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WESTERN NATIONAL PARKS ASSOCIATION
Final Report

Title: Ecology of introduced Abert's squirrels

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Objectives:

1. Determine the status of introduced Abert's squirrels in Saguaro National Park East, Rincon District
2. Assess ecological overlap of introduced Abert's squirrels with uncommon native Arizona gray squirrels

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 in 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. The introductions were remarkably successful in establishing this squirrel; one site was the Santa Catalina-Rincon Mtn complex (Brown 1984). 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). This unique subspecies 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 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. 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. 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. This formal status was retained until the abolition of the category by the USFWS after which the Coronado National Forest considered the species to be sensitive. Both species occur 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 NP.

The Rincons 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.

Objectives:

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

Study Site. The study area was located in the Rincon Mountains District of Saguaro National Park. Boundaries of the park are 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.

General Approach:

We observed two distinct types of tree squirrel nests in the Rincon Mountains: nests composed of pine needles and nests composed of oak leaves. Arizona gray squirrels have been reported to use Apache pines 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, cottonwood and sycamore trees (Best & Riedel 1995). In contrast, Abert's squirrels primarily construct nests of pine needles and branches (Nash & Seaman 1977). Abert's have been rarely observed utilizing cavities of oaks and cottonwoods for nests (Hoffmeister 1986) and the use of leaf nests by Abert's is virtually unknown (Brown 1984). 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 historical 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) (Steele and Koprowski 2001). Due to ruggedness of terrain, 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 along the transect, we chose the nearest tree with a DBH of larger than 10 cm as the focal tree for our random vegetation plot. We recorded descriptive and vegetative characteristics of nest trees and random trees as well as the surrounding area with a 10-m diameter circular plot. Characteristics included elevation, slope, and aspect, as well as number, species, and DBH of all trees within the plot, dominant vegetation type, fire history (Baisan 1990), distance to water, distance to nearest clearing/trail, amount of dead vegetation, amount of canopy cover, and amount of ground cover (Higgins et al. 1996). Canopy cover and shrub density were only collected between May and September. Random transects serve for comparison of squirrel habitat preference, as well as random habitat sites to compare with known squirrel territories.

Vegetation Analysis. From a circular plot (radius = 10 m) around each tree (nest and random), we measured several vegetation characteristics for all trees. Characteristics included: (1) tree species (Ponderosa pine, Southwestern white pine, Arizona white oak, Silverleaf oak), (2) diameter at breast height (DBH), (3) tree height, (4) number of interdigitated branches (branches two feet or less from another tree; the distance that a squirrel could jump), (5) habitable crown area (crown width from lowest large branches to top of crown), (6) canopy cover (averaged for each plot using a spherical crown densiometer), and (7) fire class (0 - (no fire scarring) - 4 (completely burned)). For the nest trees only, we recorded (1) nest height, and (2) nest composition.

Statistical Analysis. To analyze vegetation characteristics between nest and random trees, pine and oak trees, we used a 2-sample t-test. We used correlation analysis to examine the relationships between vegetation characteristic results. Analyses were completed with JMP-IN 5.1 (SAS Institute Inc. 1989) and Microsoft Excel 2001 statistics package.

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. Captured squirrels were transferred from traps to a cloth handling cone, physical data collected, and fitted with a radiocollar. Animals were released immediately at the site of original capture.

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 appear 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 summer and fall in Miller Canyon and Happy Valley Saddle (*Fig. 1*). 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, and upper Miller Canyon but appeared absent from lower elevation sites including Grass Shack Campground.

Nest Trees vs. Random Trees. We discovered 87 nest trees in the higher elevations of the Rincon Mountains, only 8 of which were leaf nests in oak trees. We surveyed 9 random transects and measured characteristics of 36 nest and 9 random trees. Nest trees ($n = 36$) differed from random trees ($n= 9$) for all variables except tree species. Squirrels selected nest trees with greater DBH (mean = 52.3) than random trees (2-tailed t-test, mean= 15.9; $t= 4.0$, $df = 31$, $p= 0.0004$, *Fig. 2*). Tree height was almost twice as great in nest trees (mean= 16.4) than random trees (2-tailed t-test, mean = 8.1; $t= 4.8$, $df= 42$, $p< 0.0001$, *Fig. 3*). Nest trees had an average of two more interdigitated branches (mean = 4.4) than random trees (mean = 2.4; $t= 2.4$, $df= 31$, $p= 0.0229$, *Fig. 4*). Habitable crown area in nest trees was on average 5 m wider (mean = 10.7) than random tree crown area (mean = 5.7; $t= 3.5$, $df= 42$, $p= 0.001$). Nest trees provided a greater overall percentage of canopy cover (mean = 78.9) than random trees (mean = 61.3), a difference of nearly 20 percent ($t= 3.5$, $df= 35$, $p= 0.0012$, *Fig 5*). The majority of nest trees were in fire classes 1 and 2, while the majority of random trees were within fire class 0 or 3 (*Fig. 6*).

