (primarily logging) had occurred on the site.

Design

I measured or estimated habitat (vegetation and topographic) variables during May, June, and July 1991 in the ten selectively logged study sites. I did measurements/estimates at each bird count point, and (with the exception of tree age and height) at three additional points located 70 m from the count point in random compass directions. When sampling sites overlapped, I chose another random point. Hejl and Woods measured vegetation variables at five random plots located within a 100-m radius of the bird count point in old-growth and mature second-growth stands. They obtained topographic characteristics and tree age at each bird count point.

I used 11.3-and 7.3-m-radius circles (.04 and .017 ha, respectively) to sample most vegetation parameters. The vegetation measures comparable with Hejl and Woods' methods were: species and number of stumps (20-50 cm and >50 cm dbh), large trees (>50 cm DBH), and snags (20-50 cm and >50cm dbh) in an 11.3-m-radius circle; species and number of medium trees (20-50 cm dbh) and logs (20-50 cm and >50 cm dbh) in a 7.3-m-radius circle. I visually estimated debris, forb, grass, shrub, small tree

(<20 cm dbh), and total ground cover within 11.3-m-radius circles. Hejl and Woods' estimates of percent cover were considerably more detailed. They sampled 25 points within each 11.3-m-radius circle with a "scope-a-job" to calculate per cent cover for downed wood, forbs, grass, litter, rock, small shrubs, large shrubs, soil, and tree canopy. Comparisons of cover means between my selectively logged sites and the old-growth and mature second-growth sites are potentially inappropriate due to the difference in sampling methods.

I measured basal area with a 10-factor prism, and slope with a clinometer at each point, and I estimated relative slope position (low, medium and high) and distance from the nearest stream. Results for these variables are comparable with Hejl and Woods' results except distance from the nearest stream, which they did not measure or estimate.

Measures of tree age, diameter, and height were consistent with Hejl and Woods' methods. I cored one tree, representing the area's largest size class, on the downhill side at 5 dm (as measured from the uphill side) at each count point. I saved the core and counted the rings later to determine age. I also measured the tree's diameter at the coring point and the tree's height with a clinometer.

In accord with Hejl and Woods' methods, I outlined selectively logged stands on aerial photos and digitized them in order to calculate stand size. The absence of large trees determined the edge of the stand.

I modeled bird counting methods after Hejl and Woods (1991) to compare species richness and relative abundance in selectively logged sites with their old-growth and mature second-growth sites. Count points were located on a linear transect running through the site. Points were 200 m apart and at least 100 m from the edge of the stand or a road. The ten selectively logged sites contained anywhere from two to five points each, while almost all the old-growth and mature second-growth sites contained five points (one old-growth site contained two points and one mature second-growth site had four points).

I conducted ten-minute counts, four times during the breeding season (15 May to 15 July) of 1991. Ten-minute counts include significantly more species than five-minute counts but avoid most of the duplicate counting inherent in twenty-minute counts (Verner1988).

Interobserver variability was not controlled between selectively logged sites and Hejl and Woods' old-growth and mature second-growth sites. Four observers who underwent a common training program did bird counts in the old-growth and mature second-growth stands. They had from one to six years of professional bird-counting experience as well as amateur bird-watching backgrounds. I counted all birds on the selectively logged sites. This was my second year of professional bird-counting. I had several years of amateur bird-watching previous to this study. No attempt was made to assess the difference in bird identification or hearing ability between myself and the other observers. The validity of comparisons between selectively logged sites and old-growth and mature second-growth sites may be questioned due to the lack of a common training and testing program (Kepler and Scott 1981; Ramsey and Scott 1981).

The four visits to each site were spread evenly throughout the breeding season to accommodate seasonal changes in detection (Best 1981) and to match Hejl and Woods' methods. I performed counts between 0630 and 1130, thereby avoiding identification difficulty during the cacophonous dawn chorus. Direction of transect travel at a site alternated with each visit during the season to minimize any possible variation in bird detectability during the morning hours (Robbins 1981a).

I included any birds detected (seen or heard) in the stand, regardless of distance, in the analysis. I did not use observations believed to be duplicates. Birds flushed when approaching a point were counted on old-growth and mature second-growth sites but not on selectively logged sites. The number of flushed birds was extremely low, however, and probably did not affect comparisons of the three stand types. Birds flying over my sites were classified, based upon observable behavior, as either on or off the stand at the time of the point counts. Hejl and Woods' methods included a third category for flyovers: "unknown". The observer was unable to categorize "unknown" birds as on or off the stand with certainty. "Unknown" birds were classified as off the stand for the purposes of this comparison of bird abundance among stand types.

Comparisons of radically different habitats have shown differences in bird detectability (Verner 1985), but all habitats sampled in this study were moderate to densely forested areas; no habitat extremes were compared (e.g. forest vs. clearcut, forest vs. grassland). I doubt that the sound transmission properties of the three treatment types differed appreciably. Differences in detectability between relatively similiar habitats should not significant affect the comparative analysis (Emlen and DeJong 1981).

Robbins (1981b) found that number of songbirds detected is generally inversely correlated with wind speed and amount of rain. Therefore, in accord with Hejl and Woods' study, I did not perform bird counts on rainy (more than a light sprinkle) or windy (greater than 21 mph) days.

Analysis

I did not statistically analyze the means of habitat variables between treatment types. However, I listed summary statistics of the habitat variables for the three stand types in Table 1 and used them comparatively in the results and discussion sections.

I calculated the mean number of bird detections within the stand at a given point (across the four visits at a given point) and then calculated the mean number per point across the five (or fewer) points within a site to generate a site mean and then used site means in an ANOVA to compare treatments for all normally distributed data (Figure 2). Significant P-values (<0.05) indicated that treatment means were not all equal. No multiple comparisons of means, however, was performed . I examined histograms and normal probability plots to determine whether data were normally distributed. If not, Kruskal-Wallis H, a non-parametric test, ranked the mean number of detections per point across sites to determine any significant differences among treatments. I also analyzed BSR (bird species richness) among stand types for all sites and for only those sites with five sampling points.

I performed Pearson chi-square tests for all combinations of bird species and habitat variables in selectively logged sites. The Pearson chi-square statistic measured independence of bird abundance and the various habitat variables. I did not analyze chi-square distributions in which the average of expected counts was less than five and the smallest expected count was less than one. Due to the high number of chi-square tests performed it is likely that some significant associations are spurious. Multi-collinearity among habitat variables, though, makes any estimate of spurious associations practically impossible.

