EVALUATING BIOLOGICAL EFFECTS OF FOREST MANAGEMENT PRACTICES BY MONITORING THE NEST SUCCESS OF LANDBIRDS

FINAL REPORT

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EXECUTIVE SUMMARY

We used point counts and multi-species nest monitoring to assess the effects of forest thinning (commercial and biomass combined) on breeding bird communities in commercially managed Sierran mixed conifer forest. During three successive seasons of study (1998-2000), we found and monitored 537 active nests of 37 species on ten 36-ha study plots in the northern Sierra Nevada. Five of the study plots had been thinned between 1990 and 1993; the other five plots served as controls. Point count data indicated that birds were present in much greater densities (approximately 1.6 times as many individual birds counted) on the thinned plots than on the control plots. The overwhelming majority of nests we found (74%) also were located on the thinned plots. Nest survivorship rates for each of four nesting guilds (ground-nesters, shrub-nesters, canopy-nesters, and cavity-nesters), however, were statistically equivalent between thinned and control plots, though there was a slight, non-significant tendency for nests on the control plots to succeed in greater proportions than nests on thinned plots, particularly among ground- and cavity-nesting species. Given the dramatic preponderance of birds on the treatment plots, the treatment plots clearly produced many more fledglings each year than the control plots, even if the non-significant differences in nest success rates were real.

Several ecologically inter-related forest attributes correlated with increased abundance of nesting birds, but the presence of a much more extensive shrub understory on the thinned plots appeared to be the primary factor driving differences in bird communities on the two sets of plots. We surmise that the thinning protocol successfully stimulated vigorous shrub growth, particularly of Deer Brush (*Ceanothus integerrimus*), and conclude that the presence of this well-developed shrub understory is highly beneficial to the majority of breeding birds in the Sierran mixed conifer community. This type of thinning thus appears to be a useful tool for enhancing habitat value for forest-nesting birds, at least within stands affected by historical fire suppression.

INTRODUCTION

This project was initiated in 1998 to study the effects of mechanical commercial and biomass thinning on avian nest success and community composition in mixed conifer timberlands of the northern Sierra Nevada. Combination biomass/commercial thinning, the removal of small-diameter, low value trees from dense stands, combined with the harvesting of commercially valuable trees to yield approximately 25-foot spacing among the remaining stems, has been a fairly common treatment on Sierra timberlands since the 1978 passage of the Public Utility Regulatory Policies Act (PURPA), which created a market for the power generated by burning chipped trees (Kucera and Barrett 1995). The process has been implemented fairly extensively across northern California's forests, with an estimated 60,000 acres of California forest thinned annually during the mid-1990s (Kucera and Barrett 1995). In addition to generating extra income when energy market conditions are favorable, this combination thinning may reduce the risk of fire reaching the forest canopy, lower the competition among remaining trees for light, soil moisture and nutrients, and increase the value of the wood products that can ultimately be harvested from the remaining trees.

Thinning may be a particularly appealing timber management tool in the Sierra, where twentieth century fire suppression has dramatically altered forest conditions throughout much of the range (extensively reviewed in Sierra Nevada Ecosystems Project, 1996). In particular, fire suppression has tended to favor shade tolerant tree species such as White Fir and Incense Cedar at the expense of less shade-tolerant species. The suppression of periodic fire has also resulted in an increased density of small trees in many forest types, with a concomitant reduction in the density of large trees through commercial harvest and mortality, and an increased risk of catastrophic crown fires (Agee 1993). Evidence suggests that increased overall tree density in some forest types has also substantially reduced the extent of shrub understory (Sierra Nevada Ecosystems Project, 1996). Avian community composition has undoubtedly been strongly altered by these long-term structural and compositional changes in Sierra habitats, but such effects have been poorly studied.

If mechanical thinning can restore some formerly fire-induced forest characteristics, then it has the potential to benefit wildlife species that may have suffered as a result of ecological changes resulting from fire suppression. Although commercial thinning in Douglas-fir stands of western Oregon has been shown to increase the abundance of breeding birds (Hagar et al. 1996), fairly little empirical research has been conducted on the effects of commercial and/or biomass thinning on forest conditions in the Sierra Nevada, and very little work has explicitly addressed the effects on wildlife in the Sierra. An exception is the work of Kucera and Barrett (1995), which suggests that biomass thinning implemented across a variety of locations across northern California failed to spur vigorous shrub growth, and concludes that "wildlife that benefits from dense understory or post-fire brushfields, e.g., deer, many birds and rodents, may not benefit from biomass thinning, especially in the short term." They add, however, that biomass thinning may benefit wildlife dependent on late-seral forest characteristics over time. While Sierran mixed conifer forests stands with relatively open canopies and well-developed shrub understories have been shown to host higher densities of singing birds than stands with high canopy closure and poorly developed shrub understories (Beedy 1981), it thus remains to be established that thinning can effectively produce these conditions, and if it can, that bird communities actually respond favorably.

This study was designed to look at the responses of breeding bird communities to commercial and biomass thinning in a commercially managed, Sierran mixed conifer forest. We sought to test how forest characteristics induced by thinning would affect avian community composition and the nesting success of all four major nesting guilds— ground-nesting birds, shrub-nesting birds, canopy-nesting birds, and cavity-nesting birds. We further sought to identify simple, easily quantified habitat attributes associated with high levels of avian productivity. Our hope was that identifying these attributes would enable managers of Sierran mixed conifer forest to deliberately manage for them, and thereby bolster bird populations throughout Sierran timberlands.

METHODS

Study site. In the spring of 1998 we established and marked two clusters of five 36-ha study plots on Sierra Pacific Industries timberlands in Tehama County, California. One cluster of study plots (hereafter, ‘control plots’) was located between 3800' and 5100' on a south-facing slope where selection overstory logging was conducted in the in the late 1950s and again in 1978 and 1994 (different plots were entered in different years). The other cluster (hereafter, ‘treatment plots’) was located about five kilometers to the southeast, between 4100' and 4600' on a roughly parallel south-facing slope where similar selection harvesting occurred in the late 1930's/early 1940's, and then again between 1978 and 1988, and once more in a small area in 1994. The two slopes were selected for the study because they were similar in aspect, slope, forest type, and seral stage, but differed in that the combination commercial/biomass thinning protocol was applied only on the treatment plots, between 1990 and 1993. The stands were marked prior to treatments to retain vigorous, healthy trees at about a 25 foot spacing. Prior to harvest, treatment plot basal area averaged approximately 250 sqft/acre, and stem density averaged 400 stems/acre; post-harvest basal area was reduced to 75-100 sqft/acre, and post-harvest stem density averaged 75-100 stems/acre (S. Self, pers. comm.).

Plot boundaries were determined by a process that involved randomly selecting starting points on a map, and then extending boundaries out in randomly chosen cardinal directions. Boundaries were turned 90 degrees when they approached within 200 m of another plot, or within 100 m of a riparian buffer area that had been managed differently than the upland forest.

All ten plots were established in Sierran mixed conifer forest (California Dept. of Fish and Game, 1999), comprised of varying proportions of White Fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), Ponderosa Pine (*Pinus ponderosa*), Incense Cedar (*Calocedrus decurrens*) and Sugar Pine (*Pinus lambertina*), with occasional small stands and single individuals of Black Oak (*Quercus kelloggii*) and Canyon Live Oak (*Quercus chrysolepsis*), as well as Mountain Dogwood (*Cornus nuttallii*), Bigleaf Maple (*Acer macrophyllum*) and California Hazelnut (*Corylus cornuta*). Deer Brush (*Ceanothus integerrimus*) was by far the dominant understory shrub, but other relatively common shrubs included Mahala Mat (*Ceanothus prostratus*), Creeping Snowberry (*Symphoricarpos mollis*), Sierra Gooseberry (*Rhibes roezlii*), and to a lesser extent, Greenleaf Manzanita (*Arctostaphylos patula*), Poison Oak (*Toxicodendron diversilobum*), and Bush Chinquapin (*Chrysolepsis sempervirens*).

Field methods. Our crew each year consisted of a highly experienced crew leader (except for 1999, when two supervisors shared the position) and five field technicians. Each field technician was responsible for searching for nests and monitoring nesting attempts on two study plots: one treatment plot and one control plot. This ensured that differences in observer abilities did not bias our results. Additionally, the crew leader divided his or her time among all ten plots, assisting each of the technicians as needed.

Each year crew leaders spent the first two weeks of May intensively training crews in bird and plant identification, nest searching, nest monitoring, and habitat description protocols. Training in bird identification included work in the field as well as time spent practicing with taped songs and calls and an instructional CD ROM. As the crew leader became satisfied that each field technician was mastering the necessary skills, technicians spent less time receiving instruction, and more time working on their study plots alone.

Once the formal training session was completed and the data collection phase of the season began, the crew spent their time searching for and monitoring nests of all species present on the plots, alternating daily between control plots and treatment plots. Equal effort was thus devoted to control and treatment plots. Nest searching followed the guidelines in Martin and Geupel (1993), and nest observations and habitat data were recorded in accordance with Martin et al. (1997), with some slight modifications. Once discovered, active nests were visited at least every four days, but more often every two days. Nests were considered successful if they fledged at least one young bird. Nest-fate determinations were based on nesting intervals described in Ehrlich et al. (1988), and the criteria described in Manolis et al. (2000). Fledging and nest failure events were assumed to occur at the midpoint between nest visits.

We conducted point counts three times each year during the height of the singing season (all counts conducted between May 23 and June 18) at nine systematically arrayed points (hereafter a ‘transect’) on each study plot. Each year three crew members conducted all the point count surveys, such that each replicate was conducted by a different observer, and all ten plots were surveyed by the same three observers. Observers received intensive training in bird identification and distance estimation, and did not conduct point counts until the crew leader tested and verified their skills. Point counts began within ten minutes of official local sunrise, and were generally completed by 9 a.m. The order of points was shifted for each replicate survey so that each point, on average, was surveyed at about the same time of day. Point counts were not conducted if it was raining (even lightly) or if the wind was blowing hard enough to generate substantial noise interference. Point counts lasted five minutes, during which observers noted every bird seen or heard, and recorded birds detected within a 50 m radius separately from birds detected from greater than 50 meters. Individual birds believed to have already been detected from a previous point on the same day were recorded as such, and were included only once in our analysis.

Detailed habitat data were collected within 5.0 m radius subplots (for shrubs, saplings and ground cover) and 11.3 m radius subplots (for trees and snags) centered on each nest, as well as at 36 systematically arrayed points on each of the ten study plots. Canopy cover estimates were determined with spherical densiometers, and tree heights were estimated with clinometers.

Throughout this report live trees were classified into three size categories: small, medium, and large. Small trees were defined as being at least 5 m tall and having dbh greater than or equal to 8 cm, but less than 23 cm. Trees less than 5 m tall or less than 8 cm dbh were considered saplings, and were not included in tree density estimates. Medium trees were defined as those with dbh greater than or equal to 23 cm, but less than 38 cm. Large trees were those with dbh of 38 cm or greater. Snags were defined as completely dead trees greater than or equal to 2 m tall and at least 12 cm dbh. The ‘shrub/sapling’ component of the forest refers to all woody plants (shrub species or tree species) that were greater than 20 cm tall and either less than 5 m tall or less than 8 cm dbh.

Data analysis. All data collected were entered into electronic databases, which were then systematically reviewed for accuracy. Point count analyses included only birds detected within the 50 m radius, to prevent bias in the event that detectability over longer distances differed between treatment and control plots. In accordance with the recent guidelines proposed by Manolis et al. (2000), Mayfield nest success rate calculations incorporate nests with uncertain fates, with exposure terminated on the last observed active date. Nests with known fates were assumed to terminate at the midpoint between the last observed active date and the first observed inactive date (Manolis 2000 et al.).

Total nest survival rate, the probability that a nest will last the duration of the nesting cycle without failing due to predation or other causes, is generally calculated as

$$D^L,$$

where D is the daily nest survival rate, and L is the number of days in the species' nesting cycle. This calculation is less straightforward, however, when the objective is to pool data from several different species to yield a nesting guild average, because each species has its own nesting cycle length. The problem is in fact more complicated still, because the species composition of each nesting guild varies slightly between control and treatment plots. We addressed this problem by calculating eight separate average nesting cycle lengths, one for each combination of nesting guild and experimental group (i.e., ground nesters on the control plots, ground nesters on the treatment plots, shrub nesters on the control plots, etc.). Within each combination of nesting guild and experimental group, we calculated the average nesting cycle as

$$\frac{L_s(N_s)}{N_t},$$

where L_s is the length of the nesting cycle for each species represented (based on information in Ehrlich et al. 1988), N_s is the number of nests of each species included in the calculation, and N_t is the total number of nests in that combination of nesting guild and experimental group. Table 1 presents average nesting cycle lengths for each nesting guild and experimental group.