Nest Trees: Pines vs. Oaks. Comparing nest pine trees ($n= 41$) and nest oak trees ($n= 8$) yielded no significant differences in vegetation characteristics nor did nest height in pines (mean = 10.4) did not vary significantly from nest height in oaks (mean = 8.4).

Nests in pine trees and oak trees differed in their composition. Nests in pines were made of pine needles and small branches, oak nests were comprised almost exclusively of oak leaves and small branches.

Correlation of Vegetation Characteristics in Nest vs. Random Trees. In nest trees, crown area and DBH were highly correlated ($r= 0.715$), with weaker but significant correlations between tree height and DBH ($r= 0.627$), crown area and tree height ($r= 0.627$), and nest height and tree height ($r= 0.625$).

In random trees there was very little correlation between vegetation characteristics and weak correlations between tree height and DBH ($r= 0.525$) and tree height and number of interdigitated branches ($r= 0.535$).

Trapping and Radiocollaring. We amassed > 3,500 trap-hours (Grass Shack: 400 h; Happy Valley Saddle: 1,850 h; Miller Canyon; 1,350.5 h) . We captured 9 squirrels (8 Abert's, 1 Arizona gray) on 16 occasions over 1,850 trap-hours at Happy Valley Saddle. We affixed radiocollars to five Abert's squirrels (3 males, 2 females) and an Arizona gray squirrel (female) and located 10 active nests.

Nest Tree Characteristics by Squirrel Species. We used radiotelemetry to locate the nests of each squirrel species by locating signals in the early evening hours after squirrels had retired to their nests for the day. Known Abert's squirrel dreys ($n = 8$) were found in large (DBH = 54.2 ± 8.5 cm) and tall (23.6 ± 2.2 m) Ponderosa pine (*Pinus ponderosa*) trees with 4.3 ± 0.5 interconnecting trees. The two Arizona gray squirrel known nests were also found in large (DBH = 73.9 ± 6.5 cm) and tall (22.0 ± 0.3 m) Ponderosa pines with 2.5 ± 0.5 interconnecting trees, but one was in a cavity made from a fallen oak snag now lodged in the live tree again suggesting an association between Arizona gray squirrels and oaks.

Conclusions:

Altogether, the introduction of Abert's squirrels in the Santa Catalina-Rincon Mountain complex has been successful in establishing the species. Abert's squirrels were found in each of the high elevation ponderosa pine or mixed conifer forest sites. Arizona gray squirrels appear to be uncommon in the areas studied. The few dreys located in Miller Canyon and at Grass Shack Campground, where Arizona gray squirrels have been seen, appear to be decaying.

Unfortunately, Abert's squirrels appear to be more abundant and coping well in the introduced setting. 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. 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.

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Figure 1. Arizona gray squirrel foraging in Silverleaf oak near Happy Valley Saddle off of the Miller Creek Trail. Photograph by Don Swann.

Figure 2. Trees containing nests of tree squirrels (*Sciurus*) had a greater diameter at breast height (DBH) than trees measured at random in Saguaro National Park East.

