

SAGUARO NATIONAL PARK

Final Report

Title: Ecology of introduced Abert's squirrels in Saguaro National Park

Date Submitted: 15 February 2008

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Introduction

A major threat to biological diversity is the intentional or accidental introduction of non-native species to ecosystems (Primack 1993). Such introductions can disrupt the function of their new ecosystem through a number of mechanisms to include the spread of disease, competition, predation, reproductive success, and induced habitat change. Because exotic species did not evolve in their new ecosystem, the results of translocations are unpredictable. In some cases, the species is so poorly adapted to the new environs that the introduced population becomes extinct, and the impact on the ecosystem is negligible. However, some exotics are quite successful and have a profound and negative impact on the ecosystem (Primack 1993). For example, the prognosis for the European red squirrel (*Sciurus vulgaris*) in the British Isles is poor, and the likely outcome extinction due to the introduction of the eastern gray squirrel (*Sciurus carolinensis*) from the USA over 120 yr ago (Rushton et al. 1997).

Exotic species are a problem in many management settings; however, in fragmented environments introduced species can be especially problematic. National parks often serve as such relicts of habitat. Abert's squirrels (*Sciurus aberti*), a large diurnal tree squirrel of 600-800g, were introduced to several montane forests by the Arizona Game & Fish Department in 1940-41 to increase hunting opportunities (Davis and Brown 1988). The introductions were remarkably successful in establishing this squirrel; one site was the Santa Catalina-Rincon Mountain complex (Brown 1984) where 59 individuals were introduced (Davis and Brown 1988). Introductions were stopped when concerns were expressed over the impact of the exotic tree squirrels on the uncommon native Catalina gray squirrel (*Sciurus arizonensis catalinae*: Cockrum 1960, Lange 1960).

Subspecific status of *Sciurus arizonensis* is poorly known. Hoffmeister (1986) used morphometrics to suggest that the species should be monotypic; however, Yensen and Valdes-Alarcon (1999) questioned this decision based upon the apparent lack of overlap in cranial

morphometrics and suggested that a reassessment of the intraspecific taxonomy is necessary. The Catalina gray squirrel is smaller and morphologically distinct from the nearest population to the south (Hoffmeister 1986) and has likely been isolated on these mountains without congeneric competitors since the last ice age that occurred some 7,000 to 10,000 years ago (VanDevender & Spaulding 1979). The introduced Abert's squirrel has been implicated in the decline of the uncommon native in the last half of the 20th century (Lange 1960, Brown 1984); however, the evidence is only anecdotal and some doubt the validity of this claim (Davis and Sidner 1992). Both species rely on the reproductive tissues of trees for survival, and the potential for ecological overlap is immense (Best & Riedel 1995, Nash & Seaman 1977). Moreover, Abert's squirrels are known to reduce cone crops of ponderosa pine by as much as 55% (Allred et al. 1994), a known food source of Catalina gray squirrels (Best & Riedel 1995). As a result, the potential for ecologically significant interactions between the species is high. The conservation status of Arizona gray squirrels is poorly understood; however, the species is considered threatened in Mexico (Yensen and Valdes-Alarcon 1999). In 1991, Catalina gray squirrels were afforded protection as a Category 2 species (Drewry 1991) in recognition of potentially precarious status and the dearth of life history information; yet to date not a single paper on the ecology of Arizona gray squirrels exists. This formal status was retained until the abolition of the category by the U.S. Fish and Wildlife Service after which the Coronado National Forest considered the species to be sensitive. Both species historically occurred in the higher elevations of the East Unit of Saguaro National Park, where their distribution and populations are poorly known. The impact of a potentially invasive species must be documented to assess the consequences of its presence in the forest ecosystems of Saguaro National Park.

Abert's squirrels were first documented in the Rincon Mountains in 1959 (Davis and Sidner 1992) after their release in the Santa Catalina Mountains in 1940-41, suggesting a natural colonization event (Davis and Brown 1988). Abert's squirrels have been observed at Spud Rock, Manning Camp, near Mica Tower, along the trail to Happy Valley Knoll, Deerhead Spring, near Man Head Rock, and 3.2 km above Cow Head Saddle (Davis and Sidner 1992). No voucher specimens are known for Abert's squirrels in the Rincon Mountains (Davis and Sidner 1992). Davis and Sidner (1992) considered Abert's squirrels to be common in the high elevation forests of the Rincons.

Catalina gray squirrels were first formally described by Doult (1931) from a specimen taken in 1927 at Soldier Camp in the Santa Catalina Mountains of Pima County, Arizona, and first documented in the Rincon Mountains in 1932 by Huey (Davis and Sidner 1992). Catalina gray squirrels are considered to be low elevation pine-oak and riparian dwellers (Davis and Sidner 1992); however, this species can also be found in high elevation forests (Brown 1984, Hoffmeister 1986). In support of the potential habitat segregation of these 2 species, Swann and Powell (2006) only trapped and remotely photographed Abert's squirrels in high elevations, whereas Catalina gray squirrels were never trapped and photographed twice at mid-elevations and once at high elevations. Four specimens of Catalina gray squirrel were collected by Huey from Spud Rock Cabin at about 7300 ft (Cockrum 1960, Hoffmeister 1986). Davis and Sidner (1992) considered Catalina gray squirrels to be rare in Saguaro National Monument and this conclusion is supported by the lack of captures and the lowest relative abundance of any mammal documented by remote infrared-triggered photography in the mid- and high elevation surveys of Swann and Powell (2006).

The Rincon Mountains represent a fragment of montane forest surrounded by a matrix of hostile habitat for most non-volant forest dwelling mammals. Managing wildlife populations in such discrete isolated refugia presents numerous challenges in particular when human usage promises to effect changes in the forest fragments and the desert matrix (DeBano et al. 1995). Natural disturbances such as fire, disease, and windfall provide challenges to effective resource management. Exotic species introduced by humans to habitat isolates, however, can have particularly devastating consequences to native communities. Because of the success in expanding their range following introductions, Abert's squirrels demonstrate the potential for significant impact on the forests of Saguaro National Park. Uncommon competitors such as the Catalina gray squirrel are likely to serve as excellent indicators of impact and enable development of prudent management strategies. Herein, we document the persistence and not the uncommon occurrence of Catalina gray squirrels in the Rincon Mountains and Saguaro National Park. Furthermore, we document the considerable abundance and overlap that occurs between introduced Abert's squirrels and native Catalina gray squirrels.

Objectives:

1. Survey the distribution of exotic Abert's and native Catalina Gray Squirrels in Saguaro National Park East.
2. Identify localities where overlap does and does not occur.
3. Quantify vegetation characteristics in areas where the species occur.
4. Assess nest characteristics and use of each species

Methods

Study Site. The study area was located in the Rincon District of Saguaro National Park approximately 21 km east of Tucson, Arizona. The park encompasses the 23,443-ha Saguaro Wilderness Area. Our study area is within the higher park elevations, from 1372 to 2641 m (Mica Mountain Peak) and includes oak woodland, pine-oak woodland, pine forest, and mixed conifer forest. During 2003 and 2004, our study was focused at Grass Shack Spring (1615 m), Happy Valley Saddle (1890 m), Spud Rock Spring (2256 m) and Manning Camp (2438 m). During 2005, we surveyed for squirrel dreys (leaf nests) and activity in Happy Valley Saddle and at varying elevations within Chiminea Canyon, Miller Canyon, and the gallery forest along Paige Creek adjacent to Forest Service Road 35. Fieldwork in 2006 was concentrated in Happy Valley Saddle and upper portions of Miller Canyon.