All chi-square tests with only one degree of freedom included Yates' Correction. Non-parametric tests were used when normality of data distributions could not be established, and the significance threshold for all statistical tests was $p < 0.05$, unless otherwise noted. All statistical tests were two-tailed. Error bars on graphs represent standard errors unless otherwise noted, and p-values are indicated on graphs as follows: * ≤ 0.05, ** ≤ 0.01, and *** ≤ 0.001. Values throughout the text are presented as mean±standard error.

RESULTS

General plot characteristics.

Although substantial variation in aspect existed within and among plots (Figure 1), all were generally south-facing, and average aspect across the five treatment plots ($x = 142 \pm 14$) and the five control plots ($x = 161 \pm 9$) did not differ (*Mann Whitney U* = 18.0, $p = 0.25$). Slope varied considerably within and among plots (Figure 2), with control plots ($x = 13.2 \pm 0.7\%$) steeper than treatment plots ($x = 9.5 \pm 1.5\%$), although the difference was not significant (*Mann Whitney U* = 20.5, $p = 0.09$). Average canopy height was slightly greater on treatment plots ($x = 23.3 \pm 0.8$m) than on control plots ($x = 21.4 \pm 0.7$), though it varied fairly substantially among control plots (Figure 3), and the difference was not significant (*Mann Whitney U* = 6.0, $p = 0.18$).

Commercial/biomass thinning has had a clear effect on canopy cover, which averaged 66.3± 3.7% on control plots compared to 53.0± 3.5% on treatment plots, a statistically significant difference (Figure 4; *Mann Whitney U* = 22.0, $p = 0.047$). Average canopy cover for each of the ten plots was significantly inversely correlated with average percent cover in the shrub/sapling vegetative layer ($R^2 = 0.42$, $p = 0.044$), and with Deer Brush cover ($R^2 = 0.63$, $p = 0.006$;

Figure 5). Average percent shrub/sapling cover differed significantly between control plots (x = 17.6±1.1%) and treatment plots (x = 37.6±3.5%; *Mann Whitney U* = 2.0, *p* = 0.028), though most of the difference was accounted for by just three of the treatment plots (Figure 6). Deer Brush cover (by far the most abundant shrub species on the plots) differed even more dramatically between control plots (x = 4.7±1.5%) and treatment plots (x = 15.4±1.7%; *Mann Whitney U* = 0.0, *p* = 0.009), with all control plots except C5 exhibiting comparatively low values (Figure 7). Average height of Deer Brush did not differ significantly between control and treatment plots (*Mann Whitney U* = 13.5, *p* = 0.834), and varied only slightly among individual study plots (Figure 8).

Not surprisingly, thinning on the treatment plots appears to have had a much greater effect on the density of small tress than on larger trees (Figure 9). Average density of large conifers and overall species composition varied substantially among individual plots (minimum = 62.3 trees/ha; maximum = 101.8 trees/ha) but was nearly identical between control plots and treatment plots overall (*Mann Whitney U* = 14.0, *p* = 0.75). Medium-sized conifers occurred at nearly twice the density on the control plots as on the treatment plots, a significant difference (*Mann Whitney U* = 24.0, *p* = 0.016). Small conifers occurred at over three times the density on the control plots as on the treatment plots, again a significant difference (*Mann Whitney U* = 23.0, *p* = 0.028). While density of medium and small conifers was uniformly low across plots T1, T2, T3 and T4, plot T5 was an outlier, with a tree densities more typical of the control plots than the treatment plots (Figure 9).

Patterns in the species composition of each size class of conifers differed somewhat between experimental groups (control plots versus treatment plots) but were quite consistent within each group (Table 2). In comparison with control plots, treatment plots generally exhibited comparatively high proportions of Incense Cedar and low proportions of Sugar Pine and Ponderosa Pine among small and medium-sized trees; among large trees, treatment plots exhibited a comparatively low proportion of Incense Cedar and Douglas-fir and high proportions of White Fir and Sugar Pine (Table 2).

Snags were generally more abundant on the control plots than on the treatment plots (*Mann-Whitney* $U = 17{,}822$, $p = 0.026$), although T5 had a greater density of snags than did any other plot (Figure 10).

Two species of oak, Black Oak and Canyon Live Oak, commonly occurred on the study plots, though Canyon Live Oak was almost entirely restricted to the steeper, rockier portions of the control plots. Oaks of both species tended to be very patchily distributed. Black Oak density varied greatly between individuals plots (Figure 11) but did not differ systematically between control plots and treatment plots (*Mann-Whitney* $U = 16$, $p = 0.46$).

Point count results.

Table 3 presents point count results on control versus treatment plots. During nine point surveys on the treatment plots (three replicates during each of three years), we detected an average of 262.1 individual birds within a 50 m radius of the 45 point count stations, compared with only 165.1 detections on the control plots, a highly significant difference ($X^2 = 21.6$, $p < 0.01$). The average number of species detected during point counts on the control plots ($x = 33.0$ species) was slightly less than the average number detected on the treatment plots ($x = 36.7$ species), but the difference was not significant. Of the 44 total species detected, 32 were detected more frequently on the treatment plots, while only 12 were detected more often on the control plots, again a highly significant difference ($X^2 = 8.2$, $p < 0.01$).

Table 4 presents plot-specific point count detection totals for each species with at least one nest found on any of our study plots. Control plot and treatment plot totals for ground-nesting species were statistically equivalent ($X^2 < 0.01$, $p > 0.05$), but treatment plot totals were much higher than control plot totals for shrub nesters ($X^2 = 14.6$, $p < 0.001$), canopy nesters ($X^2 = 6.18.0$, $p < 0.05$), cavity nesters ($X^2 = 4.13$, $p < 0.05$), all cup nesters pooled ($X^2 = 11.8$, $p < 0.001$), and all species pooled ($X^2 = 16.2$, $p < 0.001$).

Correlations between point count results and habitat variables.

We used linear regression to test the relationship between the average number of birds detected on the ten study plots and each of five inter-related habitat variables— canopy cover (%), shrub/sapling cover (%), percent of cover of Deer Brush, large conifer density (>38 cm dbh), and small conifer density. The inter-relatedness of these characteristics makes it difficult to isolate which particular factors birds are responding to; nonetheless, Table 5 presents coefficients of determination and p-values for all statistically significant relationships.

-Detections of five species correlated significantly with canopy cover: Dusky Flycatcher, Cassin's Vireo, Hammond's Flycatcher, Hermit Warbler, and Mountain Chickadee. All five showed increased abundance with decreased canopy cover, at least within the range of canopy cover values present on our plots (44.6% - 75.1%).

-Detections of six species correlated significantly and positively with shrub/sapling cover: Dusky Flycatcher, Cassin's Vireo, Hammond's Flycatcher, Warbling Vireo, Hermit Warbler, and Mountain Chickadee. Detections of one species, Steller's Jay, were significantly negatively correlated with shrub/sapling cover.

-Deer Brush cover correlated with detection totals for more species (nine) than any other habitat variable investigated. Eight species were detected more often where there was more Deer Brush (Dark-eyed Junco, Dusky Flycatcher, Cassin's Vireo, Hammond's Flycatcher, Warbling Vireo, Audubon's Warbler, Hermit Warbler, and Mountain Chickadee), while Steller'Jay was detected more frequently in plots with less Deer Brush.

-Detection totals of only two species correlated significantly with large conifer density: Dark-eyed Junco, which was detected less frequently where there were more large conifers, and Black-headed Grosbeak, which was detected more frequently where large conifers were more abundant.

-Small conifer density generally correlated with bird detections much more strongly than did large conifer density. Six species exhibited negative correlations with small conifer density (Dusky Flycatcher, Cassin's Vireo, Hammond's Flycatcher, Warbling Vireo, Hermit Warbler and Mountain Chickadee), while one species (Steller's Jay) exhibited a positive relationship.

When detections among species in the same nesting guild were pooled, ground nester detections correlated highly significantly (and negatively) with large conifer density, but with no other habitat variable investigated (Table 5). Pooled detections of shrub nesting species correlated significantly and positively with shrub/sapling cover and with Deer Brush cover, but significantly and negatively with canopy cover and small conifer density. Pooled detections of canopy nesting species correlated significantly and positively with shrub/sapling cover and with Deer Brush cover. Cavity-nester detections correlated significantly and positively with Deer Brush cover, but significantly and negatively with canopy cover and small conifer density. All nesting species pooled showed highly significant negative correlations with canopy cover and small conifer density, a highly significant positive correlation with shrub/sapling cover, and an extremely strong positive correlation with Deer Brush cover, which explained a remarkable 92% of the variation in detection totals of nesting species.

Nest monitoring results.

Pooling results from all three years of the study, we found a total of 537 active nests on the ten study plots; 139 (25.9%) were found on the control plots, and 398 (74.1%) were found on the treatment plots (Table 6). As shown in Figure 12, this preponderance of nests found on the treatment plots was highly significant for ground nests ($X^2 = 14.1$, $p < 0.001$), shrub nests ($X^2 = 86.4$, $p < 0.001$), canopy nests ($X^2 = 10.9$, $p < 0.001$), and cavity nests ($X^2 = 27.5$, $p < 0.001$), as well as all nesting guilds pooled ($X^2 = 124.0$, $p < 0.001$). The number of active nests found on individual study plots correlated very strongly with average number of point count detections, pooled across all species known to have nested on at least one of the ten study plots ($R^2 = 0.848$, $p < 0.001$; Figure 13).

Individual species for which we found a statistically significant preponderance of active nests on the treatment plots included Dark-eyed Junco ($X^2 = 10.7$, $p < 0.01$), Dusky Flycatcher ($X^2 = 74.0$, $p < 0.001$), Hammond's Flycatcher ($X^2 = 14.5$, $p < 0.001$), Warbling Vireo ($X^2 = 17.4$, $p < 0.001$), White-headed Woodpecker ($X^2 = 5.79$, $p < 0.05$), Red-breasted Sapsucker ($X^2 = 9.1$ $p < 0.01$), Mountain Chickadee ($X^2 = 8.52$, $p < 0.01$), and Red-breasted Nuthatch ($X^2 = 4.97$, $p < 0.05$). No species exhibited a statistically significant preponderance of active nests on the control plots.

We were able to determine the fate of 470 (87.5%) of the 537 active nests we observed. Of these nests with known fates, 222 (47.2%) successfully fledged at least one nestling, while 248 (52.8%) failed to fledge any nestlings. As Figure 14 shows, a large though not significant preponderance of successful ground nests were located on the treatment plots ($X^2 = 3.45$, $p > 0.05$), while the preponderance of successful canopy nests on the treatment plots was significant ($X^2 = 5.78$, $p < 0.05$), and the preponderance of successful shrub nests ($X^2 = 35.8$, $p < 0.001$), cavity nests ($X^2 = 8.49$, $p < 0.01$), and nests from all nesting guilds pooled ($X^2 = 47.8$, $p < 0.001$) were highly significant. Four individual species exhibited a statistically significant preponderance of successful nests on the treatment plots: Dark-eyed Junco ($X^2 = 4.36$, $p < 0.05$), Dusky Flycatcher ($X^2 = 21.0$, $p < 0.001$), Hammond's Flycatcher ($X^2 = 8.10$, $p < 0.01$), and Black-headed Grosbeak ($X^2 = 7.11$, $p < 0.01$). No species exhibited a statistically significant preponderance of successful nests on the control plots.

Daily nest survival rates and standard errors for each nesting guild are indicated in Figure 15. Values are remarkably similar across experimental groups, and none of the comparisons even approach statistical significance (Table 7).

Figure 16 displays total nest success rate and standard errors for each nesting guild in both experimental groups. On both the treatment and the control plots, cavity-nesters had relatively high nest success, shrub- and canopy nesters had intermediate nest success rates, and ground-nesters had the lowest nest success rates. None of the within-guild comparisons across experimental groups was statistically significant, though there was a very slight non-significant tendency for nests on control plots to have a higher probability of succeeding, at least among ground, shrub, and cavity nesters. Among shrub nesting species this tendency may be due to the fact that *Empidonax* flycatchers, which only nested on the treatment plots, have relatively long, protracted nesting cycles (Ehrlich et al. 1988). Even if their daily nest survival probabilities were equivalent to those of other species, their longer exposure period would lead to a lower overall probability of success.

In order to produce indices of nesting productivity for each plot type, we multiplied the average number of birds in each nesting guild that were detected during each five-plot point count survey by the Mayfield nest success rate for that nesting guild (Table 8). Point count detection rates (50 m radius) probably provide a more reliable index of abundance of breeding birds than does the number of nests found, as the difficulty of finding nests may differ between plot types. Productivity indices for ground-nesting species were slightly higher on the control plots, but productivity indices for shrub-, canopy-, and cavity-nesting species were dramatically higher on the treatment plots.

Micro-habitat correlates with nest placement and nest success.

