

Influence of patch area on bird species diversity in coniferous forests

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Abstract

I examined the effect of forest fragment area on bird species richness and abundance in high-elevation Engelmann spruce (*Picea engelmanni*) and sub-alpine fir (*Abies lasiocarpa*) patches in Gunnison County, Colorado. Point counts were used to survey birds in 26 forest patches, ranging from 0.06 to 8.17 ha in size, between June and July 2009. I did a regression analysis of species richness versus patch area as well as total abundance versus area. I analyzed the effect of edge by using a regression of species richness versus edge to area ratio. I found that bird species richness and total number of individuals had a positive relationship with patch area. Species richness decreased with increasing edge relative to area. My results indicate that small patches can be used by only a few species of birds, suggesting that larger patches are capable of supporting higher diversity.

Introduction

Habitat fragmentation is an increasing problem for many species of birds around the world. The construction of roads, followed by more severe human impacts in the forms of deforestation and development, causes forests to become patchy (Lees and Peres 2009). Deforestation is causing a decrease in species diversity in fragments because less vagile dispersers can no longer move between patches (Lees and Peres 2009).

High elevation forests are one of the few environments left in North America that are relatively unaffected by human activity (Leupin *et al.* 2004). Large tracts of coniferous forest at high elevations in the Rocky Mountains still remain unfragmented. Since the 1990s, previously slow-growing regions of the western United States have experienced rapid development resulting in only few, scattered areas that retain high bird abundance (Hansen *et al.* 2002). Ski runs, such as those around Mount Crested Butte Ski Resort in western Colorado, are a clearly visible example of fragmentation in forests composed of Engelmann spruce (*Picea engelmanni*) and sub-alpine fir (*Abies lasiocarpa*); these provide nesting and foraging habitats for several species of small birds. Large forests have less edge relative to area than do smaller patches,

allowing greater nesting success for birds due to better protection from predators and extreme weather (Lees and Peres 2009).

Multiple studies have been done on the effect of habitat fragmentation on bird diversity in Rocky Mountain ecosystems (Hejl 1992; Stuart-Smith and Hayes 2003; Leupin *et al.* 2004), but the connection between patch size and bird species diversity has not yet been clearly determined in this type of habitat. Some species of birds will be more severely affected by fragmentation than others (Manu *et al.* 2007). Edenius and Sjöberg (1997) found a nested pattern in bird species richness in forest patches in Sweden, indicating that the species found in small patches were subsets of those occurring in larger patches. Here, I looked at the avian species richness-forest area relationship in coniferous patches. I also examined the relationship between species richness and amount of edge. I tested the hypothesis that larger patch areas have higher avian species richness. Large forest patches should have more species present because of reduced edge effects as well as increased availability of habitats for different species of birds to use.

Methods

Twenty-six spruce-fir patches were selected using Google Earth satellite imagery in the valley around Rocky Mountain Biological Laboratory (RMBL), at Mount Crested Butte Ski Resort, and in Washington Gulch in Gunnison County, Colorado. The forest patches near RMBL and in Washington Gulch were assumed to have formed naturally. In contrast, the forests on Mount Crested Butte have been fragmented by human created ski runs and roads. Patches are defined as continuous spruce-fir groves of 0.06 – 8.17 ha with trees further than 5 m from the main group of trees not included in the patch area (Lees and Peres 2009). Surrounding habitat was mainly meadow, though more than half of the patches were bordered on at least one side by aspens or willows. Patches were chosen between 2870 m and 3100 m above sea level to keep elevation fairly constant between sites. Patch area and perimeter were measured using ArcMap Version 9.3.

Bird abundance was measured using 20-m fixed radius point counts (Schieck 1997) from a randomly chosen point within each forest patch, excluding points that were less than 20 m from the edge. Conifers are relatively dense compared to forests composed of other trees, such as aspens, so a 20 m radius is necessary in order to accurately estimate species richness

and abundance of birds in the patch. Multiple point counts were done in large patches, with 40 m between center points of counts. Each count was 10 min in duration, with a 1 min rest period before the actual count began, and included birds detected visually and aurally. Method of identification (song or sight) and estimated horizontal distance from observer were recorded for each bird observed to avoid counting individuals multiple times. Birds that were observed flying overhead were not counted. All counts were done between 0530 and 1030 hours. Each patch was visited twice, once early and again late in the summer. The second visit was made approximately 2 weeks later, to account for juveniles that hatched after the first round of point counts. The order in which patches were visited was randomized. Patches that were visited in the first half of the morning during the first round of counts were visited after 0800 hours for the second round, to account for differences in temperature and amount of sunlight.