General Approach. We observed two distinct types of tree squirrel nests in the Rincon Mountains: nests composed of pine (*Pinus*) needles and nests composed of oak (*Quercus*) leaves. Arizona gray squirrels are reported to use Apache pines (*P. engelmannii*) for nesting, but rely largely on oak trees and construct conspicuous leaf nests (Best & Riedel 1995, Hoffmeister 1986). Arizona gray squirrels also nest within the cavities of ash (*Fraxinus*), cottonwood (*Populus*) and sycamore (*Plantanus*) trees (Fig. 1, Best & Riedel 1995). In contrast, Abert's squirrels primarily construct nests of pine needles and branches (Nash & Seaman 1977). Abert's squirrels have been rarely observed utilizing cavities of oaks and cottonwoods for nests (Hoffmeister 1986). From Fall 2003 until Winter 2004, we relocated historic nest sites and

searched for new nests. We measured vegetation at a sampling of nests found, as well as vegetation measurements from randomly selected trees.

Sampling Design. Between Fall 2003 and Winter 2004 we relocated and searched historic locations of sightings of Catalina gray and Abert's squirrels (Davis & Sidner 1992, Cockrum 1960), as well as surrounding riparian zones. We also performed cluster sampling around known nests (Morrison et al. 1999). In summer 2004 we conducted a stratified random sample (Morrison et al. 1999) of 13 100-m transects in higher elevation (1372 m and up) oak, pine, and spruce/fir zones of the park, to search transects for sign of both Catalina gray and Abert's squirrels (nests, cone cobs, cone scales, and clipped twigs, Fig. 2) (Steele and Koprowski 2001). Due to ruggedness of terrain and relatively low availability of suitable tree squirrel habitat, the start of most transects were located no more than 800 m from a trail. Transect locations were randomly generated using ArcView. Tree squirrels build conspicuous bolus-shaped nests (dreys) that are readily distinguishable from bird nests (Brown 1984). We included both active and inactive nests, as judged by their level of disrepair. At a randomly determined location, we chose the nearest tree with a DBH of larger than 10 cm as the focal tree for a random vegetation plot.

We recorded descriptive and vegetative characteristics of focal nest and random trees. Characteristics included: (1) tree species, (2) diameter at breast height (DBH), (3) tree height, (4) number of interdigitated branches (branches ≤ 1 m from another tree; the distance that a squirrel could jump), (5) habitable crown area (crown width from lowest large branches to top of crown), and (6) canopy cover (averaged for each plot using a spherical crown densiometer). For the nest trees only, we also recorded nest height and nest composition. We recorded characteristics for the surrounding area as well with a 10-m diameter circular plot. For each circular plot (radius = 10 m) around the focal tree (nest and random), we measured vegetation characteristics to include elevation, slope, and aspect, as well as number, species, and DBH of all trees (> 10 cm DBH) within the plot, amount of canopy cover, and understory density (measured by the number of 10 cm sections covered on a 2-m pole, and the number of shrub stems within the plot: Higgins et al. 1996). Canopy cover and shrub density were collected between May and September to avoid periods of leaf loss. Random transects serve for comparison of squirrel habitat preference, as well as random habitat sites to compare with known squirrel territories. We also selected an

additional 36 random points in Happy Valley Saddle and upper Miller Canyon as these were the locations where we found the most overlap and nests for the 2 species.

To analyze vegetation characteristics in a univariate manner between nest and random trees as well as pine and oak trees, we used 2-sample *t*-tests. To analyze differences between random sites, Abert's squirrels, and Arizona gray squirrels we used ANOVA. In a multivariate approach we performed a factor analysis with a PCA rotation of the habitat plot variables followed by a varimax rotation. We examined site (Abert's squirrel nest, Arizona gray squirrel nest, random) differences between the first two principal components with an ANOVA on the principal components scores. Differences between groups in an ANOVA were assessed by Tukey-Kramer HSD. Group membership of Arizona gray squirrel and Abert's squirrel nest sites were also compared in a stepwise Discriminant Function Analysis where all individual habitat variables were pared down to the most descriptive. Most analyses were completed with JMP-IN 5.1 (SAS Institute Inc. 1989), and the PCA rotation was performed in Minitab (Minitab Inc. 2000).

Trapping and Radiocollaring Efforts. Peanuts and peanut butter were scattered at 15 baiting stations in an attempt to habituate squirrels to trap locations and Tomahawk live-traps were set during daylight hours to check every 2-3 hours. Trapping success was extremely poor and we quickly realized that Arizona gray squirrels were extremely uncommon; therefore, we shifted our focus to collar any animal that was captured and to use these animals to locate definitive nest sites that would provide insight to the status and ecology of both species. This change from the original proposal was necessary due to the low density of the native species, yet we feel permitted greater emphasis on trapping and survey efforts. Five stations north of the campground in Happy Valley Saddle were the most successful and much of the trapping effort was concentrated at these sites after initial surveys of the Rincons were concluded (Fig. 3). Captured squirrels were transferred from traps to a cloth handling cone (Koprowski 2002), physical data collected (sex, age, reproductive condition, body mass), and fitted with a radiocollar. Animals were released immediately at the site of original capture. Radiocollared squirrels were followed to nests < 2 hours before sundown to find additional nests for analysis. During these periods, lost collars (collars found with no signs of predation) and squirrel mortalities were identified and recorded. Seasonal fluctuations in body mass were analyzed with

multiple regression and ANOVA in JMP-IN 5.1 (SAS Institute Inc. 1989). Mean $\pm$ SE are presented throughout the text.

Results

Survey. We found no evidence of Arizona gray squirrel presence in Chiminea Canyon or along Paige Creek. Four dreys were located at Grass Shack but all appeared to be old and in decay; Arizona gray squirrels were sighted at this location in 2004 and photographed by Don Swann, National Park Service. However, Arizona gray squirrels were observed on numerous occasions throughout the study period in Miller Canyon and Happy Valley Saddle. In particular, both Arizona gray squirrels and Abert's squirrels made daily visits to ephemeral pools at Happy Valley Saddle as other water sources diminished in the fall. Abert's squirrels were recorded from all high elevation sites including Manning Camp, Spud Rock Campground, Happy Valley Saddle, Mica Mountain, and upper Miller Canyon but appeared absent from lower elevation sites including Grass Shack Campground.