For every species with at least ten nests of known fate, we compared values for five micro-habitat variables measured at successful nests with those measured at failed nests: canopy cover, shrub/sapling cover, Deer Brush cover, the density of large diameter trees, and the density of small diameter trees. Canopy cover, large tree density and small tree density were measured in an 11.3 m radius plot centered on the nest, while shrub/sapling cover and Deer Brush cover were measured in a 5 m radius plot centered on the nest.

Successful nests of five species had values for one or more micro-habitat variables that differed significantly from those of failed nests (Table 9). Successful Western Tanager nests were constructed in areas with greater canopy cover than failed Western Tanager nests, while Black-headed Grosbeak showed the opposite pattern; successful nests were constructed in areas with less canopy cover. Nest success of only one species, Spotted Towhee, showed a response to shrub/sapling cover; shrub/sapling cover around successful nests was much greater than that around failed nests. Deer Brush cover differed between failed and successful nests for more species (three) than any other habitat variable; successful Spotted Towhee nests were placed in areas with more Deer Brush cover than failed Towhee nests, whereas successful Dark-eyed Junco and Western Tanager nests were constructed in areas with less Deer Brush cover than their failed counterparts. Successful nests of both White-headed Woodpecker and Black-headed Grosbeak nest had fewer large dbh trees around them than failed nests. Density of small dbh trees did not differ between failed and successful nests of any species.

We also found that Deer Brush shrubs that served as substrate for nests (of any species) averaged significantly taller than Deer Brush shrubs in general; this was true both on the control plots (t = 2.78, df = 152, p = 0.006) and on the treatment plots (t = 10.33, df = 348, $p < 0.001$).

DISCUSSION

Bird communities on the treatment and control plots clearly differed dramatically. Nest-finding and point count data both corroborate that shrub-, canopy-, and cavity-nesting species occurred on the treatment plots in much higher density than on the control plots. Point count data suggest that ground-nesting species were equally abundant on control and treatment plots, although we found many more ground nests on the treatment plots.

The combination commercial/biomass thinning protocol was implemented between 1990 and 1993, five to eight years before the beginning of our study, and eight to eleven years before the end. Thinning on the treatment plots clearly succeeded in stimulating vigorous shrub growth, a result that appears to be at odds with the findings of Kucera and Barrett (1995). Although slight differences not attributable to the thinning (i.e. slope, conifer community composition) exist between the two clusters of plots, the increased density of birds on the treatment plots, particularly of shrub-nesting species, clearly seems to be linked to the thinning treatment. Our results suggest that shrub growth, stimulated by thinning, may have been the primary mechanism responsible for the difference, at least among shrub-nesting species. While this makes intuitive sense for shrub-nesters, it is less clear why canopy and cavity nesting species should respond so strongly to shrub growth. For birds with life-histories less tied to shrubs, extent of the shrub layer may therefore be an easily quantifiable proxy for a variety of ecological variables with which it correlates. Hammond's Flycatcher— a canopy nesting species showing a strong preference for our thinned plots— for example, forages for aerial insects by sallying into the open spaces beneath the overstory canopy and between trees (Mannan 1984, Hagar et al. 1996). This species may therefore be responding to the increased space available for foraging underneath the canopy, rather than the increase in the extent of shrubs, although increased shrub growth likely results from the same conditions that produce good flycatcher foraging habitat.

While nesting density clearly differed greatly between the two sets of plots, nest success rates did not. This was somewhat surprising, given that anecdotal observations suggested that predator guilds on the two sets of plots were quite distinct. In general, Steller's Jays, Gray Squirrels, and Black Bears seemed more abundant on the control plots, while California Ground Squirrels and chipmunks were more abundant on the treatment plots. Additionally, Brown-headed Cowbirds were present in low numbers on the treatment plots, but virtually absent from the control plots. During the three years of this study, however, we only confirmed cowbird parasitism at six nests-- three Cassin's Vireo nests, two Warbling Vireo nests, and one Audubon's Warbler nest. All six were located on the treatment plots. Overall, nests on control plots exhibited slightly higher success rates than nests on treatment plots, but the differences were not significant. Even if real, the differences were not large enough to make up for the reduced nesting density of shrub-, canopy-, and cavity-nesters; overall avian productivity was clearly much higher on the treatment plots.

Forest conditions that stimulate vigorous shrub growth, particularly Deer Brush, appear highly beneficial to the majority of breeding birds in the Sierran mixed conifer community, even if the precise ecological mechanisms are difficult to identify. Multi-species management is usually a balancing act between the conflicting needs of different species of concern. The combination of commercial/biomass thinning on our study plots appears to provide a rare exception to the general rule that habitat attributes benefiting some species of concern are detrimental to numerous others. Even birds normally thought of as forest-interior species, such as Brown Creeper and Golden-crowned Kinglet appeared not to be deleteriously impacted by the thinning, while many species clearly benefit. Thinning that promotes Deer Brush in Sierran mixed conifer stands affected by historical fire suppression thus appears to be a useful tool for enhancing habitat value for forest-nesting birds, while at the same time possibly making timberlands more resistant to catastrophic fire, and providing additional revenue sources.

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LITERATURE CITED

Agee, J. K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, D.C.

Beedy, E. C. 1981. Bird communities and forest structure in the Sierra Nevada of California. Condor 83:97-105.

California Department of Fish and Game. 1999. CWHR version 7.0 personal computer program. Sacramento, CA.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The birder's handbook. Simon and Schuster Inc., New York.

Hagar, J. C., W. C. McComb, and w. H. Emmingham. 1996. Bird communities in commercially thinned and unthinned Douglas-fir stands of western Oregon. Wildlife Society Bulletin 24:353-366.

Kucera, T. E. and R. H. Barrett. 1995. Effects of whole-tree removal on wildlife habitat in forests of northern California. Final report to California Department of Fish and Game Contract FG3118WM.

Mannan, R. W. 1984. Habitat use by Hammond's flycatchers in old-growth forests, northeastern Oregon. Murrelet 65:84-86.

Manolis, J. C., D. E. Anderson, and F. J. Cuthbert. 2000. Uncertain nest fates in songbird studies and variation in Mayfield estimation. Auk 117:615-626.

Martin, T. E. and G. R. Geupel. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. Journal of Field Ornithology 64:507-519.

Martin, T.E., C. Paine, C. J. Conway, W. M. Hochachka, P. Allen, and W. Jenkins. 1997. BBird Field Protocol. Montana Cooperative Wildlife Research Unit, Missoula.

Sierra Nevada Ecosystems Project. 1996. Final Report to Congress. Centers for Water and Wildland Resources, University of California, Davis.

Table 1. Nest cycle lengths used in the calculation of Mayfield nest survival rates. See text for explanation.

Nesting Guild	Nesting Cycle Length (days)	
	Control	Treatment
Ground	28.76	28.88
Shrub	27.23	31.93
Canopy	32.26	31.31
Cavity	39.70	41.66

Table 2. Conifer community composition within each of three size classes on each experimental plot. Numbers indicate the proportion of conifers comprised of each species, for the indicated size class. Small trees were defined as being at least 5 m tall and having dbh greater than or equal to 8 cm, but less than 23 cm. Trees less than 5 m tall or less than 8 cm dbh were considered saplings, and were not included in tree density estimates. Medium trees were defined as those with dbh greater than or equal to 23 cm, but less than 38 cm. Large trees were those with dbh of 38 cm or greater.

Plot	White Fir			Douglas-fir			Ponderosa Pine			Sugar Pine			Incense Cedar		
	lg.	md.	sm.	lg.	md.	sm.	lg.	md.	sm.	lg.	md.	sm.	lg.	md.	sm.
c1	0.08	0.27	0.41	0.30	0.24	0.21	0.23	0.21	0.24	0.20	0.18	0.09	0.19	0.10	0.06
c2	0.17	0.19	0.33	0.30	0.38	0.29	0.13	0.15	0.18	0.17	0.12	0.08	0.22	0.15	0.12
c3	0.03	0.03	0.13	0.45	0.56	0.45	0.22	0.16	0.20	0.10	0.12	0.09	0.20	0.12	0.13
c4	0.13	0.11	0.22	0.21	0.25	0.26	0.27	0.28	0.32	0.08	0.19	0.06	0.31	0.16	0.14
c5	0.09	0.21	0.30	0.44	0.28	0.30	0.11	0.16	0.21	0.13	0.16	0.05	0.24	0.18	0.14
all c	**0.10**	**0.15**	**0.30**	**0.35**	**0.35**	**0.28**	**0.20**	**0.20**	**0.23**	**0.13**	**0.15**	**0.09**	**0.23**	**0.14**	**0.11**
t1	0.13	0.20	0.26	0.30	0.33	0.29	0.23	0.11	0.06	0.26	0.10	0.03	0.08	0.26	0.36
t2	0.22	0.39	0.40	0.20	0.28	0.15	0.13	0.08	0.09	0.31	0.08	0.02	0.14	0.17	0.34
t3	0.21	0.47	0.33	0.11	0.25	0.33	0.15	0.04	0.01	0.46	0.06	0.02	0.06	0.18	0.30
t4	0.45	0.49	0.36	0.17	0.22	0.19	0.14	0.07	0.04	0.20	0.09	0.04	0.03	0.13	0.37
t5	0.05	0.14	0.26	0.35	0.36	0.27	0.26	0.17	0.07	0.24	0.15	0.02	0.10	0.18	0.38
all t	**0.23**	**0.29**	**0.29**	**0.23**	**0.30**	**0.26**	**0.18**	**0.11**	**0.06**	**0.29**	**0.11**	**0.02**	**0.08**	**0.19**	**0.36**

Table 3. Average number of birds detected within a 50 m radius during each point count transect on control and treatment plots.

	Average no. of detections per transect, 50 m radius	
Species	Control Plots	Treatment Plots
Osprey	0.00	0.11
Mountain Quail	1.00	0.67
Anna’s Hummingbird	0.11	1.33
Calliope Hummingbird	0.00	0.22
Unidentified Hummingbird	0.33	1.00
Red-breasted Sapsucker	0.33	2.67
Downy Woodpecker	0.00	0.11
Hairy Woodpecker	1.00	2.22
White-headed Woodpecker	0.78	2.67
Northern Flicker	1.22	3.00
Pileated Woodpecker	0.67	0.11
Unidentified Woodpecker	0.78	1.22
Olive-sided Flycatcher	0.11	0.33
Western Wood-Pewee	0.33	0.89
Hammond’s Flycatcher	0.56	12.89
Dusky Flycatcher	0.33	29.89
Unidentified Flycatcher	0.11	1.11
Cassin’s Vireo	7.44	15.22
Warbling Vireo	0.67	5.56
Steller’s Jay	7.11	2.67
Common Raven	0.33	0.22
Mountain Chickadee	7.33	14.33
Red-breasted Nuthatch	7.56	10.00
Brown Creeper	4.67	6.89
Golden-crowned Kinglet	6.56	6.22
Townsend’s Solitaire	1.89	0.78
Hermit Thrush	0.67	1.78
American Robin	1.33	2.44
Nashville Warbler	12.22	4.11
Yellow Warbler	0.56	2.33
Audubon’s Warbler	14.44	22.00
Blck.-throated Gr. Warbler	2.56	0.33
Hermit Warbler	13.33	22.00
MacGillivray’s Warbler	0.56	1.44
Wilson’s Warbler	0.00	0.11
Unidentified Warbler	0.78	0.22
Western Tanager	19.78	20.78
Spotted Towhee	7.00	6.89
Chipping Sparrow	1.22	4.00
Fox Sparrow	1.78	5.78

Table 3, cont.

Dark-eyed Junco	19.11	25.11
Black-headed Grosbeak	7.78	5.78
Lazuli Bunting	9.33	5.67
Brown-headed Cowbird	0.00	2.11
Purple Finch	0.44	0.22
Cassin’s Finch	0.11	0.22
Unidentified Finch	0.22	0.00
Pine Siskin	0.44	5.33
Evening Grosbeak	0.22	1.11
Total	**165.11**	**262.11**
Total number of species	**39**	**44**

Table 4. Plot-specific point count detection totals for each species with at least one nest found on any of our study plots. Detection totals represent the average number of birds detected within a 50 m radius during each point count transect.