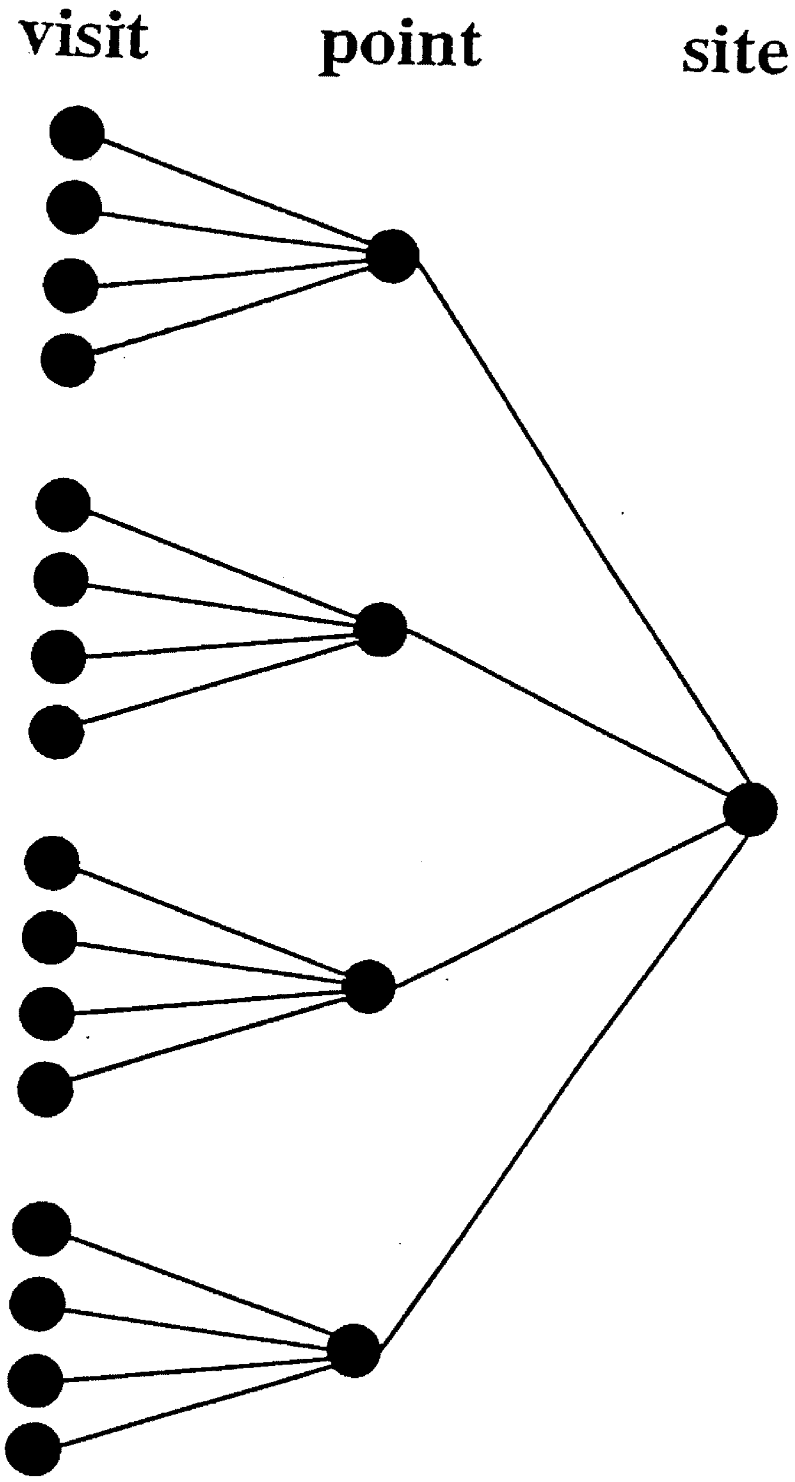


Figure 2 - Study design schematic of a representative site with four bird survey points.

Results

Habitat Variables

Habitat variables for the three stand types are summarized in Table 1 with variable descriptions found in Table 2. Though I did no statistical analysis of habitat variables among the three stand types some obvious relationships stand out. The number of snags and large trees is very similiar between selectively logged and old-growth stands but considerably lower in mature second-growth stands. Medium logs and trees are more abundant in mature second-growth stands. The number of large stumps combined with existing large trees in selectively logged stands indicates that these stands were more productive old-growth sites historically than the old-growth sites in Hejl and Woods' study. Stand size greatly differed among the three stand types. The small size of selectively logged stands and to a lesser degree old-growth stands may have an impact upon bird species dependent upon large tracts of old-growth forest. The dominant trees in both selectively logged and old-growth stands exceeded a mean of 200 years, the age considered minimal for the development of old-growth conditions by McClelland (1977). Dominant trees were slightly taller and wider on old-growth than selectively logged sites, perhaps the result of high grading on the selectively logged sites. As expected, tree age, tree diameter, and tree height were decidedly less on mature second-growth sites. Slope was less

Table 1 - Quantitative summary of habitat variables (as defined in Table 2) from selectively logged (SL), old-growth (OG), and mature second-growth (MA).

Variable	Stand Type	Mean	Standard Error of Mean	Minimum	Maximum	N
Med logs (PIPO)	SL	27.1	9.4	8.0	109.6	10
Med logs (PIPO)	OG	19.7	4.2	0.00	67.5	16
Med logs (PIPO)	MA	51.3	7.2	4.2	115.3	16
Med logs (PSME)	SL	18.3	4.5	0.00	36.0	10
Med logs (PSME)	OG	32.6	9.6	0.00	151.2	16
Med logs (PSME)	MA	16.4	4.2	0.00	55.6	16
Med logs	SL	47.1	9.7	12.0	109.6	10
Med logs	OG	104.3	17.9	16.1	258.8	16
Med logs	MA	132.2	14.3	35.8	243.2	16
Lg logs (PIPO)	SL	13.2	3.0	3.9	31.8	10
Lg logs (PIPO)	OG	10.5	1.8	0.00	19.7	16
Lg logs (PIPO)	MA	1.7	0.60	0.00	7.8	16
Lg logs (PSME)	SL	1.7	0.90	0.00	8.0	10
Lg logs (PSME)	OG	3.9	1.2	0.00	12.0	16
Lg logs (PSME)	MA	0.00	0.00	0.00	0.00	16
Lg logs	SL	14.9	3.3	3.9	31.9	10
Lg logs	OG	22.8	3.0	4.2	43.6	16
Lg logs	MA	8.7	2.4	0.00	40.0	16

Table 1 - (cont)

Variable	Stand Type	Mean	Standard Error of Mean	Minimum	Maximum	N
Med snags (PIPO)	SL	10.2	2.4	0.00	22.4	10
Med snags (PIPO)	OG	3.0	0.66	0.00	10.0	16
Med snags (PIPO)	MA	3.5	0.80	0.00	12.0	16
Med snags (PSME)	SL	7.8	2.9	0.00	32.4	10
Med snags (PSME)	OG	12.3	3.2	1.0	42.9	16
Med snags (PSME)	MA	1.8	1.0	0.00	16.0	16
Med snags	SL	19.0	5.1	0.18	57.5	10
Med snags	OG	17.0	3.4	1.0	46.9	16
Med snags	MA	5.9	1.3	0.00	19.9	16
Lg snags (PIPO)	SL	3.6	0.85	0.00	4.4	10
Lg snags (PIPO)	OG	2.2	0.58	0.00	8.0	16
Lg snags (PIPO)	RA	0.47	0.22	0.00	2.5	16
Lg snags (PSME)	SL	0.5	0.43	0.00	4.4	10
Lg snags (PSME)	OG	1.6	0.69	0.00	11.0	16
Lg snags (PSME)	MA	0.06	0.06	0.00	1.0	16
Lg snags	SL	4.5	1.3	0.60	12.5	10
Lg snags	OG	4.4	0.86	0.00	12.0	16
Lg snags	MA	0.59	0.30	0.00	4.0	16

Table 1 - (cont)

Variable	Stand Type	Mean	Standard Error of Mean	Minimum	Maximum	N
Med stumps (PIPO)	SL	9.0	2.8	0.00	24.8	10
Med stumps (PIPO)	OG					
Med stumps (PIPO)	MA					
Med stumps (PSME)	SL	9.8	3.9	0.00	38.1	10
Med stumps (PSME)	OG					
Med stumps (PSME)	MA					
Med stumps	SL	18.8	4.4	0.00	41.5	10
Med stumps	OG	5.6	1.2	0.00	16.1	16
Med stumps	MA	43.5	5.4	0.00	75.9	16
Lg stumps (PIPO)	SL	12.5	3.9	0.00	30.4	10
Lg stumps (PIPO)	OG					
Lg stumps (PIPO)	MA					
Lg stumps (PSME)	SL	2.4	1.4	0.00	11.6	10
Large stumps (PSME)	OG					
Lg stumps (PSME)	MA					
Lg stumps	SL	14.9	3.7	0.00	30.04	10
Lg stumps	OG	0.63	0.00	0.00	4.2	16
Lg stumps	MA	0.63	0.00	0.00	4.2	16