Nest Sites vs. Random Sites. We discovered 87 nest trees in the higher elevations of the Rincon Mountains, only 6 of which were leaf nests in oak trees. Squirrels used Ponderosa pine trees more for nests than their availability on the landscape and also nested in Arizona White pines (*Pinus reflexa*), Silver-leaf oaks (*Quercus hypoleuroides*), and Arizona white oaks (*Q. arizonica*; Fig. 4). Arizona gray squirrels were almost exclusively found nesting in oaks ($n = 5$). We surveyed 9 random transects and measured characteristics of 44 nest and 45 random trees. Squirrels selected nest trees (mean = 55.02 ± 2.57 cm SE) with greater DBH than random trees (mean = 31.12 ± 2.54 cm; $t = 6.62$, $df = 87$, $p < 0.0001$). Tree height was almost twice as great in nest trees (mean = 21.33 ± 0.99 m) than random trees (mean = 11.29 ± 0.97 m; $t = 7.25$, $df = 87$, $p < 0.0001$). Nest trees had more interdigitated branches (mean = 4.02 ± 0.25 branches) than random trees (mean = 2.44 ± 0.25 branches; $t = 4.51$, $df = 87$, $p < 0.0001$). Habitable crown area in nest trees was on average 5.3 m taller (mean = 11.22 ± 0.57 m) than random tree crown area

(mean = 5.89 ± 0.57 ; $t = 6.47$, $df = 86$, $p < 0.0001$). Nest sites (mean = $12.02^\circ \pm 2.16^\circ$) were found on less steep sites than random sites (mean = $23.64^\circ \pm 2.07^\circ$; $t = 3.89$, $df = 84$, $p = 0.0002$) but did not differ by aspect. Nest trees provided a greater overall percentage of canopy cover (mean = $80.48 \pm 2.34\%$) than random sites (mean = $66.09 \pm 2.28\%$; $t = 4.43$, $df = 85$, $p < 0.0001$). However, nest sites (mean = 11.2 ± 1.04 trees/plot or 373 ± 34.5 trees/ha) had on average about 2 fewer live trees per plot (80 trees/ha) than random sites (mean = 13.6 ± 1.02 trees/plot or $455 \text{ trees/ha} \pm 34.1$; $t = 1.67$, $df = 87$, $p = 0.09$), but nest sites did have higher overall basal area (mean = $1.16 \pm 0.07 \text{ m}^2/\text{plot}$ or $38.9 \pm 2.42 \text{ m}^2/\text{ha}$) than random sites (mean = $0.77 \pm 0.07 \text{ m}^2/\text{plot}$ or $25.8 \pm 2.39 \text{ m}^2/\text{ha}$; $t = 3.85$, $df = 87$, $p = 0.0002$), indicating squirrels selected sites with overall fewer but larger trees. Nest sites also had more logs (mean = 1.69 ± 0.09 logs/site or 63.63 ± 3.04 logs/ha) than random sites (mean = 0.76 ± 0.09 logs/site or 25.19 ± 3.03 logs/ha; $t = 2.37$, $df = 87$, $p = 0.02$) and a higher volume of logs (nest site mean = $0.89 \pm 0.07 \text{ m}^3/\text{plot}$ or $29.53 \pm 1.78 \text{ m}^3/\text{ha}$; random site mean = $0.31 \pm 0.07 \text{ m}^3/\text{plot}$ or $10.27 \pm 1.77 \text{ m}^3/\text{ha}$; $t = 2.84$, $df = 87$, $p = 0.006$). Understory was more dense at random sites than at nest sites. Our 2-m pole had over 6 more sections covered at random sites (mean = 9.87 ± 0.91 sections) than at nest sites (mean = 3.59 ± 0.92 sections; $t = 4.83$, $df = 87$, $p < 0.0001$). Also, shrub stem densities were found at random sites (mean = 36.11 ± 5.18 stems/plot) than nest sites (mean = 22.59 ± 3.81 stems/plot; $t = 3.14$, $df = 87$, $p = 0.0023$).

Nest Trees: Abert's squirrels vs. Arizona gray squirrels. Comparing Abert's squirrel nests ($n = 36$) and Arizona gray squirrel nests ($n = 6$) yielded no significant differences in DBH, crown height, or interdigitated branches (all $p > 0.25$). Nest tree height ($t = 2.42$, $df = 42$, $p = 0.02$) and also nest height ($t = 1.86$, $df = 42$, $p = 0.07$) tended to be higher in Abert's squirrel nests (means: tree = 22.0 ± 0.82 m, nest = 14.72 ± 0.72 m) than in Arizona gray squirrel nests (means: tree = 16.11 ± 2.29 m, nest = 10.75 ± 2.01 m). Abert's squirrel nests were almost always found in pines (97.2 % of 36) and Arizona gray squirrel nests in oaks (83.3 % of 6). The surrounding habitat of nests in pine trees did not differ from that of nests in oak trees for slope, aspect, number of live or dead trees, number of large ($> 40\text{cm}$ DBH) live or dead trees, number of logs, volume of logs, or basal area. However, canopy cover and understory measurements differed between Abert's squirrel nests and Arizona gray squirrel nests. Arizona gray squirrel nest sites (mean = 87.85 ± 4.23 %) had moderately higher canopy cover than Abert's squirrel

nest sites (mean = 79.24 ± 1.73 %; $t = 1.88$, $df = 40$, $p = 0.067$, Fig. 5). Our 2-meter pole had seven more sections covered at Arizona gray squirrel nest sites (mean = 9.67 ± 2.03 sections) than at Abert's squirrel nest sites (mean = 2.63 ± 0.81 sections; $t = 7.035$, $df = 42$, $p = 0.0025$, Fig. 6) and 38 more stems/plot at Arizona gray squirrel nest sites (mean = 55.5 ± 8.89 stems/plot) than Abert's squirrel nest sites (mean = 17.39 ± 3.53 stems/plot; $t = 3.98$, $df = 42$, $p = 0.0003$). The number of shrub stems at Arizona gray sites was not significantly higher than at random sites (mean = 36.11 ± 5.18 stems) but both differed from Abert's squirrel sites ($F = 6.82$, $df = 2, 86$, $p = 0.0018$, Fig. 7).

A multivariate perspective revealed further differences between sites. The first two principal components described 43% of the variation of our 12 variables. High first principal component scores indicated increased basal area, large trees, and canopy cover with low levels of understory density. High second principal component scores indicated increased log volume and number, fewer live trees, lower understory density, and less steep areas. Abert's squirrel nest sites (means: PC1 = 0.59, PC2 = 0.44) had higher PC scores than random sites (means: PC1 = -0.50, PC2 = -0.32) for both PC1 ($F = 6.57$, $df = 2, 83$, $p = 0.002$) and PC2 ($F = 16.17$, $df = 2, 83$, $p < 0.0001$). Arizona gray squirrel sites (means: PC1 = 0.27, PC2 = -0.21) had high standard errors likely due to small sample sizes and did not differ from either Abert's sites or random sites (Tukey-Kramer HSD > 0.05).

Arizona gray squirrel and Abert's squirrel nest sites were described by canopy cover, number of live trees, volume of logs, sections of a 2-m pole covered, and the number of shrubs within a 10-m radius circular nest plot (DFA: 9.5% misclassification rate, 2/36 misclassified Abert's, 2/6 misclassified Arizona gray, Hotelling-Lawley = 0.97, $df = 5$, $p = 0.0002$). The separation between species was seen in the first canonical variable where Abert's sites were characterized by lower canopy cover, more live trees, higher log volume, fewer sections of the 2-m pole covered, and fewer shrub stems than Arizona gray squirrel nest sites.

