

USE OF MIXED-CONIFER AND SPRUCE-FIR FORESTS BY AN
INTRODUCED POPULATION OF ABERT'S SQUIRRELS
(*SCIURUS ABERTI*)

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ABSTRACT—Abert's squirrels (*Sciurus aberti*) are thought to depend on ponderosa pine (*Pinus ponderosa*) for food sources, cover, and nest sites. Records of Abert's squirrels using other food sources, forest types, and nest trees are rare. In the 1940s, Abert's squirrels were introduced to ponderosa pine forests on Mount Graham in the Pinaleno Mountains of southeastern Arizona. Since 1989, while studying Mount Graham red squirrels (*Tamiasciurus hudsonicus grahamensis*), we recorded Abert's squirrel sightings. In over 41,000 field-hours of studying Mount Graham red squirrels, we documented 498 Abert's squirrel sightings in both mixed-conifer and spruce-fir forests. Behaviors observed included feeding, collecting nest material, nest building, intraspecific chases, and interactions with the endangered red squirrels in this nontraditional habitat.

RESUMEN—Se cree que las ardillas de Abert (*Sciurus aberti*) dependen del pino ponderosa (*Pinus ponderosa*) para comida, cobijo, y sitios para anidar. Registros de ardillas de Abert utilizando otras fuentes de comida, tipos de bosque, o árboles de anidación son escasos. En la década de 1940, ardillas de Abert fueron introducidas en bosques de pino ponderosa de Mount Graham, en las montañas Pinaleno del sureste de Arizona. Desde 1989, mientras estudiábamos las ardillas rojas de Mount Graham (*Tamiasciurus hudsonicus grahamensis*), registramos avistamientos de ardillas de Abert. En más de 41,000 horas de campo estudiando las ardillas rojas de Mount Graham, documentamos 498 avistamientos de ardillas de Abert, tanto en bosques de coníferas mixtas como en bosques de abetos y píceas. Las conductas observadas incluyeron alimentación, colección de material de anidación, construcción de nidos, persecución intraespecífica, e interacciones con las ardillas rojas en peligro de extinción en este hábitat no tradicional.

Abert's squirrels (*Sciurus aberti*) inhabit ponderosa pine (*Pinus ponderosa*) forests from southern Wyoming to northern Mexico (McKee, 1941; Keith, 1965; Brown, 1984). Although described as dependent on ponderosa pine for food, cover, and nest sites (Keith, 1965; Patton, 1975; Brown, 1984; Murphy and Linhart, 1999), Abert's squirrels have been reported in pinyon pine (*P. edulis*), Douglas-fir (*Pseudotsuga menziesii*), and spruce-fir (*Picea-Abies*) forests, and above treeline at 3,850 m on Humphrey's Peak, Coconino County, Arizona (Ferner, 1974; Hall, 1981; Cooper, 1987). Despite a gastrointestinal tract that demonstrates some specialization for ponderosa pine (Murphy and Linhart 1999), Abert's squirrels also

have been observed using other food sources, including hypogeous fungi, acorns, dwarf mistletoe (*Arceuthobium vaginatum*), and Douglas-fir cones (Keith, 1965; Ferner, 1974; Stephenson and Brown, 1980; Brown, 1984; Pederson et al., 1987).

During the 1940s, 69 Abert's squirrels (38 male, 31 female) were transplanted to the ponderosa pine forest on Mount Graham in the Pinaleno Mountains, Graham County, Arizona (Brown, 1984; Davis and Brown, 1988). Nearly 30 years later, Minckley (1968) reported that Abert's squirrels were abundant on Mount Graham from 1,830 m to approximately 3,270 m. Also present on Mount Graham, in primarily the mixed-conifer and spruce-fir forests, is

the native Mount Graham red squirrel (*Tamiasciurus hudsonicus grahamensis*), an isolated population of red squirrels differing morphologically and genetically from other populations of North American red squirrels (United States Fish and Wildlife Service, 1993; Sullivan and Yates, 1994). The Mount Graham red squirrel was believed to be extinct in the 1960s, but was subsequently documented and listed as endangered in 1987 (Minckley, 1968; Spicer et al., 1985).