Species	**c1**	**c2**	**c3**	**c4**	**c5**	**all c**	**t1**	**t2**	**t3**	**t4**	**t5**	**all t**
GROUNDNESTING												
Mountain Quail	0.00	0.00	0.11	0.33	0.56	**1.00**	0.22	0.00	0.11	0.33	0.00	**0.67**
Townsend’s Solitaire	0.22	0.44	0.33	0.22	0.67	**1.89**	0.11	0.11	0.11	0.22	0.22	**0.78**
Nashville Warbler	2.33	4.11	2.33	1.00	2.33	**12.11**	2.00	0.11	0.11	0.44	1.44	**4.11**
Spotted Towhee	2.11	2.22	0.78	1.00	0.89	**7.00**	1.78	1.33	2.00	1.33	0.44	**6.89**
Dark-eyed Junco	4.89	2.89	2.44	4.33	4.56	**19.11**	5.56	4.56	5.78	4.11	5.11	**25.11**
Fox Sparrow	0.33	0.44	0.00	0.44	0.56	**1.78**	0.78	2.89	1.22	0.56	0.33	**5.78**
TOTAL	**9.89**	**10.11**	**6.00**	**7.33**	**9.56**	**42.89**	**10.44**	**9.00**	**9.33**	**7.00**	**7.56**	**43.33**
SHRUB NESTING												
Dusky Flycatcher	0.00	0.11	0.00	0.00	0.22	**0.33**	4.11	6.67	7.11	8.56	3.44	**29.89**
Hermit Thrush	0.00	0.33	0.00	0.00	0.33	**0.67**	0.00	0.22	0.67	0.89	0.00	**1.78**
Cassin’s Vireo	1.56	1.78	1.78	0.67	1.67	**7.44**	3.11	3.33	3.78	3.22	1.78	**15.22**
Yellow Warbler	0.00	0.22	0.22	0.00	0.11	**0.56**	0.33	1.33	0.33	0.22	0.11	**2.33**
MacGillivray’s Warbler	0.22	0.00	0.11	0.11	0.11	**0.56**	0.44	0.22	0.22	0.44	0.11	**1.44**
Black-headed Grosbeak	2.11	1.44	2.33	1.22	0.78	**7.89**	0.56	0.89	1.22	2.11	1.00	**5.78**
Lazuli Bunting	2.33	1.33	1.44	2.44	1.78	**9.33**	1.11	1.00	0.89	2.22	0.44	**5.67**
Chipping Sparrow	0.33	0.22	0.22	0.22	0.22	**1.22**	0.78	1.00	1.00	1.11	0.11	**4.00**
TOTAL	**6.56**	**5.44**	**6.11**	**4.67**	**5.22**	**28.00**	**10.44**	**14.67**	**15.22**	**18.78**	**7.00**	**66.11**
CANOPY NESTING												
Sharp-shinned Hawk	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	**0.00**
Northern Goshawk	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	**0.00**
Anna’s Hummingbird	0.00	0.00	0.11	0.00	0.00	**0.11**	0.00	0.11	0.00	1.11	0.11	**1.33**
Calliope Hummingbird	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.22	0.00	**0.22**
Western Wood-Pewee	0.11	0.22	0.00	0.00	0.00	**0.33**	0.33	0.22	0.33	0.00	0.00	**0.89**
Hammond’s Flycatcher	0.00	0.33	0.00	0.11	0.11	**0.56**	2.89	2.56	2.56	2.33	2.56	**12.89**
Steller’s Jay	1.11	1.00	2.00	2.44	0.56	**7.11**	0.44	0.33	0.67	0.22	1.00	**2.67**
American Robin	0.56	0.00	0.56	0.00	0.00	**1.11**	0.56	0.22	0.33	0.67	0.67	**2.44**
Warbling Vireo	0.00	0.22	0.00	0.11	0.33	**0.67**	0.44	1.00	0.56	2.56	1.00	**5.56**
Audubon’s Warbler	3.00	3.22	1.89	3.00	3.33	**14.44**	3.89	5.11	4.44	3.56	5.00	**22.00**

Table 4, cont.

Blk.-throated Gr. Warbler	0.78	0.33	1.11	0.33	0.00	**2.56**	0.00	0.00	0.11	0.00	0.22	**0.33**
Hermit Warbler	3.67	1.56	1.56	3.33	3.22	**13.33**	4.11	3.56	4.44	5.56	4.33	**22.00**
Western Tanager	5.67	3.11	3.67	4.44	2.89	**19.78**	3.89	3.33	4.89	4.56	4.11	**20.78**
Purple Finch	0.44	0.00	0.00	0.00	0.00	**0.44**	0.11	0.00	0.11	0.00	0.00	**0.22**
Evening Grosbeak	0.22	0.00	0.00	0.00	0.00	**0.22**	0.44	0.00	0.00	0.56	0.11	**1.11**
TOTAL	**15.56**	**10.00**	**10.89**	**13.78**	**10.44**	**60.67**	**17.11**	**16.44**	**18.44**	**21.33**	**19.11**	**92.44**
CAVITY NESTING												
Northern Flicker	0.22	0.00	0.33	0.22	0.44	**1.22**	0.22	0.78	0.56	0.78	0.67	**3.00**
Wh.-headed Woodpecker	0.11	0.00	0.11	0.44	0.11	**0.78**	0.33	0.67	0.78	0.33	0.56	**2.67**
Red-breasted Sapsucker	0.00	0.00	0.00	0.11	0.22	**0.33**	0.78	0.33	0.22	0.00	0.22	**1.56**
Hairy Woodpecker	0.00	0.11	0.11	0.22	0.56	**1.00**	0.22	0.11	0.67	0.56	0.67	**2.22**
Pileated Woodpecker	0.00	0.11	0.33	0.00	0.22	**0.67**	0.00	0.00	0.00	0.00	0.11	**0.11**
Mountain Chickadee	0.89	0.89	0.67	2.78	2.11	**7.33**	2.89	3.22	2.78	3.56	2.00	**14.44**
Red-breasted Nuthatch	1.56	1.33	2.00	1.67	1.00	**7.56**	2.22	2.11	2.00	1.78	1.89	**10.00**
Brown Creeper	0.00	0.56	1.89	1.00	1.22	**4.67**	1.33	2.89	0.56	0.22	1.89	**6.89**
TOTAL	**2.78**	**3.00**	**5.44**	**6.44**	**5.89**	**23.56**	**8.00**	**10.11**	**7.56**	**7.22**	**8.00**	**40.89**
ALL CUP NESTING	**32.00**	**25.56**	**23.00**	**25.78**	**31.11**	**137.44**	**38.00**	**40.11**	**43.00**	**47.11**	**33.67**	**201.89**
ALL	**34.78**	**28.56**	**28.44**	**32.22**	**37.00**	**161.00**	**46.00**	**50.22**	**50.56**	**54.33**	**41.67**	**242.78**

Table 5. Coefficients of determination and p-values for all statistically significant correlations between the average number of birds detected on each of the ten study plots and five inter-related habitat variables— canopy cover (%), shrub/sapling cover (%), percent of cover of Deerbrush, large conifer density (>38 cm dbh), and small conifer density (8-23 cm dbh).

	Canopy Cover			Shrub/Sapling Cover			Deerbrush Cover			Large Conifer Density			Small Conifer Density		
Species	R^2	*p*	Sign	R^2	*p*	Sign	R^2	*p*	Sign	R^2	*p*	Sign	R^2	*p*	Sign
Dark-eyed Junco							0.350	0.072	+	0.509	0.021	-			
Ground-nesters pooled										**0.754**	**0.001**	-			
Dusky Flycatcher	0.593	0.009	-	0.827	0.000	+	0.880	0.000	+				0.630	0.001	-
Cassin’s Vireo	0.532	0.017	-	0.727	0.004	+	0.751	0.001	+				0.610	0.008	-
Black-headed Grosbeak										0.338	0.078	+			
Shrub-nesters pooled	**0.550**	**0.014**	-	**0.933**	**0.000**	+	**0.783**	**0.001**	+				**0.549**	**0.014**	-
Hammond’s Flycatcher	0.434	0.038	-	0.398	0.050	+	0.692	0.003	+				0.545	0.015	-
Steller’s Jay				0.321	0.088	-	0.620	0.007	-				0.320	0.088	+
Warbling Vireo				0.658	0.004	+	0.536	0.016	+				0.327	0.084	-
Audubon’s Warbler							0.503	0.022	+						
Hermit Warbler	0.356	0.069	-	0.309	0.095	+	0.616	0.007	+				0.280	0.116	-
Canopy-nesters pooled				**0.431**	**0.039**	+	**0.566**	**0.012**	+						
Mountain Chickadee	0.706	0.002	-	0.369	0.063	+	0.716	0.010	+				0.585	0.010	-
Cavity-nesters pooled	**0.604**	**0.008**	-				**0.455**	**0.032**	+				**0.712**	**0.002**	-
All nesting species pooled	**0.629**	**0.006**	-	**0.640**	**0.005**	+	**0.924**	**0.000**	+				**0.648**	**0.005**	-

Table 6. Active nests found on treatment and control plots during the three years of the study. Nests were only considered active if they were known to contain eggs or nestlings while under observation.

	Control Plots			Treatment Plots		
	Active Nests	Known Fates	No. Succ. (%)	Active Nests	Known Fates	No. Succ. (%)
Ground-nesting species:						
Mountain Quail	0	0	0 (0.0)	2	2	0 (0.0)
Townsend's Solitaire	4	4	2 (50.0)	7	7	3 (42.9)
Nashville Warbler	2	2	2 (100)	0	0	--
Spotted Towhee	6	6	3 (50.0)	7	7	3 (42.9)
Dark-eyed Junco	22	22	10 (45.5)	51	50	23 (46.0)
Fox Sparrow	0	0	0 (0.0)	7	7	2 (28.6)
Total Nests	**34**	**34**	**17 (50.0)**	**74**	**73**	**31 (42.5)**
Total Species	**4**			**5**		
Shrub-nesting species:						
Dusky Flycatcher	0	0	--	76	67	23 (34.3)
Hermit Thrush	1	1	0 (0.0)	4	4	2 (50.0)
Cassin's Vireo	10	8	3 (37.5)	22	21	9 (42.9)
Yellow Warbler	0	0	--	6	6	4 (66.7)
MacGillivray's Warbler	0	0	--	2	2	2 (100)
Black-headed Grosbeak	1	1	0 (0)	16	16	9 (56.3)
Lazuli Bunting	10	10	6 (60.0)	6	6	4 (66.7)
Chipping Sparrow	0	0	--	10	6	5 (83.3)
Total Nests	**22**	**20**	**9 (45.0)**	**142**	**128**	**58 (45.3)**
Total Species	**4**			**8**		

Table 6, cont.

Tree-nesting species:						
Sharp-shinned Hawk	1	0	0 (0.0)	0	0	--
Northern Goshawk	1	1	0 (0.0)	0	0	--
Anna’s Hummingbird	1	1	0 (0.0)	2	2	1 (50.0)
Calliope Hummingbird	2	2	2 (100)	0	0	--
Western Wood-Pewee	0	0	--	1	1	1 (100)
Hammond’s Flycatcher	1	0	0 (0.0)	19	16	10 (62.5)
Steller’s Jay	3	2	1 (50.0)	0	0	--
American Robin	6	5	2 (40.0)	5	5	0 (0.0)
Warbling Vireo	1	1	1 (100)	22	19	6 (31.6)
Audubon’s Warbler	8	7	2 (28.6)	17	13	9 (69.2)
Black-throated Gray Warbler	4	2	1 (50.0)	0	0	--
Hermit Warbler	4	3	2 (66.7)	6	4	2 (50.0)
Western Tanager	20	18	5 (27.8)	21	18	5 (27.8)
Purple Finch	1	0	0 (0.0)	0	0	--
Evening Grosbeak	0	0	--	1	1	0 (0.0)
Total Nests	**53**	**42**	**16 (38.1)**	**94**	**79**	**34 (43.0)**
Total Species	**13**			**9**		
Cavity-nesting species:						
Northern Flicker	4	4	3 (75.0)	12	9	3 (33.3)
White-headed Woodpecker	2	2	2 (100)	12	11	7 (63.6)
Red-breasted Sapsucker	0	0	--	11	9	7 (77.8)
Hairy Woodpecker	1	1	0 (0.0)	4	4	3 (75.0)
Pileated Woodpecker	1	1	1 (100)	0	0	--

Table 6, cont.

Mountain Chickadee	4	3	1 (33.3)	19	14	6 (42.9)
Red-breasted Nuthatch	8	5	3 (60.0)	21	16	11 (68.8)
Brown Creeper	10	9	7 (77.8)	9	6	3 (50.0)
Total Nests	**30**	**25**	**17 (68.0)**	**88**	**69**	**40 (58.0)**
Total Species	**7**			**7**		
All non-cavity-nesting species:						
Total Nests	**109**	**96**	**42 (43.8)**	**310**	**280**	**123 (43.9)**
Total Species	**21**			**22**		
All species:						
Total Nests	**139**	**121**	**59 (48.8)**	**398**	**349**	**163 (46.7)**
Total Species	**28**			**29**		

Table 7. Observation-days and comparisons of daily nest survival rates on control and treatment plots.