Table 1 - (cont)

Variable	Stand Type	Mean	Standard Error of Mean	Minimum	Maximum	N
Med trees (PIPO)	SL	70.3	9.9	25.0	129.4	10
Med trees (PIPO)	OG	28.3	4.9	0.00	87.6	16
Med trees (PIPO)	MA	127.2	14.5	51.8	215.0	16
Med trees (PSME)	SL	68.2	14.3	0.00	149.6	10
Med trees (PSME)	OG	66.6	10.3	0.00	163.3	16
Med trees (PSME)	MA	59.6	11.2	0.00	167.2	16
Med trees	SL	139.5	12.7	92.9	223.0	10
Med trees	OG	98.9	11.6	8.0	175.2	16
Med trees	MA	190.2	14.6	103.5	298.7	16
Lg trees (PIPO)	SL	24.8	2.7	6.7	36.0	10
Lg trees (PIPO)	OG	17.1	1.7	8.3	28.6	16
Lg trees (PIPO)	MA	9.4	2.4	1.7	39.9	16
Lg trees (PSME)	SL	3.8	1.1	0.00	8.3	10
Lg trees (PSME)	OG	8.5	3.3	0.00	56.5	16
Lg trees (PSME)	MA	1.7	0.50	0.00	6.6	16
Lg trees	SL	28.8	3.2	6.7	44.2	10
Lg trees	OG	27.2	3.7	15.0	71.5	16
Lg trees	MA	11.0	2.4	3.3	41.5	16

Table 1 - (cont)

Variable	Stand Type	Mean	Standard Error of Mean	Minimum	Maximum	N
Basal area	SL	190.5	11.2	135.7	264.5	10
Basal area	OG	217.4	19.6	54.8	435.4	16
Basal area	MA	220.6	16.5	123.1	354.8	16
Slope	SL	42.0	5.3	9.0	59.4	10
Slope	OG	51.4	3.0	25.2	70.0	16
Slope	MA	22.8	2.6	11.6	45.2	16
Stand size	SL	40.6	9.1	11.7	93.9	10
Stand size	OG	79.6	13.3	14.3	193.7	16
Stand size	MA	206.0	36.6	40.2	526.9	16
Stream distance	SL	342.7	42.1	185.0	600.0	10
Stream distance	OG					
Stream distance	MA					
Rel slope position	SL	1.9	0.16	1.0	2.7	10
Rel slope position	OG	2.2	0.11	1.2	3.0	16
Rel slope position	MA	2.0	0.11	1.5	3.0	16

Table 1 - (cont)

Variable	Stand Type	Mean	Standard Error of Mean	Minimum	Maximum	N
Tree age	SL	307.1	22.8	169.8	432.0	10
Tree age	OG	223.2	15.4	151.2	347.2	16
Tree age	MA	99.9	6.3	70.8	158.6	16
Tree diameter	SL	66.3	2.3	57.4	78.4	10
Tree diameter	OG	71.1	2.2	55.0	87.2	16
Tree diameter	MA	45.1	1.3	36.5	53.2	16
Tree height	SL	30.6	1.3	23.9	39.0	10
Tree height	OG	33.4	1.4	23.2	39.1	16
Tree height	MA	22.7	0.86	18.7	28.6	16
Debris cover	SL	10.0	4.3	41.7	13.2	10
Debris cover	OG					
Debris cover	MA					
Forb cover	SL	16.5	1.8	7.2	23.3	10
Forb cover*	OG	13.1	2.0	2.9	33.6	16
Forb cover*	MA	12.6	2.0	3.2	27.7	16

*Not comparable to selectively logged sites due to differences in sampling methods.

Table 1 - (cont)

Variable	Stand Type	Mean	Standard Error of Mean	Minimum	Maximum	N
Grass cover	SL	52.7	2.3	42.5	65.0	10
Grass cover*	OG	21.0	2.0	5.9	33.6	16
Grass cover*	MA	23.6	2.0	6.4	35.2	16
Shrub cover	SL	29.5	5.3	9.7	65.9	10
Shrub cover (sm)*	OG	12.1	1.4	2.4	20.5	16
Shrub cover (lg)*	OG	7.2	1.2	2.0	17.8	16
Shrub cover (sm)*	MA	9.3	1.6	0.80	21.9	16
Shrub cover (lg)*	MA	3.4	0.64	0.00	9.3	16
Small tree cover	SL	19.7	4.3	7.0	41.7	10
Small tree cover*	OG	25.0	7.0	0.00	80.0	16
Small tree cover*	MA	20.0	9.0	0.00	107.0	16
Total ground cover	SL	75.2	3.4	60.0	95.0	10
Total ground cover	OG					
Total ground cover	MA					

*Not comparable to selectively logged sites due to differences in sampling methods.

Table 2 - Description of variables (used in Tables 1 and 5) characterizing habitat on selectively logged, old-growth, and mature second-growth sites. Density measured per ha.

Variable	Description
Med logs (PIPO)	Density of ponderosa pine logs 20-50 cm dbh
Med logs (PSME)	Density of Douglas-fir logs 20-50 cm dbh
Med logs	Density of all logs 20-50 cm dbh
Lg logs (PIPO)	Density of ponderosa pine logs >50cm dbh
Lg logs (PSME)	Density of ponderosa pine log >50 cm dbh
Lg logs	Density of all logs >50 cm dbh
Med snags (PIPO)	Density of ponderosa pine snags 20-50 cm dbh
Med snags (PSME)	Density of Douglas-fir snags 20-50 cm dbh
Med snags	Density of all snags 20-50 cm dbh
Lg snags (PIPO)	Density of ponderosa pine snags >50 cm dbh
Lg snags (PSME)	Density of Douglas-fir snags >50 cm dbh
Lg snags	Density of all snags >50 cm dbh
Med trees (PIPO)	Density of ponderosa pine trees 20-50 cm dbh
Med trees (PSME)	Density of Douglas-fir trees 20-50 cm dbh
Med trees	Density of all trees 20-50 cm dbh
Lg trees (PIPO)	Density of ponderosa pine trees >50 cm dbh
Lg trees (PSME)	Density of Douglas-fir trees >50 cm dbh
Lg trees	Density of all trees >50 cm dbh
Med stumps (PIPO)	Density of ponderosa pine stumps 20-50 cm dbh
Med stumps (PSME)	Density of Douglas-fir stumps 20-50 cm dbh
Med stumps	Density of all stumps 20-50 cm dbh
Lg stumps (PIPO)	Density of ponderosa pine stumps >50 cm dbh
Lg stumps (PSME)	Density of Douglas-fir stumps >50 cm dbh
Lg stumps	Density of all stumps >50 cm dbh
Basal area	Basal area per ha
Slope	Slope (%)
Stand size	Stand size (ha)
Stream distance	Distance to nearest stream (m)

Table 2 - (cont)

Variable	Description
Rel slope position	Relative slope position: 1 = lower 1/3 of slope, 2 = middle 1/3 of slope
Tree age	Tree age (yrs)
Tree diameter	Tree diameter (cm) at breast height
Tree height	Tree height (m)
Debris cover	% debris cover
Forb cover	% forb cover
Grass cover	% grass cover
Shrub cover	% shrub cover
Shrub cover (sm)	% cover of small shrubs
Shrub cover (lg)	% cover of large shrubs
Small tree cover	% cover of small trees (<20 cm dbh)
Total ground cover	% total ground cover

steep on mature second-growth than the other two stand types, a likely reason these sites were harvested.

