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Selection of foraging habitat by Northern Goshawks on the Coconino National Forest

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The objective of this study is to address the importance of vegetation structure and prey abundance on selection of foraging habitat by northern goshawks in ponderosa pine forests. Thus we are investigating habitat selection within the home range, rather than how home ranges are located in a larger landscape. Our methods were to: (1) Obtain accurate (± 25 m) radio-locations on foraging adult breeding goshawks on the Coconino National Forest, and use these locations as centers of Used Plots; (2) Index prey abundance and measure vegetation/habitat parameters at each Used Plot; (3) Contrast these data with similar data obtained at nearby paired plots with no evidence of goshawk use.

Summary of Progress on Field Work:

Month	What we did:
Jun 1994	1. increased aerial telemetry to 2 flights/week. 2. captured and radio-tagged 9 adult goshawks (4 male, 5 female), bringing total sample of radio-tagged adults to 16 birds. 3. Validated our track-station index for sciurids at 15 plots.
Jul-Aug 1994	1. maintained aerial telemetry at 2 flights/week. 2. used ground telemetry to obtain precise foraging locations of adult goshawks for use as center points of Used Plots. 3. measured vegetation characteristics at foraging locations ("Used Plots") and at paired locations ("Contrast Plots"). We sampled 53 pairs of plots, in addition to 14 plots from the 1993 season. We obtained ≥2 pairs of plots for each of 16 goshawks (6 M, 10 F). 4. indexed density of dominant prey species on these same pairs of plots. Prey surveys were done within 1 week of identifying an area as a foraging site, usually the next day. A total of 64 pairs of plots were sampled. We obtained ≥2 pairs of plots for each of 14 goshawks (5M, 9F).
Sep 1994	1. continued aerial telemetry at 1 flight per week.

Planned Activities:

Oct 94- Mar 95	1. Continue aerial telemetry at 1 flight per week
Dec 94-Feb 95	1. Using snowmobiles as necessary, obtain precise walk-in locations on foraging goshawks during winter. 2. Sample vegetation and prey at paired plots, following same procedures as during Jul-Aug 1994.

FIELD METHODS

Teams of 2 trackers, maintaining radio contact with each other, followed individual birds until the bird seemed to be foraging in 1 general area for at least 30 minutes, based on observed alternation between short (< 3 minutes) bursts of fast pulse rate (presumably flying) and moderately brief (< 10 minutes) periods of slow pulse rate (presumably scanning for prey). Then both trackers approached to within about 100 m of the bird; at this distance there is virtually no signal "bounce" and birds rarely move in response to our activities. Then the observers walked in slowly, keeping exactly to their bearings, scanning the area in front of them for a perched or flushing bird. Either the observed flushing perch or the intersection of the 2 bearing lines was flagged. If the paced lengths of the bearing lines exceeded 150m and the goshawks was not observed, then the attempt was abandoned without further disturbing the bird that day. In over 75% of the cases, we observed the radio-tagged goshawk, or found goshawk feathers or prey remains at the point where the bearings intersected.

The radio-tracking team then flagged out Used Plot centered on the bird location, and immediately selected and flagged a Contrast Plot, centered on the nearest forested location >300 m from any other location for that goshawk.

Prey abundance was indexed on the Used and Contrast Plots. Prey assessments were usually on the first day after the goshawk location was obtained, but occasionally up to 4 days later, so that we sampled the same prey population that was available to the goshawk. A Used Plot and its paired Contrast Plot were always sampled on the same day. Abundance of avian prey was indexed using standard point counts at plot centers (Ralph et al 1992). Each plot was observed for a 10-minute period within 1 hour after sunrise, and a second 10-minute period within 2 hours before sunset, counting all birds heard or seen within 50 m of the plot center.

We grouped the tallies of avian prey into 3 size classes for analysis, based on published body mass. Large birds (75-145 g) included: American robin, Steller jay, northern flicker, Lewis woodpecker, mourning dove, and Clark nutcracker. Medium birds (30-62 g) included hairy woodpecker, hermit thrush, bluebirds, and evening grosbeak, and small birds (12-21 g) included house finch, pine siskin, sparrows, most flycatchers, nuthatches, and dark-eyed junco.