Nest Substrate	Control Plot Obs.-Days	Treatment Plot Obs.-Days	Comparison of daily nest survival rates	
			Chi-square	*p*
Ground	378	796	0.34	0.56
Shrub	340	2234	0.01	0.92
Canopy	863	1376	0.17	0.73
Cavity	615	1685	0.57	0.45
All cup	1581	4506	0.02	0.90
All	2196	6191	0.19	0.66

Table 8. Productivity indices, calculated as (point count detections) x (Mayfield nest survival rate), for each nesting guild on each set of experimental plots.

	Point Count Detections		Mayfield Nest Survival Rate		Productivity Index	
Nesting Guild	Controls	Treatments	Controls	Treatments	Controls	Treatments
ground	42.89	43.33	0.27	0.21	**11.58**	10.15
shrub	28.00	66.11	0.41	0.36	11.48	**23.80**
canopy	60.67	92.44	0.37	0.35	22.45	**32.35**
cavity	23.56	40.89	0.59	0.49	13.90	**20.04**

Table 9. Species for which successful nests had values for one or more micro-habitat variables that differed significantly from those of failed nests. Variables considered included canopy cover, shrub/sapling cover, Deerbrush cover, the density of large diameter trees, and the density of small diameter trees.

	Canopy Cover (%)				Shrub/Sapling Cover (%)				Deerbrush Cover (%)				Large Trees (count)			
	Median				Median				Median				Median			
Species	succ.	fail	U	p	succ.	fail	U	p	succ.	fail	U	p	succ.	fail	U	p
White-headed Woodpecker													2.0	5.0	5.0	0.012
Spotted Towhee					66.9	38.3	36.0	0.032	46.9	19.5	35.0	0.046				
Dark-eyed Junco									4.3	14.2	464.5	0.006				
Western Tanager	82.7	70.0	205.5	0.008					0.2	7.3	51.5	0.005				
Black-headed Grosbeak	54.7	74.5	20.0	0.023									1.0	2.5	19.0	0.017

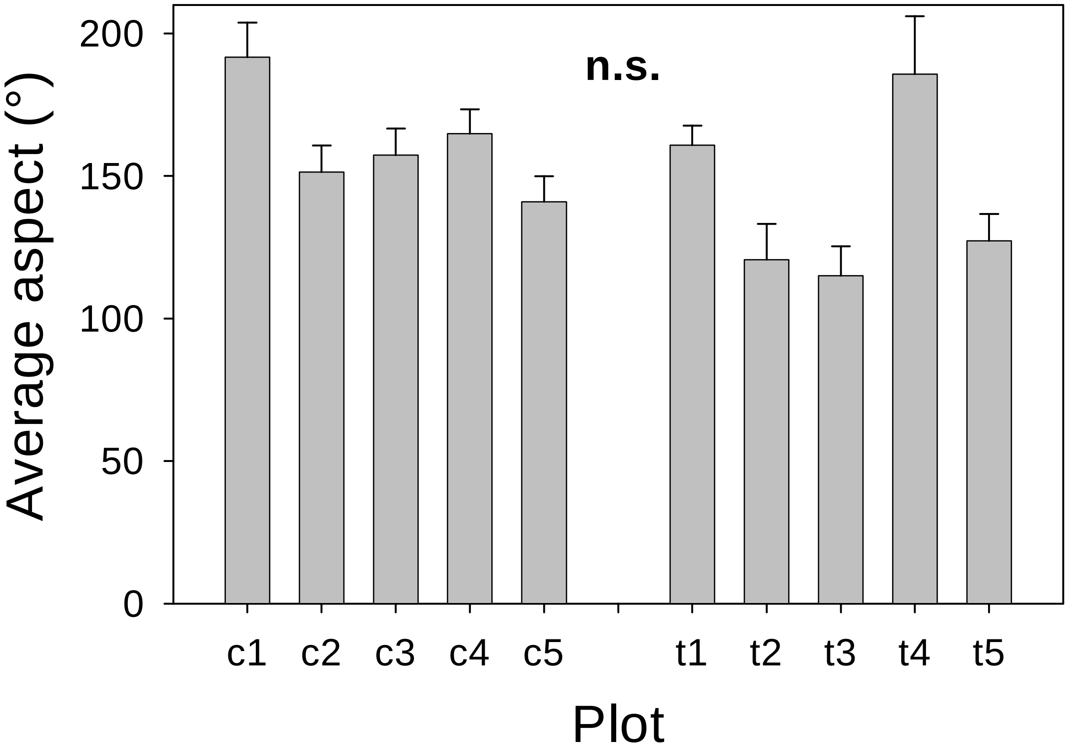

Figure 1. Average aspect of control and treatment plots.

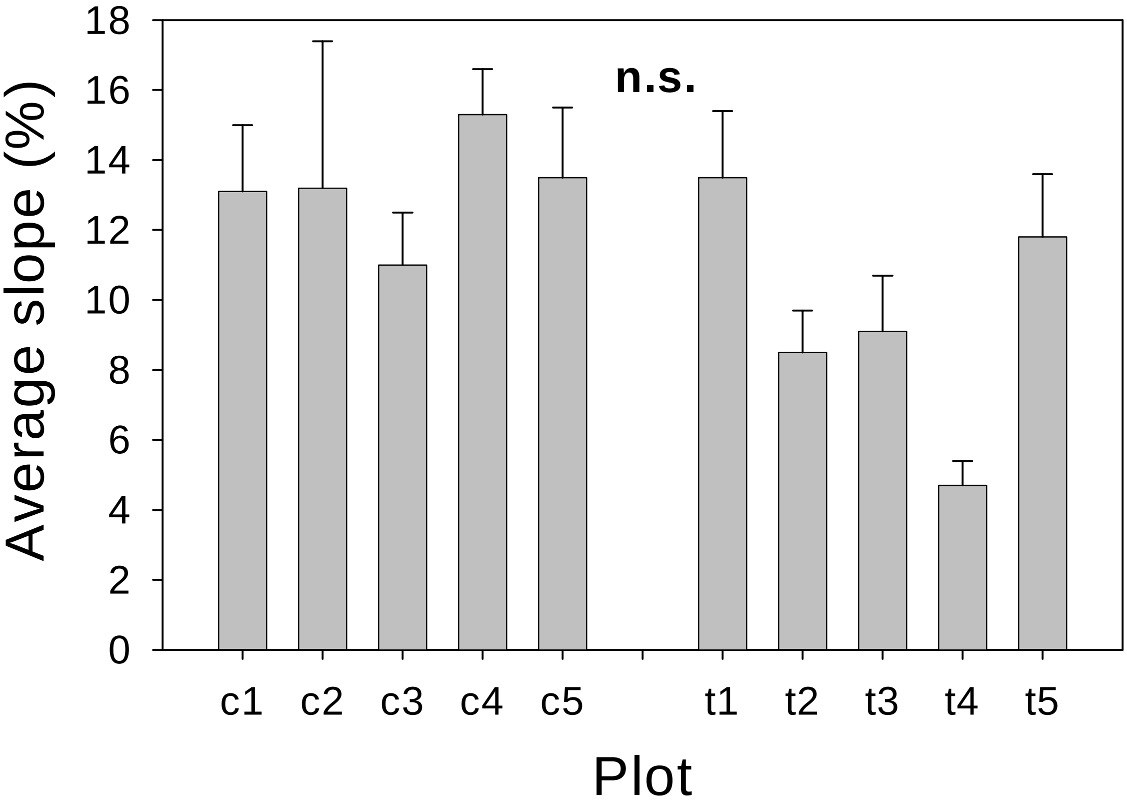

Figure 2. Average slope of control and treatment plots.

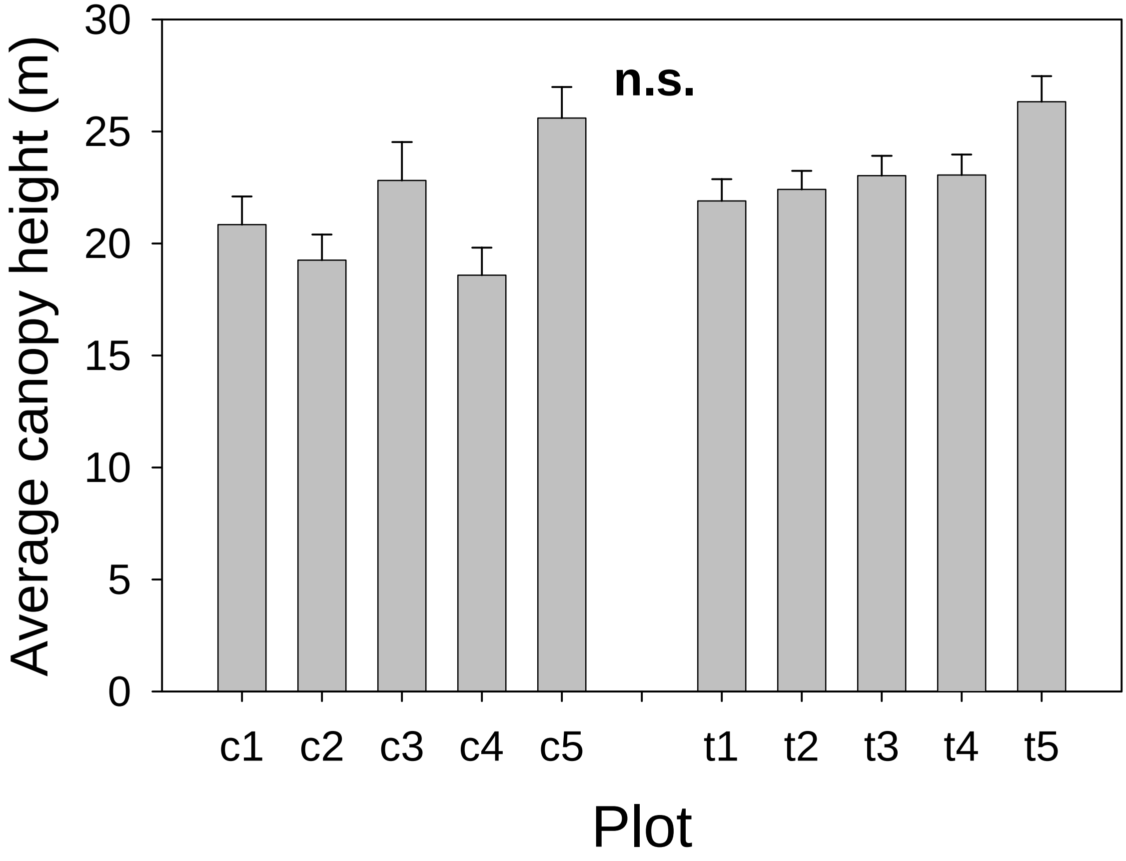

Figure 3. Average canopy height of control and treatment plots.

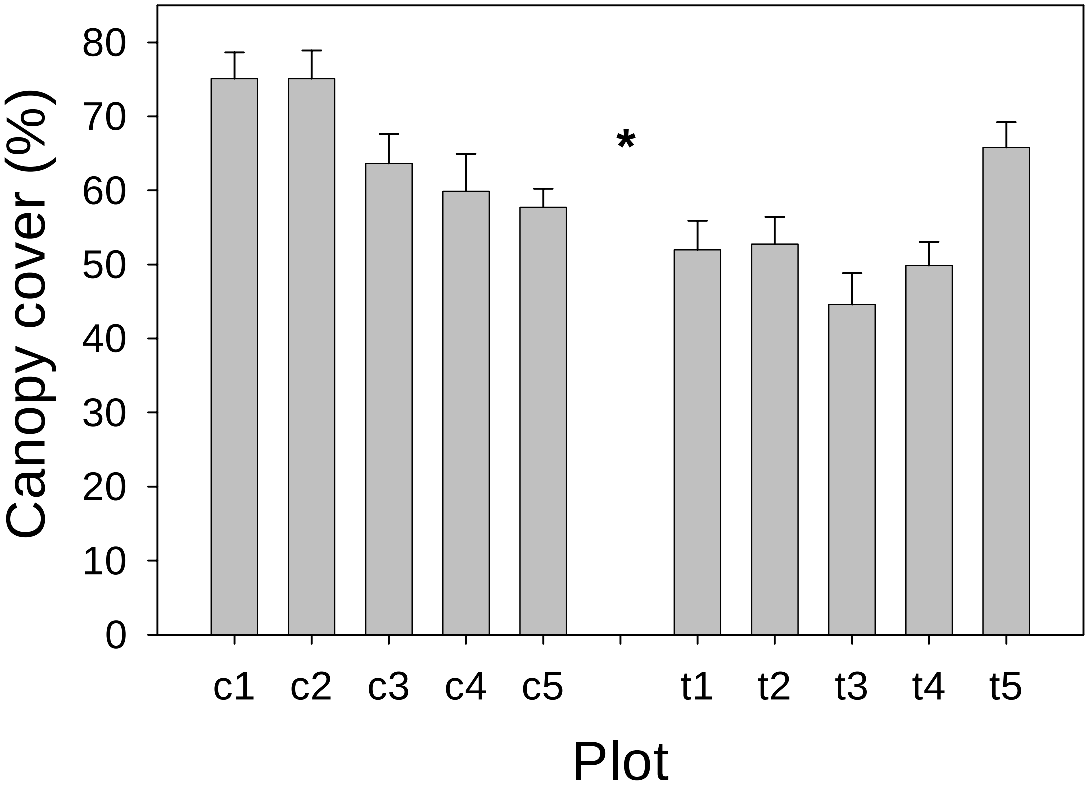

Figure 4. Average canopy cover of control and treatment plots.