To investigate the relationship between number of species and area, I summed the number of individuals of each species identified in each patch for the first and second rounds of point counts and did a regression analysis of bird species richness versus patch area, as well as bird species richness versus edge to area ratio. The observations from the two sets of counts were combined to get the best representation of all species present in the patches. I also analyzed the total number of individual birds per patch versus patch area.

Results

A total of 26 bird species was observed from June to July 2009, of which 11 were conifer-dwelling passerines and the rest generalists or edge species (Table 1). Approximately 80 percent of the birds observed were singing males. Species richness and frequency are shown in Appendix 2. The results suggest nestedness in the species occurrences. The species found in patches with low species richness are, in general, subsets of those occurring in patches with higher richness (Rashleigh 2008). The most common species, the mountain chickadee *Poecile gambeli*, ruby-crowned kinglet *Regulus calendula*, pine siskin *Carduelis pinus*, and golden-crowned kinglet *Regulus satrapa* were observed in a majority of patches, while the least common, including the red-tailed hawk *Buteo jamaicensis*, yellow warbler *Dendroica petechia*, orange-crowned warbler *Vermivora celata*, and pine grosbeak *Pinicola enucleator*, were only found in the largest third of patches.

Table 1. Total number of individuals observed in point counts for spruce-fir patches in Gunnison County, Colorado between June – July 2009.

Conifer-dwelling species	Total individuals counted	Generalist or edge species	Total individuals counted
Mountain Chickadee	121	Pine Siskin	54
Ruby-crowned Kinglet	75	American Robin	15
Golden-crowned Kinglet	49	American Crow	14
Red-breasted Nuthatch	27	Woodpecker	10
Brown Creeper	14	Cordilleran Flycatcher	9
Gray Jay	13	Hummingbird	7
Hermit Thrush	11	Northern Flicker	6
Pine Grosbeak	7	Warbling Vireo	5
Yellow-rumped Warbler	3	House Wren	5
Dark-eyed Junco	2	Orange-crowned Warbler	4
Steller's Jay	1	Common Raven	3
		Red-naped Sapsucker	3
		White-crowned Sparrow	3
		Yellow Warbler	2
		Red-tailed Hawk	1

The regression analysis revealed a strong positive relationship ($R^2 = 0.633$) between number of species and patch area, as shown in Figure 1. There was also a strong positive relationship ($R^2 = 0.815$) between number of individuals and patch area (Figure 2).

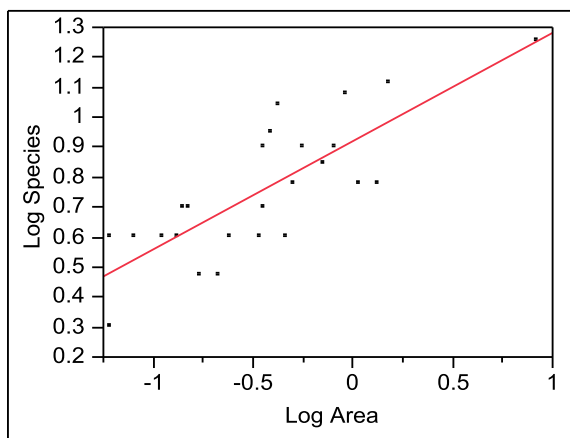


Figure 1. Log number of species versus log area (hectares) for birds in 26 spruce-fir patches in Gunnison County, Colorado ($R^2 = 0.633$).

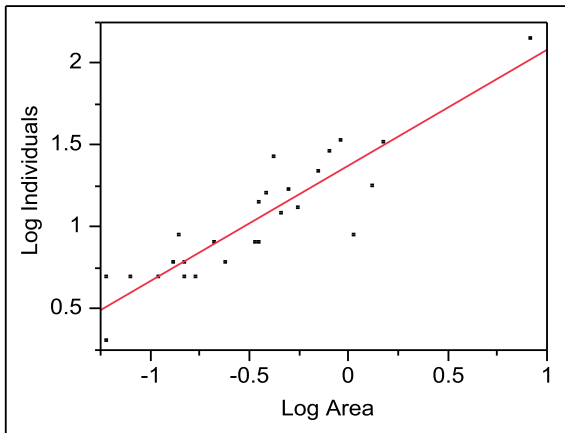


Figure 2. Log number of total individuals observed versus log area (hectares) for birds in 26 spruce-fir patches in Gunnison County, Colorado ($R^2 = 0.815$).

The regression analysis showed that there was a negative relationship ($R^2 = 0.494$, Figure 3) between edge and number of species observed.

