Measuring Ecological Effects of Prescribed Fire Using Birds as Indicators of Forest Conditions

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Abstract—*To evaluate the ecological effects of prescribed fire, bird and vegetation surveys were conducted in four study areas of the Klamath National Forest where prescribed fires are being used for management. Bird and vegetation data were collected at sites treated with prescribed fire and nearby untreated control sites. Data were collected at stations from 2000 (pre-treatment) to 2004 (1-4 years post treatment). The treated sites ranged from 9 to 30 ha, and during the course of the study 25-73% of each area was treated with prescribed fire. Over this time period, there was no consistent change in the volume of vegetation in either the tree or shrub strata. Similarly, there was no measurable effect of prescribed burning on the composition of the overall bird community. Spatial variation and annual variation in abundance appear to be more important than the change induced by prescribed burning at this scale and intensity. The abundance of eight individual species that have been identified as conservation focal species for coniferous forests was also investigated. There were no consistent changes in the abundance of these species that we could attribute to the application of prescribed fire. These results suggest that the prescribed fire applied in these treatment units had negligible effects on landbird community composition.*

Introduction

Biodiversity and ecosystem function may be closely linked to historical fire regimes. These regimes have been altered by fire suppression policies implemented in the 20th century (Agee 1993). In an attempt to restore fuel conditions created by historical fire regimes (i.e. mixed-severity; Huff and others 2005), management agencies are using prescribed burns and mechanical fuels treatments that mimic the effects of natural fire. However, the ability of these management activities to mimic the effects of natural fire on habitat structure and animal populations is not well understood (Tiedemann and others 2000). For example, prescribed fire treatments may fail to create the range of habitat conditions used by birds after naturally occurring wildfires (Smucker and others 2005).

Like many national forests across the west, the Klamath National Forest in northern California is currently using prescribed fire as a tool to reduce fuels and improve forest health (S. Cuenca, personal communication). However, the ability of prescribed fire to achieve the desired ecological effects is largely uninvestigated (Tiedeman and others 2000; Huff and others 2005). Monitoring is essential to evaluate the ability of fire-related management activities to achieve desired ecological conditions (Huff and others 2005). One approach to designing monitoring projects is to focus on groups of organisms that can provide cost-effective information about ecological conditions of interest

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(Vos and others 2000; Gram and others 2001). Birds are an effective tool for monitoring because: (1) many species are easily and inexpensively detected using standardized sampling protocols; (2) species respond to a wide variety of habitat conditions; and (3) accounting for and maintaining many species with different ecological requirements can be used to implement landscape scale conservation strategies (Hutto 1998). Changes in the abundance of bird species associated with desired habitat conditions can thus be used to gauge the ability of management actions to maintain or improve that habitat condition and provide inferences about which habitat conditions are contributing to these changes.

To evaluate the impacts of prescribed burning in the Klamath National Forest, we compared vegetation structure and bird abundance over a five-year period. The objectives of this project were to (1) describe the effects of prescribed burning on vegetation structure and bird community composition and (2) evaluate if these effects are consistent with the ecological goals of coniferous forest management.

Methods

Study Sites and Sampling Design

Our study site was on the Klamath National Forest in northern California (fig. 1). The forest vegetation in the area of these prescribed fires is diverse (Whittaker 1960) and includes both conifer and hardwood species. Dominant conifers include Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), incense-cedar (*Calocedrus decurrens*), and white fir (*Abies concolor*). Dominant hardwoods include tanoak (*Lithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), canyon live oak (*Quercus chrysolepis*), California black oak (*Q. kellogii*), Oregon white oak (*Q. garryana*), and big-leaf maple (*Acer macrophyllum*). The relative composition of these species varies with elevation, aspect, and soils. Generally, these forests correspond to the Douglas-fir, Mixed Evergreen Hardwood, or White Fir Types described by Huff and others (2005). Fire-related studies in these vegetation types show a mix of fire severities, frequencies, and sizes typically characteristic of low and moderate-severity fire regimes (Agee 1991; Wills and Stuart 1994; Taylor and Skinner 1998, 2003). Over time, such mixed-severity fires create forests with multiple age classes, often with Douglas-fir or ponderosa pine as an emergent canopy above various hardwoods.