Trapping and Radiocollaring. We amassed > 430 trap-days (Grass Shack: 40 d; Happy Valley Saddle: 283 d; Miller Canyon; 135 d). We captured 17 squirrels (14 Abert's, 3 Arizona gray) at Happy Valley Saddle. We affixed radiocollars to 9 Abert's squirrels (4 males, 5 females) and an Arizona gray squirrel (female) and located 14 active nests (analyzed above). We only analyzed changes in mass in Abert's squirrels due to small sample sizes for Arizona gray

squirrels. After accounting for seasonal differences, mass and sex were not significant factors for predicting differences in mass so they were removed from further analysis. Mass varied by season (mean winter mass = 698 ± 32.0 g, spring = 711 ± 6.7 g, summer = 602 ± 9.7 g, fall = 695 ± 16.2 g; $F = 8.83$, $df = 3, 32$, $p = 0.0002$). Fall, spring, and winter masses did not differ significantly but the average Abert's squirrel summer mass was significantly less than the other three seasons ($p < 0.05$, Tukey-Kramer HSD). It is unclear if this relationship is due to year, as without accounting for seasons Abert's squirrels are significantly heavier in 2005 (mean = 700 ± 19.5 g) than 2006 (mean = 610 ± 10.6 g; $t = 4.47$, $df = 34$, $p < 0.0001$), or season as there is an unequal distribution of masses over seasons (e.g. all summer measurements were taken in 2006 after a prolonged dry period). Each of the 3 Catalina gray squirrels was captured at Happy Valley and they weighed 610 g (11 Nov 2006), 670 g (11 July 2006), and 685 g (3 December 2005).

In Happy Valley Saddle nests and sign of squirrel activity were concentrated in the Ponderosa Pine and Ponderosa Pine-Oak forests near the creek. The forest quickly changes to a Pinyon-Juniper forest as one moves away from the creek (Fig. 8) and lacks trees tall enough for tree squirrel nests and also becomes much denser in shrubs up to 2m tall. These areas may still provide food in Mexican pinyon pine cones (*Pinus cembroides*), juniper (*Juniperus*) berries, and manzanita (*Arctostaphylos*) berries. Both species of squirrel may have ventured into these areas as radio collars were found outside the ponderosa pine belt (Fig. 9).

Conclusions

Altogether, the introduction of Abert's squirrels in the Santa Catalina-Rincon Mountain complex has been successful in establishing this non-native species within the montane complex (Lange 1960, Davis and Brown 1988). Abert's squirrels were found at each of the high elevation ponderosa pine or mixed conifer forest sites. Arizona gray squirrels appear to be uncommon in the areas studied despite their historical occurrence at these sites. Very few Arizona gray squirrel dreys were located and only in Miller Canyon, Happy Valley Saddle, Spud Rock Campground, and at Grass Shack Campground. Unfortunately, non-native Abert's squirrels appear to be considerably more abundant and coping well in the introduced setting.

Low elevation oak dominated landscapes and riparian stringers such as Grass Shack Campground may provide a small refuge for Arizona gray squirrels from the introduced Abert's squirrels that are not often found using oak. The high elevation forests where we located Arizona gray squirrels also have the introduced species present. For example, we regularly noted multiple Arizona gray squirrels near Happy Valley Saddle, however, Abert's squirrels were also commonly observed and trapped at the location and a mating chase of Abert's squirrels was observed there on 1 May 2005 with 4 males (2 collared). The capture of the female Arizona gray squirrel and presence of at least two other males at Happy Valley Saddle in the area is encouraging. Arizona gray squirrels have been seen in other locations as well. A pair of Arizona gray squirrels was seen on the Heartbreak Ridge trail about 1 km north of Happy Valley Lookout and there are active nests in Spud Rock Campground. Historically, Arizona gray squirrels have been reported at Grass Shack Campground (Davis and Sidner 1992), Spud Rock Campground (Huey in Cockrum 1960), Happy Valley Saddle and approaching Rincon Mountain (Davis and Sidner 1992). We verified the persistence of Catalina gray squirrels at each of these sites; however, only with intensive observational and trapping efforts over the course of several years.

As previously noted, concern over the introduction of Abert's squirrels has previously been expressed (Lange 1960); however, some biologists have suggested that Abert's squirrels likely pose little threat (Davis and Sidner 1992) because the species coexist in other locations within Arizona (Brown 1984). Given the considerable ecological overlap of these species (Brown 1984, Hoffmeister 1986) and the relative rarity of the native Catalina squirrel, we believe that such a determination is not yet possible and that the scant data on rarity support the potential detrimental impact of Abert's squirrels in Saguaro National Park.

Future investigations should focus on the ecology of Arizona grays in the lower elevation pine-oak forests to which they appear to be relegated following the successful invasion of Saguaro National Park-East by introduced Abert's squirrels. Vegetation composition at nest sites of the two species is remarkably similar, except for the understory component. Arizona gray squirrels may prefer sites with average levels of understory but this is not commonly seen in tree squirrels (Pasch and Koprowski 2006, Edelman and Koprowski 2006, Merrick et al. 2007). Another possibility is that Abert's squirrels competitively exclude Arizona gray squirrels from the best nest sites and force them to use marginal habitat (Fig. 10), a concern about introduced

Abert's squirrels in other areas (Hoffmeister 1986). In nearby sky islands such as the Huachuca Mountains and the Santa Rita Mountains, *Sciurus arizonensis* appears more common throughout the mixed conifer forests at high elevations (Koprowski, pers. obs.) and the closely related *S. nayaritensis* in the Chiricahua Mountains is also common at high elevations (Brown 1984, Hoffmeister 1986). Conservation of the Arizona gray squirrel would benefit from continued examination of the true nature of this interspecific relationship.

In part due to this study, the status of Arizona gray squirrels and the potential statewide impact of Abert's squirrel introductions have been added to the list of sensitive elements for funding under the Arizona Game and Fish Department's Heritage Grant competition. This formal recognition is a major step in the continued conservation of the native species and likely the non-native species as well. In November 2007, I submitted a grant proposal in collaboration with Dr. Melanie Culver at the University of Arizona that will further investigate the genetic and conservation status of Arizona gray squirrels range-wide to include further studies in the Rincon Mountains and Saguaro National Park.

Management Recommendations

Swann and Powell (2006) suggest the need for additional data on the status of the native Catalina gray squirrel and the introduced Abert's squirrel. We concur with this conclusion and suggest:

1. Continued monitoring efforts to document the distribution of Catalina gray squirrels, especially in riparian areas using remotely-triggered photography and perhaps hair tubes.
2. Identification of low elevation sites that harbor Catalina gray squirrels but do not contain non-native Abert's squirrels.
3. Obtain a voucher specimen for Abert's squirrels in the Rincons and deposit this specimen in a natural history museum collection for there remains no museum record that formally documents the presence of the species within the park.
4. Identify strategies to conserve riparian corridors and other areas with significant growth of

oak at lower elevations

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Figure 1. Arizona gray squirrel (*Sciurus arizonensis*) leaf nest in a Silver-leaf oak (*Quercus hypoleucoides*) near Happy Valley Saddle, Rincon District, Saguaro National Park.