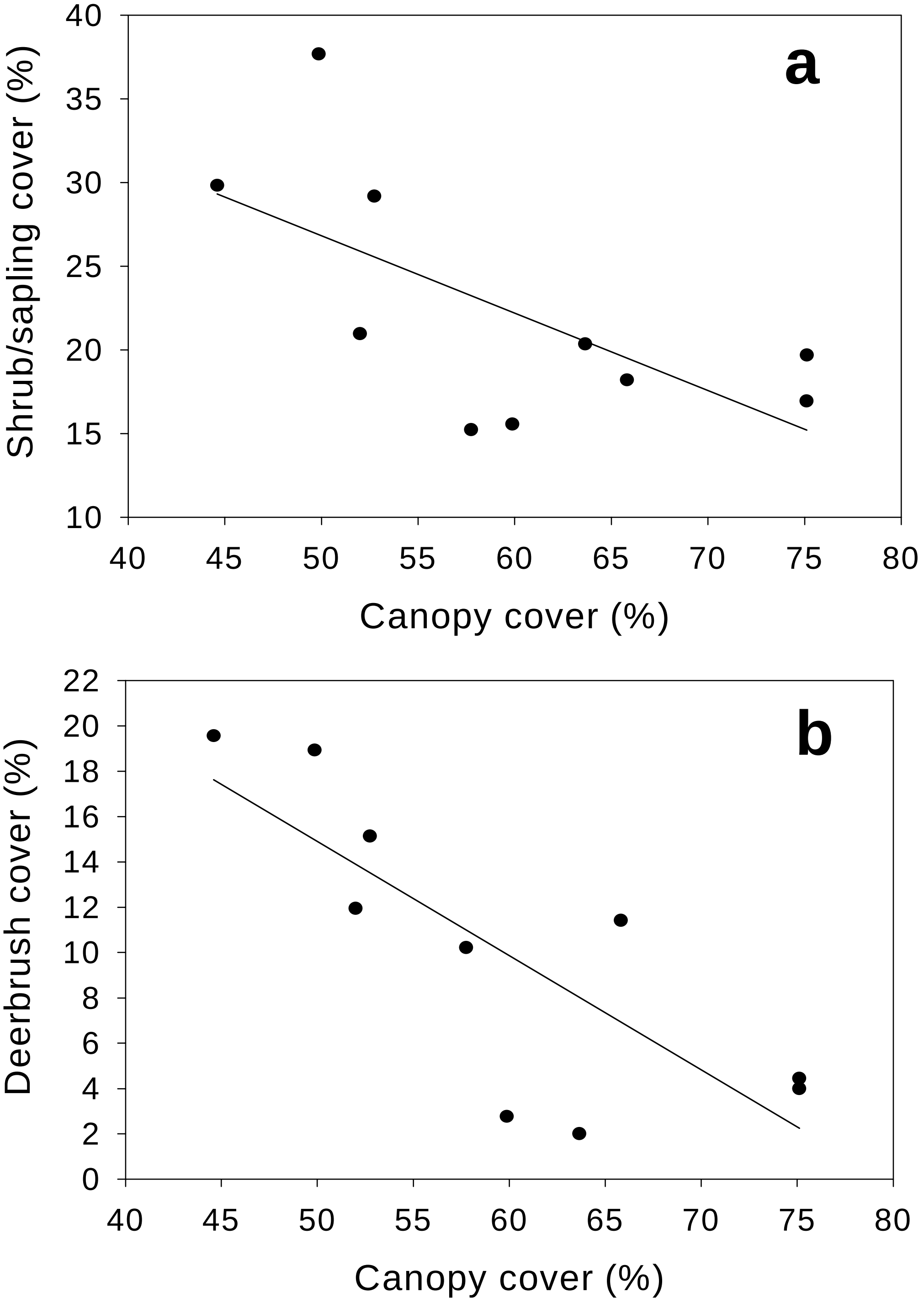

Figure 5. Relationship between canopy cover and (a) shrub/sapling cover, and (b) Deer Brush cover.

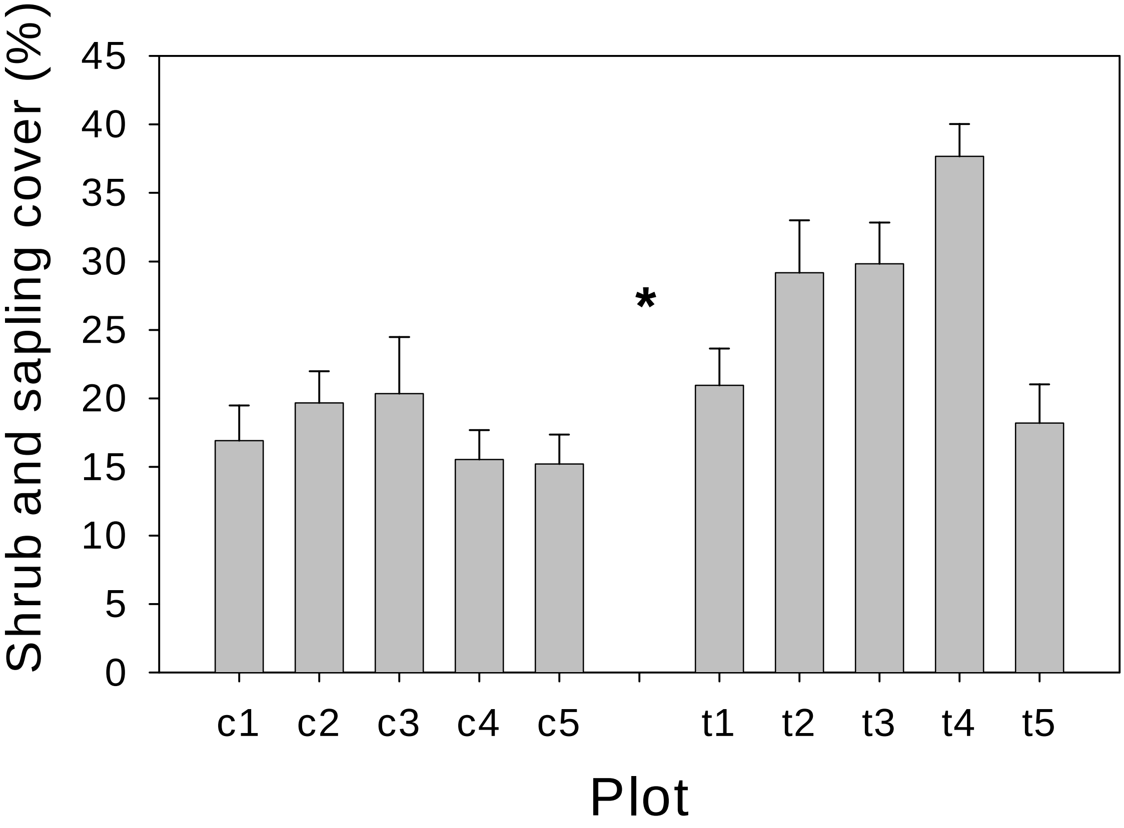

Figure 6. Average shrub/sapling cover on control and treatment plots.

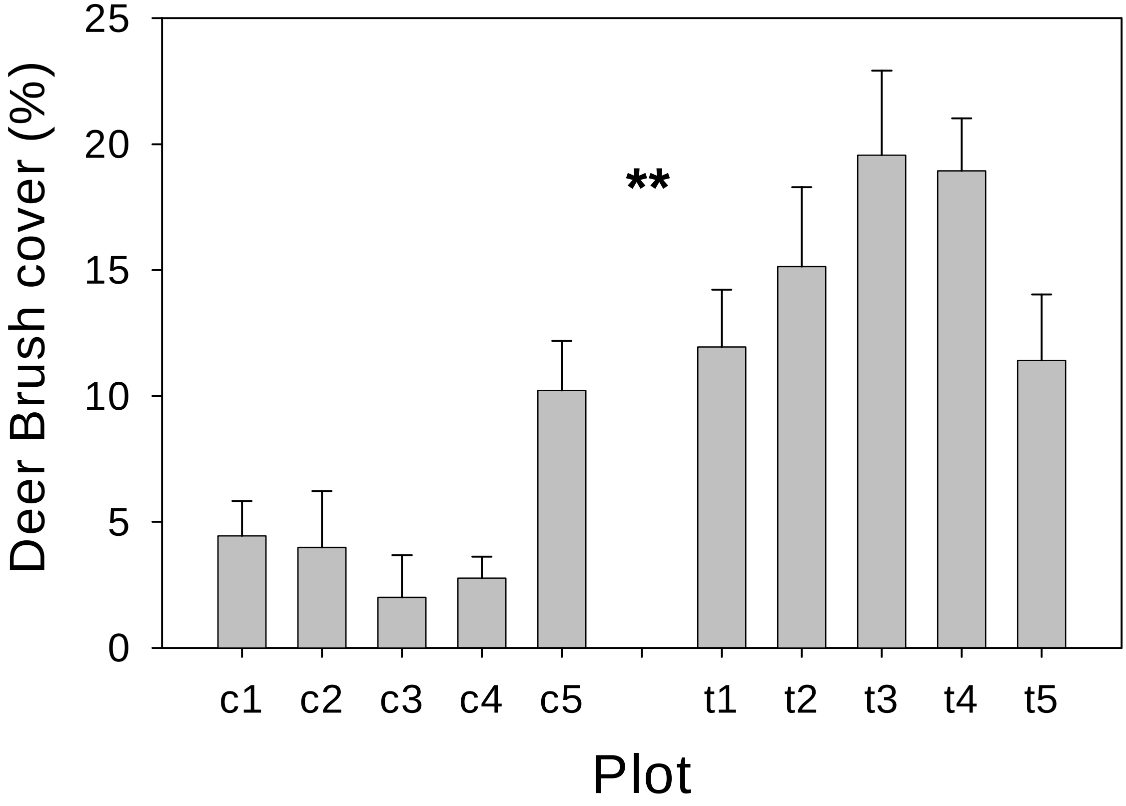

Figure 7. Average Deer Brush cover on control and treatment plots.

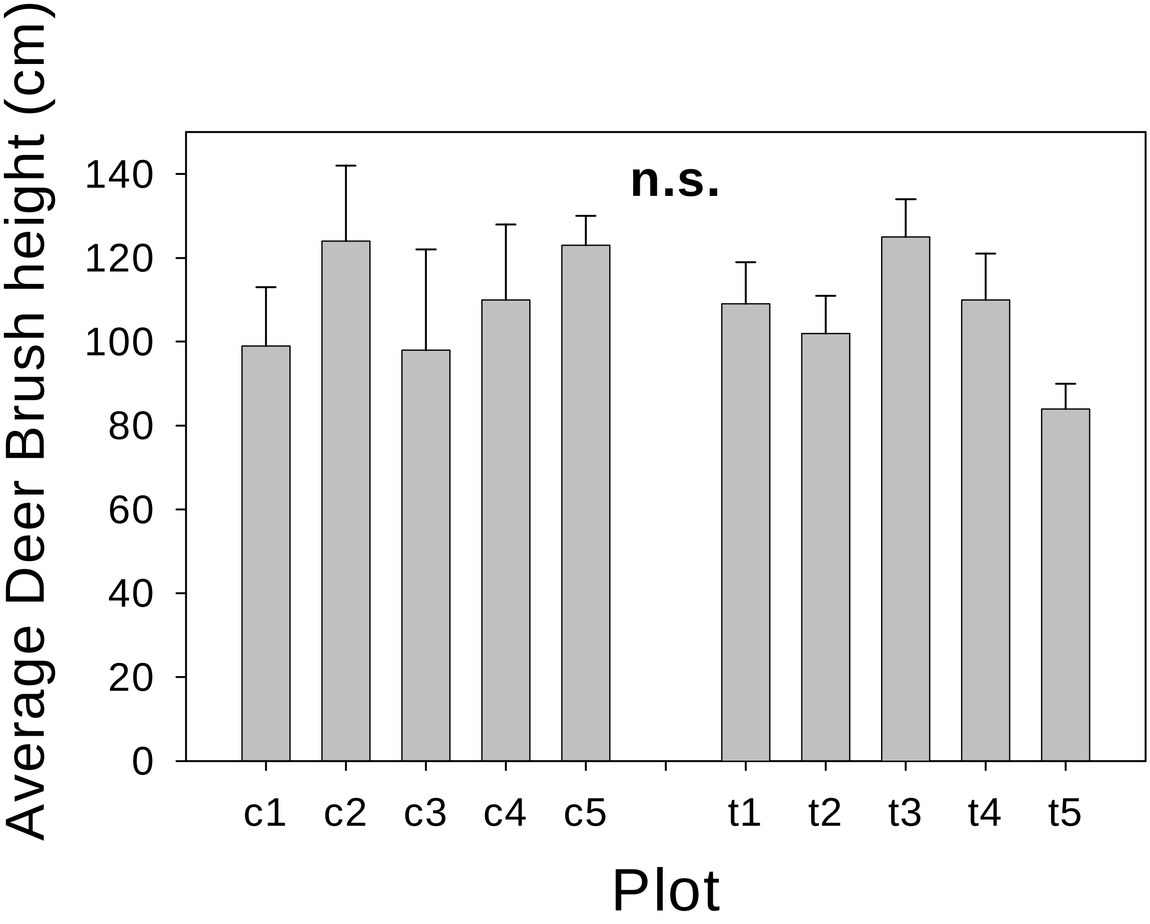

Figure 8. Average height of Deer Brush on control and treatment plots.