Bird Species Richness

Bird species richness (BSR) did not differ statistically ($P<0.05$) among stand types either including all stands ($F = .60$; df = 2, 39; $P = .5701$) or including only those stands containing five sampling points ($F = .99$; df = 2, 33; $P = .39$) (Table 3). Though not significant, BSR was slightly higher on selectively logged stands according to both analysis methods

Combined Abundance Patterns

The number of individual birds per point was significantly greater in mature second-growth stands than selectively logged sites ($F = 4.07$; df = 2,199; $P = .0184$). The number of individuals per point averaged 12.7 (range: 0.0 to 21.5) in mature second-growth stands, 11.6 (range: 0.0 to 21.5) in old-growth stands, and 10.8 (range: 7.3 to 15.0) in selectively logged stands. Significant differences in combined abundance patterns were strongly influenced by a small number of ground gleaning species. For example, substantially greater numbers of evening grosbeaks, chipping sparrows, and dark-eyed juncos contributed to the statistically significant difference betweeen mature second-growth and selectively-logged stands. Stand types did not differ significantly when these three bird species were omitted from the analysis ($F = .96$; df = 2, 199; $P = .3848$). The brood parasitic

Table 3 - Mean bird species richness (per site) in old-growth (OG), selectively logged (SL), and mature second-growth (MA) sites. P-values derived from ANOVA F test.

All sites:

	OG	SL	MA	P-value
N	16	10	16	
Mean BSR	28.16	29.90	28.31	.5701
Range	16 to 36	24 to 35	22 to 35	

Sites with 5 sample points:

	OG	SL	MA	P-value
N	15	6	15	
Mean BSR	28.93	31.17	28.40	.3900
Range	23 to 36	24 to 35	22 to 35	

brown-headed cowbird also provided a large absolute difference in abundance between mature second-growth and selectively logged stands.

Abundance Patterns of Individual Species

Seventy species were recorded in the three stand types during the 1991 breeding season, and 39 species were found in all three stand types (Table 4). Bird count data was normally distributed in each stand type for fourteen species while data for the other 56 species was non-normally distributed. I recorded a total of 53 bird species in selectively logged stands. On Hejl and Woods' sites, fifty-two species were counted in mature second-growth and 48 in old-growth stands.

Fourteen species differed significantly ($P<0.05$) in abundance among the three stand types, while the remaining 56 did not (Table 4). Based upon a subjective interpretation of bird species' means it appeared that seven of the fourteen species were more abundant in selectively logged stands than at least one of the other two stand types: these included the pileated woodpecker, Hammond's flycatcher[1], common raven (*corvus corax),* Swainson's thrush, solitary vireo (*Vireo solitarius*), Townsend's warbler, and red crossbill. Five of the fourteen species appeared significantly more abundant in old-growth stands than at least one of the other two

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[1] Undifferentiated Empidonax observations were classified as either Hammond's flycatcher or dusky flycatcher based upon proportions of positively identified birds within the stand type.

Table 4 - Mean abundance (per point per site) of bird species in selectively logged (SL), old-growth (OG) and mature second-growth (MA) sites. P-values (significant P-value <0.05*) derived from the ANOVA F test (indicated by A) and Kruskal-Wallis H test (indicated by K).

Species	SL	OG	MA	P-value
Turkey vulture	0.01	0.00	0.00	.89 K
Sharp-shinned hawk	0.03	0.00	0.01	.22 K
Northern goshawk	0.01	0.00	0.00	.94 K
Red-tailed hawk	0.05	0.03	0.02	.63 K
American kestrel	0.01	0.02	0.00	.91 K
Blue grouse	0.02	0.01	0.00	.67 K
Ruffed grouse	0.05	0.07	0.08	.90 K
Mourning dove	0.06	0.00	0.00	.37 K
Flammulated owl	0.00	0.01	0.00	.94 K
Western screech owl	0.00	0.00	0.01	.94 K
Great horned owl	0.02	0.00	0.00	.90 K
Common nighthawk	0.02	0.00	0.00	.37 K
Calliope hummingbird	0.01	0.00	0.03	.91 K
Rufous hummingbird	0.02	0.00	0.00	.64 K
Red-naped sapsucker	0.02	0.02	0.00	.49 K
Williamson's sapsucker	0.07	0.05	0.01	.30 K
Hairy woodpecker	0.07	0.10	0.08	.75 K
Three-toed woodpecker	0.00	0.01	0.00	.94 K
Black-backed woodpecker	0.01	0.00	0.00	.89 K
Northern flicker	0.11	0.10	0.03	.07 K
Pileated woodpecker	0.10	0.11	0.02	.02 K*
Olive-sided flycatcher	0.00	0.01	0.00	.60 K
Western wood-pewee	0.02	0.00	0.07	.01 K*
Hammond's flycatcher[1]	0.45	0.39	0.05	.00 K*
Dusky flycatcher[1]	0.17	0.15	0.70	.03 A*
Gray jay	0.15	0.15	0.08	.38 K
Stellar's jay	0.01	0.02	0.02	.91 K
Clark's nutcracker	0.02	0.06	0.13	.84 K
Black-billed magpie	0.00	0.00	0.01	.95 K
Common raven	0.18	0.04	0.02	.00 K*
Black-capped chickadee	0.08	0.03	0.14	.04 K*
Mountain chickadee	0.39	0.74	0.60	.57 A

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[1] Undifferentiated Empidonax observations classified Hammond's Flycatcher or Dusky Flycatcher based upon proportions of positively identified birds within each stand type.

Table 4 - (cont)

Species	SL	OG	MA	P-value
Red-breasted nuthatch	1.06	1.29	1.20	.08 A
White-breasted nuthatch	0.03	0.04	0.02	.54 K
Brown creeper	0.01	0.03	0.00	.58 K
Rock wren	0.00	0.00	0.01	.94 K
House wren	0.00	0.00	0.02	.94 K
Winter wren	0.00	0.01	0.01	.91 K
Golden-crowned kinglet	0.04	0.03	0.00	.16 K
Ruby-crowned kinglet	0.78	0.69	0.96	.33 A
Mountain bluebird	0.01	0.00	0.00	.81 K
Townsend's solitaire	0.22	0.40	0.36	.48 A
Swainson's thrush	0.36	0.33	0.08	.00 A*
Hermit thrush	0.14	0.16	0.03	.54 K
American robin	0.29	0.42	0.58	.04 A*
Varied thrush	0.01	0.09	0.00	.04 K*
Cedar waxwing	0.00	0.00	0.01	.94 K
Solitary vireo	0.43	0.26	0.51	.02 A*
Warbling vireo	0.08	0.04	0.15	.05 K*
Orange-crowned warbler	0.09	0.07	0.04	.50 K
Nashville warbler	0.03	0.05	0.04	.61 K
Yellow warbler	0.00	0.00	0.01	.74 K
Yellow-rumped warbler	0.67	1.49	1.25	.41 A
Townsend's warbler	0.34	0.69	0.09	.00 A*
MacGillivray's warbler	0.13	0.08	0.06	.17 K
Wilson's warbler	0.00	0.00	0.08	.40 K
Western tanager	0.85	0.88	0.99	.54 A
Black-headed grosbeak	0.00	0.00	0.01	.94 K
Lazuli bunting	0.06	0.07	0.04	.52 K
Rufous-sided towhee	0.01	0.03	0.03	.87 K
Chipping sparrow	1.19	1.16	1.78	.07 A
Song sparrow	0.00	0.00	0.01	.94 K
Dark-eyed junco	0.55	0.70	0.74	.27 A
Western meadowlark	0.00	0.00	0.08	.40 K
Brown-headed cowbird	0.14	0.01	0.56	.00 K*
Pine grosbeak	0.01	0.00	0.00	.89 K
Cassin's finch	0.14	0.45	0.15	.58 K
Red crossbill	0.27	0.03	0.16	.00 K*
Pine siskin	0.59	0.48	0.46	.99 A
Evening grosbeak	0.11	0.14	0.64	.17 K

stand types and seven of the fourteen species appeared significantly more abundant in mature second-growth stands than at least one of the other two stand types.