Working with a fire planner and district biologist form the Klamath National Forest, we identified four study areas where a series of control burns were to be implemented (fig. 1). Using maps of planned prescribed fire treatments, we established groups of stations (sites) where fire treatments were planned (treated sites), and where they were at least 1000 m from where fires were planned (control sites). Stations were established at least 250 m apart. For all analyses we consider sites as independent replicates and generated a single measurement for each site by averaging across stations.

The application of prescribed burns within the study areas was patchy. Sometimes, burns were applied such that stations were located along their edges or just outside the boundaries of burns. As a result, it is difficult to use a simple dichotomous classification of treated vs. untreated stations. Furthermore, stations were surveyed each year, but between surveys new treatments were applied. As a result the proportion of treated area around the points increased throughout the course of the study. To quantify the proportion of

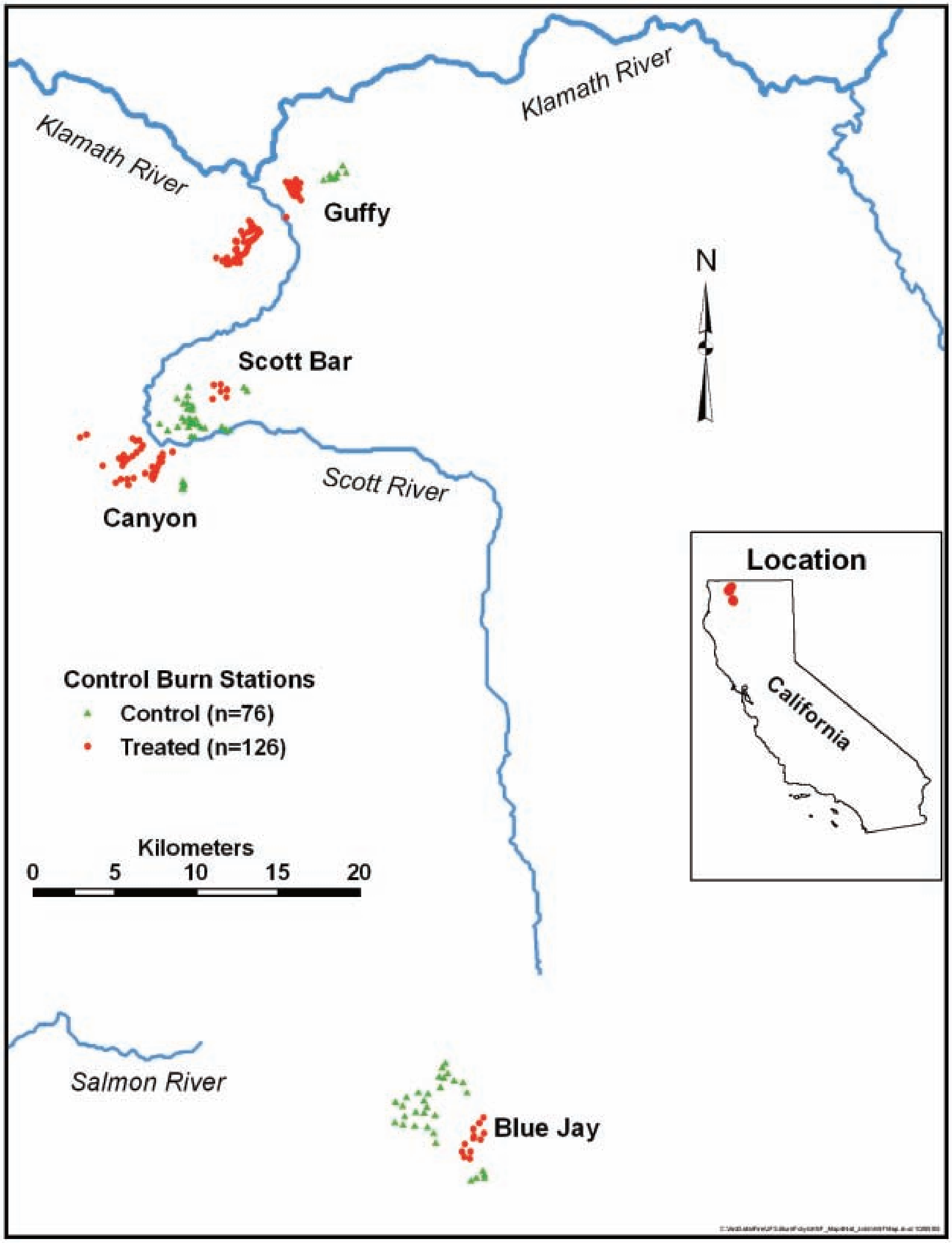

Figure 1—Map showing the location of four study areas where we studied the effects of prescribed fire on bird communities in the Klamath National Forest in northern California. Triangles represent stations at treated sites, and circles represent stations at control sites.