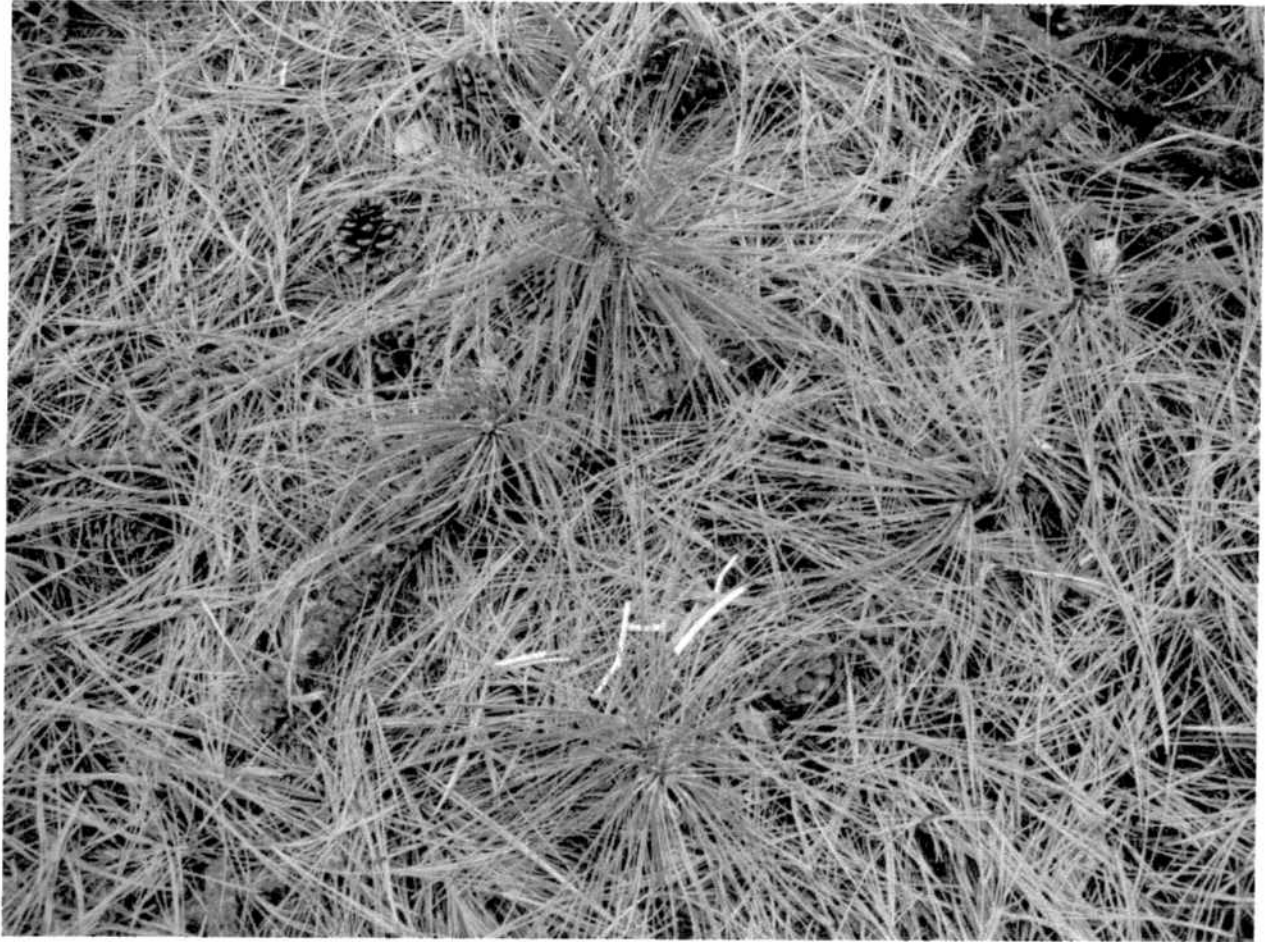


Figure 2. Clipped branches and bark stripped twigs indicating Abert's squirrel (*Sciurus aberti*) presence.

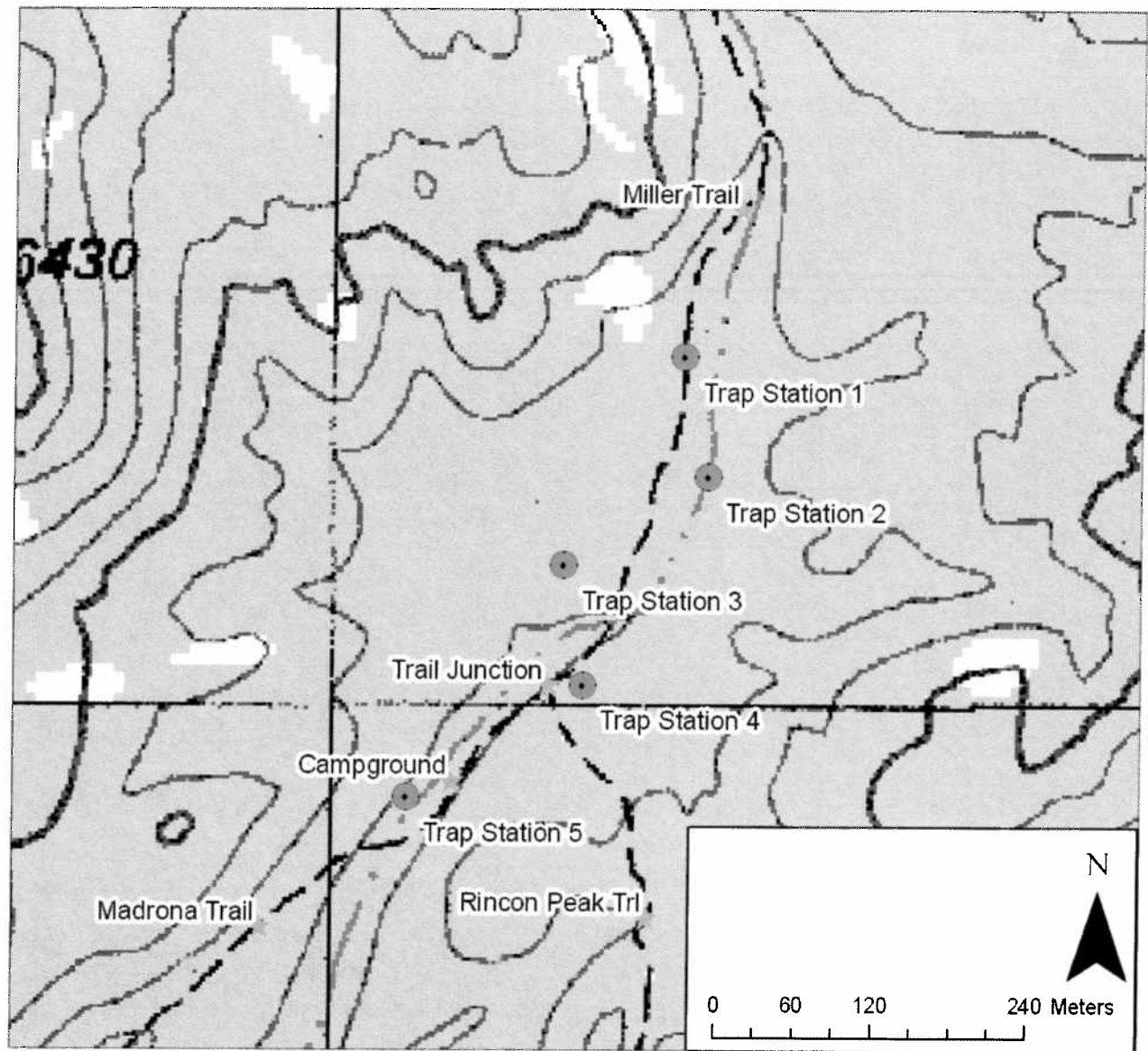


Figure 3. Trapping stations for Abert's squirrels (*Sciurus aberti*) and Arizona gray squirrels (*Sciurus arizonensis*) in Happy Valley Saddle of the Rincon District of Saguaro National Park.