Abundance of sciurids was indexed by counting the number of visits to 100 track stations placed on a 100x100 station grid with 15-m spacing (i.e., 2.25 ha), centered on the plot center. Each station was a 4x5x10-inch box, open at each end, baited with peanut butter and oats. A 4x10" chalked aluminum plate was elevated by velcro attachments just above the floor, and thus track plates were protected from rain, wind, and flooding. Stations were set out immediately after the point counts for avian prey, and were picked up 1 hour before sunset, at which time all tracks were recorded to genus. Although lagomorphs are important prey for goshawks, we were unable to assess their abundance. For analysis, we grouped squirrels into large squirrels (Abert's and rock), medium squirrels (golden-mantled and red), and chipmunks (grey-necked and cliff).

Although we could have increased the number of tracks detected by running track plots for > 1 day and by pre-baiting, we chose not to do so for 2 reasons: (1) The higher count may not be a better index of animal numbers available to the goshawk, but may reflect animals drawn to the bait from outside the plot. (2) Increasing the days of mammal sampling from 1 to 2 would cut in half the number of plots or birds that we can sample. In general it is better to increase sampling at higher levels (i.e., more plots and more birds) than to increase within-site sampling (Link et al. 1994, Ecology 75:1097-1108; also see my analyses below).

During the last 2 weeks of June 1994, we obtained live-trapping estimates of mammalian prey on 15 plots for the 3 days immediately after each plot was sampled with the track stations. We used product-moment correlation coefficients to quantify the correlation between track numbers and animal numbers for each sciurid species.

Table 1. Abundance of prey on 56 Used Plots (used by adult goshawks during Jun-Aug) and 56 paired Contrast Plots, averaged across those 14 adult goshawks (9F, 5M) for which at least 2 pairs of plots were sampled. Significance level (P) is that of a 2-tailed t-test (13 d.f.) of the null hypothesis that the true mean difference is zero.

Prey Group	Used Plots Mean (SD)	Contrast Plots Mean (SD)	Difference	P if < 0.1
Abert's and rock squirrels	0.82 (2.1)	0.60 (1.1)	+0.22	
Golden-mantled and red squirrels	2.14 (2.0)	3.49 (3.6)	-1.35	
Chipmunks	2.92 (2.8)	2.49 (1.8)	+0.44	
Large birds	0.84 (0.9)	0.77 (0.79)	-0.07	
Medium birds	1.01 (0.8)	2.30 (2.12)	-1.29	0.03
Small birds	6.85 (3.5)	8.63 (3.1)	-1.78	0.07

Vegetation was sampled on 1.77-ha (75-m radius) plots, using the same plot centers as for the prey surveys. Each such plot was systematically sampled with strip plots that covered 5% of the area, within which we measured tree heights, canopy heights, tree diameters, canopy closure (by point-intercept at 91 points), ground cover (by point intercept, tallying each of 91 points as grass, forb, shrub, rock, soil, litter, downed wood, etc.), and shrub-sapling numbers. We tallied all large (> 12" dbh) and small snags, and all large logs (≥12 inches in diameter at midpoint and ≥8 feet long) and small logs (6-12" in diameter at midpoint and > 4 ft long; or >12" diam and 4-8-ft long) on 14% of the plot.

We also recorded 3 physiographic parameters at each Used and Contrast Plot. They were: slope (%), aspect (the nearest of the 8 standard compass directions), and topographic position (flat, midslope, ridge, or drainage).

For each pair of Used and Contrast plots, we computed the *difference* in prey abundance indices and vegetation parameters. This approach reduced problems that arise due to seasonal changes in indices of prey abundance. The mean of the differences also has a much smaller standard error than the difference of the means, and is thus advantageous for statistical testing. We then computed an average difference for each trait for each radio-tagged goshawk. We used paired-comparisons t-tests to whether the mean difference across birds was different from zero.