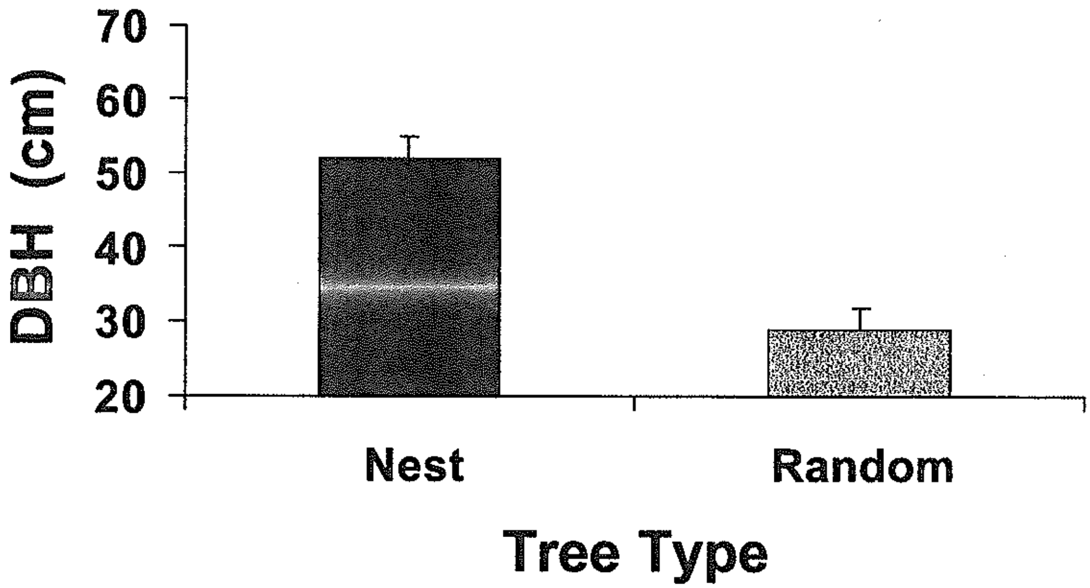

Figure 3. Nest trees of tree squirrels (*Sciurus*) were taller than randomly selected trees in Saguaro National Park East.

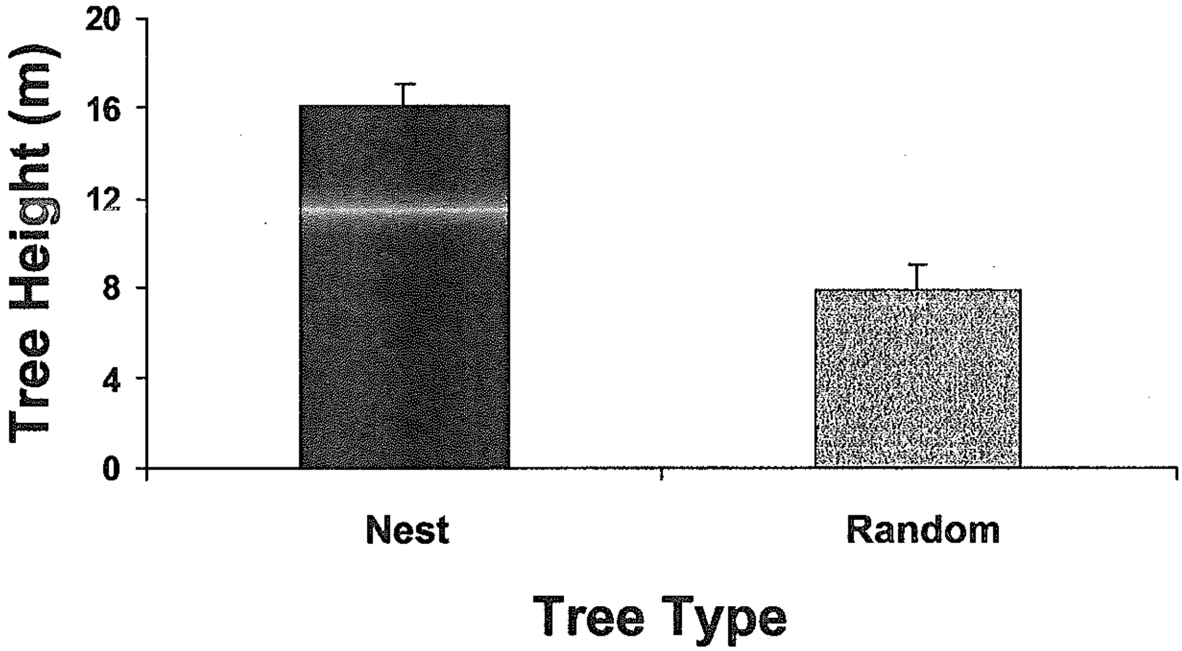

Figure 4. Nest trees of tree squirrels (*Sciurus*) had more interdigitated branches than randomly selected trees in Saguaro National Park East.