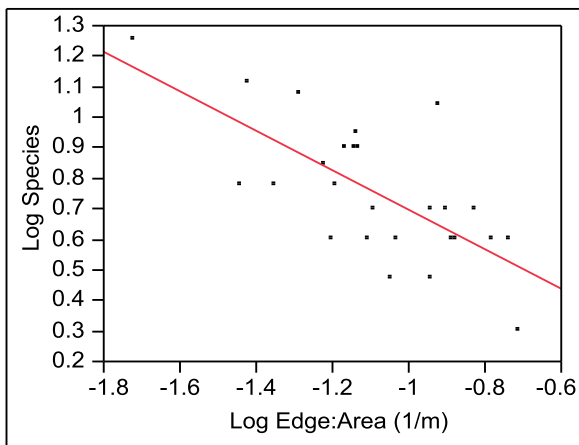


Figure 3. Log number of species versus log edge (meters) to area (square meters) ratio for birds in 26 spruce-fir patches in Gunnison County, Colorado ($R^2 = 0.494$).

Discussion

As the edge to area ratio of a patch increases, the species richness decreases, as shown in Figure 3. This trend indicates that long, narrow forest strips do not have enough interior habitat

or food resources for species that nest or forage in conifers, as well as that small patches only provide space for a few species. When considering the conservation implications of this pattern, it seems that maintaining large forested areas rather than small patches is preferable for avian species diversity, as was suggested by the study conducted by Edenius and Sjöberg (1997) in Swedish spruce forests.

Appendix 1

Proportion of patch area sampled in point counts varied ($R^2 = 0.665$) between sites. As shown in Figure 4, large patches were undersampled, indicating that the species richness values were conservative estimates of the true number of species. This trend supports the strong relationship observed between area and species richness, as well as between edge to area ratio and species richness. Had the large patches been more completely sampled, the relationship would still hold, and most likely be stronger.

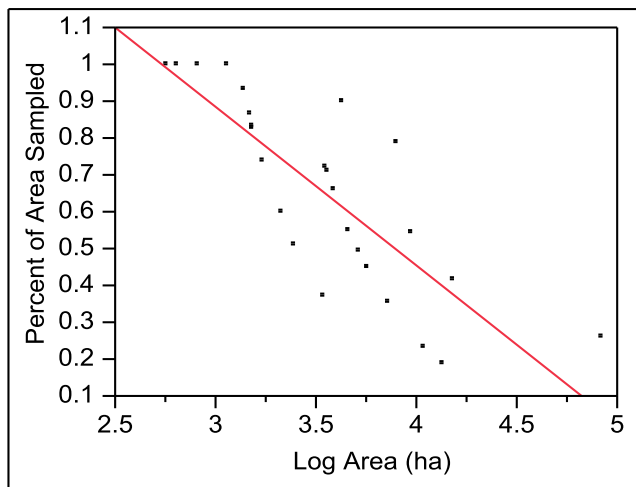


Figure 4. Proportion of each spruce-fir patch sampled in point counts versus log area (hectares) in Gunnison County, Colorado ($R^2 = 0.665$).

Appendix 2

Species-site relationship for 26 conifer patches in Gunnison County, Colorado. Species are organized by descending species frequency and patches by decreasing species richness. Species occurrence at a site is indicated by 1 and absence by 0.

	Patch																										Sp. freq	
Species	15	19	13	20	10	1	18	24	12	14	23	17	3	4	22	16	8	2	21	7	25	26	9	6	11	5		
Poecile gambeli	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	24	
Regulus calendula	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	1	1	1	1	1	0	1	0	19
Carduelis pinus	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	0	1	1	0	0	0	0	17
Regulus satrapa	1	1	1	1	1	0	1	0	1	1	0	1	0	0	1	0	1	0	1	0	1	0	0	1	1	0	15	
Corvus brachyrhynchos	1	1	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	9	
Sitta Canadensis	1	1	1	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	8	
Selasphorus sp.	1	1	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	7	
Certhia Americana	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	7	
Picoides sp.	1	1	0	1	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	7	
Empidonax occidentalis	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	7	
Turdus migratorius	1	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	6	
Perisoreus canadensis	1	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	
Colaptes auratus	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	
Catharus guttatus	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5	
Vireo gilvus	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	
Troglodytes aedon	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	
Corvus corax	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
Sphyrapicus nuchalis	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	
Zonotrichia leucophrys	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	
Junco hyemalis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	
Pinicola enucleator	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
Dendroica coronata	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
Vermivora celata	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
Dendroica petechia	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Buteo jamaicensis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Cyanocitta stelleri	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Species richness	18	13	12	11	9	8	8	8	7	6	6	6	5	5	5	5	4	4	4	4	4	4	4	3	3	2		
Area (ha)	8.17	1.5	0.92	0.42	0.38	0.8	0.56	0.35	0.71	0.5	1.32	1.06	0.15	0.14	0.35	0.15	0.11	0.13	0.34	0.08	0.06	0.46	0.24	0.17	0.21	0.06		

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