

FINAL REPORT -- Heritage Grant I96008
BIRD ABUNDANCE AND DIVERSITY PRIOR TO RESTORATION TREATMENTS FOR
OLD-GROWTH PONDEROSA PINE

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INTRODUCTION

Many federal land management agencies and congressional leaders of both political parties have embraced the idea that ponderosa pine forests should be restored to the structural and functional conditions that prevailed prior to the current era of dominant Euro-American influence. In particular, there is a strong impetus to restore the forest structure suggested by Covington and Moore (1992, 1994), i.e., a density of about 13 to 56 trees per acre, basal areas of about 63 square feet per acre, and stands dominated by large yellow pines with few snags or downed logs. It is quite likely that federal agencies will implement these changes over large areas during the next decade. However, we do not know how wildlife will respond to these treatments. Careful documentation of wildlife response to the first large-scale experiment may suggest desirable changes to future experimental treatments, and will help shape future AGF recommendations.

All too often wildlife abundance, reproduction, or other parameters are measured only *after* a manipulation, and data are analyzed under the assumption that, prior to treatment, the treated area did not differ from the "control" site. But in this design, treatment effects are hopelessly confounded with site effects (Hurlbert 1984). The remedy is to collect pre-treatment data at both control and treatment sites; this creates a Before-After-Control-Impact Pairs design (BACIP design: Stewart-Oaten and Murdoch 1986).

This study is an initial effort to monitor the response of passerine birds to the first large-scale effort to restore old-growth ponderosa pine conditions, namely the effort on the Bureau of Land Management's (BLM) Mount Trumbull Resource Conservation Area (MTRCA). Accordingly we quantified bird distribution, abundance, and (for selected species) reproductive parameters on 2 areas (approximately 300 to 400 ha each) of ponderosa pine forest in the BLM's. In the near future, 1 of these 2 areas will be thinned and burned in an attempt to restore Old Growth conditions to the ponderosa pine forest. This study presents the first 2 years of "Before" data for a BACIP design to quantify avian response to these treatments. We anticipate collecting a third year of pre-treatment data (although not on this Heritage Grant), and collecting the same type of observations for 3 years after treatment.

The following table lists all products specified in the Heritage Grant contract, and products delivered with this report.

Products specified in Heritage Grant contract	Products delivered in this report
Estimates of bird diversity and abundance on Control Area (minimum of 20 census stations) and Treatment Areas (minimum of 20 census stations) in 1996 and 1997.	Estimates of bird diversity and abundance on Control Area (46 stations) and Treatment Areas (48 stations) in 1996 and 1997. Analysis of difference between Areas and years.
Data on reproductive success of 2-6 focal species, in both Control and Treatment Areas, based on nest search and monitoring. Focal species should attempt to include at least 1 species susceptible to cowbird parasitism.	Data on reproductive success of 7 focal species, in both Control and Treatment Areas, based on nest search and monitoring. Species include solitary vireo (most susceptible species to cowbirds).
Vegetation data at each census station, and a description of vegetative differences between the Control and Treatment Areas.	Vegetation data at each census station, and a description of vegetative differences between the Control and Treatment Areas.
All original data sheets and field instructions.	All original data sheets and field instructions will be attached after final revisions
-- nest site selection not part of contract --	An analysis of nest site selection at the level of the nest tree, and at the level of the 20x20-m area around the nest.
-- power analysis not part of contract --	An analysis of statistical power of this study design, with recommendations to modify data collection in 1998-1999 to increase power.

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STUDY AREA

The Mount Trumbull Resource Conservation Area (MTRCA) lies on the Arizona Strip about 50 miles southwest of Fredonia, Arizona. The surrounding regional landscape is desert, with the ponderosa pine forest restricted to about 5000 acres, mostly above 6500 feet in elevation on the slopes of Mt Trumbull and Mt Logan. Gambel oak, juniper, pinyon, and locust occur commonly throughout much of the ponderosa pine forest.

METHODS

Layout and Number of Sampling Points

In our original proposal, we had planned to divide the area into ponderosa pine, pine-oak, and pine-juniper strata. However, after working at the site we found oaks so widespread that most of the area qualifies as pine-oak. We further decided not to sample in areas with greater than 30% basal area in pinyon or juniper. Thus we had only one stratum.

Researchers under the direction of Dr. Covington mapped a square grid of sample points, spaced 300-m apart, across the MTRCA. Our crews located these points on the ground, marking each point with rebar and a bright plastic rebar cap. We identified 48 points in areas scheduled for treatment starting in 1998 ("Treatment Area") and another 46 points in a 400-ha area currently not scheduled for treatments ("Control Area").

We used these 101 points in 2 ways. First they were the center points of 75-m radius plots on which we censused birds. Second, these were center points of 20x20-m plots on which we measured vegetation and physical characteristics of the habitat. These vegetation surveys became our measure of "available habitat" that we contrasted to those habitats chosen for nesting by birds in focal species.

Note: At the time we selected these areas, treatments in these areas were to begin in 1998; in fact, treatments may not begin until the year 2000 or later.

Vegetation measurements

We measured vegetation on 20x20 m square plots. On each plot we tallied the number of trees by species in each of 6 size classes corresponding to the US Forest Service's Vegetation Structural Stages (VSS), namely 0-1", 1-5", 5-12", 12-18", 18-24", and >24" dbh. We tallied snags separately from live trees. We tallied canopy closure and ground cover (including herbaceous vegetation and shrubs) by point intercept at 49 points. We tallied all logs on the plot. We used the dwarf mistletoe rating system developed by Hawksworth to index mistletoe infections in 10 ponderosa pines on each plot. (Note: To our surprise, we found no dwarf mistletoe in ponderosa pine in any plot; true mistletoe occurred frequently in junipers). We counted the number of oak clumps on each plot and measured the aerial extent of oak clumps. We defined an oak clump as a patch of at least 5 living oak stems ($\geq \frac{1}{2}$ m tall) with the base of each stem <1.5 m from its nearest neighbor and each crown within $\frac{1}{2}$ m of the nearest crown in the patch. For 4 randomly-selected large (>15" dbh) ponderosa pines on each plot, we measured the distance to the nearest neighboring large ponderosa pine. We also recorded aspect, percent slope, and whether or not the plot was within 20 m of a drainage.

We established and measured vegetation on plots centered on nest trees and intersection points on the 300-m grid (available habitat). The available habitat plots share a plot center with the 20x50-m rectangular plots established by Dr. Covington, and originally we had intended to use the vegetation data collected by Dr. Covington's crews at these sites. However, we felt that smaller plots, such as a 20x20-m square, would better reflect the scale on which birds select nest sites, and would thus be appropriate for nest plots. To avoid problems in comparing 20x20-m nest plots to 20x50-m plots measuring available habitat, we used a single plot size for all plot types. Also, unlike Dr. Covington's crews (who we using the plots to reconstruct pre-settlement conditions), we did *not* offset our available habitat plots to avoid roads, old landings, or rock outcrops.

Bird diversity and abundance

We indexed presence and abundance of passerine birds by 8-minute point counts on circular fixed-radius plots (Ralph et al. 1993), tallying all birds heard or seen within 75-m of the point. We also recorded whether the bird was detected 0-50 m, or 50-75 m, from the point. We did not sample when noise from wind or other sources (airplanes, cicadas) exceeded 3 on the Beaufort noise scale. Our sampling protocol will be attached to the final report. Crews trained during May 1-30 of each year, and carried out the surveys during May 28-July 10 of each year. During our initial 1996 effort, we visited each point 4 times (May 29-June 2, June 12-14, June 27-29, and July 10-12). Because the fourth visit added little additional information (Quarterly Report Jul-Sep 1996), we visited each point 3 times in 1997 (May 31-June 2, June 13-16, and June 28-30), dropping the mid-July visit (which had the fewest detections). Because both total detections and numbers of species detected decreased after 8:30 and again after 9:00 during 1996 (Quarterly Report Jul-Sep 1996), we completed all point counts by 8:30 AM in 1997.

We estimated abundance of each species in each year as the maximum number of birds detected during the 3 June visits, excluding known juveniles, birds of unknown species, and birds that flew through the plot without using it. Our use of the maximum of the 3 counts assumes that the birds we detected used the plot throughout the breeding season, but that our ability to detect them fluctuated.

We used the SPSS SamplePower software to estimate the power of our sampling effort to detect changes in species richness (number of species), overall avian abundance, and abundance of individual species between the pre- and post-treatment periods. These analyses will allow adjustments to the study design for increased power or efficiency. For instance, the analysis can indicate whether we should increase (or possibly could reduce) the number of years of observations or number of census plots.

Our overall study design consists of 40 census plots each in the Control and Treatment Areas (3 visits per year, and other details as described above), and 2 or 3 years of observation in each of the pre- and post-treatment time periods, with restoration influences to be evaluated by an ANOVA of the null hypothesis that diversity and abundance will change between the pre- and post-treatment Periods in similar amounts in the Treatment and Control Areas. Note that although we sampled 46 points (Control Area) and 48 points (Treatment Area) in 1996-1997, the precise boundaries of the treatment units have not been set, and we have not fully analyzed our data on the vegetation of the plots. Doubtless some "treatment" plots will not be treated, some "control" plots will lie too close to the treated edge, and some plots will be dropped because, for instance, there is too much juniper. We believe that it is realistic to assume that 40 plots per Area will remain in the final analysis.