Of the twenty-three species found exclusively in one stand type, none had a statistically significant abundance pattern. The eight species appearing exclusively in selectively logged stands were the turkey vulture (*Cathartes aura*), northern goshawk (*Accipiter gentilis*), mourning dove (*Zenaida macroura*), great horned owl (*Bubo virginianus*), common nighthawk (*Chordeiles minor*), rufous hummingbird (*Selasphorus rufus*), black-backed woodpecker (*Picoides arcticus*), and pine grosbeak (*Pinicola enucleator*). Eleven species occurred exclusively in mature second-growth stands and five species in old-growth stands.

Species-habitat Associations in Selectively Logged Stands

The Cassin's finch was significantly associated with seven habitat variables, including three measures of cover; the hermit thrush with five habitat variables; the American robin and brown-headed cowbird with three independent variables each; the chipping sparrow, dark-eyed junco, dusky flycatcher, evening grosbeak, Hammond's flycatcher, MacGillivray's warbler (*Oporonis tolmiei*), northern flicker, and red crossbill with two independent variables each; and the pileated woodpecker, ruby-crowned kinglet, solitary vireo, Swainson's thrush, Townsend's solitaire (*Myadestes townsendi*), and Townsend's warbler with one habitat variable apiece (Table 5).

Table 5 - Significant (P<0.05) Pearson chi-squares and direction of association for bird species and habitat variables.

Bird Species Variable	Habitat Variable	Pearson Statistic	Direction of Association
Northern flicker	Shrub cover	.0261	Positive
Northern flicker	Total ground cover	.0335	Positive
Pileated woodpecker	Lg trees	.0083	Positive
Hammond's flycatcher	Rel slope position	.0300	Low
Dusky flycatcher	Tree diameter	.0170	Negative
Dusky flycatcher	Stand size	.0221	Positive
Ruby-crowned kinglet	Stand size	.0360	Negative
Townsend's solitaire	Forb cover	.0359	Negative
Swainson's thrush	Small tree cover	.0150	Positive
Hermit thrush	Lg snags	.0021	Positive
Hermit thrush	Total ground cover	.0024	Positive
Hermit thrush	Shrub cover	.0073	Positive
Hermit thrush	Stand size	.0241	Negative
Hermit thrush	Stream distance	.0247	Positive
American robin	Shrub cover	.0013	Negative
American robin	Total ground cover	.0022	Negative
American robin	Med stumps	.0093	Positive
Solitary vireo	Lg stumps	.0176	Negative
Townsend's warbler	Tree height	.0156	Positive
MacGillivray's warbler	Stream distance	.0365	Negative
MacGillivray's warbler	Grass cover	.0438	Negative
Chipping sparrow	Stand size	.0003	Positive
Chipping sparrow	Slope	.0429	Positive

Table 5 - (cont)

Bird Species Variable	Habitat Variable	Pearson Statistic	Direction of Association
Dark-eyed junco	Med logs	.0013	Negative
Dark-eyed junco	Med trees	.0062	Negative
Brown-headed cowbird	Small tree cover	.0128	Positive
Brown-headed cowbird	Stand size	.0216	Negative
Brown-headed cowbird	Stream distance	.0227	Positive
Cassin's finch	Stand size	.0000	Positive
Cassin's finch	Stream distance	.0018	Negative
Cassin's finch	Site slope	.0034	Positive
Cassin's finch	Grass cover	.0060	Negative
Cassin's finch	Total ground cover	.0197	Negative
Cassin's finch	Tree age	.0208	Negative
Red crossbill	Med trees (PIPO)	.0352	Positive
Evening grosbeak	Lg stumps	.0041	Negative
Evening grosbeak	Shrub cover	.0289	Negative

Stand size was associated with six bird species; shrub cover and stream distance with four bird species each; small tree cover and total ground cover with three bird species each; grass cover, large stump density, medium tree density and site slope with two bird species each; and forb cover, large snag density, large tree density, medium log density, medium tree density (PIPO), relative slope position, tree age, tree diameter and tree height with one bird species apiece.

DISCUSSION

In this study, bird abundance for most species differed little between selectively logged and untreated ponderosa pine/Douglas-fir old-growth. Individual bird species abundance between the two older stand types and mature second-growth stands differed more dramatically. The Hammond's flycatcher, common raven, pileated woodpecker, Swainson's thrush, varied thrush, Townsend's warbler, and red crossbill demonstrated a strong association with older stand conditions. In contrast, many species, especially ground gleaners and some shrub/small-tree nesters show a strong, if less exclusive, association with the mature, second-growth stands.

The similiarity in individual bird species abundance between selectively logged and old-growth stands corresponds with the comparability of crucial vegetation variables between the two older stand types. Numbers of large snags and large trees were virtually the same on selectively logged and old-growth sites, though a greater number of ponderosa pine large snags and large trees existed on selectively logged sites (Table 1). Instead of creating sub-old-growth conditions, selective logging merely reduced the number of large trees to the minimal old-growth levels (Green et al. 1992) found in Hejl and Woods' old-growth sites

The continued existence of key old-growth components in selectively logged stands especially benefited the pileated woodpecker and northern flicker. McClelland (1977) and Bull and

Meslow (1977) demonstrated that pileated woodpeckers depend on large-dbh snags or broken-top large live trees for nest sites (with a strong preference for ponderosa pine snags and trees over Douglas-fir) in the northern Rockies and inland Pacific Northwest. Accordingly, pileated woodpeckers were positively associated with the number of large trees in selectively logged stands. Pileated woodpeckers preferred large Douglas-fir snags and logs for foraging in northwest Montana (McClelland 1977). The lower numbers of large Douglas-fir snags and logs on selectively logged (1.7/ha) than on old-growth (3.9/ha) sites (Table 1) has not for the present, however, translated into fewer pileated woodpeckers. Stand size is another potentially important habitat factor for pileated woodpeckers. McClelland estimated that a pileated woodpecker pair needs, depending on food supply, approximately 200-400 ha as a breeding territory in the northern Rockies with at least 40 ha of old-growth for long-term nesting habitat. The mean size of selectively logged sites in this study (40.6 ha) barely achieves the old-growth acreage minimum suggested by McClelland. I did no landscape analysis in this study to determine the suitability of surrounding areas to meet foraging needs. Northern flickers occur in almost every terrestrial habitat in North America as long as sufficient nest sites and open ground for feeding occur together (Ehrlich et al. 1988). Timber harvest with snag retention in ponderosa pine forest in Arizona did not affect northern flicker abundance, but timber harvest that included snag removal did significantly reduce their numbers (Scott and Oldenmeyer 1982).

The low number of medium and large snags and large trees in mature second-growth (Table 1) apparently had a severe effect on pileated woodpecker and northern flicker abundance.