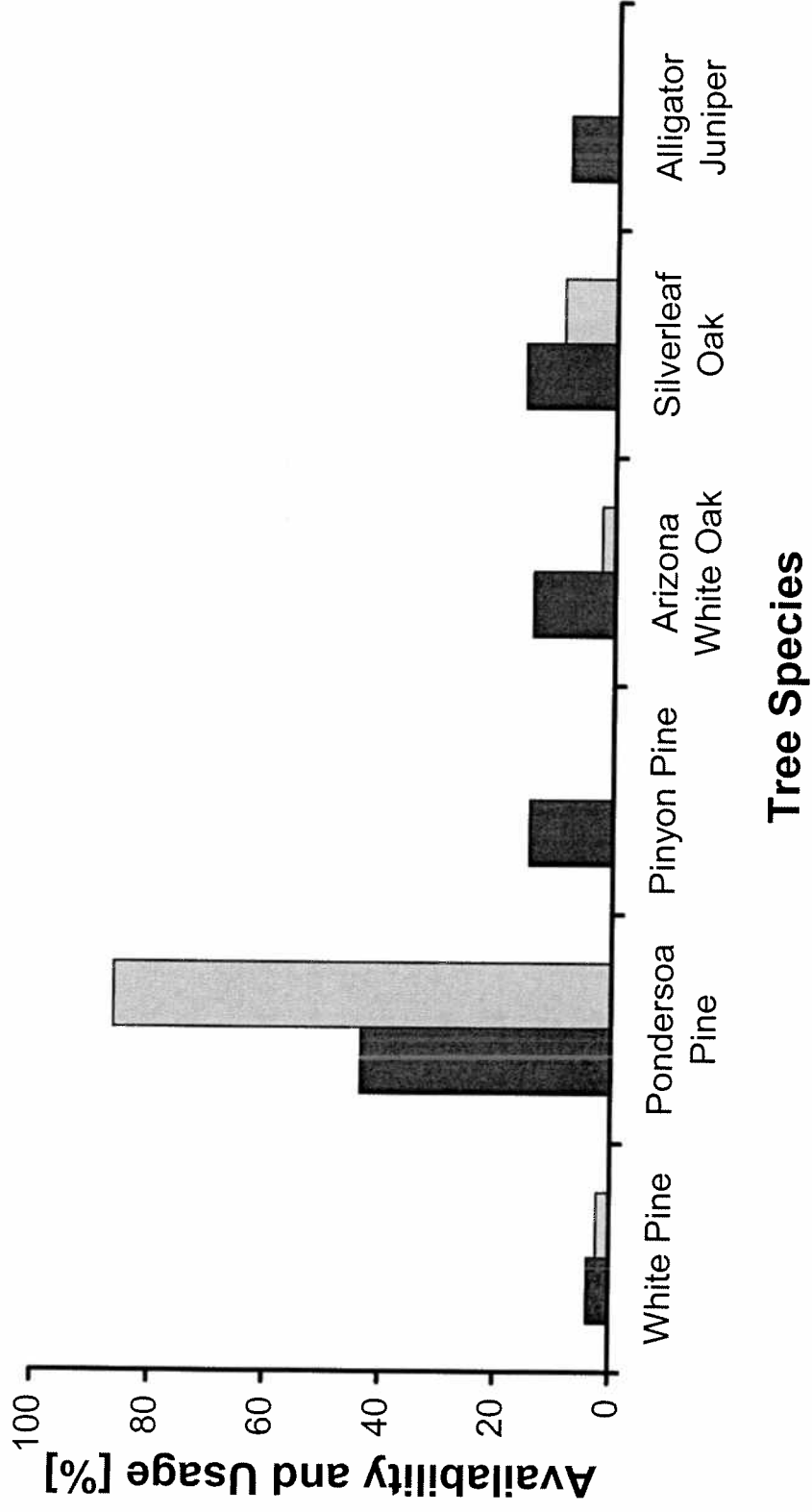


Figure 4. Availability of tree species (black bars) in the upper elevation forests of Saguaro National Park East compared to the usage of tree species by tree squirrels (gray bars) for nests.

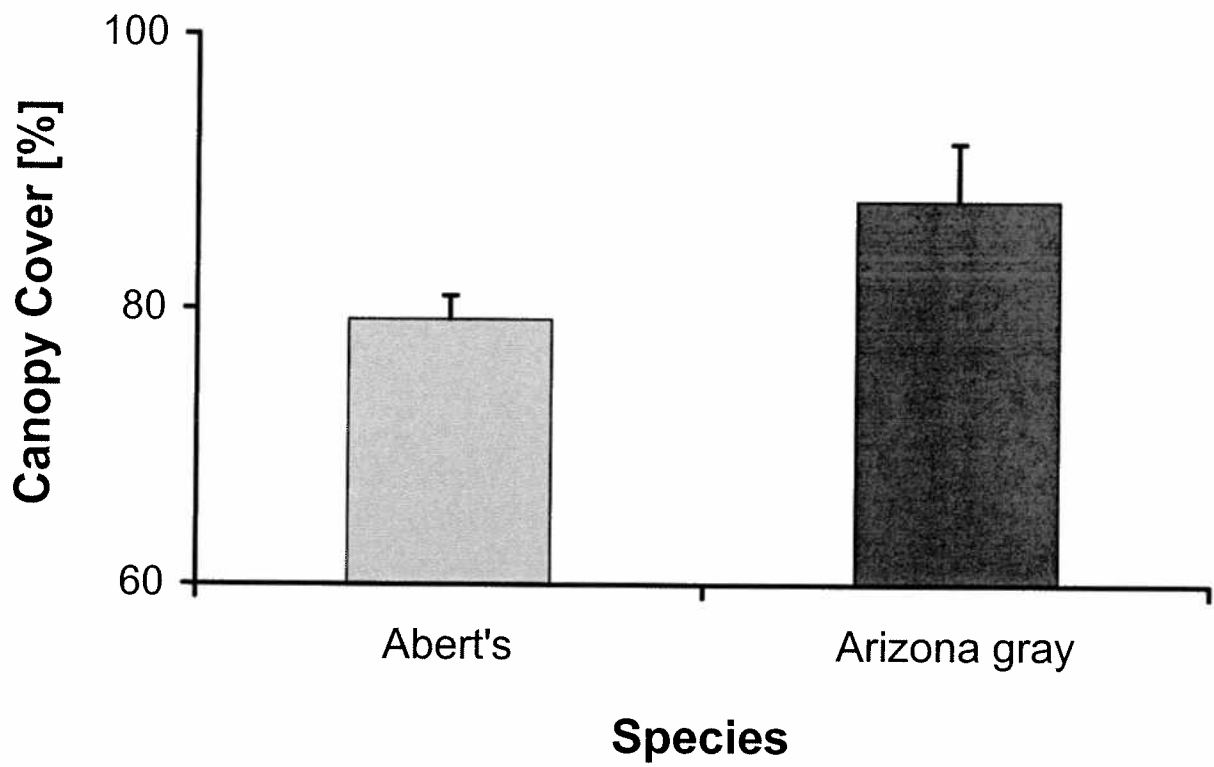


Figure 5. Arizona gray squirrel (*Sciurus arizonensis*) nests had more canopy cover then Abert's squirrel (*S. aberti*) nests in Saguaro National Park East.