each treated site that was burned, we used a geographical information system to create a 50 m buffer around all points that fell within 50 m of a polygons that had been treated between 1999 and 2004 and then calculated the percent of this area that was treated in each year of the study (table 1).

Data Collection

Vegetation sampling—Vegetation structure was measured at all stations in all years of the study. We used a relevé method (Ralph and others 1993) to collect vegetation data at each station on variable radius plots. Within these

Table 1—Four study units in then Klamath National Forest, California, where prescribed burning was applied between 2000 and 2004. Location of sites are identified in Figure 1.

Area	Site	Number of stations	Total area (ha)[1]	Percent treated[2]				
				2000	2001	2002	2003	2004
Blue Jay	treated	12	9	0	0	18	25	25
	control	31						
Scott Bar	treated	6	5	0	0	0	0	71
	control	8						
McGuffy	treated	69	53	33	33	33	33	59
	control	8						
Canyon	treated	39	30	53	62	64	66	73
	control	29						

[1]Number of ha encompassed by a 50 m buffer around the points in each unit.
[2]Cumulative percent of the buffer-defined area that was treated for each year.

plots, we recognized two vegetation layers: a tree layer (generally >5 m), shrub layer (generally >0.5 m and <5 m). For each layer, we visually estimated height of the top of the tree layer (canopy height) and the bottom of the tree layer (canopy base height). We also estimated shrub height and shrub base height. For each layer, we recorded total cover of all vegetation in each layer as one of six cover classes (0, 0 to 5, 5 to 25, 25 to 50, 50 to 75, and 75 to 100 percent) and used the center point of each cover class as the measurements.

Breeding season point counts—Bird abundance was evaluated using standardized point count methodologies (Ralph and others 1993). Five-minute bird counts were conducted between sunrise and 1000 PDT on each station, and all landbird species seen and heard were recorded. The distance to each individual was estimated to the nearest meter. Counts were conducted only on days when the wind was <20 kph and it was not raining. All observers were experienced and had been trained for distance estimation and species identification. Only birds detected ≤50 m of each point were used in the analysis. This criterion was chosen to reduce the possibility of double counting individuals, including detections that were outside of treated or control areas, and alleviate biases introduced if detection rates differed between treated and control areas (Schieck 1997; Siegel and DeSante, 2003). Flyover detections were excluded from the analysis. We restricted our analysis to passerines and woodpeckers, and excluded four species (Common Raven, American Dipper, Violet-green Swallow, and American Crow) that we expected would be highly influenced by habitat characteristics unaffected by prescribed fire.

Data Analyses

Vegetation structure—We used the relevé data to generate indices that represented the volume of vegetation of the tree layer and shrub layer. The volume of the tree layer was calculated by subtracting the canopy base height from the canopy height, and then multiplying this distance by the total cover value for the tree layer. The same method was used to calculate an index for the volume of the shrub layer. Within each year, we averaged all measurements within each site, and used this single tree and shrub layer value in all subsequent analyses.

To describe the difference between vegetation volume of treatment and control sites, we used:

$$d = \log(V_{treatment} / V_{control}),$$

where *d* describes the difference between the vegetation volume (*V*) in the control sites and treatment site. When there is no difference between control and treatment sites $d = 0$, when treatment sites have greater vegetation volume than controls, *d* is positive, when treatment sites have less vegetation volume *d* is negative. Because prescribed fire was expected to raise the canopy base height and reduce shrub cover, we predicted that *d* would become increasingly negative over the course of the study.