While "high grading" on selectively logged sites eliminated the most likely source of future large snags and broken-top trees, it did not immediately produce cavity-nesting conditions inferior to those on Hejl and Woods' old-growth sites. Historically, the selectively logged stands in this study contained far more large trees than the old-growth sites that Hejl and Woods selected for analysis. By adding large stumps/ha and large trees/ha on selectively logged sites, I extrapolate that these sites had approximately 50 percent more large trees prior to logging than Hejl and Woods' old-growth stands (43.7/ha vs. 27.2/ha). The minimal old-growth conditions of my selectively logged sites and Hejl and Woods' old-growth sites for large tree stocking becomes more evident when comparing them to stocking levels in similiar studies in the western United States. Mannan and Meslow's old-growth stands, dominated by Douglas-fir and ponderosa pine, had 48 large (>50cm dbh) trees/ha. Older selectively logged ponderosa pine stands in Arizona were called minimum old-growth by Mannan and Siegel. They had approximately 34 large (>50cm dbh) trees/ha with 40 percent of the overstory trees removed. This is a slightly higher stocking level than my selectively logged sites or Hejl and Woods' old-growth sites. Mannan and Siegel's undisturbed old-growth sites had many more large (>50 cm dbh) trees (65 to 85 large trees/ha) than either my sites or Hejl and Woods'. The wide disparity in stocking levels for sites that were all termed "old-growth" should provide caution in analyzing such sites without quantitative knowledge of structural characteristics. Due to past logging, the stocking levels of large trees in the present old-growth ponderosa pine/Douglas-fir sites of the northern Rockies is likely to be inferior to historic conditions. Bird species dependent on a high density of large trees, and the consequent large snags and logs, may now exist at reduced levels of abundance.

Selective logging did not adversely affect Swainson's thrushes in this study. Both selectively logged and old-growth sites provided sufficient openness and light penetration to allow for the development of a vegetative understory. Swainson's thrushes are commonly associated with shrubby, damp areas in conifer forests (American Ornithologists' Union 1983; Ehrlich et al. 1988) and were positively associated in my selectively logged sites with the density of small trees (Table 5). Small trees possibly provide the same structural elements as shrubs. The mature second-growth sites in this study may have provided too few openings for the development of sufficient understory to attract Swainson's thrushes. These sites contained high numbers of medium trees relative to selectively logged and old-growth sites. Mature second growth sites also had lower small shrub, large shrub, and small tree coverage than old-growth sites (Table 1). Varied thrushes generally occur in moister areas of coniferous forest than Swainson's thrushes (Ehrlich et al. 1988). Varied thrushes may appear more frequently on old-growth sites due to the higher proportion of shady, foliage dense Douglas-firs (Table 1). Hermit thrushes were most common in high shrub cover areas in the selectively logged stands of this study (Table 5). Kilgore (1971) found no hermit thrushes in giant sequoia forest after the removal of dense stands of small trees. The large absolute difference in hermit thrush abundance between Hejl and Woods' old-growth and mature second-growth stands was similiar to results in old-growth and managed Douglas-fir/ponderosa pine forest in northeastern Oregon (Mannan and Meslow 1984). The shrubby habitat preferred by hermit thrushes for nesting (Ehrlich et al. 1988) was more prevalent in Hejl and Woods' old-growth than in their mature second-growth stands (Table 1). Mannan and Meslow's managed sites were practically devoid of the small trees also favored for nesting by hermit thrushes, containing only .4 small trees (2.5-10 cm dbh)/.05 ha; 14.5 small trees/.05 ha were found on their old-growth sites. Differences in sampling methodology for shrub and small tree cover make vegetation comparisons problematic between my selectively logged sites and the old-growth and managed sites of Hejl and Woods and Mannan and Meslow. However, the high percentage of cover for both shrubs and small trees on my selectively logged sites, 29.5 and 19.7 percent, respectively, indicates more vegetative similiarity with their old-growth than with their younger managed sites.

Hammond's flycatcher nests are commonly built on a horizontal limb of tall conifer trees (Ehrlich et al.1988). In the Flathead Lake and Glacier Park areas of Montana, Davis (1954) found Hammond's flycatchers in dense, mixed deciduous-coniferous forests of tall trees, particularly by small openings where they can hawk insects. Logging created openings in selectively logged stands; forest openings occurred in old-growth when large decadent trees fell. Selectively logged and old-growth stands in this study provided the key components of tall trees (Table 1) and forest openings used by Hammond's flycatchers.

Unlike the Hammond's flycatcher, the degree of past selective logging in this study appears to have negatively affected Townsend's warblers. Townsend's warblers have generally responded negatively to logging in the Rocky Mountains (Medin 1985; Hutto et al. 1993). In Medin's study and in studies involving more severe cutting (Hutto et al. 1993) the Townsend's warbler was even relatively less common than in this study's selectively logged stands. Mannan and Meslow (1984) found Townsend's warblers to be significantly more abundant in old-growth than thinned 85-year old stands. A compilation of studies and personal communications by Meslow (1978) also found virtually no usage of second-growth habitats by Townsend's warblers in the western United States. Peterson's study (1982) in hemlock and grand fir forests of northern Idaho is one exception to these otherwise unvaried results. He found more Townsend's warblers in tall shrub and sapling conifer "life forms" than in early successional stages or old-growth, illustrating the potential for regional differences in habitat usage and the need for replication of his study results. The greater numbers of Townsend's warblers on old-growth than selectively logged sites is probably due to two factors: tree species composition and tree height. Selectively logged sites had very few large Douglas-fir trees, whereas Douglas-fir composed 1/3 of the large trees on Hejl's old-growth sites. Townsend's warblers preferred Douglas-fir canopy to ponderosa pine canopy as nesting sites in northeastern Oregon (Mannan and Meslow 1984). The relatively high abundance of Townsend's warblers in my selectively logged stands, though, indicates that Townsend's warblers will use tall ponderosa pines for nesting and foraging in the absence of Douglas-fir, albeit to a lesser degree. Townsend's warblers were significantly associated with tree height on the selectively logged stands of this study (Table 5). Marzluff and Lyon (1983), looking at bird species in a wide variety of settings in western Montana, noted that Townsend's warblers were most commonly observed in upper foliage. The relatively small difference in mean tree height (3 m) between selectively logged and old-growth sites may be an ecologically significant factor contributing to the greater abundance of Townsend's warblers on old-growth sites.

Most species less abundant in mature second-growth stands than the other two stand types (Hammond's flycatcher, pileated woodpecker, Swainson's thrush, and Townsend's warbler) were species depending on specific components or combinations of components of older forests: snags, large trees, tall trees, downed wood, increased understory. In contrast, those individual species more abundant in mature second-growth stands were species commonly associated with an open forest understory.

American robins have generally responded positively to tree removal, except for the immediate aftermath of clearcutting, in studies in western coniferous forests (Medin 1985; Hutto et al. 1993). Primarily a ground and low vegetation gleaner (Ehrlich et al. 1988), American robins seem to be responding to the increased understory openness of the treated sites. One of the most dramatic increases in abundance occurred when shrub and sapling layers were specifically targeted for removal in a giant sequoia forest in California (Kilgore 1971). In the selectively logged stands of this study, American robin abundance was negatively associated with both shrub and total ground cover (Table 5). It is questionable whether robin numbers would remain elevated after the initial openness of the post-treatment period gave way to increased shrub and small tree growth, as in my selectively logged stands. The higher stocking level of medium trees and apparent lower shrub cover in Hejl and Woods' mature second-growth sites describes a more open understory than in my selectively logged sites. American robins were also less common in thinned and untreated ponderosa pine old-growth than in managed forest composed of numerous, even-aged, immature trees in Arizona (Mannan and Siegel 1988).