In these analyses we chose an alpha level of 0.05 and an acceptable level of power of 80%, both conventional values. Selecting the smallest difference that one wishes to detect is a more subjective process. We started the analyses hoping to be able to detect a change of 20% in species richness and total bird abundance; we reasoned that smaller changes in total numbers would be of questionable ecological significance. We wish to be able to detect a 30% change in numbers of an individual species, but also evaluated power to detect changes of 50%; again we reasoned that subtler changes would not only be expensive to detect but their ecological significance would be more difficult to interpret.

Fledging Success

Reproduction is a better index of habitat quality than species presence or density (Van Horne 1983, Vickery et al. 1992). Therefore, in addition to documenting changes in species occurrence, we monitored reproduction for a suite of 7 focal species that would be expected to respond to the treatments. To do so, we established six Nest Search Grids (3 on the Control Area and 3 on the Treatment Area). Each Grid is about 36-ha (600x600m in most cases, one plot is rectangular to stay in the ponderosa pine type) and is marked on the ground with a numbered wooden stake every 50 meters. The stakes allow us to reference the location of each nest for revisiting, and eliminates the need to put out additional flagging or other marks which could attract predators to nests. We monitored each nest every 2-7 days until the nest failed or until the young birds apparently left the nest. We followed the protocols of Martin and Geupel (1992) to

maximize our success and minimize our impact on the birds. We considered a nest successful if it survived to within 3 days of the earliest fledging date expected on the basis of inferred dates of egg-laying or hatching.

Focal Species for Monitoring Reproduction and Nest Site Selection	Reason for including this species
Mountain chickadee	branch and foliage gleaner in pine and oak
Northern flicker	important primary excavator; feeds on ants
Pygmy nuthatch	bark and branch gleaner in pines; primary excavator in pines
Solitary vireo	most susceptible to cowbirds; nests in small oaks
Western bluebird	cavity nester; ground feeder
Western tanager	foliage gleaner (especially pines); nests in pine canopy
White-breasted nuthatch	secondary cavity nester in oaks (primarily) and pines

Mayfield (1961) pointed out that the number of successful nests will always give a biased estimate of true reproductive success because nests found later in the season have a greater likelihood of fledging young. To remedy this problem, Mayfield suggested closely monitoring nests through all phases of the nesting season (building, incubation, egg-laying, nestling, and fledging) and calculating probability of nest survival per day of exposure for each phase. Because we discovered relatively few nests in the earlier phases, we were unable to apply this method. Instead, for each species, we are using the number of successful nests to estimate the *relative* nest success on the Treatment Area compared to the Control Area. After treatment we will test to see if this ratio has changed, using an analytic technique such as a Chi-squared analysis.

Our efforts searching for and monitoring nests are carefully balanced between the Control and Treatment Areas. To insure this balance, each observer was assigned a pair of Nest Search Grids (1 each on Control and Treatment Areas) to monitor for the duration of each field season. After an observer expended a day's effort on a Nest Search Grid in the Treatment Area, he or she spent the same number of hours and used the same start and finish times on a paired Nest Search Grid on the Control Area the following day. This balancing of effort is crucial to our approach. By carefully balancing our effort, we can state whether the proportion of total nests on the Treatment Area changed with treatment. The *proportion* should be free of bias, even though the true reproductive success on an Area is unknown.

We also conducted statistical power analyses for our effort to detect whether restoration treatments influence fledging success of these species. In these analyses, we used Chi-square analysis of the null hypothesis that the proportion of total successful nests (for each species) that occur in the Treatment Area will not change between the pre-treatment and post-treatment Periods. Anticipating the difficulty of detecting changes in ratios, we conducted analyses with alpha (risk of type I error) of 0.05 and 0.10. We calculated how many successful nests we must find (per species, in each of the pre- and post-treatment Periods) to conclude that a change of 10, 20, or 30 percentage points would be statistically significant.

Nest Site Selection

Although not required by the contract, we collected data on nest site selection by 7 focal species. Because we were already searching for nests of these species to determine fledging success, and because we were already collecting data on habitat available to the birds, we recognized an opportunity to gain this additional data at little cost. The extra measurements required for this effort involved only 30 minutes per nest to measure vegetation. These data add significantly to our understanding of the ecology of these species, and will help managers interpret any responses observed during the post-treatment period.

We measured vegetation characteristics on 20x20-m plots centered on 128 nests of 7 focal species using the procedures outlined above. We compared these characteristics to that on 89 plots (also 20x20-m)

representing habitat available to the birds. In addition, we studied nest site selection at a finer scale, namely the nest tree, comparing nest trees to trees available in different species, size classes, and tree class (snag versus live).

RESULTS AND DISCUSSION

Bird diversity and abundance

General patterns.—Table 1 summarizes bird abundance for 1996 and 1997. The 12 most abundant species across the 2 years were white-breasted nuthatch (#1), Grace's warbler, mountain chickadee, pygmy nuthatch, western tanager, yellow-rumped warbler, solitary vireo, spotted towhee, western bluebird, Steller jay, dark-eyed junco, and gray flycatcher (#12). Brown-headed cowbirds were extremely rare during 1996 and 1997 (Table 1). These nest parasites may increase in the more open post-treatment landscape, especially if grazing animals maintain a low stubble height.

Differences between years.—Seven plots on the treatment area were relocated between 1996 and 1997 in order to avoid having plots dominated by pinyon or juniper. As a result, although we censused 94 points each year, only 87 plots were sampled in both 1996 and 1997. Census plots tended to have similar number of species and total abundance across the 2 years (correlation coefficients: +0.49 for richness and +0.52 for abundance, $n = 87$, $P < 0.0005$ for each). The species list at each point also tended to be similar, but not identical, across years.

Average species richness on a census plot decreased from 9.0 species per point in 1996 to 7.5 species in 1997 (paired t-test, $n = 87$, $P < 0.0005$), and average abundance per plot decreased from 11.4 to 9.2 birds detected ($P < 0.0005$). Richness and abundance showed similar changes in Control and Treatment Areas (interaction effect in ANOVA by Area and Year: $P = 0.19$ for richness and 0.12 for abundance, $n = 96$ plots). There were significant decreases between 1996 and 1997 in numbers of 8 species (Clark nutcracker, mourning dove, pygmy nuthatch, solitary vireo, spotted towhee, Virginia warbler, white-breasted nuthatch, and western tanager), while 3 species (black-throated gray warbler, common raven, and Steller jay) increased (t-tests, $P < 0.07$). The decrease in Clark nutcrackers may reflect the irruptive nature of this species. The decreases in many of the other birds may reflect extremely dry conditions in the 1996 breeding season, and heavy snows during spring migration in 1997. The marked year-to-year variation in the absence of treatment underscores the value of collecting data for several years both before and after treatment.

Differences in avifauna between Control and Treatment Areas.—The Control and Treatment Areas did not differ in average species richness (8.4 species per point on the Control Area, 8.5 on Treatment Area, $P = 0.66$, Area effect in ANOVA by Area and Year) or average abundance (10.6 and 10.5, respectively, $P = 0.77$). However, the avifaunas (species composition) differed between the areas (Table 2). Nine species were significantly ($P < 0.07$, Area effect in ANOVA by Area and Year) more abundant on the Control Area: brown creepers, common ravens, hermit thrushes, spotted towhee, Townsend solitaires, violet-green swallows, Virginia warblers, warbling vireos, and yellow-rumped warblers. On the other hand, 6 species (ash-throated flycatchers, black-throated gray warblers, Clark nutcrackers, gray flycatchers, mourning doves, and northern flickers) were significantly more abundant on the Treatment Area (Table 2). Many of these avifaunal differences probably reflect the vegetation differences between the 2 Areas (below).

Most of the species that differed between the Control and Treatment Areas were present in moderate numbers on the Control Area; thus the Control Area should serve its intended purpose as a statistical index of trends unrelated to the Treatments. However, 4 species (ash-throated warbler, black-throated gray warbler, Clark nutcracker, and mourning dove) were so rarely detected on the control area (Table 2) that we may be unable to infer any treatment effects for these species. Indeed 3 of these species showed apparently significant Year by Area interactions (Table 2) that were probably due simply to the absence of these species on the Control Area.

Power Analysis.—We are satisfied with our statistical ability to detect meaningful changes in species richness (number of species) and total avian abundance. With 1 year of observation in each of the pre- and post-treatment Periods, we would have about 60% power to detect a 20% change in richness or total bird numbers, this increased to about 71% power with 2 years of observations in each period (Figure 1). Because Years are nested within Period, we could not directly estimate how much power will increase with a 3rd year of observation in each Period. Based on the 11% increase in power due to adding the 2nd year, and the law of diminishing returns, we expect that power will increase to about 80% with a 3rd year of observation.