RESULTS

The results herein are tentative and subject to further analysis.

Track Stations as an Index of Sciurid Abundance

Track station visitation rates were highly correlated with the number of animals live trapped on the 15 plots that were double-sampled in June 1994. The correlations (r^2) were 0.71 for golden-mantled squirrels, 0.79 for chipmunks, and 0.76 for rock squirrels (Figure 1). Most plots had zero tracks and zero captures of Abert squirrels and red squirrels, so no meaningful analysis was possible for these species.

Prey Abundance

Prey abundance did not seem important in selection of foraging areas by goshawks. The only statistically significant trends were that there were *fewer* small and medium-sized birds on Used Plots compared to Contrast Plots (Table 1, Figure 4). These 2 differences may have no ecological significance because small and medium-sized birds are not important goshawk prey. The only real value of this result is to show that our field and analytic methods are powerful enough to detect differences if they are present.

Large birds, and sciurids of all sizes, did not differ in abundance between used and contrast plots. We used our data to estimate the sample size (number of radio-tagged goshawks) that would be required to detect a significant ($P < 0.05$) difference in prey abundance for each of the remaining 4 prey categories. This analysis suggests we would need a sample of 130 radio-tagged birds to conclude that goshawks were selecting sites higher in abundance of chipmunks. We would need much larger samples for large avian prey and the other 2 squirrel groups. We conclude that it would be futile to gather more breeding-season data using this sampling scheme.

This result does NOT mean that "prey abundance in not important in goshawk ecology." For instance, goshawks may choose to nest only in habitats that have "enough" prey. Our study merely shows that in selecting sites *within a home range*, goshawks apparently did not pay much attention to prey density. Research on a landscape scale may well demonstrate that territory size, population density, and breeding success vary with prey density.

Physiographic Characteristics

There was no difference between Used Plots and Contrast Plots in percent slope, aspect, or topographic position. For instance, the mean slope on Used Plots was 7.4% (SD = 7.5%) compared to 6.3% (SD = 5.1%) on the Contrast Plots.

Vegetation Characteristics

The most striking finding was that Used Plots showed enormous variation in vegetation structure. Goshawks used sites ranging from doghair thickets to widely-spaced stands of large trees. In terms distribution of tree diameters (Figure 2, top), tree density (Figure 2, middle) and canopy closure (Figure 2, bottom), the range of sites used by goshawks was impressively broad, and comparable to the range found in Contrast Plots.

Despite the wide variation in vegetation structure among Used Plots, the Used Plots did differ from Contrast Plots in several vegetative characteristics (Table 2). Used plots had more trees overall (a tree was defined as > 4" dbh), more trees in the 8-16" dbh and >16" dbh size classes, and more trees >18m tall. Used plots had greater canopy closure as well. Although for most parameters the mean difference was small (e.g., canopy closure averaged 48% on Used Plots and 43% on Contrast Plots), the difference was so consistent across birds (Figure 3) that they were statistically significant.

We used our data to estimate the sample size (number of radio-tagged goshawks) that would be required to detect a significant ($P < 0.05$) difference in the 12 characteristics that showed no significant difference so far. Although 22 goshawks might be sufficient to detect a difference in the number of trees 12-18m tall, we would need samples of >33 goshawks to detect significant differences in other characteristics. We conclude that little if anything would be gained from gathering more breeding-season data using this sampling scheme.

Table 2. Vegetation characteristics on 63 Used Plots (used by adult goshawks during Jun-Aug) and 63 paired Contrast Plots, averaged across those 16 adult goshawks (10F, 6M) for which at least 2 pairs of plots were sampled. Significance level (P) is that of a 2-tailed t-test (15 d.f.) of the null hypothesis that the true mean difference is zero.