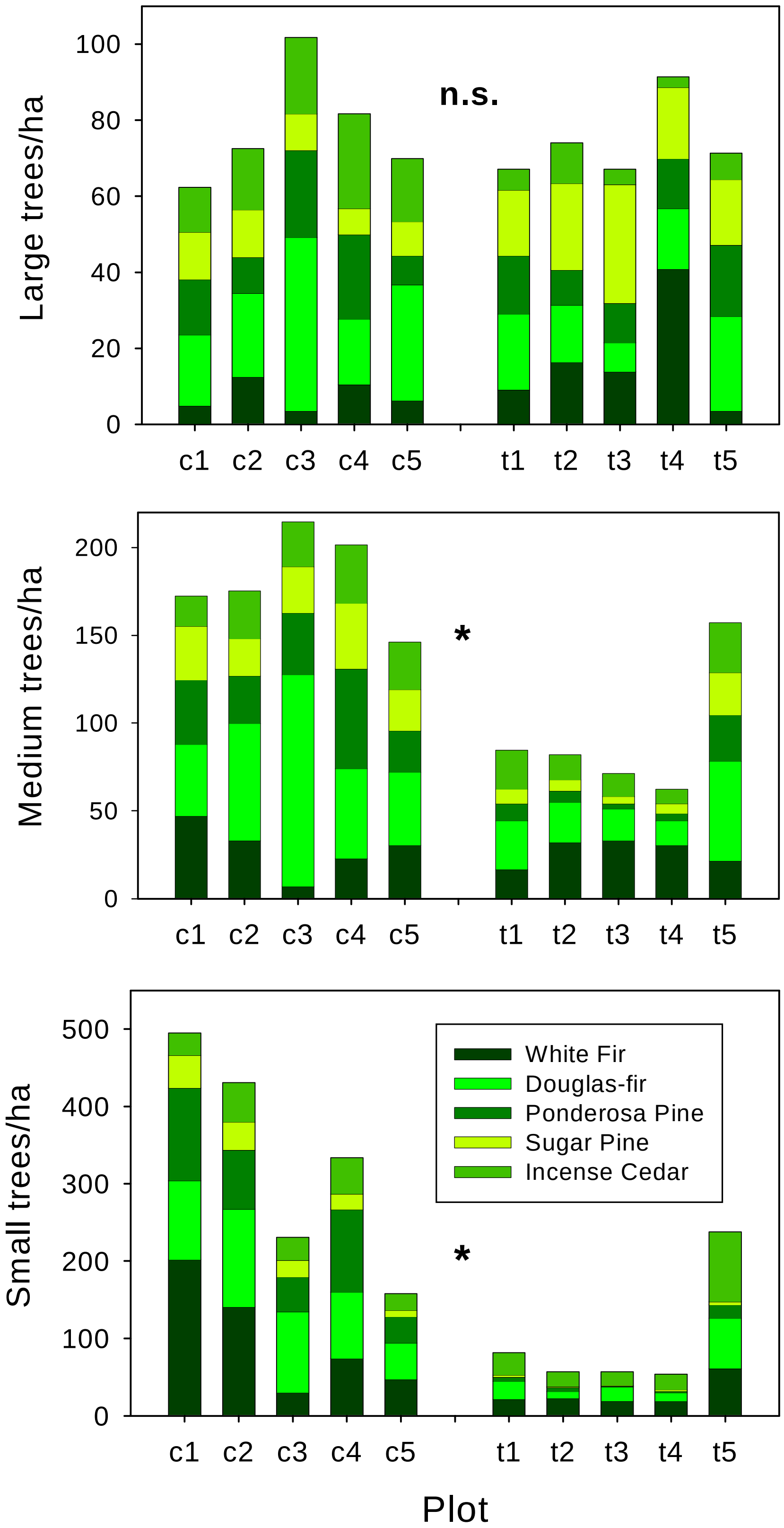

Figure 9. Species composition of large, medium, and small tree classes on each study plot.

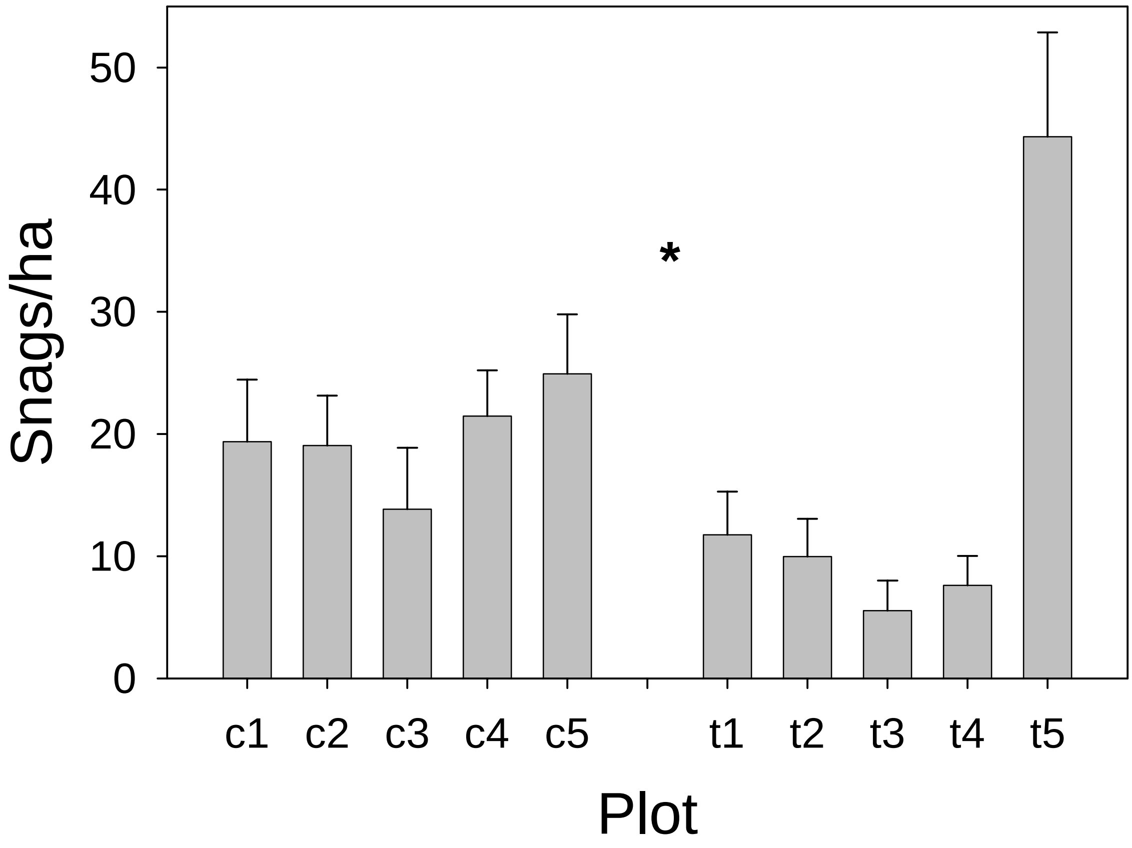

Figure 10. Average density of snags on control and treatment plots.

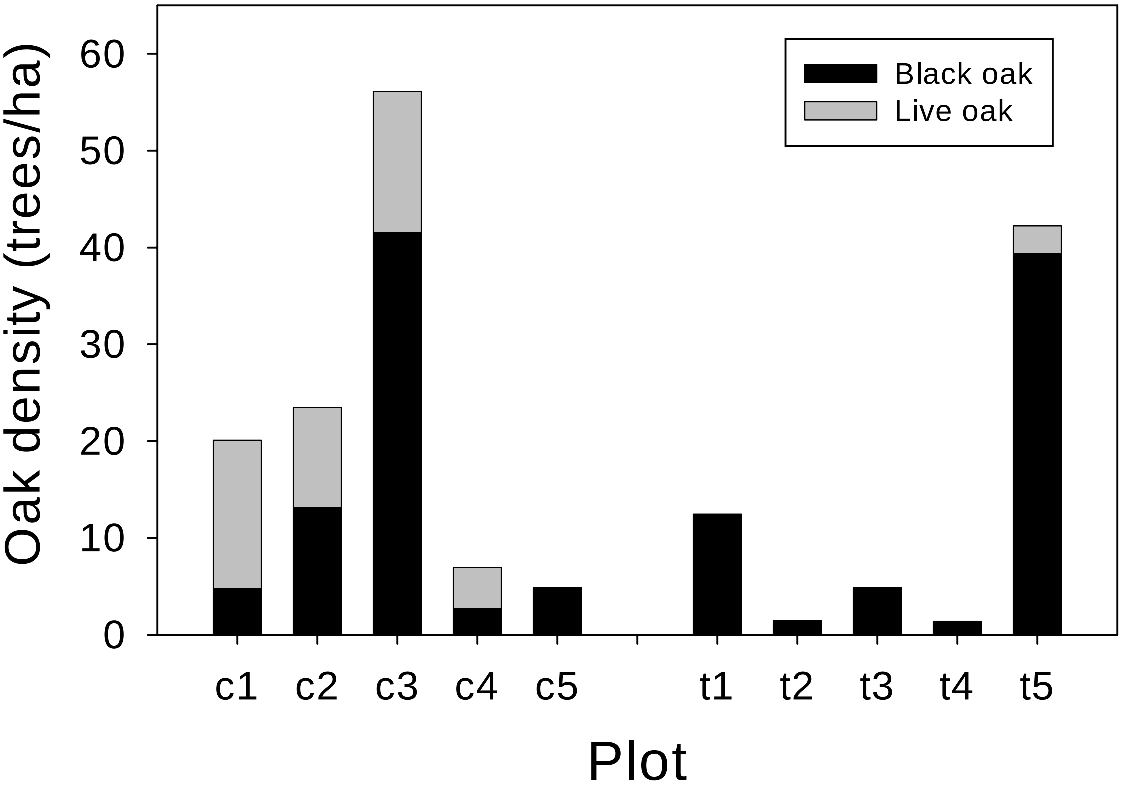

Figure 11. Oak density on control and treatment plots.

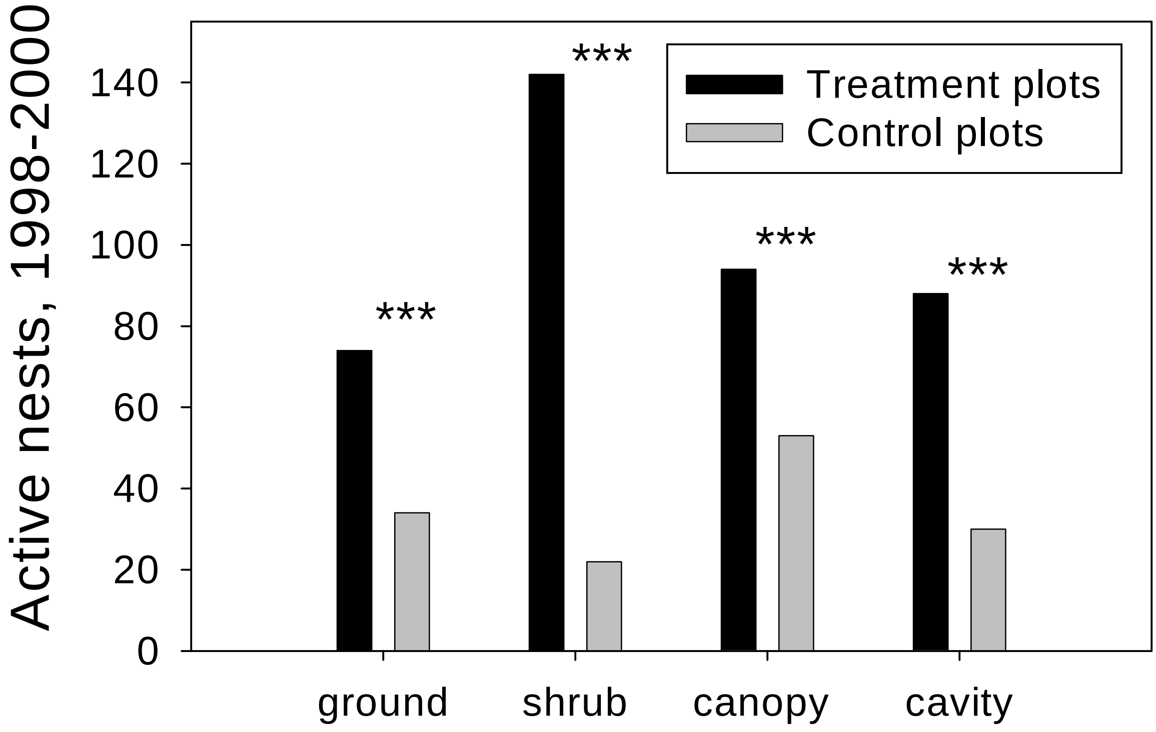

Figure 12. Active nests found on control and treatment plots.