Our sampling scheme is not expected to detect (i.e. confer statistical significance upon) that changes of 30% in the abundance of individual species. Our analyses indicated that >100 census plots in each Area would be needed to detect changes as small as 30%. Examining the maps, we conclude that a maximum of 84 independent points can fit into the Control Area (with a 75-m plot radius and bird home range diameters of about 100m, plot centers must be at least 200m apart). Because some of these plots would doubtless be deleted eventually (see *Methods*), we would probably have at most 80 plots, far short of the 100 needed to detect changes of 30% in the abundance of an individual species.

We have satisfactory power to detect changes of 50% in the abundance for the most abundant species, but with only 2 years of data we cannot do so for less abundant species (Figure 2). As with total avian abundance, power to detect a 50% change in individual species increased substantially as number of years of observation increased from 1 to 2 years (Figure 3). Given the delay in implementing treatments on Mt Trumbull, we have the opportunity to collect a 3rd year of pre-treatment data, and we feel it is important to do so. The 3rd year of observation will substantially increase our ability to detect smaller changes, and to detect changes for a greater fraction of the individual species.

Differences in Vegetation between Control and Treatment Areas

Compared to the Treatment Area, the Control Area had significantly ($P < 0.05$) more logs and large ponderosa pines, and significantly fewer pinyon pine, junipers, oak clumps, and small oaks (Table 3). After we measure vegetation on 11 additional plots on the Control Area (to provide a total of 46), the magnitude of these differences may change, but we expect similar patterns will remain.

We would prefer greater similarity of vegetation between the Control and Treatment Areas. These vegetation differences probably cause ash-throated warblers, black-throated gray warblers, Clark nutcrackers, and mourning doves to differ markedly in abundance between the Control and Treatment Areas (Table 2). As explained above, we feel that, except for these 4 species, the Control Area should still serve its purpose as a statistical index of avian trends unrelated to treatments.

Fledging Success

Pre-treatment data summary.—We discovered a total of 142 nests of the 7 focal species during 1996-1997, including 28 nests that failed and 3 successful nests that did not fall in either the Control or Treatment Area. We measured vegetation at all 142 nests, but only 111 nests are useful for analysis of fledging success (Table 4). In terms of the overall study design, the null hypothesis, for each species, is that the proportion of successful nests falling in the Treatment Area will not change between the pre- and post-treatment periods. The restoration treatments will be judged to have a significant influence on fledging success of a species if that proportion is significantly different in the post-treatment period.

Power analysis.—Our power analysis suggests that, in each of the pre- and post-treatment Periods, we would have to find 300 successful nests to have 80% power to detect a shift of 10 percentage points in the proportion of successful nests that lie in the Treatment Area at an alpha of 0.10. We would need 135 nests to detect a shift of 15%, again with alpha of 0.10. We conclude, given the number of nests we were able to find during 1996-1997 (Table 4), that our effort will not find changes of 10% to 20% statistically significant (Figure 4).

Our effort can reliably detect larger changes in nest success. For instance, we need only 30 successful nests to detect a shift of 30% at an alpha of 0.10, and 39 nests at an alpha of 0.05 (Figure 4). In light of the cost associated with nest-searching, we favor accepting an alpha of 0.10 so that 30 (instead of 39) successful nests will be sufficient. Assuming we can carry out a 3rd field season in 1998, we should easily obtain 30 successful nests each for white-breasted nuthatch, western bluebird, western tanager (Table 4), and we may approach this level for the other species. To do so, we plan to expand each nest grid by 50% (from 36 ha to 54 ha) before the 1998 field season; the geometry of the study area prohibits further expansion. Even with the enlarged nest search grids, we may need 2 more field seasons (1998 and 1999) to reach the 30-nest threshold for some species.

Nest Site Selection

Although not required by the contract, we collected data on nest site selection by 7 focal species.

At the level of the individual tree chosen as a nest site, most cavity nesters showed a strong preference for snags, using snags in greater proportion than expected based on available trees (Table 5). However, except for the northern flicker, all cavity nesters used live trees for 42% (mountain chickadee, pygmy nuthatch) to 80% (white-breasted nuthatch) of their nests. The 2 cup-nesters (solitary vireo, western tanager) nested exclusively in live trees, with tanagers nesting almost exclusively in ponderosa pine (Table 5). Although the solitary vireo nested in a broad range of tree sizes, the other 6 bird species showed a strong preference for nesting in the largest trees; this was true for both pines and oaks, live and snag (Table 6).

At the level of the 20x20-m plot, species differed in their habitat preferences (Tables 7-13). Solitary vireos and white-breasted nuthatches selected habitats with more oak (Table 7, 8), perhaps reflecting their tendency to nest in oak trees. On the other hand, northern flickers, pygmy nuthatches, and western tanagers showed an aversion to oaks, especially small-diameter oaks (Tables 10, 11, 12). Despite the preference for large nest trees, few species showed any tendency to respond to the spacing of large (>15" dbh) trees. The only 2 species that did (white-breasted nuthatch, mountain chickadees) seemed to prefer a wider than average spacing among large trees (Tables 7, 12). Solitary vireos, white-breasted nuthatch, western bluebirds, and western tanagers seemed to prefer gentler slopes (Table 7, 8, 9, 10). White-breasted nuthatches and western bluebirds both tended to pick nest locations with high canopy closure (Tables 8, 9).

These findings may help interpret bird responses to the restoration treatments. For instance if western bluebirds were to decline with treatment, despite creation of what will certainly be more favorable foraging conditions, it may be due to their aversion to nesting in more open sites. We will also learn more about a species' habitat selection patterns by repeating these measurements after treatment. Perhaps many birds that are indifferent to (for example) canopy closure or spacing of large trees in the dense pre-treatment landscape will manifest selection with respect to these habitat features in the more open post-treatment landscape.

CONCLUSIONS

Although we succeeded in completing all tasks specified in this contract, the data presented herein comprise a baseline survey that will be of value primarily for comparison with similar data to be collected after treatment. Because it is crucial that future data be collected using compatible, if not identical, procedures, our protocols (i.e., instructions to field crews on how to carry out measurements) and original data forms will be appended to the final report.

To increase statistical power of this effort, we strongly recommend collecting additional pre-treatment data at Mt Trumbull during 1998, and perhaps 1999. Delays in implementing the restoration treatments at Mt Trumbull will certainly allow for additional data collection. Funding to continue these avian studies was included in the 5-year (1996-2000) study that AGFD has undertaken with funding from BLM (this project also includes studies of deer, squirrels, and reptiles). We have prepared this report

promptly so that we can focus our field efforts wisely in 1998. With a productive 1998 season, we believe that we will need only a pared-back 1999 season, freeing up dollars from the BLM-AGFD project budget to achieve other objectives in 1999.

Even in the absence of post-treatment data, this effort provides a 2-year picture of abundance, diversity, reproduction, and nest site selection by birds in Mt. Trumbull's pine-oak forest. We found substantial year-to-year changes in abundance and species diversity. We documented strong selection for nest sites at the level of the nest tree, as well as at the level of a 20x20-m plot. Selection for larger trees and snags emerged as important trends in the species studied; individual species differed in their selection for other habitat attributes. These habitat selection patterns will help managers anticipate, and to interpret the mechanisms that underlie, bird responses to the restoration treatments.

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Table 1. Abundances of birds during June 1996 and June 1997. We indexed abundance as the maximum number of birds detected within a 75-m radius during 3 visits each year, excluding birds flying through the plot. Species with a mean of "0" were present on the study area, but not detected during our censuses. Means and standard deviation reflect all 94 census plots, but significance level (*P*) is of a paired t-test (2-tailed) using *n* = 87 census points visited in both years.

Species	1996		1997		<i>P</i>
	Mean	SD	Mean	SD	
Acorn woodpecker	0.02	0.21	0.03	0.22	1.00
American crow	0.01	0.10	0.01	0.10	1.00
American kestrel	0.00	0.00	0.00	0.00	*
American robin	0.07	0.26	0.04	0.20	0.48
Ash-throated flycatcher	0.03	0.18	0.05	0.22	0.41
Black-chinned hummingbird	0.05	0.34	0.00	0.00	0.13
Bewick wren	0.00	0.00	0.00	0.00	*
Blue-gray gnatcatcher	0.01	0.10	0.02	0.14	1.00
Brown-headed cowbird	0.01	0.10	0.00	0.00	0.32
Black-headed grosbeak	0.26	0.48	0.28	0.56	0.52
Brown creeper	0.06	0.29	0.01	0.10	0.96
Black-throated gray warbler	0.10	0.33	0.26	0.65	0.005
Broad-tailed hummingbird	0.06	0.25	0.07	0.26	0.53
Band-tailed pigeon	0.02	0.15	0.04	0.20	0.42
Bushtit	0.03	0.23	0.00	0.00	0.18
Cassin finch	0.00	0.00	0.02	0.14	0.16
Chipping sparrow	0.41	0.65	0.35	0.57	0.086
Clark nutcracker	0.05	0.27	0.00	0.00	0.058
Cordilleran flycatcher	0.01	0.10	0.01	0.10	1.00
Common raven	0.03	0.18	0.13	0.43	0.060
Dark-eyed junco	0.37	0.57	0.45	0.59	0.87
Dusky flycatcher	0.12	0.32	0.07	0.26	0.29
Flammulated owl	0.00	0.00	0.01	0.10	0.32
Gray flycatcher	0.35	0.50	0.46	0.57	0.07
Grace's warbler	0.94	0.79	0.86	0.79	0.28
Green-tailed towhee	0.01	0.10	0.00	0.00	0.32
Hairy woodpecker	0.38	0.55	0.24	0.45	0.11
Hermit thrush	0.07	0.26	0.07	0.34	0.76
House wren	0.03	0.18	0.00	0.00	0.08
Lesser goldfinch	0.00	0.00	0.03	0.17	0.08
Mountain chickadee	0.95	0.82	0.85	0.82	0.30
Mourning dove	0.15	0.39	0.03	0.17	0.012
Northern flicker	0.22	0.49	0.22	0.52	0.87
Northern goshawk	0.00	0.00	0.01	0.10	0.32
Olive-sided flycatcher	0.00	0.00	0.01	0.10	0.32
Pinyon jay	0.00	0.00	0.00	0.00	*
Plain titmouse	0.01	0.10	0.03	0.22	0.42
Pygmy nuthatch	1.32	0.96	0.21	0.43	<0.0005
Red-breasted nuthatch	0.03	0.18	0.01	0.10	0.32
Red crossbill	0.17	0.65	0.15	0.47	0.61
Red-tailed hawk	0.01	0.10	0.00	0.00	0.32