Vegetation Characteristic	Contrast Plots Mean	Contrast Plots SD	Used Plots Mean	Used Plots SD	Difference (Used-Cont)	P (if < .1)
% ground cover						
grasses and forbs	9.93	7.96	9.75	8.68	- 0.2	
bare ground including roads	14.66	6.14	12.22	5.12	- 2.4	0.096
litter	66.07	10.03	68.51	11.97	+ 2.5	
downed wood or stump	2.78	1.74	3.06	1.98	+ 0.3	
rock	5.82	3.05	4.74	2.59	- 1.1	0.085
number of shrubs in plane of tape	36.1	34.8	39.3	42.4	+ 3.2	
% Canopy Closure	43.1	8.4	48.3	11.0	+ 5.3	0.006
Large snags on 0.25-ha plot	0.83	0.52	1.09	0.97	+ 0.3	
Small snags on 0.25-ha plot	5.1	6.1	7.4	14.9	+ 2.4	
Large logs on 0.25-ha plot	4.7	2.2	4.4	2.1	- 0.3	
Small logs on 0.25-ha plot	6.7	3.0	7.7	4.2	+ 1.1	
TREES/HECTARE:						
total trees (> 4" dbh)	478	188	614	270	+136	0.008
0-8" dbh	658	453	761	540	+103	
8-16" dbh	213	60	259	82	+ 46	0.039
>16" dbh	30.4	17.3	51.6	25.6	+ 21	0.0005
0-6 m tall	390	253	438	248	+ 48	
6-12 m tall	300	199	400	399	+100	
12-18 m tall	142	67	167	59	+ 25	
>18 m tall	30	27	63	78	+ 33	0.069

Sex Differences

Although we have done no statistical analyses for differences between the sexes, scatterplots (e.g., Figure 3, 4) clearly indicate that the sexes did not differ in habitat selection in any meaningful way.

What's next?

Analyses.–The next level of analysis will be to examine interactions between vegetation structure and prey abundance, using data from the 54 pairs of plots where we sampled both vegetation and prey. Although small sample size may preclude strong inferences from our data, such analyses may suggest directions for further research.

Field Work.--Our methods have sufficient power to detect differences in both prey abundance and vegetation structure between Used and Contrast Plots. Given the answers already obtained, and the huge sample sizes that would be needed to detect additional differences during the breeding season, we see little to be gained from collecting more of the same data during the 1995 breeding season.

We now plan to apply the same methods to investigate selection of habitat during winter (Dec-Feb). We are currently attempting to locate and repair 2 snowmobiles for a winter season. Our funding appears sufficient for an 8-week field season, perhaps 10 weeks if snowmobile repairs are minimal.