Bird community composition— For each site and year we calculated average abundance (individuals/station) of all bird species and used these values in a species x site matrix. We then tracked the movement of each site in ordination space to evaluate the degree to which the bird community composition changed over the course of the study. Because our four areas covered a wide range of elevations and habitats, we expected substantial spatial differences in bird community composition. Therefore, we analyzed two sets of birds; 'all birds' included all the passerines and woodpeckers that were detected during the study and 'core birds,' which was a subset that was restricted to species that were detected at all sites in at least one year of the study. We evaluated changes in bird community composition through time using detrended correspondence analysis (DCA) conducted in PC-ORD (McCune and Mefford 1999).

Abundance of coniferous forest focal species—To investigate species-specific responses to fuels treatments we selected 'core' birds that were identified by either the California or Oregon/Washington Partners in Flight coniferous forest conservation plans (Altman 2000; CalPIF 2002). Within each year, we averaged the number of individuals detected per station, and used this single value for each site in all subsequent analyses. Similar to the analysis of vegetation volume, we described the difference in bird abundance between treated and untreated sites as:

$$d = \log(A_{treatment} + 1 / A_{control} + 1),$$

where *d* describes the difference between bird abundance (*A*) at control sites and treated sites. Because some species were not detected at some sites in some years, we used Naperian (N + 1) logarithms.

Results

Application of Prescribed Fire

Prescribed fires were applied at all four sites over the five years of the study (table 1). At two sites (Guffy and Canyon) a third to half of the area had already been treated before the study began, however, in both these areas treatments continued throughout the course of the study (table 1), thus we would expect the trajectory of changes at these areas to be similar to the other areas. In most of the sites we monitored for several years after the first treatments were applied, with the exception of the Scott Bar site, where we collected a single year of post-fire data.

Vegetation Structure

We found no evidence that the volume of live vegetation in the tree layer was consistently reduced at treated sites; in each year the difference between the treated and control areas was roughly symmetrical around 0, and there was no suggestion that this measurement had consistently decreased at any of the four areas (fig. 2). Our results for the volume of the shrub layer were similar (fig. 2), in that there were no sites that showed a consistent pattern of change between treated and control sites through the course of the study. In both the first and last year of the study, the measurements of the difference in total shrub cover of treated and untreated sites was symmetrically distributed around 0 (fig. 2).