Scrub jay	0.00	0.00	0.01	0.10	0.32
Solitary vireo	0.59	0.68	0.43	0.57	0.056
Spotted towhee	0.47	0.65	0.38	0.68	0.048
Steller jay	0.33	0.56	0.55	0.83	0.047
Townsend solitaire	0.13	0.34	0.20	0.42	0.20
Turkey vulture	0.01	0.10	0.00	0.00	0.32
Violet green swallow	0.24	0.60	0.15	0.47	0.15
Virginia warbler	0.21	0.48	0.09	0.31	0.032
Warbling vireo	0.11	0.34	0.15	0.41	0.49
Western bluebird	0.35	0.62	0.49	0.70	0.45
Western tanager	0.78	0.67	0.63	0.62	0.058
Western wood peewee	0.12	0.32	0.04	0.20	0.11
White-breasted nuthatch	1.05	0.71	0.89	0.74	0.033
White-throated swift	0.04	0.25	0.00	0.00	0.18
Wild turkey	0.02	0.15	0.01	0.10	0.57
Williamson sapsucker ^b	0.01	0.10	0.00	0.00	0.32
Yellow rumped warbler	0.54	0.67	0.56	0.63	0.91

^a t-test cannot be performed because the standard deviation was 0.

^b bred on site in 1996

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Table 2. Differences between Control and Treatment Areas in abundance of bird species during 1996-1997 (i.e., prior to treatments) on the Mount Trumbull study area. All species with a significant ($P < 0.07$) difference are listed (ANOVA of species abundance by Area and Year, $n = 50$ census plots on Treatment Area and 46 plots on the Control Area). When the interaction term was significant ($P < 0.07$), results are broken down by year.

Species	Year	Control Area		Treatment Area		P (Area effect)
		mean	SD	mean	SD	
Ash-throated flycatcher	both	0.00	0.00	0.10	0.25	0.003
Black-headed grosbeak	both	0.20	0.37	0.33	0.46	0.23
	1996	0.26	0.53	0.23	0.42	
	1997	0.13	0.34	0.43	0.73	
Brown creeper	both	0.08	0.21	0.00	0.00	0.019
Black-throated gray warbler	both	0.00	0.00	0.37	0.56	<0.0005
	1996	0.00	0.00	0.20	0.46	
	1997	0.00	0.00	0.55	0.90	
Clark nutcracker	both	0.00	0.00	0.06	0.18	0.048
	1996	0.00	0.00	0.11	0.39	
	1997	0.00	0.00	0.00	0.00	
Common raven	both	0.13	0.29	0.02	0.14	0.033
Gray flycatcher	both	0.29	0.37	0.55	0.53	0.002
Hermit thrush	both	0.13	0.29	0.00	0.00	0.001
Mourning dove	both	0.02	0.10	0.17	0.29	0.001
	1996	0.00	0.00	0.32	0.10	
	1997	0.04	0.21	0.02	0.15	
Northern flicker	both	0.13	0.27	0.33	0.49	0.006
Spotted towhee	both	0.53	0.69	0.33	0.53	0.034
Townsend solitaire	both	0.24	0.35	0.10	0.25	0.019
Violet-green swallow	both	0.32	0.56	0.08	0.23	0.007
Virginia warbler	both	0.25	0.42	0.06	0.19	0.002
Warbling vireo	both	0.20	0.36	0.05	0.21	0.005
Yellow-rumped warbler	both	0.45	0.44	0.70	0.51	0.007

Table 3. Vegetation and physical characteristics on 35 0.04-ha plots on the Control Area and 49 such plots on the Treatment Area, in ponderosa pine forest at the Mount Trumbull study area. (Note: we will measure habitat characteristics on 11 additional plots on the Control Area in 1998.)

Characteristic	Control Area		Treatment Area		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0.40 ^b
316-45°	40	50	37	49	
46-135°	31	47	24	43	
136-225°	23	43	18	39	
226-315°	3	17	16	37	
Flat	3	17	4	20	
% ground cover					0.01 ^b
Rock	4.3	4.8	5.7	7.8	
Bare ground, including roads	8.8	9.1	16.4	13.2	
Litter	81.1	14.6	71.0	17.1	
Shrub	3.9	7.9	4.5	6.4	
Grass or forb	1.8	4.1	2.1	3.9	
% slope	10.2	8.6	10.6	9.9	0.85
% Canopy Closure	47.3	15.2	44.9	11.6	0.46
Logs	2.3	2.1	1.0	1.2	0.001
Total trees (excluding locust)	33.9	29.49	38.27	26.57	0.26
Ponderosa pines:					
0-12.7 cm dbh	12.8	16.8	9.0	14.9	0.29
12.7-30.5 cm dbh	10.0	10.8	8.6	9.4	0.44
>30.5 cm dbh	4.3	3.1	2.6	2.1	0.015
Oaks:					
0-12.7 cm dbh	2.6	9.3	5.4	10.4	0.028
12.7-30.5 cm dbh	2.9	6.4	1.7	2.4	0.84
>30.5 cm dbh	0.06	0.23	0.04	0.20	0.73
Pinyon or Junipers:					
0-12.7 cm dbh	0.97	2.43	8.12	9.42	<0.0005
12.7-30.5 cm dbh	0.17	0.51	2.59	3.17	<0.0005
>30.5 cm dbh	0.03	0.17	0.27	0.76	0.025
Locust stems	5.8	19.9	0.7	2.5	0.077
Total snags	2.4	4.7	3.8	5.7	0.10
Ponderosa pine snags					
0-12.7 cm dbh	0.80	2.92	0.22	0.59	0.31
12.7-30.5 cm dbh	0.06	0.24	0.12	0.48	0.56
>30.5 cm dbh	0.06	0.24	0.04	0.20	0.73
Oak snags					
0-12.7 cm dbh	0.9	2.4	2.5	4.8	0.017
12.7-30.5 cm dbh	0.54	1.48	0.45	.96	0.74
>30.5 cm dbh	0.00	0.00	0.06	.32	0.17
Area occupied by oak clumps (m ²)	23.4	51.4	26.0	42.1	0.81
Number of oak clumps	0.8	1.2	1.6	1.8	0.010
Mean large tree spacing (m)	4.8	2.6	5.7	3.1	0.27
(n plots with trees > 15")	(28)		(23)		

^a chi-square analysis.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

Table 4. Number of nests that fledged young during 1996-1997 on the Control and Treatment Areas at the Mt. Trumbull study site.

Species	Number of Nests Fledging Young			Approx. Ratio (Treatment to Total)
	Treatment Area	Control Area	Total	
Mountain chickadee	4	7	11	0.40
Northern flicker	5	4	9	0.55
Pygmy nuthatch	7	3	10	0.70
Solitary vireo	8	5	13	0.60
White-breasted nuthatch	11	9	20	0.55
Western bluebird	17	7	24	0.70
Western tanager	14	10	24	0.60
Total	66	45	111	

Table 5. Percentage of trees by species and tree class (live or snag) available on MTRCA, in comparison to trees selected for nests by 7 focal species. Available tree distribution tallied on 89 plots (20x20-m each).

Tree category	Available	Mountain chickadee	Northern flicker	Pygmy nuthatch	Solitary vireo	White-breasted nuthatch	Western bluebird	Western tanager
Live ponderosa pine	58%	42%	0%	42%	34%	25%	35%	97%
Live Gambel oak	17%	0%	0%	0%	59%	42%	27%	3%
Live pinyon or juniper	17%	0%	0%	0%	7%	13%	4%	0%
Ponderosa pine snag	1%	42%	50%	50%	0%	8%	27%	0%
Gambel oak snag	6%	17%	50%	8%	0%	13%	8%	0%
Pinyon or juniper snag	1%	0%	0%	0%	0%	0%	0%	0%
Total	3422 trees	12 nests	8 nests	12 nests	29 nests	24 nests	26 nests	30 nests

Table 6. Percentage of trees, by size class within tree category, available on MTRCA, in comparison to trees selected for nests by 7 focal species.