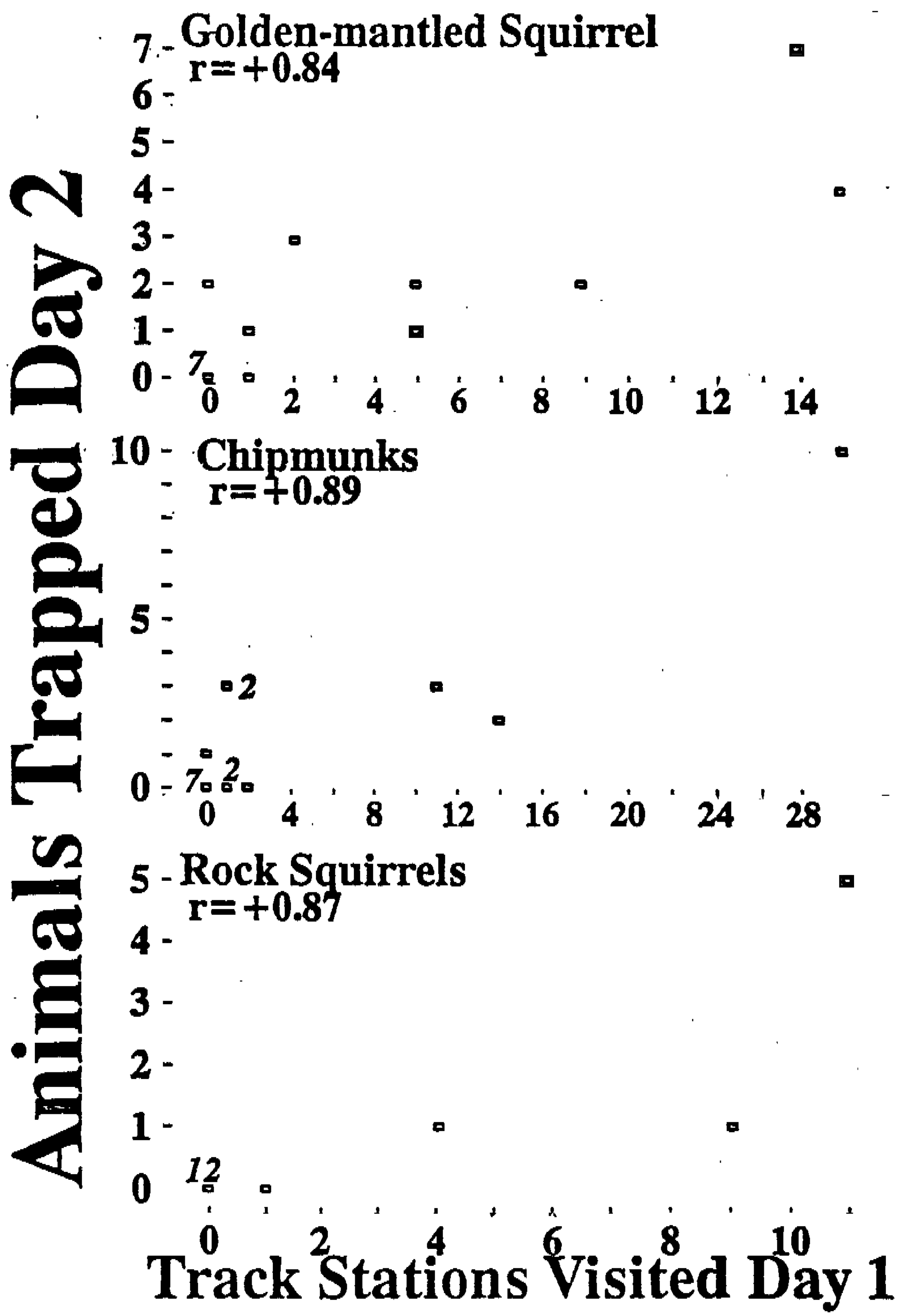

Figure 1. Correlation between number of track stations visited by animals of a taxon during a diurnal period and number of individuals of that taxon trapped the next day on the same plot on 15 plots double-sampled in June 1994. Numbers in italics indicate number of plots with identical x-y coordinates.