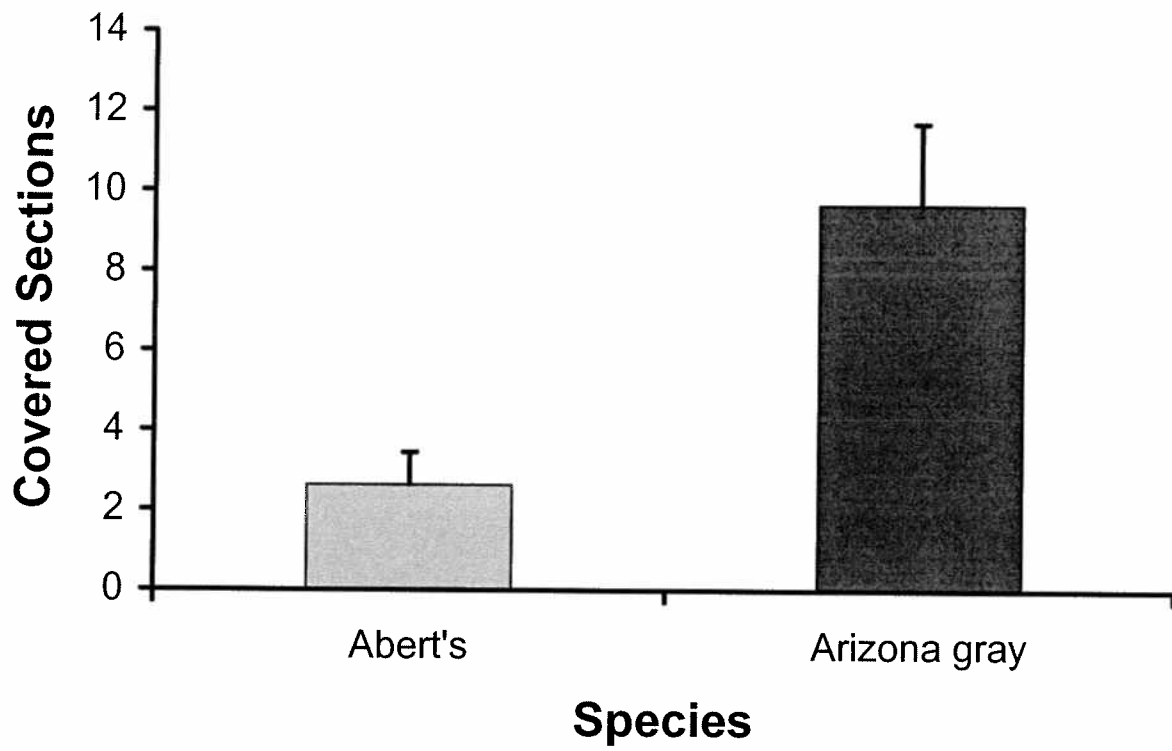


Figure 6. Habitat surrounding Arizona gray squirrel (*Sciurus arizonensis*) nests had denser understory, covering more 10 cm sections of a 2 m pole, than habitat surrounding Abert's squirrel nests in Saguaro National Park East.

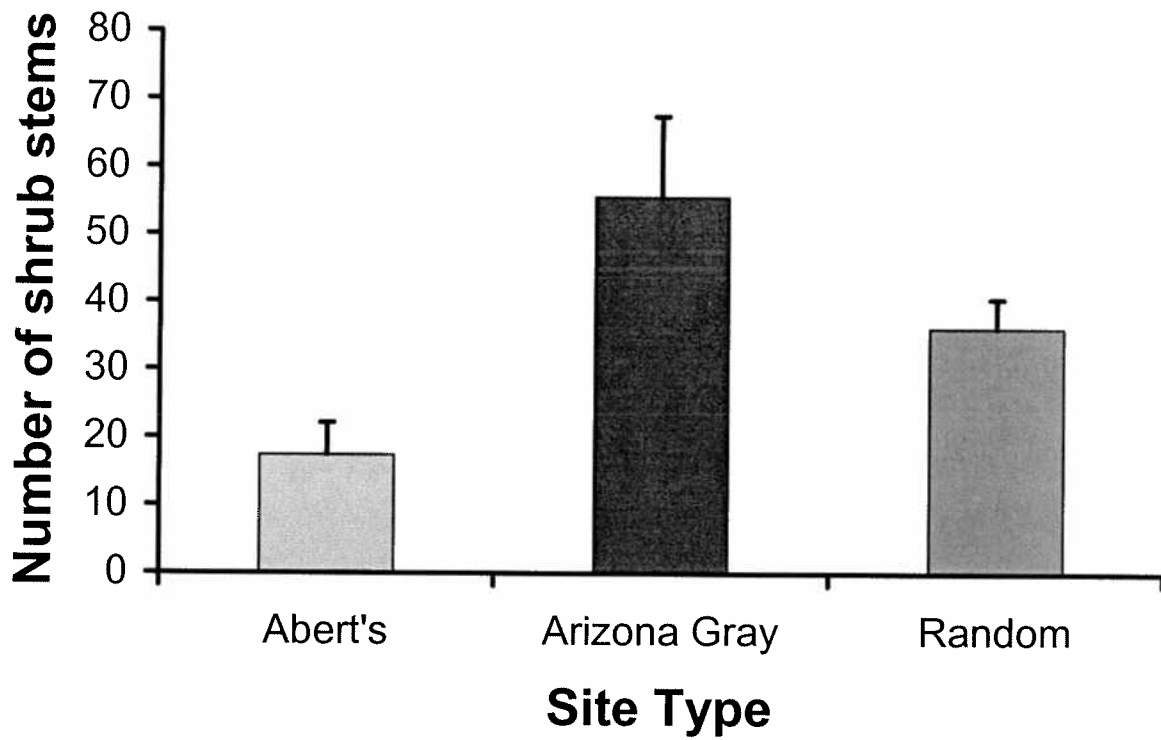


Figure 7. Habitat surrounding Abert's squirrel nests had more open understory, less shrub stems per plot, than habitat surrounding Arizona gray squirrel (*Sciurus arizonensis*) nests and random points in Saguaro National Park East.