Tree category	Size class	Available	Mountain chickadee	Northern flicker	Pygmy nuthatch	Solitary vireo	White-breasted nuthatch	Western bluebird	Western tanager
Live ponderosa pine	0-1"	9%	0%	0%	0%	0%	0%	0%	0%
	1-5"	36%	0%	0%	0%	30%	0%	0%	0%
	5-12"	40%	0%	0%	0%	20%	0%	0%	14%
	12-18"	12%	20%	25%	0%	30%	0%	0%	31%
	18-24"	2%	0%	25%	40%	20%	16%	0%	28%
	>24"	1%	80%	50%	60%	0%	84%	100%	28%
	total	1991 trees	5 nests	4 nests	5 nests	10 nests	6 nests	9 nests	29 nests
Ponderosa pine snags	0-1"	20%	0%	0%	0%		0%	0%	
	1-5"	57%	0%	0%	0%		0%	0%	
	5-12"	16%	40%	0%	33%		33%	0%	
	12-18"	6%	20%	25%	17%		0%	43%	
	18-24"	0%	0%	0%	33%		33%	43%	
	>24"	2%	40%	75%	17%		33%	14%	
	total	51 snags	5 nests	4 nests	6 nests	none	3 nests	7 nests	none
Live Gambel oak	0-1"	43%				13%	0%	0%	0%
	1-5"	24%				7%	0%	0%	0%
	5-12"	33%				73%	90%	86%	100%
	12-18"	0.5%				7%	10%	14%	0%
	18-24"	0%				0%	0%	0%	0%
	>24"	0.2%				0%	0%	0%	0%
	total	565 trees	none	none	none	15 nests	10 nests	7 nests	1 nest
Gambel oak snags	0-1"	1%	0%		0%		0%	0%	
	1-5"	75%	0%		0%		0%	0%	
	5-12"	22%	100%		100%		50%	50%	
	12-18"	1%	0%		0%		50%	50%	
	18-24"	0.5%	0%		0%		0%	0%	
	>24"	0%	0%		0%		0%	0%	
	total	204 snags	2 nests	none	1 nest	none	2 nests	2 nests	none

Table 7. Vegetation and physical characteristics on 27 0.04-ha plots in which solitary vireos nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

Characteristic	Used Plots		Available Plots		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0.08 ^a
316-45°	22	42	38	49	
46-135°	37	49	28	45	
136-225°	11	32	19	40	
226-315°	22	42	11	33	
Flat	7	27	3	18	
% ground cover					0.18 ^b
Rock	3.9	5.5	5.1	6.8	
Bare ground, including roads	14.6	10.8	13.2	12.0	
Litter	67.1	23.0	75	17	
Shrub	10.0	14.4	4.1	6.9	
Grass or forb	4.3	6.4	2.3	4.5	
% slope	5.9	5.8	10.6	9.4	0.003
% Canopy Closure	48.7	15.8	46	13	0.38
Logs	2.4	2.5	1.6	1.7	0.19
Total trees (excluding locust)	27.7		35.2	27.4	0.23
Ponderosa pines:					
0-12.7 cm dbh	8.0	11.2	10.1	15.4	0.73
12.7-30.5 cm dbh	6.4	7.3	8.9	9.8	0.11
>30.5 cm dbh	3.3	2.9	3.4	2.7	0.72
Oaks:					
0-12.7 cm dbh	3.3	8.3	4.2	9.8	0.76
12.7-30.5 cm dbh	4.7	6.6	2.1	4.4	0.006
>30.5 cm dbh	0.22	0.4	0.04	0.21	0.04
Pinyon or Junipers:					
0-12.7 cm dbh	1.4	3.2	4.9	8.0	0.005
12.7-30.5 cm dbh	0.4	1.1	1.5	2.7	0.008
>30.5 cm dbh	0.04	0.2	0.2	0.6	0.13
Locust stems	11.6	35.2	2.7	12.7	0.25
Total snags	2.6	2.6	3.2	5.2	0.63
Ponderosa pine snags					
0-12.7 cm dbh	0.22	0.51	0.44	1.89	0.56
12.7-30.5 cm dbh	0.04	0.19	0.09	0.38	0.77
>30.5 cm dbh	0.07	0.27	0.04	0.21	0.52
Oak snags					
0-12.7 cm dbh	1.0	1.5	1.8	3.9	0.63
12.7-30.5 cm dbh	0.78	1.15	0.51	1.23	0.10
>30.5 cm dbh	0.07	0.27	0.04	0.24	0.40
Area occupied by oak clumps	39.5	70.0	23.7	44.9	0.17
Number of oak clumps	1.30	1.23	1.24	1.58	0.51
Mean large tree spacing (m)	7.9	4.4	5.2	2.8	0.33
(n plots with trees > 15")	(16)		(56)		

^a chi-square analysis.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

Table 8. Vegetation and physical characteristics on 24 0.04-ha plots in which white-breasted nuthatches nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

Characteristic	Used Plots		Available Plots		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0.0207 ^a
316-45°	17	38	38	49	
46-135°	54	51	28	45	
136-225°	13	34	19	40	
226-315°	8	28	11	33	
Flat	8	28	3	18	
% ground cover					0.057 ^b
Rock	2.0	3.6	5.1	6.8	
Bare ground, including roads	8.6	7.2	13.2	12.0	
Litter	83.9	9.7	75	17	
Shrub	2.9	4.0	4.1	6.9	
Grass or forb	2.4	4.8	2.3	4.5	
% slope	7.2	5.9	10.6	9.4	0.035
% Canopy Closure	53	9	46	13	0.003
Logs	2.1	1.8	1.6	1.7	0.120
Total trees (excluding locust)	34.0	12.6	35.2	27.4	0.479
Ponderosa pines:					
0-12.7 cm dbh	6.8	11.3	10.1	15.4	0.515
12.7-30.5 cm dbh	9.5	7.5	8.9	9.8	0.417
>30.5 cm dbh	4.0	2.6	3.4	2.7	0.219
Oaks:					
0-12.7 cm dbh	1.8	2.7	4.2	9.8	0.439
12.7-30.5 cm dbh	4.2	5.7	2.1	4.4	0.110
>30.5 cm dbh	0.75	1.0	0.04	0.21	0.002
Pinyon or Junipers:					
0-12.7 cm dbh	4.2	6.8	4.9	8.0	0.867
12.7-30.5 cm dbh	2.1	3.5	1.5	2.7	0.508
>30.5 cm dbh	0.7	1.5	0.2	0.6	0.056
Locust stems	0.6	3.1	2.7	12.7	0.085
Total snags	4.3	6.1	3.2	5.2	0.335
Ponderosa pine snags					
0-12.7 cm dbh	0.37	0.71	0.44	1.89	0.652
12.7-30.5 cm dbh	0.08	0.28	0.09	0.38	0.908
>30.5 cm dbh	0.08	0.28	0.04	0.21	0.461
Oak snags					
0-12.7 cm dbh	1.8	4.0	1.8	3.9	0.894
12.7-30.5 cm dbh	1.21	2.17	0.51	1.23	0.121
>30.5 cm dbh	0.25	0.61	0.04	0.24	0.086
Area occupied by oak clumps	27.4	43.0	23.7	44.9	0.716
Number of oak clumps	1.04	0.95	1.24	1.58	0.993
Mean large tree spacing (m)	8.1	4.5	5.2	2.8	0.010
(n plots with trees > 15")	(22)		(56)		

^a chi-square analysis.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

Table 9. Vegetation and physical characteristics on 26 0.04-ha plots in which western bluebirds nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

Characteristic	Used Plots		Available Plots		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0.30 ^a
316-45°	31	47	38	49	
46-135°	46	51	28	45	
136-225°	12	33	19	40	
226-315°	12	33	11	33	
Flat	0	0	3	18	
% ground cover					0.23 ^b
Rock	3.3	3.8	5.1	6.8	
Bare ground, including roads	7.3	7.4	13.2	12.0	
Litter	86.2	8.8	75	17	
Shrub	2.1	2.1	4.1	6.9	
Grass or forb	1.2	2.9	2.3	4.5	
% slope	7.7	4.2	10.6	9.4	0.031
% Canopy Closure	53	8.8	46	13	0.002
Logs	2.1	1.82	1.6	1.7	0.151
Total trees (excluding locust)	33.6	22.3	35.2	27.4	0.977
Ponderosa pines:					
0-12.7 cm dbh	14.5	18.8	10.1	15.4	0.148
12.7-30.5 cm dbh	8.0	4.6	8.9	9.8	0.571
>30.5 cm dbh	4.4	2.5	3.4	2.7	0.043
Oaks:					
0-12.7 cm dbh	2.2	6.63	4.2	9.8	0.210
12.7-30.5 cm dbh	1.3	2.26	2.1	4.4	0.600
>30.5 cm dbh	0.0	0.0	0.04	0.21	0.054
Pinyon or Junipers:					
0-12.7 cm dbh	1.8	3.72	4.9	8.0	0.025
12.7-30.5 cm dbh	1.2	2.64	1.5	2.7	0.797
>30.5 cm dbh	0.2	0.49	0.2	0.6	0.570
Locust stems	0.2	0.78	2.7	12.7	0.009
Total snags	1.9	3.45	3.2	5.2	0.275
Ponderosa pine snags					
0-12.7 cm dbh	0.04	0.20	0.44	1.89	0.010
12.7-30.5 cm dbh	0.04	0.20	0.09	0.38	0.543
>30.5 cm dbh	0.15	0.46	0.04	0.21	0.272
Oak snags					
0-12.7 cm dbh	0.85	2.13	1.8	3.9	0.120
12.7-30.5 cm dbh	0.58	1.55	0.51	1.23	0.857
>30.5 cm dbh	0.04	0.20	0.04	0.24	0.785
Area occupied by oak clumps	12.9	28.8	23.7	44.9	0.253
Number of oak clumps	0.65	1.0	1.24	1.58	0.076
Mean large tree spacing (m)	6.5	4.5	5.2	2.8	0.232
(n plots with trees > 15")	(24)		(56)		