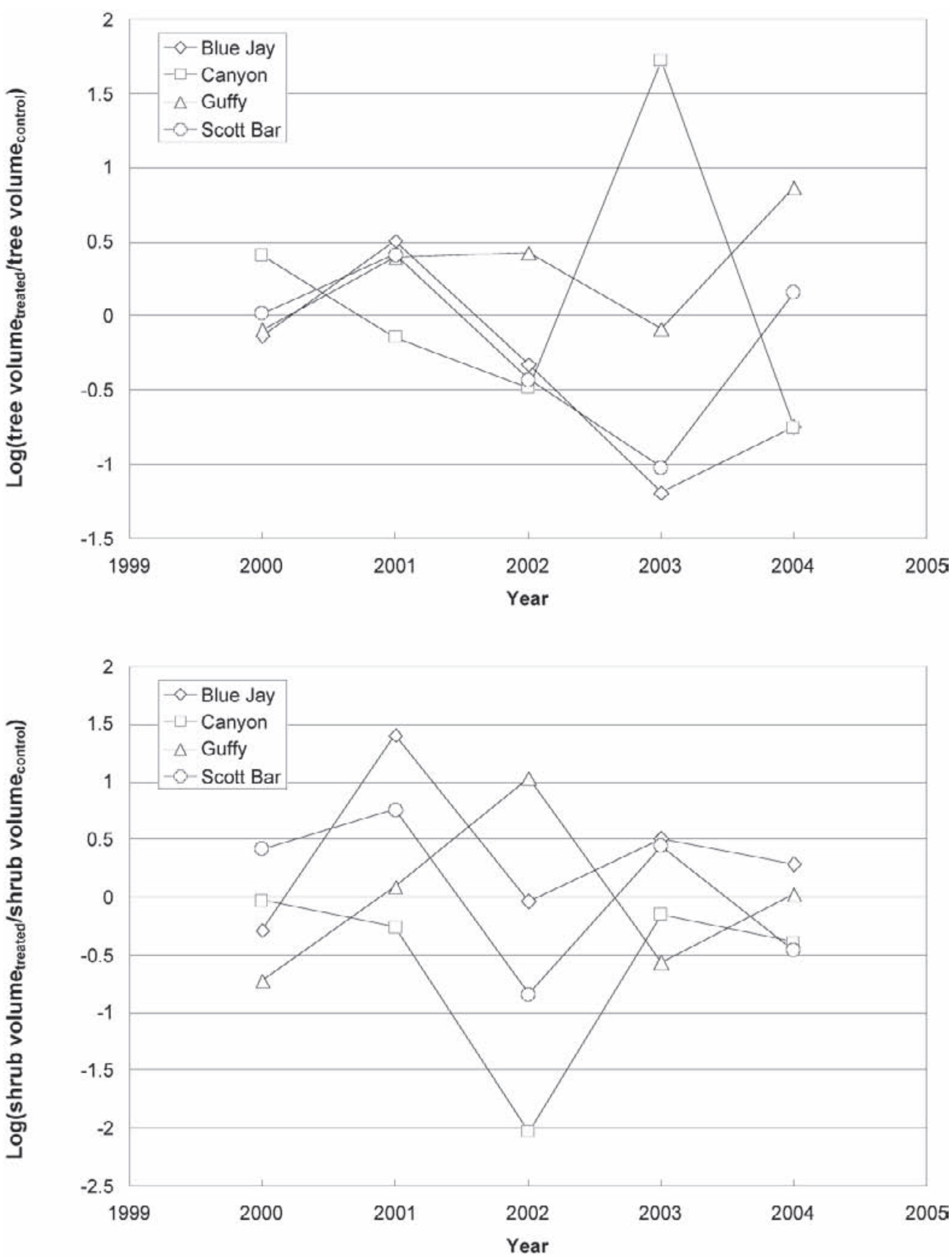

Figure 2—Log response ratios comparing vegetation characteristics of treated and control sites from the four study areas over the five-year study period.

Bird Community Composition

For ordinations of both 'all birds' and 'core birds' most of the variation in the original multidimensional space was captured in the first two axes (table 2), therefore, we limited out our interpretation to these axes. Ordination of bird communities for the treated and untreated units demonstrated substantial variation in bird communities among sites (fig. 3). In particular, the Canyon control site and Blue Jay treated site were substantially different from all the other study sites. Furthermore, it was not uncommon for sites from the same area (e.g., compare Guffy treatment to Guffy control) to be more different than sites from different areas (e.g., Guffy treatment versus Scott Bar control). These spatial patterns remained roughly the same for ordinations of all birds and core birds (fig. 3). Although there was substantial year to year variation in bird communities, both in treated and control units, there was no apparent directional movement in ordination space associated with treatments. For instance, although treated units Canyon and Blue Jay both moved during the study period, they moved toward each other, suggesting that if there was an effect of prescribed fire, it had the opposite effect in these two units.

Abundance of Focal Species

For the eight Partners in Flight coniferous forest focal species that we investigated, we could discern no obvious changes in abundance that occurred as a result of treatment (fig. 4).

Discussion

Our results suggest that the effects of prescribed fire on vegetation structure and bird community composition have been minimal in these areas of the Klamath National Forest. We found no evidence that prescribed fire treatments were associated with a persistent decrease in the volume of vegetation in the tree or shrub layer. There was substantial year to year variation, and some of these changes may represent short term changes from recent treatments, but these effects did not appear to persist, or accumulate, over the course of the study.

Similarly, our ordination results for the bird community show no evidence of a directional change in bird community composition that is unique to the treated areas (fig. 3). Even in the absence of overall community effects, we

Table 2—Coefficient of determination for the correlation between bird community detrended correspondence analysis (DCA) ordination distances and relative Euclidean distances in the original multidimensional space.

	All birds		Core birds	
DCA Axis	**Incremental R^2**	**Cumulative R^2**	**Incremental R^2**	**Cumulative R^2**
Axis 1	0.39	0.39	0.39	0.39
Axis 2	0.35	0.74	0.40	0.79
Axis 3	0.04	0.79	0.04	0.83