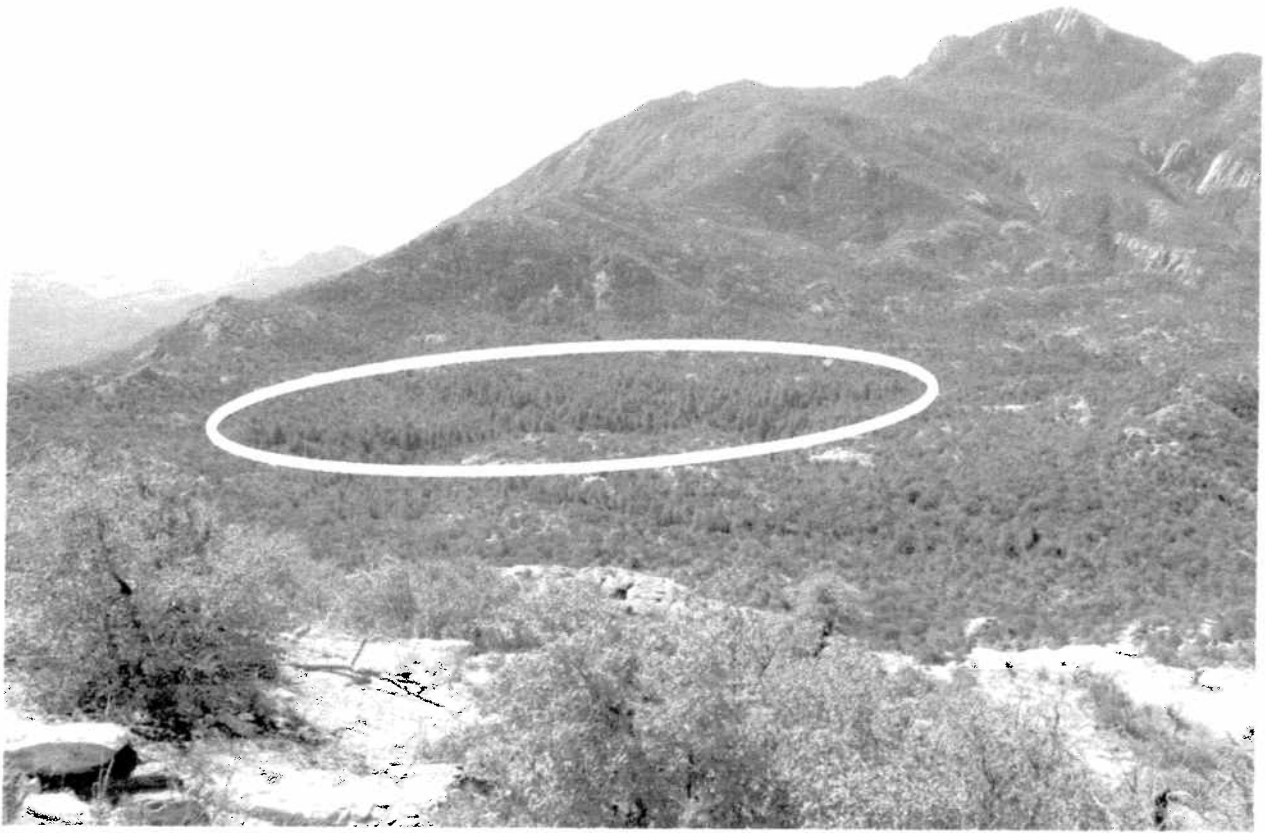


Figure 8. View looking south towards Happy Valley Saddle and Rincon Peak. The small stand of Ponderosa Pine and large oaks is center frame. The vegetation quickly changes from a Ponderosa pine forest to scrub oak and Pinyon-Juniper as distance is increased from the more mesic areas near the creek (low points in the saddle).

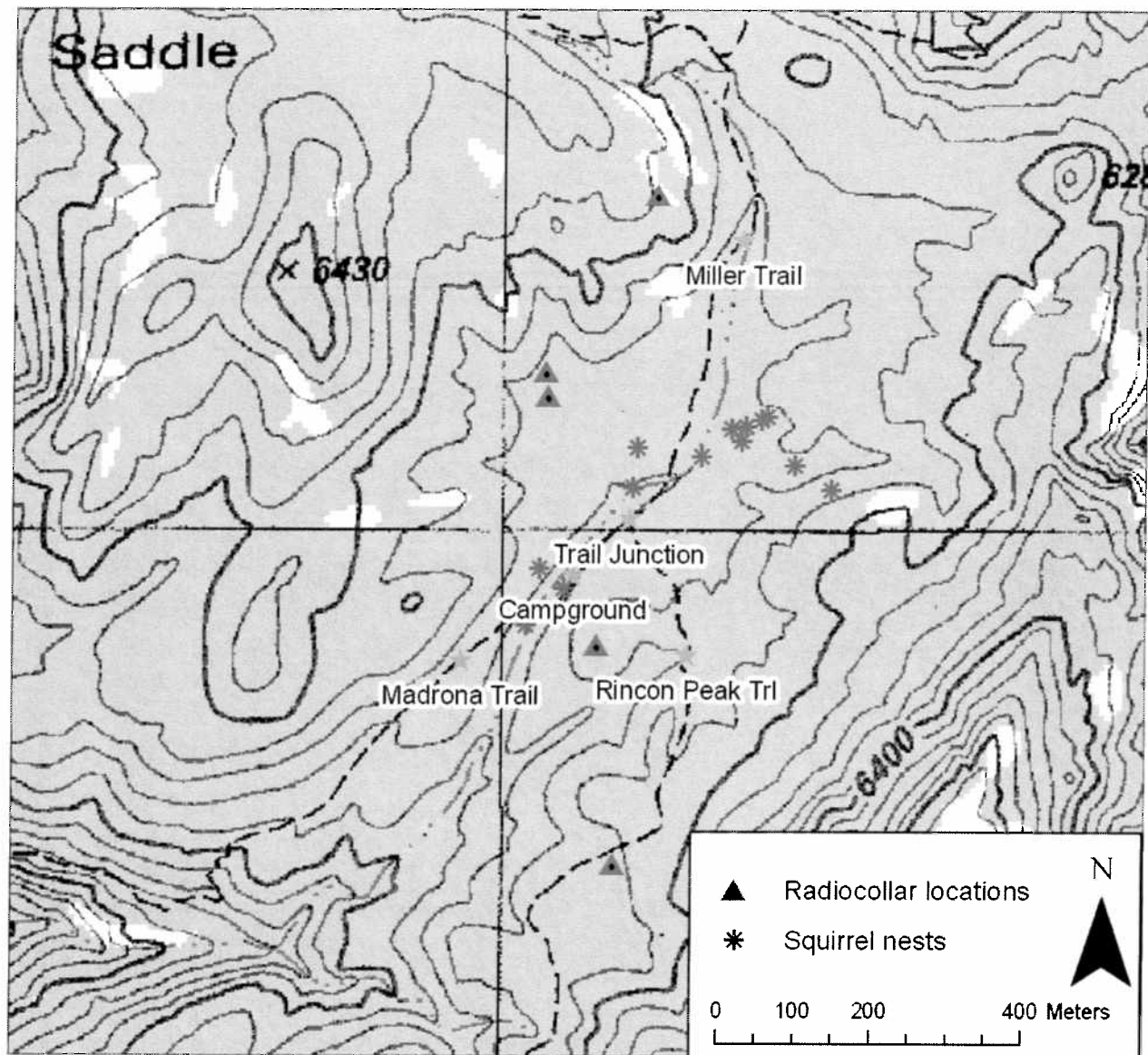


Figure 9. Nest and radiocollar recovery locations for Abert's squirrels and Arizona gray squirrels (*Sciurus arizonensis*) in Happy Valley Saddle at the Rincon District of Saguaro National Park. Nest locations are concentrated in the forests with Ponderosa pines, however, radiocollar recovery locations may indicate that squirrels range into Pinyon-Juniper forests as well. The southernmost radiocollar location was from an Arizona gray squirrel and the other four were placed on Abert's squirrels. Most nests are Abert's squirrel nests, with two close to the campground as Arizona gray squirrel nests.



Figure 10. Pine-oak mixed forest typical of Arizona gray squirrel (*Sciurus arizonensis*) nest sites in Saguaro National Park East.