^a chi-square analysis.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

Table 10. Vegetation and physical characteristics on 31 0.04-ha plots in which western tanagers nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

Characteristic	Used Plots		Available Plots		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0. 0052 ^a
316-45°	23	43	38	49	
46-135°	42	50	28	45	
136-225°	16	37	19	40	
226-315°	6	25	11	33	
Flat	13	34	3	18	
% ground cover					0. 007 ^b
Rock	2.0	4.6	5.1	6.8	
Bare ground, including roads	9.5	7.8	13.2	12.0	
Litter	76.3	17.9	75	17	
Shrub	5.6	7.1	4.1	6.9	
Grass or forb	6.6	11.3	2.3	4.5	
% slope	6.2	6.1	10.6	9.4	0. 004
% Canopy Closure	46	12	46	13	0. 982
Logs	2.4	2.4	1.6	1.7	0. 114
Total trees (excluding locust)	21.1	15.4	35.2	27.4	0. 002
Ponderosa pines:					
0-12.7 cm dbh	5.3	8.0	10.1	15.4	0. 095
12.7-30.5 cm dbh	7.0	7.8	8.9	9.8	0. 266
>30.5 cm dbh	4.9	3.2	3.4	2.7	0. 010
Oaks:					
0-12.7 cm dbh	1.4	4.3	4.2	9.8	0. 014
12.7-30.5 cm dbh	1.0	2.5	2.1	4.4	0. 101
>30.5 cm dbh	0.03	0.2	0.04	0.21	0. 763
Pinyon or Junipers:					
0-12.7 cm dbh	1.1	1.9	4.9	8.0	0. 001
12.7-30.5 cm dbh	0.2	0.7	1.5	2.7	0. 000
>30.5 cm dbh	0.03	0.2	0.2	0.6	0. 090
Locust stems	8.2	32.2	2.7	12.7	0. 462
Total snags	1.0	1.9	3.2	5.2	0. 001
Ponderosa pine snags					
0-12.7 cm dbh	0.32	0.98	0.44	1.89	0. 847
12.7-30.5 cm dbh	0.06	0.36	0.09	0.38	0. 611
>30.5 cm dbh	0.03	0.18	0.04	0.21	0. 763
Oak snags					
0-12.7 cm dbh	0.35	1.05	1.8	3.9	0. 002
12.7-30.5 cm dbh	0.16	0.58	0.51	1.23	0. 061
>30.5 cm dbh	0.03	0.18	0.04	0.24	0. 893
Area occupied by oak clumps	14.9	34.5	23.7	44.9	0. 323
Number of oak clumps	0.52	0.7	1.24	1.58	0. 013
Mean large tree spacing (m)	5.6	4.0	5.2	2.8	0. 668
(n plots with trees > 15")	(28)		(56)		

^a chi-square analysis.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

Table 11. Vegetation and physical characteristics on 8 0.04-ha plots in which northern flickers nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

Characteristic	Used Plots		Available Plots		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0.48 ^a
316-45°	50	53	38	49	
46-135°	25	46	28	45	
136-225°	0	0	19	40	
226-315°	25	46	11	33	
Flat	0	0	3	18	
% ground cover					0.89 ^b
Rock	4.5	4.4	5.1	6.8	
Bare ground, including roads	10.6	11.1	13.2	12.0	
Litter	77	21	75	17	
Shrub	5.4	9.0	4.1	6.9	
Grass or forb	2.3	4.8	2.3	4.5	
% slope	9.4	6.4	10.6	9.4	0.73
% Canopy Closure	52	17	46	13	0.26
Logs	3.0	2.4	1.6	1.7	0.032
Total trees (excluding locust)	43.6	33.4	35.2	27.4	0.44
Ponderosa pines:					
0-12.7 cm dbh	28.8	28.5	10.1	15.4	0.005
12.7-30.5 cm dbh	10	7	8.9	9.8	0.56
>30.5 cm dbh	3.4	1.4	3.4	2.7	0.59
Oaks:					
0-12.7 cm dbh	0.3	0.7	4.2	9.8	0.001
12.7-30.5 cm dbh	0.0	0.0	2.1	4.4	<0.0005
>30.5 cm dbh	0.0	0.0	0.04	0.21	0.55
Pinyon or Junipers:					
0-12.7 cm dbh	0.6	1.2	4.9	8.0	0.005
12.7-30.5 cm dbh	0.6	0.9	1.5	2.7	0.53
>30.5 cm dbh	0.0	0.0	0.2	0.6	0.37
Locust stems	0.1	0.4	2.7	12.7	0.43
Total snags	1.5	2.7	3.2	5.2	0.36
Ponderosa pine snags					
0-12.7 cm dbh	0.13	0.35	0.44	1.89	0.61
12.7-30.5 cm dbh	0.13	0.35	0.09	0.38	0.65
>30.5 cm dbh	0.50	0.76	0.04	0.21	0.12
Oak snags					
0-12.7 cm dbh	0.75	2.12	1.8	3.9	0.30
12.7-30.5 cm dbh	0.0	0.0	0.51	1.23	<0.0005
>30.5 cm dbh	0.0	0.0	0.04	0.24	0.88
Area occupied by oak clumps	1.9	5.3	23.7	44.9	<0.0005
Number of oak clumps	0.13	0.35	1.24	1.58	0.001
Mean large tree spacing (m)	6.8	6.8	5.2	2.8	0.54
(n plots with trees > 15")	()		(56)		

^a chi-square analysis; in this case results are suspect due to very small sample size.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

Table 12. Vegetation and physical characteristics on 12 0.04-ha plots in which mountain chickadees nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

Characteristic	Used Plots		Available Plots		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0.26 ^a
316-45°	42	51	38	49	
46-135°	8	29	28	45	
136-225°	42	51	19	40	
226-315°	8	29	11	33	
Flat	0	0	3	18	
% ground cover					0.006 ^b
Rock	3.7	4.5	5.1	6.8	
Bare ground, including roads	6.3	8.1	13.2	12.0	(0.002)
Litter	78	26	75	17	
Shrub	2.7	4.9	4.1	6.9	
Grass or forb	9.5	20.8	2.3	4.5	
% slope	8.6	6.6	10.6	9.4	0.48
% Canopy Closure	52	12	46	13	0.11
Logs	2.8	2.1	1.6	1.7	0.057
Total trees (excluding locust)	47.0	35.9	35.2	27.4	0.21
Ponderosa pines:					
0-12.7 cm dbh	22.0	25.4	10.1	15.4	0.20
12.7-30.5 cm dbh	13.5	13.7	8.9	9.8	0.31
>30.5 cm dbh	3.1	2.5	3.4	2.7	0.99
Oaks:					
0-12.7 cm dbh	2.7	4.7	4.2	9.8	0.87
12.7-30.5 cm dbh	2.9	3.4	2.1	4.4	0.26
>30.5 cm dbh	0.0	0.0	0.04	0.21	0.46
Pinyon or Junipers:					
0-12.7 cm dbh	2.5	3.8	4.9	8.0	0.43
12.7-30.5 cm dbh	0.3	0.8	1.5	2.7	0.022
>30.5 cm dbh	0.0	0.0	0.2	0.6	0.004
Locust stems	0.3	0.7	2.7	12.7	0.54
Total snags	3.9	5.1	3.2	5.2	0.40
Ponderosa pine snags					
0-12.7 cm dbh	2.17	5.17	0.44	1.89	0.22
12.7-30.5 cm dbh	0.25	0.62	0.09	0.38	0.39
>30.5 cm dbh	0.17	0.39	0.04	0.21	0.31
Oak snags					
0-12.7 cm dbh	0.58	1.16	1.8	3.9	0.28
12.7-30.5 cm dbh	0.58	1.44	0.51	1.23	0.82
>30.5 cm dbh	0.0	0.0	0.04	0.24	0.61
Area occupied by oak clumps	16.8	23.1	23.7	44.9	0.60
Number of oak clumps	0.67	0.98	1.24	1.58	0.25
Mean large tree spacing (m)	8.5	5.4	5.2	2.8	0.06
(n plots with trees > 15")	(12)		(56)		

^a chi-square analysis; in this case results are suspect due to very small sample size.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

Table 13. Vegetation and physical characteristics on 11 0.04-ha plots in which pygmy nuthatches nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