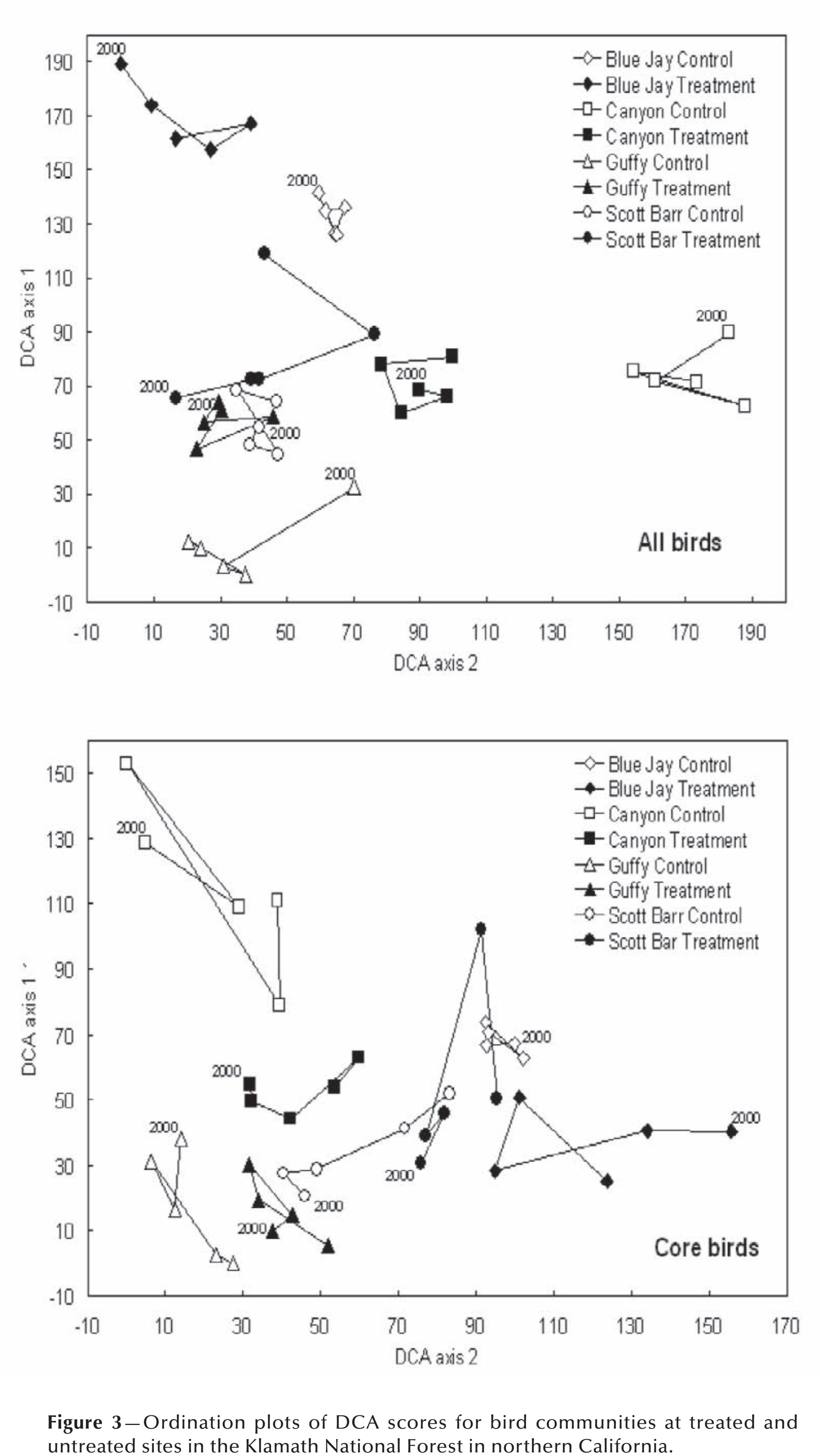

Figure 3—Ordination plots of DCA scores for bird communities at treated and untreated sites in the Klamath National Forest in northern California.