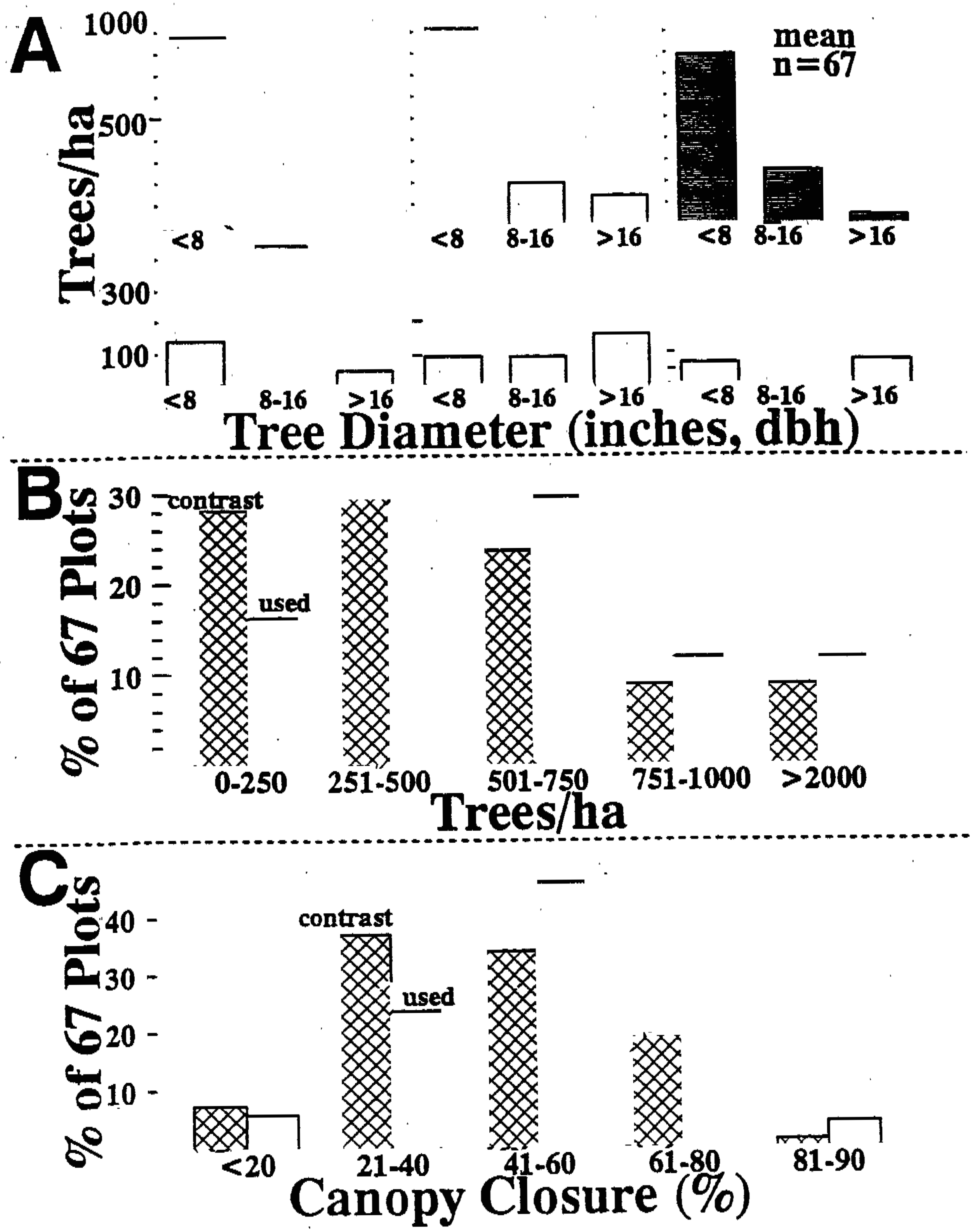

Figure 2. Plots used by goshawks varied in vegetative characteristics. (A) Distributions of tree diameters on individual Used Plots included dense doghair (upper left), pole-dominated sites (lower left), and plots dominated by large trees with varying numbers of smaller trees (lower center and lower right). Few stands resembled the mean (upper right). (B) Although goshawks tended to use plots with higher stem density, 16% of Used Plots had <250 trees/ha (<100 trees/acre, divide by 2.5 to roughly convert). (C) Although goshawk tended to use plots with higher canopy closure, 30% Used Plots had canopy closures <40%, and a few had <20% closure.