Characteristic	Used Plots		Available Plots		P
	Mean	SD	Mean	SD	
Aspect (% of plots)					0.25 ^a
316-45°	27	47	38	49	
46-135°	45	52	28	45	
136-225°	0	0	19	40	
226-315°	18	40	11	33	
Flat	9	30	3	18	
% ground cover					0.88 ^b
Rock	5	7	5.1	6.8	
Bare ground, including roads	13	17	13.2	12.0	
Litter	77	18	75	17	
Shrub	3	3	4.1	6.9	
Grass or forb	2	5	2.3	4.5	
% slope	9.4	8.4	10.6	9.4	0.67
% Canopy Closure	50	16	46	13	0.36
Logs	3.2	2.4	1.6	1.7	0.033
Total trees (excluding locust)	35.5	21.7	35.2	27.4	0.80
Ponderosa pines:					
0-12.7 cm dbh	15.4	15.0	10.1	15.4	0.13
12.7-30.5 cm dbh	8.9	5.7	8.9	9.8	0.67
>30.5 cm dbh	4.5	2.8	3.4	2.7	0.25
Oaks:					
0-12.7 cm dbh	0.5	0.8	4.2	9.8	0.014
12.7-30.5 cm dbh	0.8	2.1	2.1	4.4	0.15
>30.5 cm dbh	0	0	0.04	0.21	0.48
Pinyon or Junipers:					
0-12.7 cm dbh	4.1	6.0	4.9	8.0	0.99
12.7-30.5 cm dbh	0.9	1.9	1.5	2.7	0.42
>30.5 cm dbh	0.36	0.67	0.2	0.6	0.28
Locust stems	0.09	0.30	2.7	12.7	0.32
Total snags	2.2	3.0	3.2	5.2	0.83
Ponderosa pine snags					
0-12.7 cm dbh	0.18	0.40	0.44	1.89	0.77
12.7-30.5 cm dbh	0.09	0.30	0.09	0.38	0.87
>30.5 cm dbh	0.45	0.52	0.04	0.21	0.03
Oak snags					
0-12.7 cm dbh	1.3	2.9	1.8	3.9	0.49
12.7-30.5 cm dbh	0	0	0.51	1.23	<0.0005
>30.5 cm dbh	0	0	0.04	0.24	0.62
Area occupied by oak clumps	7.8	17.9	23.7	44.9	0.25
Number of oak clumps	0.55	0.69	1.24	1.58	0.23
Mean large tree spacing (m)	6.2	5.1	5.2	2.8	0.58
(n plots with trees > 15")	(9)		(56)		

^a chi-square analysis; in this case results are suspect due to very small sample size.

^b compositional analysis using MANOVA of log-ratio-transformed percents.

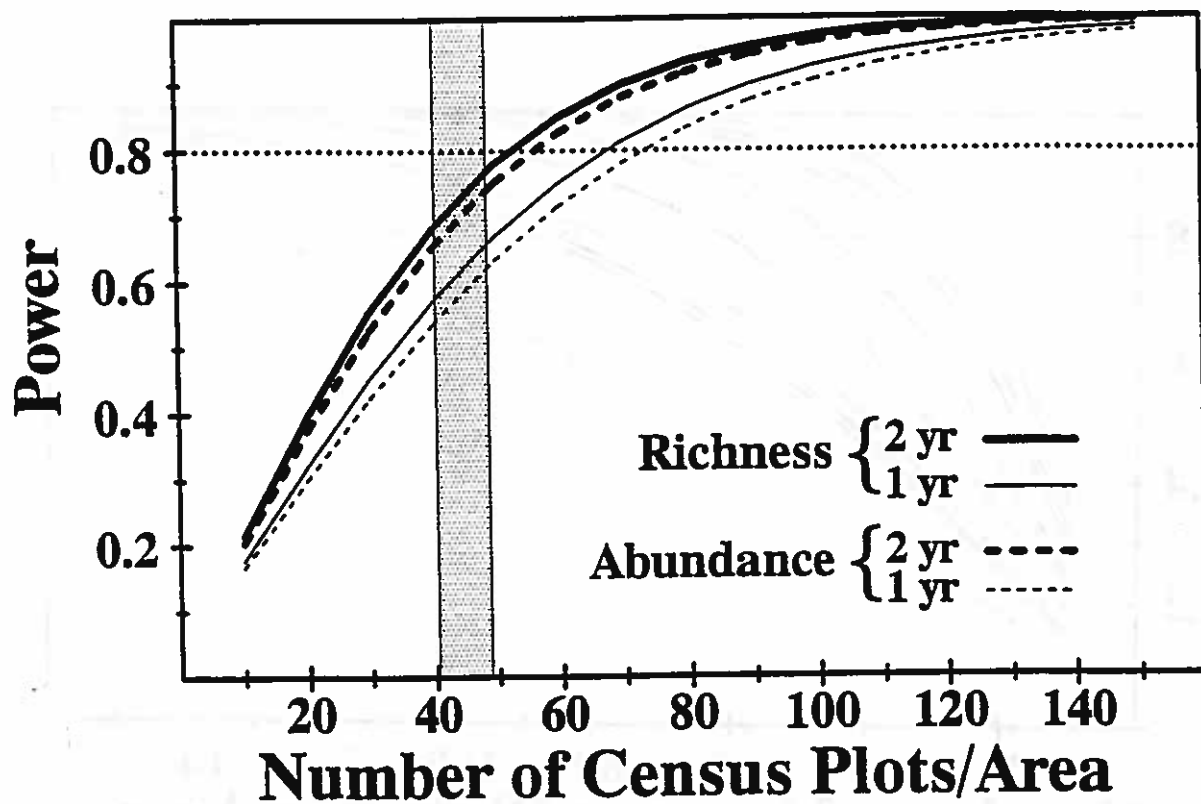


Figure 1. Power of ANOVA to detect a 20% change in species richness (solid lines) and total avian abundance (dashed lines) as a function of number of census plots in each Area (Control and Treatment) and number of years of observation in each Period (pre- and post-treatment), estimated from means and variances observed at Mt. Trumbull in 1996-1997. The dotted horizontal line indicates the desired 80% power threshold, and the shaded rectangle indicates the 40-46 census plots that will eventually be used in the final analyses (given deletion of some of the current 46-48 plots due to inappropriate vegetation or changes in treatment area boundaries).

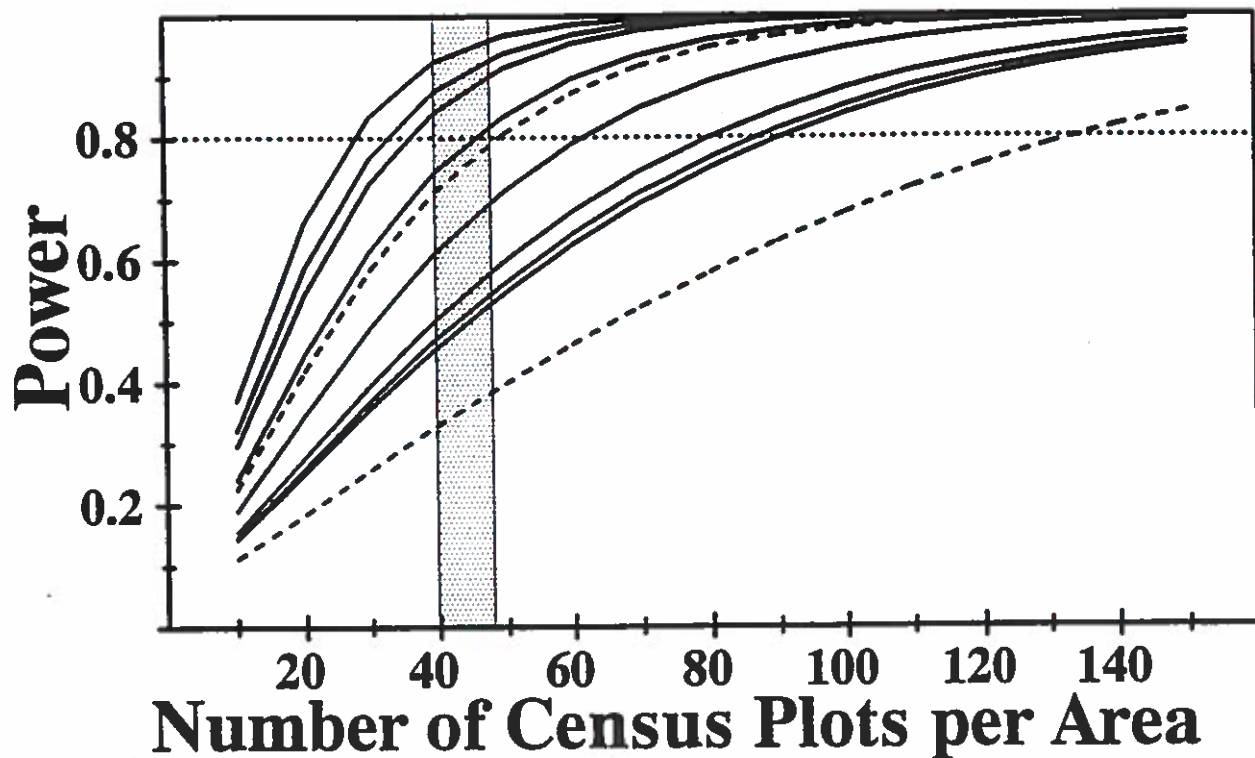


Figure 2. Power of ANOVA to detect a 50% change in abundance of individual species as a function of number of census points in each Area (Control and Treatment), estimated from means and variances observed at Mt. Trumbull in 1996-1997. From top to bottom, the lines depict power curves for mountain chickadee (3rd most abundant species during 1996-1997), Grace's warbler (2nd most abundant), western tanager (5th), pygmy nuthatch (4th), dashed line: white-breasted nuthatch (1st) and yellow-rumped warbler (6th), solitary vireo (7th), spotted towhee (8th), Steller jay (10th), dark-eyed junco (11th), and lower dashed line: gray flycatcher (12th) and western bluebird (9th). Dashed horizontal line and shaded rectangle as in Figure 1. All curves are based on 2 years of observation in each of the pre-treatment and post-treatment periods.