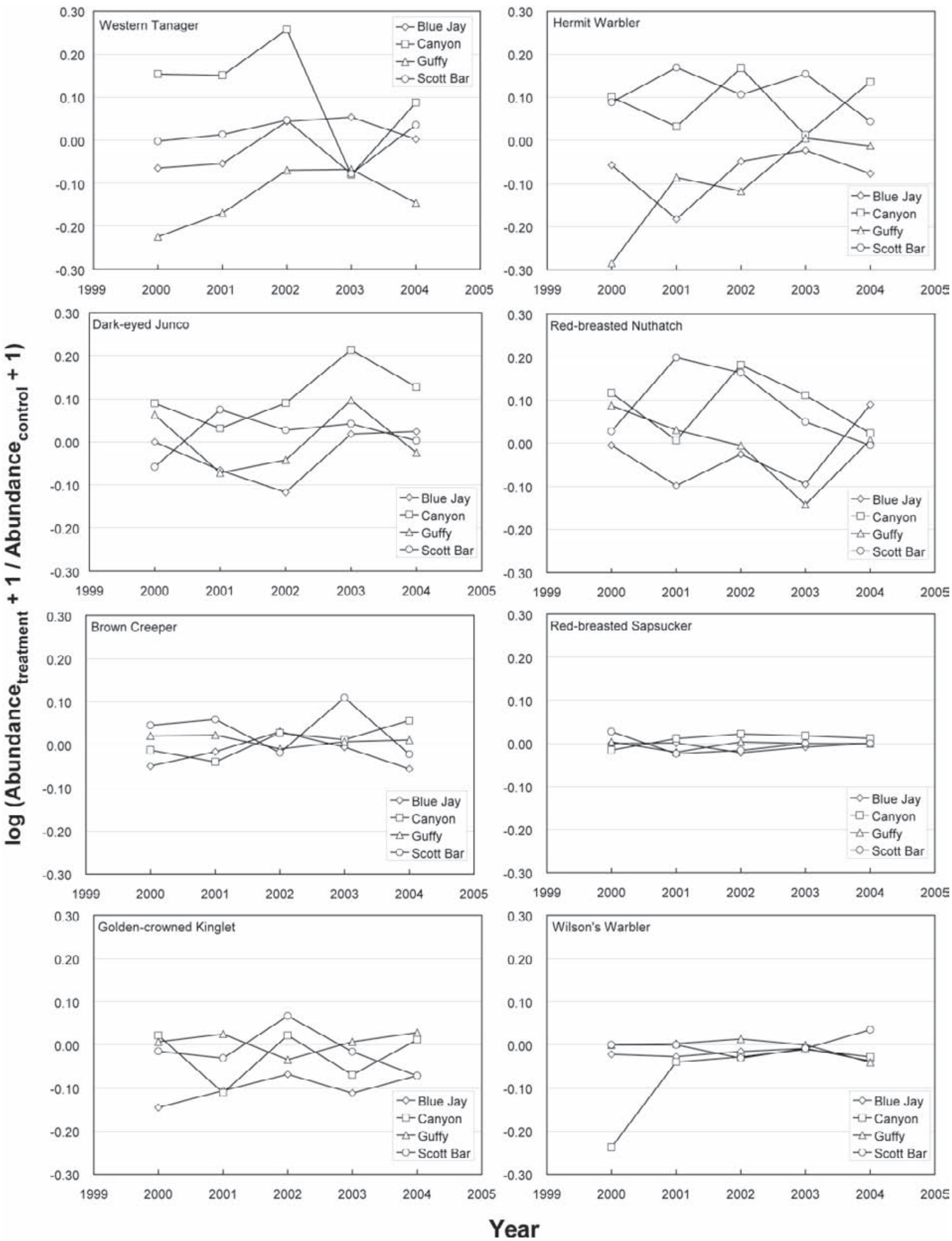

Figure 4—Log response ratios comparing bird abundance of treated and untreated sites from the four study areas over the fire-year study period.

may still be concerned about the effects of prescribed fire if they change the abundance of individual species that are of particular conservation concern. However, our analyses of the Partners in Flight focal species for coniferous forests showed no consistent trends for these species to become either more or less abundant after treatment.

There is limited evidence that fuels reduction projects in the western United States can be implemented in such a way that they are consistent with the goals of wildlife conservation and ecosystem health (Tiedemann and others 2000; Huff and others 2005). However, this study, and a similar study comparing thinned and unthinned mixed-conifer forests in the Sierra Nevada (Siegel and DeSante 2003), suggest that in conditions were prescribed fire has little effect on the volume of live vegetation, such treatments may have relatively minor consequences for bird communities. However, if the goal of these treatments includes restoring conditions in such a way that it changes the quality of wildlife habitat, our results suggest that prescribed fire in the Klamath National Forest would need to be modified to achieve the desired conditions.

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