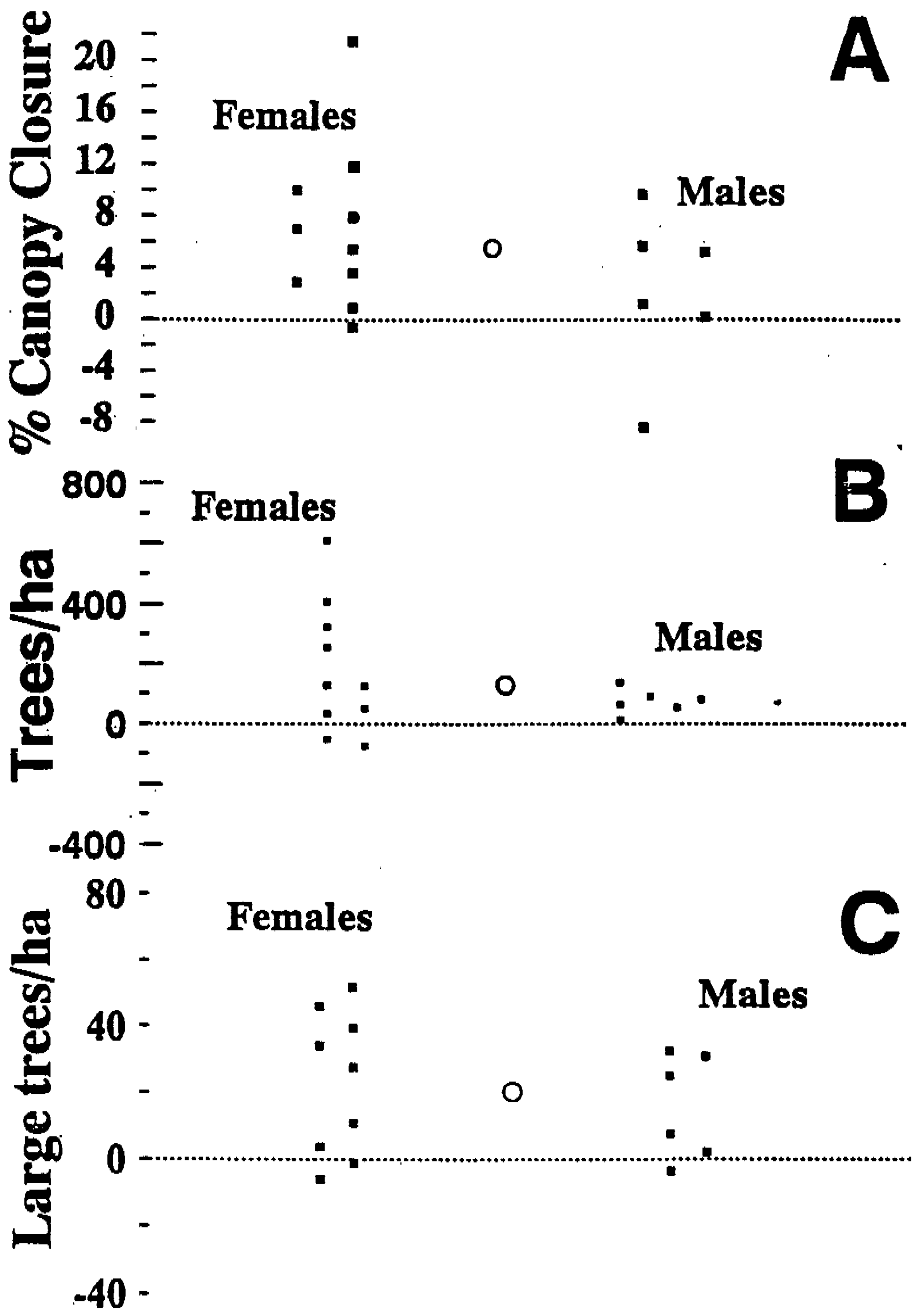

Figure 3. Differences between Used Plots and nearby paired Contrast Plots in canopy closure (A), total number of trees (B), and number of large (>16" dbh) trees per hectare (C). Each square indicates the mean difference (Used-Contrast) for one adult female (left, n = 10) or adult male (right, n = 6) goshawk. Squares above the dashed zero line indicate that the mean value for Used Plots exceeded the mean value for Contrast Plots for that goshawk. The circle represents the grand mean across 16 goshawks.