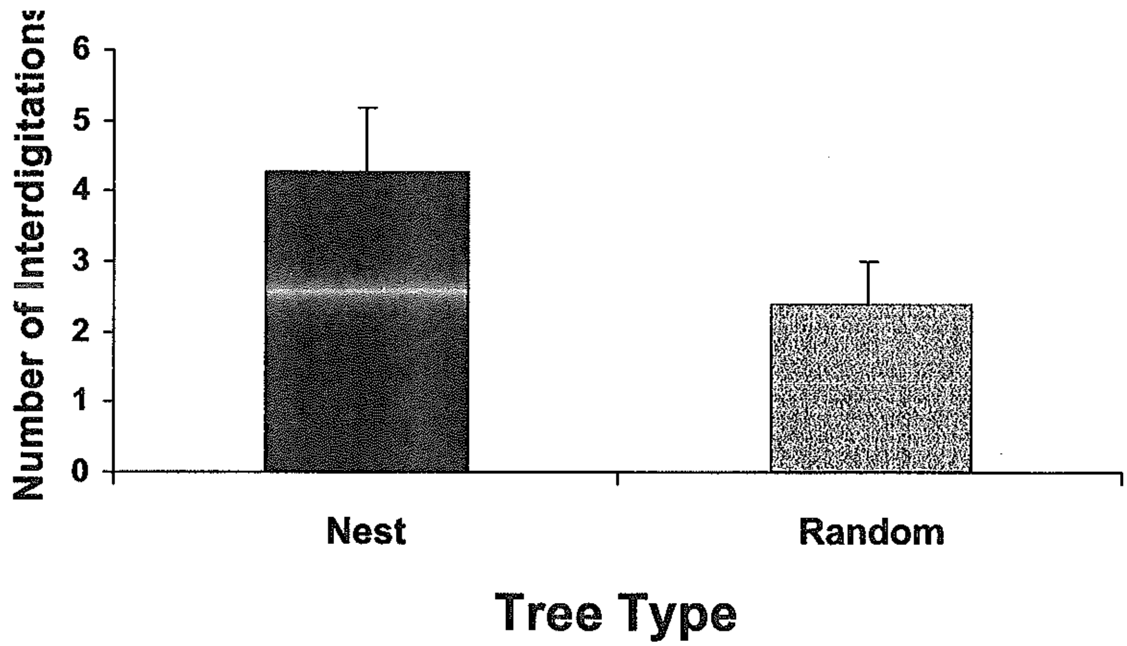

Figure 5. Trees containing nests of tree squirrels (*Sciurus*) provided a greater percentage of canopy cover in Saguaro National Park East.

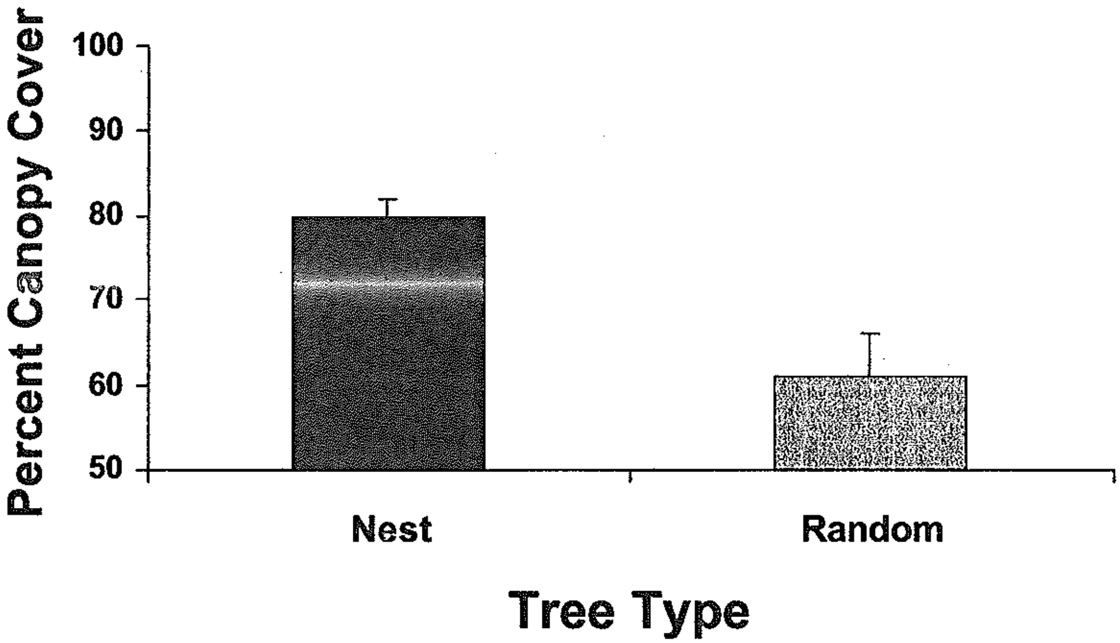

Figure 6. Nest trees of tree squirrels (*Sciurus*) are often within the 1-2 fire class range; relatively more randomly selected trees occurred within the 0 and 3 fire classes in Saguaro National Park East.