Studies in western coniferous forest show that most logging that is less extreme than clearcutting is beneficial to chipping sparrows (Medin, 1985; Hutto et al. 1993). As with the American robin, selective logging on my study sites was probably conducted too long prior to the study to positively affect those features beneficial to the ground-gleaning chipping sparrow. The open conifer forest preferred by chipping sparrows had been inundated with shade tolerant Douglas-firs and shrub species taking advantage of openings created by logging.

The greater abundance of solitary vireos in mature second-growth than old-growth stands (Table 4) agrees with results from northeastern Oregon (Mannan and Meslow 1984), though solitary vireos were nonsignificantly more abundant in Mannan and Meslow's managed stands. Results for solitary vireos differed from those reported for ponderosa pine stands in Arizona (Mannan and Siegel 1988) where solitary vireos were relatively uncommon in managed stands while maintaining a moderate to high abundance in a variety of structurally diverse ponderosa pine old-growth settings. Overall, solitary vireos exhibited no change or a slight increase in abundance when subjected to light cutting regimens in western coniferous forests, while clearcut areas contained significantly fewer solitary vireos (Medin 1985; Hutto et al. 1992).

Brown-headed cowbirds are known, primarily from studies in the eastern United States (Ambuel and Temple 1983; Brittingham and Temple 1983), to be associated with forest edge and the increased opportunity for brood parasitism of open, cup-nesting birds. The easily penetrable openness of mature second-growth stands, with their relative lack of understory, is perhaps one reason why these stands contain higher numbers of brown-headed cowbirds. Mature second-growth stands were also located closer to agricultural lands and grasslands than the other two stand types (Hejl, pers. comm. 1994). Brown-headed cowbird presence in selectively logged stands was concentrated on stands close to the agricultural lands of the Clark Fork River and Lolo Creek valleys.

In this study and ones in west-central Idaho (Medin 1985; Medin and Booth 1989), dusky flycatcher abundance did not differ between selectively logged and unlogged old-growth stands. Rather, it appears that dusky flycatchers select for a forest structure created by early to mid-successional seral stages or rotation-aged second growth. This point was reinforced by the negative association of the dusky flycatcher to tree diameter in selectively logged stands (Table 5). Dusky flycatchers were also more abundant in managed Douglas-fir/ponderosa pine stands in northeastern Oregon (Mannan and Meslow 1984).

The number of mountain chickadees was not significantly lower (though a large absolute difference existed) in the selectively logged sites of this study (Table 4). Far fewer mountain chickadees were counted on selectively logged than uncut sites in three studies in ponderosa pine and ponderosa pine/Douglas-fir habitats (Szaro and Balda 1979; Scott and Gottfried 1983; Medin and Booth 1989). While their results were also non-significant the consistency of these findings points toward the likelihood of real differences in mountain chickadee abundance between selectively logged and unlogged sites. Most studies in the Rocky Mountains have shown mountain chickadees to be significantly less abundant in partially cut than uncut forests

(Hutto et al. 1993).

Yellow-rumped warbler abundance was higher in studies in which light selective cutting occurred (Szaro and Balda 1979; Scott and Gottfried 1983; Medin and Booth 1989). More severe cutting resulted in either no difference or lower yellow-rumped warbler abundance (Franzreb and Ohmart 1978; Szaro and Balda 1979; Medin 1985; Tobalske et al. 1991). Selectively logged stands have developed a relatively dense understory and mid-canopy layer (Table 1) for the ponderosa pine forest type due to available light and fire suppression. The temporal lag between "high-grade" logging and bird censusing in this study may have eliminated whatever structural or species composition advantages that apparently benefit yellow-rumped warblers in the short term.

The unique characteristics of selectively logged stands may help explain the strongly significant relationship with red crossbills and common ravens (Table 4). Meslow's (1978) summary of studies on bird habitat use in Douglas-fir plant communities states that red crossbills nest and forage almost exclusively in older second-growth and mature forest. Wetmore et al. (1985) and Raphael (1988) also found an association of red crossbills with older, more mature spruce/fir stands. Red crossbills were not, however, more abundant in old-growth pine stands in Arizona (Mannan and Siegel 1988). Red crossbills varied greatly between years and individual sites but demonstrated no difference in abundance between old-growth and managed sites. Conifer seed production is the key to the distribution and abundance of red crossbills (Benkman 1993). Red crossbills breed in the early spring and throughout the year; late spring and early summer flocks are probably composed primarily of foraging, not nesting, juveniles. Unlike most other bird species recorded from May 15-July 15, observations of red crossbills are more purely indicative of foraging preference. I found red crossbills to be relatively common on selectively logged sites in this study, with a mean abundance of 0.29 birds per point. Cone production in selectively logged stands may have been stimulated by logging that allowed greater growth and productivity of remaining trees. Conversely, old-growth stands, stressed by an abnormally high density of trees (for the site specific conditions) due to fire suppression, may have been prevented from allocating resources to cone production. Although combined medium and large tree density is higher on selectively logged sites, the site specific conditions that allowed historically higher stocking levels may also allow more resources to be allocated to cone production than on old-growth sites. Red crossbills were also negatively associated with tree age and positively associated with the number of medium-dbh trees in selectively logged stands. Medium trees may have been able to allocate more resources to cone production than older, larger trees with their greater need to allocate photosynthate to maintenance (Oliver and Larson 1990). Red crossbills may have been responding positively to the higher number of of medium trees on selectively logged and mature second-growth stands. If the selectively logged sites of this study were more open than Hejl's old-growth and mature second-growth sites then they may provide a better searching area for the opportunistic, primarily carrion-feeding common raven. Since I did not measure canopy cover in my study, openness can only be implied from other data. Tree density indicates that selectively logged stands are more open than mature second-growth stands but not necesarily old-growth stands (Table 1).

Many of the findings of non-significance among stand types could be due to the low number of bird observations. Low numbers of observations, however, do not imply that actual differences in bird species abundance may not exist. To illustrate, uncommon species can be broken into three categories: (1) species uncommon in selectively logged, old-growth, and rotation-aged ponderosa pine/Douglas-fir stands but more abundant in other habitats (e.g., black-billed magpie, mountain bluebird (*Sialia currucoides*) and Stellar's jay (*Cyanocitta stelleri*); (2) species that are not necessarily more abundant in other habitats. Their scarcity is due to large territory area needs, (e.g., sharp-shinned hawk and northern goshawk); and (3) species that are reliably detected only through the use of different censusing techniques (e.g., owls). More extensive sampling or different census techniques are unlikely to turn up any significant differences in the first group. Species that use selectively logged, old-growth, or mature second-growth ponderosa pine/Douglas-fir forest as their primary habitat or part of their primary habitat, however, could be more accurately assessed with increased sample size (e.g., sharp-shinned hawk, northern goshawk) or with different census techniques (e.g., owls).

The major problem in comparing results among the three stand types is the lack of control of interobserver differences. Comparisons between selectively logged sites and old-growth and mature second-growth sites may not be valid due to the lack of a common training and testing program (Kepler and Scott 1981 and Ramsey and Scott 1981).

A second major factor potentially affecting the validity of study results is that only one year of data was analyzed. Data was collected in the same year and geographical region as Hejl and Woods' stand types, eliminating those potential sources of error. A multi-year comparison, however, would have minimized aberrant results in relative bird abundance derived from a single year of data.

It would have also been advisable to coordinate methods for measuring cover. Hejl and Woods' method of recording the presence or absence of shrub cover at 25 points within the sampling plot is not directly comparable to my method of visually estimating cover. In Hejl and Woods' study, shrub cover was split into measures of high and low shrub cover. Spatial overlap of the two covers prohibited an accurate measure of total shrub cover. I, on the other hand, performed a visual estimate of total shrub cover. Comparable methods for measuring shrub cover would have allowed for a more intelligent discussion of the effects of shrub cover on bird abundance.