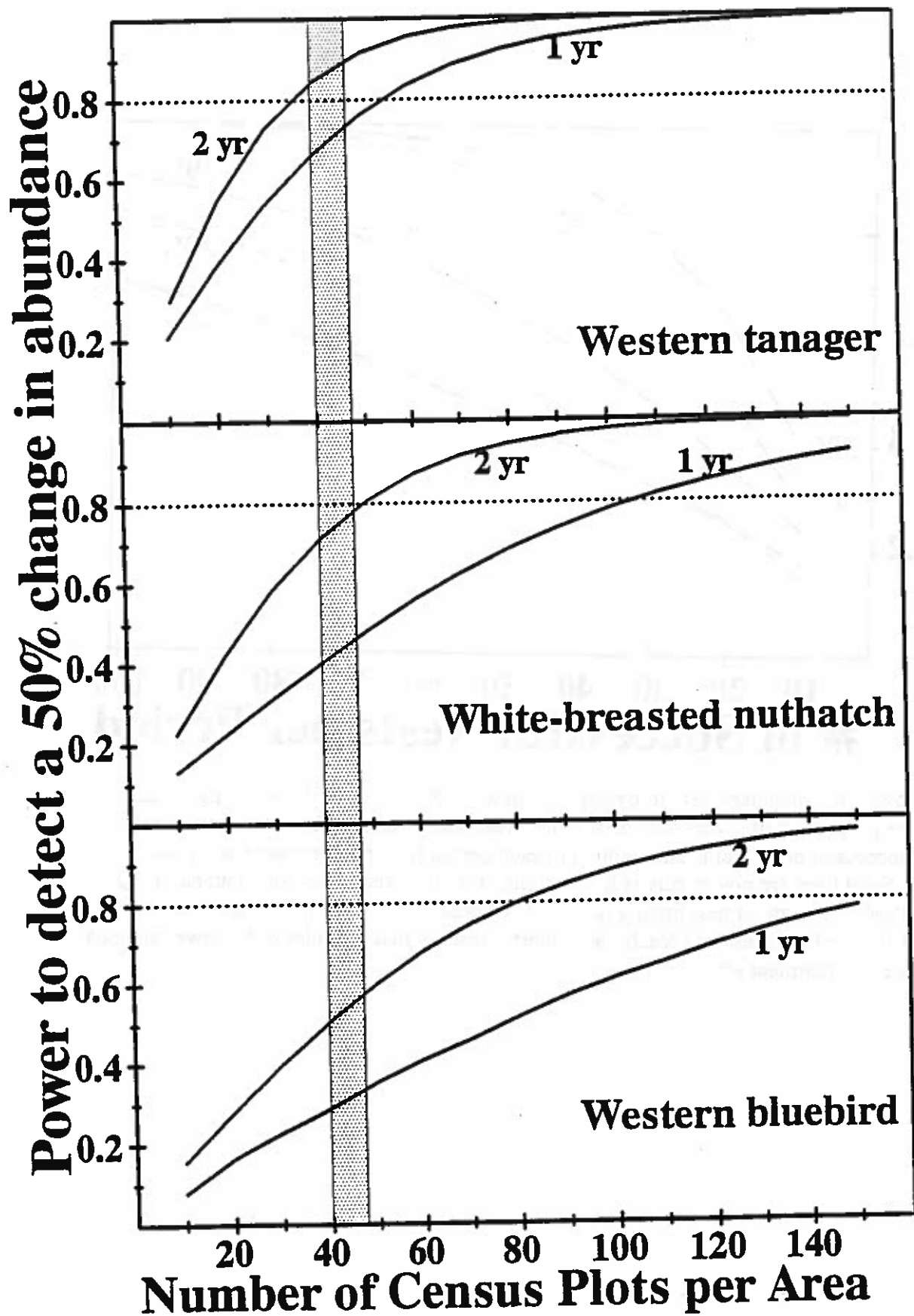


Figure 3. Power of ANOVA to detect a 50% change in abundance of a species as a function of number of years of observation in each Area (Control and Treatment), estimated from means and variances observed at Mt. Trumbull in 1996-1997. Power increased substantially as the number of years of observation increased from 1 to 2. Dashed horizontal line and shaded rectangle as in Figure 1

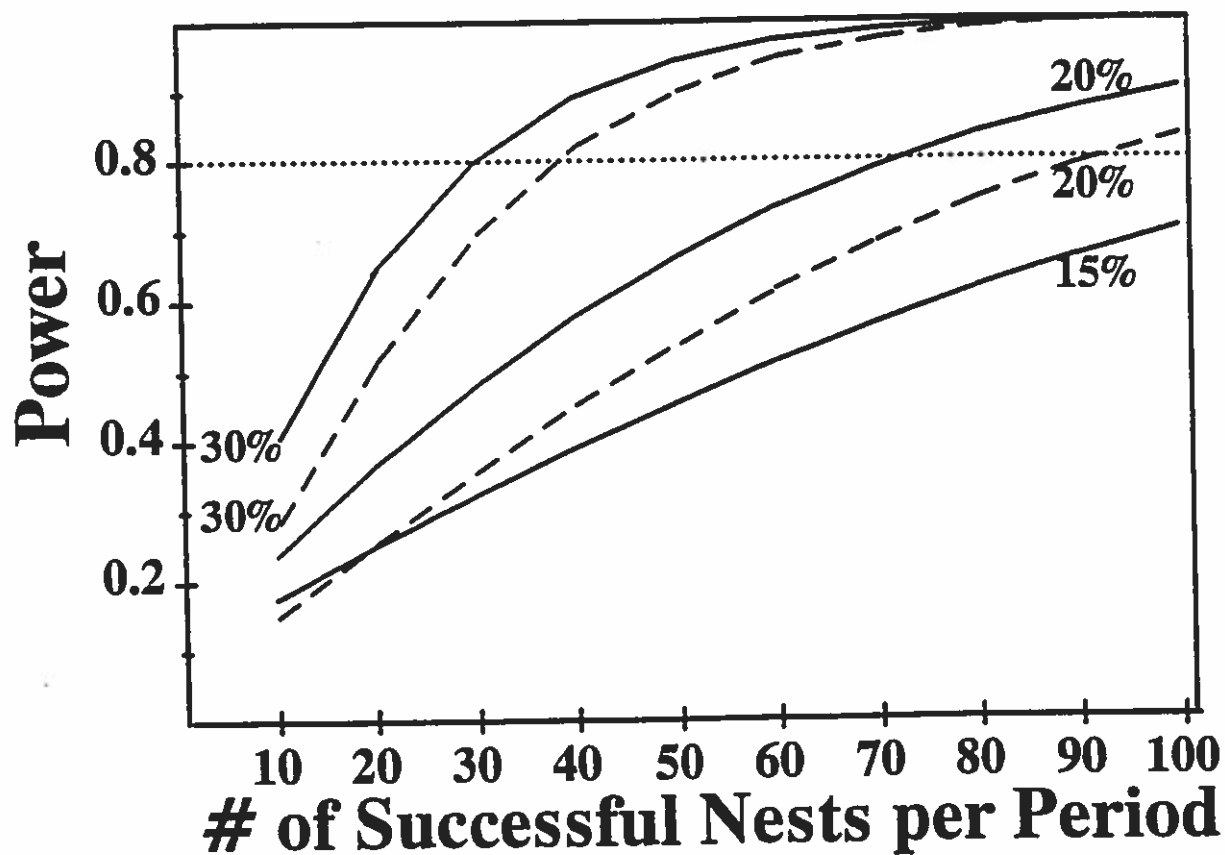


Figure 4. Power of Chi-square tests to detect a change of 15%, 20%, or 30% (i.e. percentage points) in the proportion of successful nests in the Treatment Area as a function of the total number of successful nests that must be found in each period (i.e., pre-treatment and post-treatment). Solid lines are power curves for an alpha of 0.10; dashed lines for an alpha of 0.05. Given our 1996-1997 rate of nest finding (about 10 successful nests per species per year), we would need 1 more field season to reach the 30-nest threshold that provides 80% power at alpha = 0.10 for a 30% treatment effect.