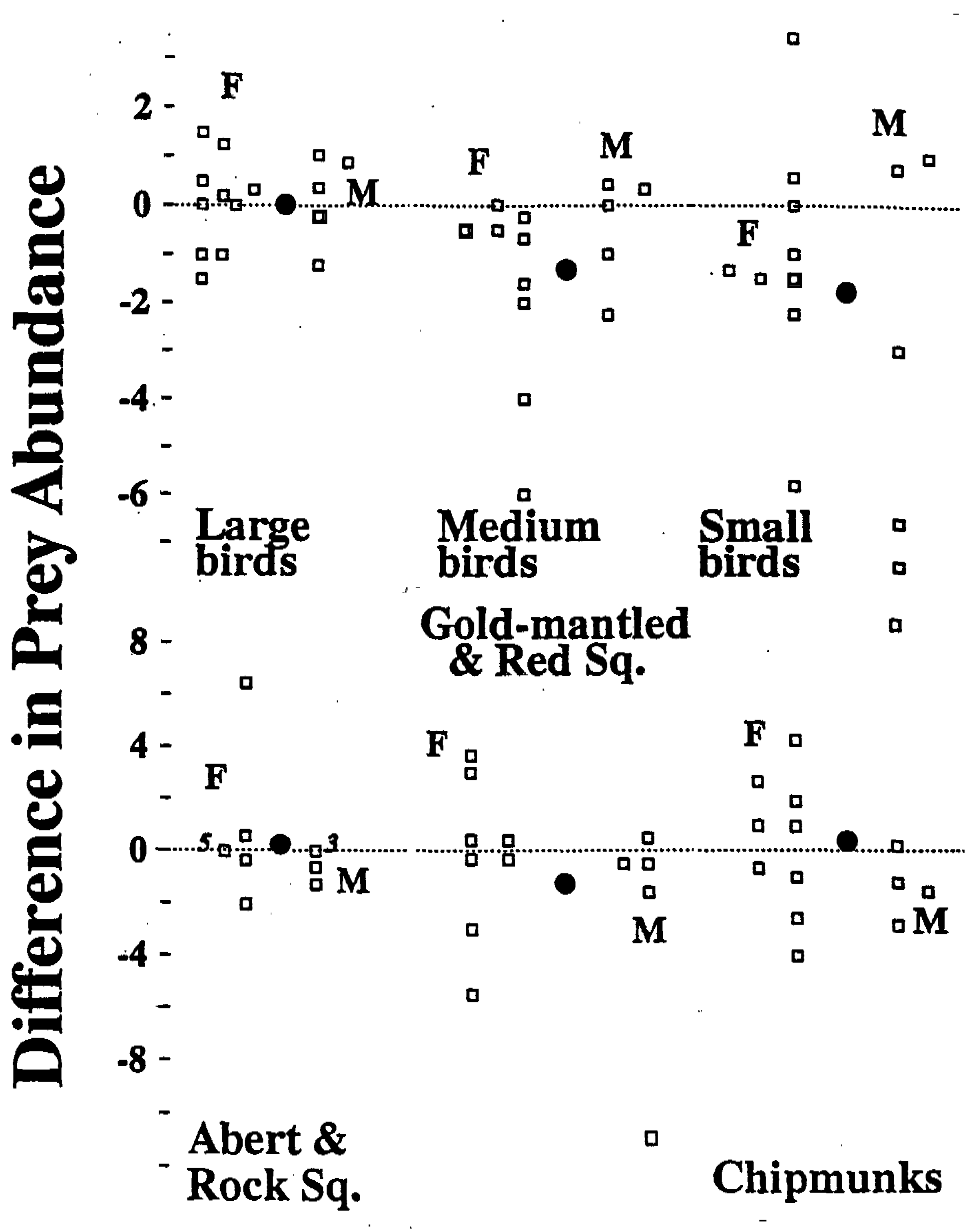

Figure 4. Differences between Used Plots and nearby paired Contrast Plots in abundance of avian prey (A) and diurnal sciurids (B). Each square indicates the mean difference (Used-Contrast) for one adult female (left, n = 9) or adult male (right, n = 5) goshawk. Squares above the dashed zero line indicate that the mean value for Used Plots exceeded the mean value for Contrast Plots for that goshawk. The circle represents the grand mean across 14 goshawks. Italicized numbers in the Abert/Rock Squirrel plot indicate number of birds with a mean difference of zero.