Snag density is another important vegetation variable that may not be confidently compared among this study's stand types. Snags were counted at each habitat sampling point on my selectively logged sites but inadequate sample size and design make statistical tests unreliable (Bull et al. 1990). The sampling intensity recommended by Bull et al. was not feasible for my relatively underfunded thesis project.

MANAGEMENT IMPLICATIONS

In the past, management of U.S. Forest Service lands has emphasized an analysis of individual resources (especially game species), but this is increasingly being supplemented with an ecosystem approach (Morrison 1993). Ecosystem management requires an understanding of broad spatial and temporal patterns and processes. Historic landscape patterns can provide a basis of information for future management of our national forests (Hejl 1992; Hutto et al. 1993). Still, an ecosystem management plan needs to be translated into practical management recommendations at the site level without losing sight of the big picture. I attempt to look at both landscape level and site considerations in the recommendations that follow.

One of the most extreme changes in landscape patterns in the northern Rockies is the depletion of old-growth forests. Most forests in Region One of the USFS manage for a 5-10 percent old-growth allocation per forest with the intent of distributing the old-growth by habitat type and elevation. Losensky's analysis (1993) of forest age classes in western Montana showed 70 percent of the ponderosa pine cover type to have been in a mature/old-growth state as of 1900. Present ponderosa pine old-growth stands (including stands that were selectively logged but still meet old-growth criteria) in western Montana represent a minute (less than 5 percent) fraction of the total area classified as the ponderosa pine type (Yanishevsky 1993). Current attempts to maintain only 5-10 percent old-growth could be insufficient to maintain the ecological integrity of the system and the conditions necessary for a bird community composition, abundance, and distribution similiar to pre-settlement time. To manage for an ecosystem capable of maintaining viable populations of endemic species we need to learn, "how to make disturbed areas islands in a matrix of natural areas, instead of vice versa" (Salwasser 1992). A natural management system for the ponderosa pine/Douglas-fir type should retain all existing old-growth stands and allow younger stands to develop into old-growth so as to maintain a more "natural" (much higher) proportion of the ponderosa pine/Douglas-fir forest type as old-growth than currently exists. While the selectively loged sites of this study are technically "disturbed areas," they still retain sufficient old-growth characteristics to maintain individual bird species abundances that are similiar to those in old-growth stands. Selectively logged ponderosa pine/Douglas-fir stands that retained old-growth characteristics should be managed as part of the ponderosa pine/Douglas-fir old-growth ecosystem. Selectively logged stands can and should play a crucial role in a construction of a management plan for the ponderosa pine/Douglas-fir forest type in the northern Rockies that better reflects historical stand conditions.

The structural characteristics and vegetative species compositions found in existing selectively logged and old-growth stands also differ greatly from what existed historically on these sites (Gruell et al. 1982; Habeck 1990). Re-creating more historically accurate species compositions and structural characteristics would probably affect bird species' abundances. The chipping sparrow, dark-eyed junco, and Cassin's finch (species associated with open coniferous forest in this study and others) should benefit from a re-creation of presettlement conditions. Brown-headed cowbirds might also benefit if they could more easily parasitize the nests in a parkland forest setting. Some species that are more abundant on existing selectively logged and old-growth ponderosa pine/Douglas-fir stands could be negatively affected by a more natural management system. For example, eliminating some Douglas-fir from these sites could negatively affect Townsend's warblers. Swainson's thrush, hermit thrush, and varied thrush populations could also suffer when shrub and small tree cover are suppressed by fire and/or mechanical harvest. Pileated woodpeckers may decline if a natural management system contains fewer large snags and downed logs. Management for natural landscape patterns and processes over a broad landscape should minimize most detrimental effects on bird species in the ponderosa pine/Douglas-fir forest type. While some species may decline in one habitat of a more naturally managed landscape they may also increase in other habitats within an overall ecosystem management plan.

It may sometimes be necessary, though, to manage outside the natural variability of habitat components believed to have existed on historic old-growth stands, especially when sensitive species are faring poorly on all habitats within the landscape. For example, relatively little is known about nesting and foraging components used by cavity nesters in presettlement old-growth ponderosa pine stands that were maintained by frequent, low intensity fires. Arno (pers. comm. 1994) believes that historic old-growth ponderosa pine stands contained fewer snags and less downed wood than exist presently. Accelerated mortality of ponderosa pines in present stands has been brought on by competition for moisture and nutrients with Douglas-fir and shrub species. Nonetheless, the photo accounts of Leiberg (1899) and Gruell et al. (1982) portray large standing snags and downed logs in pre-fire-suppression old-growth ponderosa pine stands. It is, however, impossible to provide an accurate quantitative picture from this relatively small sampling of photos. The possibility that re-created parkland ponderosa stands may be less suitable habitat for cavity-nesting species could have especially severe repercussions for the old-growth dependent pileated woodpecker. The creation of additional snags and downed logs may be a necessary management goal in the short term. In the long term any negative effects of ecosystem management could be mitigated by preserving a larger proportion of the ponderosa pine/Douglas-fir forest type as future old-growth habitat.

Selectively logged stands in this study contained similiar old-growth characteristics and individual bird species abundances as old-growth stands. This does not support the conclusion, though, that a comparable selective logging regimen in existing ponderosa pine/Douglas-fir old-growth stands would be a wise management practice. Three reasons argue strongly against the cutting of more large trees: 1) selectively logged sites possibly had more large trees historically than existing selectively logged and old-growth sites, a possible indication of historic old-growth stocking levels for the region; 2) existing selectively logged and old-growth sites contain the bare minimum number of large trees to meet USFS Region One old-growth guidelines; 3) large tree stocking levels in existing selectively logged and old-growth sites is low relative to levels found in other studies in the northern Rockies and throughout the western United States. I recommend that no logging outside that done to replicate historical conditions be done on old-growth and selectively logged ponderosa pine/Douglas-fir stands. The rareness of old-growth ponderosa pine/Douglas-fir stands in western Montana dictates against any logging which would degrade old-growth conditions. Depending on the fire history and site-specific features (habitat type) of an area, some Douglas-fir should be removed from these ponderosa pine sites and prescribed burns used to limit Douglas-fir and shrub incursions. The commercial taking of medium-sized ponderosa pines should be scrutinized carefully. Variability in historic stocking levels, based on circa 1900 photo evidence, include what appear to be relatively dense stands of ponderosa pine (Leiberg 1899; Gruell, et al. 1982). Present estimates of overstory trees per acre in 1900 for nine unentered sites in the Lolo, Bitterroot, and Flathead Forests exhibit moderate variability

(Arno 1994). Moist sites generally had higher stocking levels than dry sites, though one dry site had twice the stocking level of any other site due to site specific conditions and/or fire history. The small sample size of unentered stands precludes sweeping generalizations. More research is needed on the stocking levels of historic ponderosa pine sites and the effects of fire and site specific conditions on stocking levels. I recommend conservative management to preserve overstory ponderosa pine trees until a better idea of stocking levels is attained.

As with live tree stocking levels, conservative management is recommended to retain snags on restored old-growth sites. The retention and maintenance of snags on treated managed areas of the national forests would also benefit cavity-nesting species, including those found more frequently in old-growth conditions. The USFS Northern Region has largely ignored forest plan requirements to retain snags on logged units (Yanishevsky et al. 1994). Snag numbers must be much lower than historic levels across most of the logged areas in Region One (Hejl 1994). Strict standards for logging contractors, restrictions on firewood gathering and meaningful Forest Service monitoring could appreciably increase the number of snags on portions of the national forests managed for timber production.

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