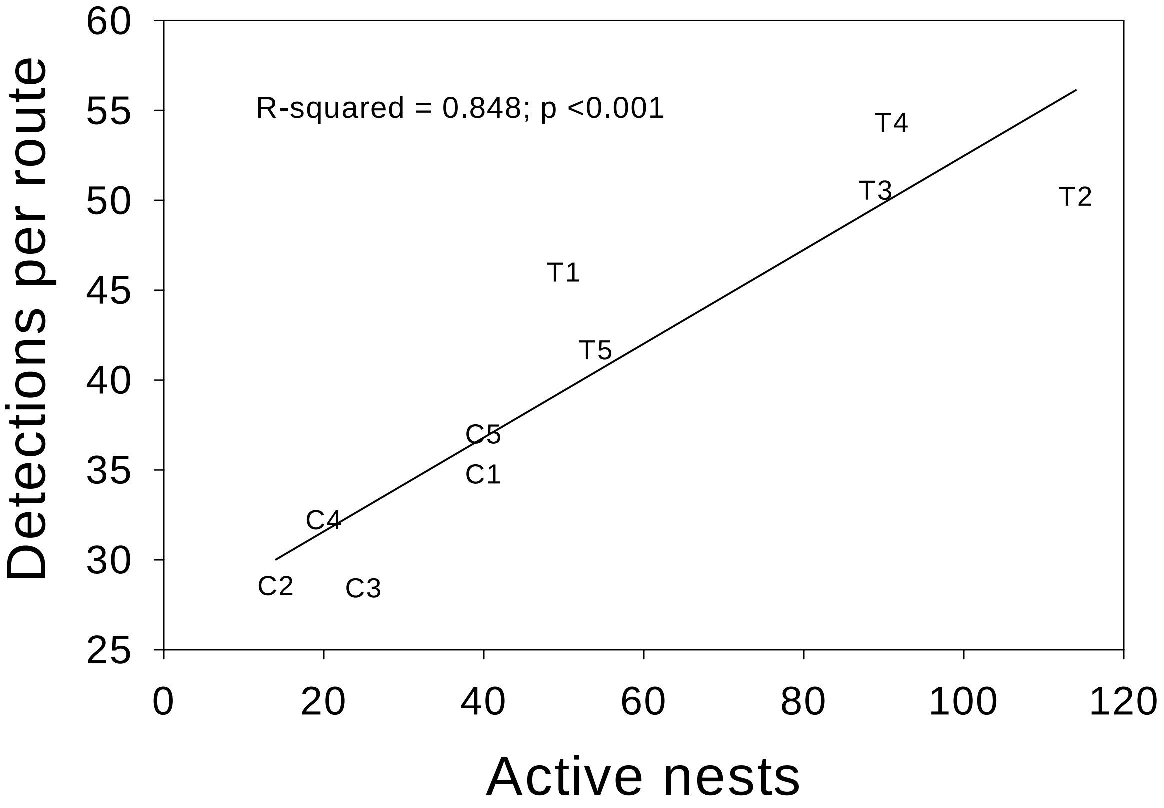

Figure 13. Relationship between the number of active nests found on each plot, and the average number of point count detections (< 50 m) of species known to have nested on at least one study plot.

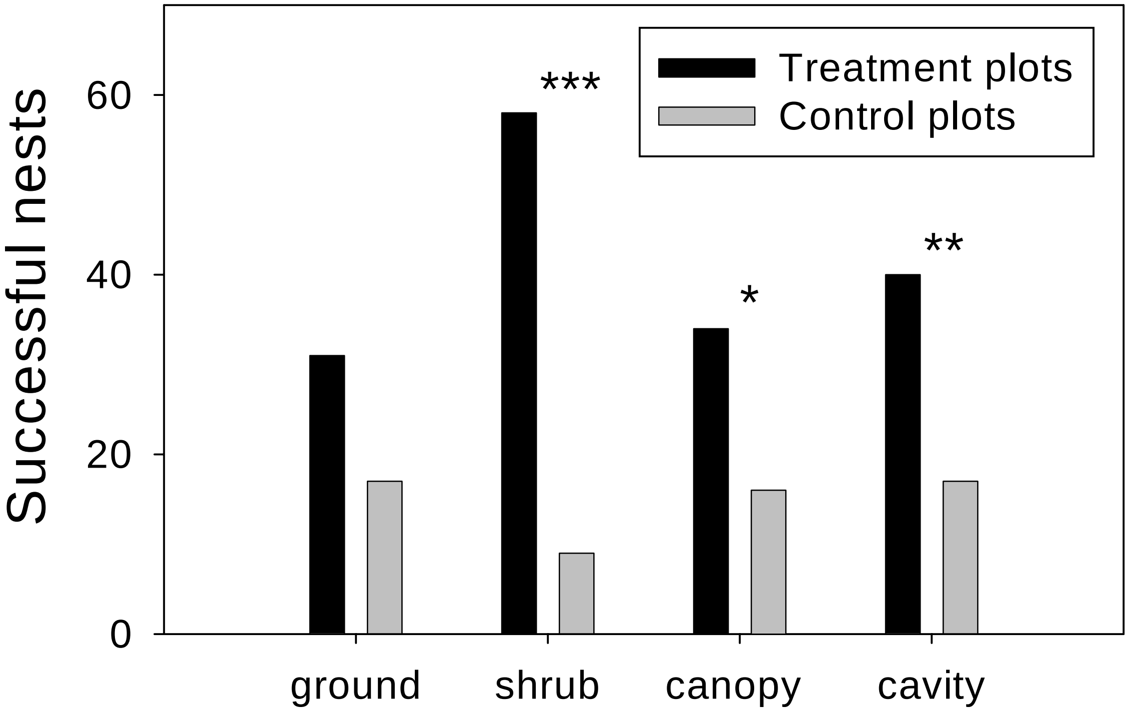

Figure 14. Number of successful nests observed on control and treatment plots.

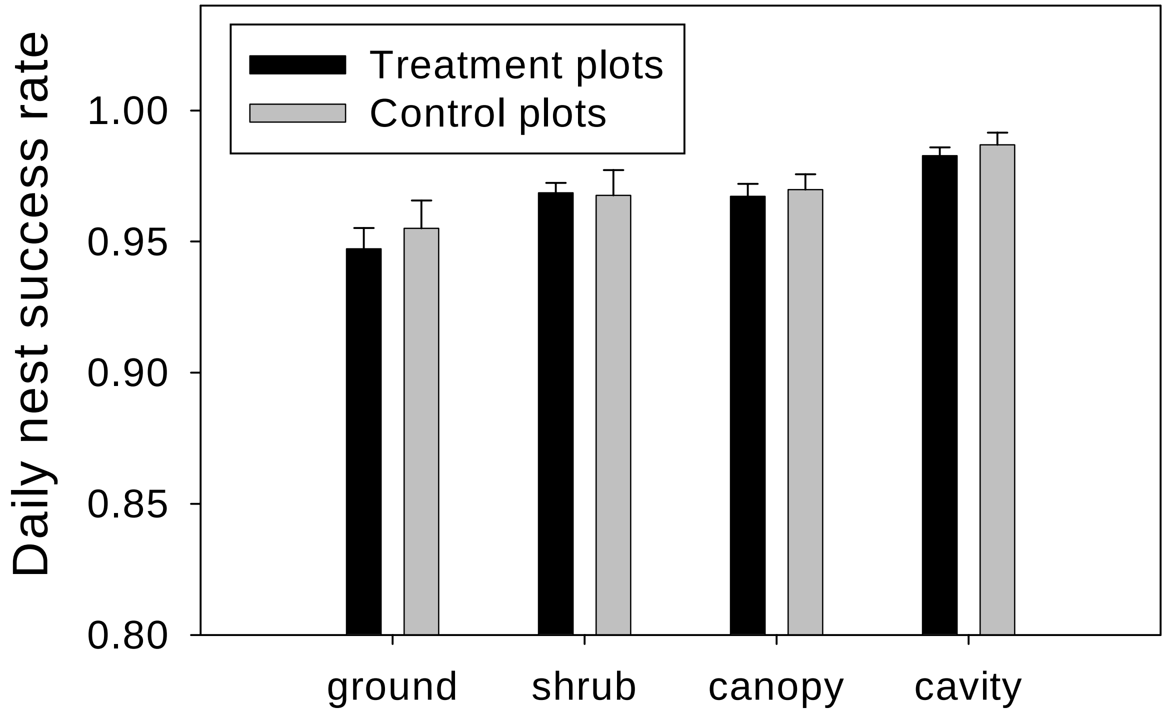

Figure 15. Daily Mayfield success rates of nests observed on control and treatment plots.

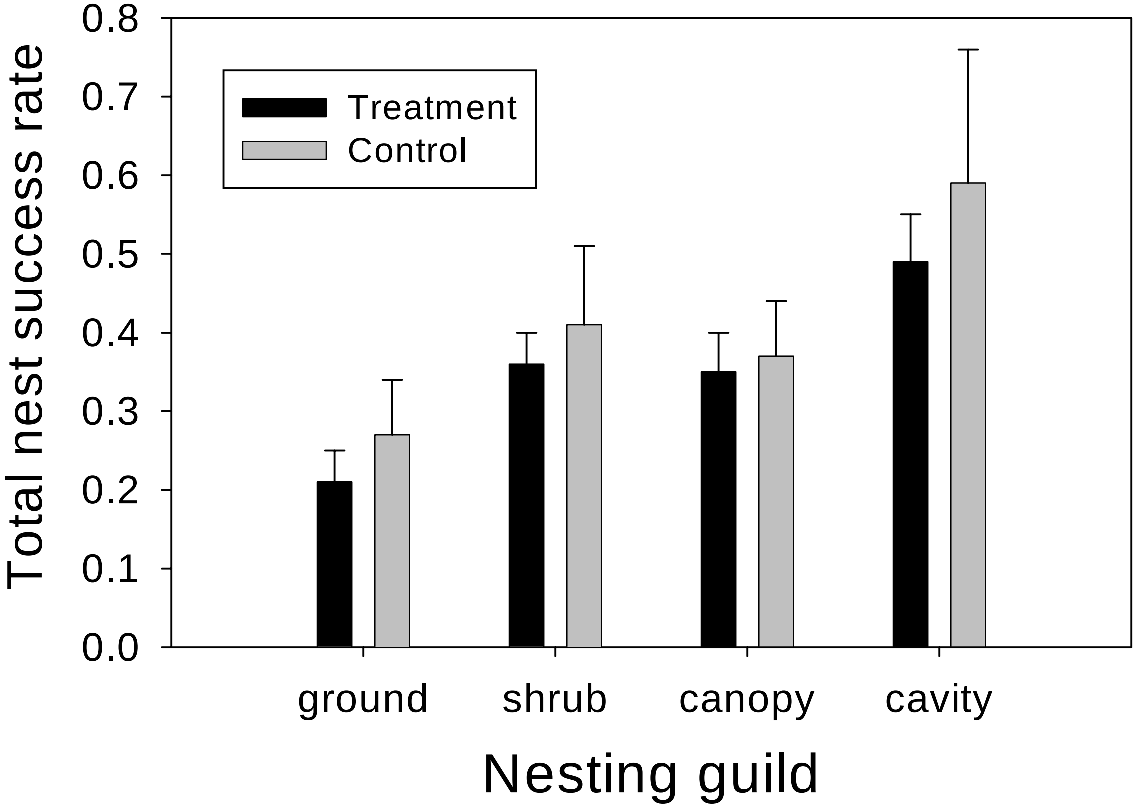

Figure 16. Total Mayfield survival rate of nests observed on control and treatment plots.