Previous researchers have speculated on the potential impact of introduced Abert's squirrels. Hoffmeister (1956) believed red squirrels were more common on Mount Graham prior to the introduction of Abert's squirrels. Minckley (1968) suggested that the introduction of Abert's squirrels could lead to the competitive exclusion of the native Mount Graham red squirrel. In much of the southwestern United States, red squirrels are sympatric with Abert's squirrels; however, red squirrels on Mount Graham had not recently experienced competition with another tree squirrel (Hoffmeister, 1956; Minckley, 1968). To date, no information exists on how the introduced species uses non-traditional habitats. From 1989 to the present, we observed the presence of Abert's squirrels in mixed-conifer and spruce-fir forests on Mount Graham and occasionally documented their behaviors during census activities for the endangered Mount Graham red squirrels. Herein, we compile these observations that suggest use of high-elevation forests by introduced Abert's squirrels.

METHODS—The approximately 300-ha study area is comprised of both mixed-conifer and spruce-fir forests on Mount Graham, Pinaleno Mountains, Graham County, Arizona. The mixed-conifer forest study site is located from approximately 2,850 m to 3,170 m. In the mixed-conifer forest, between 1995 and 1997, we measured all trees with a diameter at breast height >3 cm within 16 random 0.1-ha vegetation plots. The dominant tree species were corkbark fir (*Abies lasiocarpa*, 51.66%), Engelmann spruce (*Picea engelmannii*, 15.69%), and Douglas-fir (13.49%); ponderosa pine composed only 0.01% of the forest. In 19 similar vegetation plots in the spruce-fir forest, located above 3,050 m, Engelmann spruce and corkbark fir accounted for 61.14% and 37.94% of the forest, respectively; no ponderosa pine trees were found in the vegetation plots in the spruce-fir forest. Overall, ponderosa pine habitat on

Mount Graham is neither extensive nor continuous, but can be found from about 1,830 m to 2,745 m (Marshall, 1957; Johnson, 1988). By our estimates, the nearest forests dominated by ponderosa pine are approximately >2 km from our lowest elevation mixed-forest study site.

Abert's squirrel sightings were recorded during census visits to known red squirrel middens that were both occupied and unoccupied. Censuses were conducted nearly monthly from 1989 until 1996 and quarterly thereafter, providing a minimum of 41,000 field hours to potentially observe and record Abert's squirrel activity. Sightings of Abert's squirrels were recorded opportunistically while at middens or walking between middens, and observers varied in how consistently they recorded Abert's squirrel observations, if they recorded any at all. We searched, compiled, and analyzed field data from May 1989 to September 2001 and categorized Abert's squirrel records by sightings, type of activity, and interactions with Mount Graham red squirrels. After 12 years, we accumulated a number of observations of use of nontraditional forests by Abert's squirrels; however, as a result of unequal efforts and non-standardized observations, we were unable to compare relative densities and frequencies.

RESULTS—Behaviors—We recorded a total of 498 observations of Abert's squirrels. Abert's squirrels were seen traveling on the ground and in the canopy in both forest types. They did not travel significantly more on the ground than in the canopy between forest types ($\chi^2 = 0.027$, $df = 1$, $P = 0.87$). In both forest types, Abert's squirrels basked ($n = 3$), aggressively chased conspecifics ($n = 15$), and engaged in juvenile play ($n = 3$). In the mixed-conifer forest, 1 female was observed gathering nest material, and another was observed building a nest.

Reproductive Biology—We recorded 324 observations of Abert's squirrels (37 adults, 2 subadults, 6 juveniles, and 279 of unknown age) in mixed-conifer forest. Of these, 14 were adult females (6 lactating, 6 post-lactating, 1 reproductive, and 1 of unknown reproductive status), and 10 were scrotal adult males.

We recorded 174 observations of Abert's squirrels (14 adults, 1 subadult, 5 juveniles, and 154 of unknown age) in spruce-fir forest. Six were adult females (3 lactating, 2 post-lactating, and 1 of unknown reproductive status), and 1 was a nonscrotal male.

Two mating chases (Farentinos, 1972) were observed in mixed-conifer forest. One involved

3 Abert's squirrels (unknown age and sex), and the other involved 4 adult males and 1 adult female. No mating chases were observed in spruce-fir forest.

Feeding/Foraging Behavior—Abert's squirrels were observed foraging and feeding on the ground and in the canopy in both forest types. We observed 33 Abert's squirrels foraging in mixed-conifer forest and 13 in spruce-fir forest.

We recorded 33 observations of Abert's squirrels feeding in mixed-conifer forest: 16 feeding on cones (8 Douglas-fir, 4 white pine, 3 corkbark fir, 1 unknown), 3 feeding on tree parts besides cones, and 14 feeding on unknown food items. In spruce-fir forest, we recorded 7 observations of Abert's squirrels feeding: 3 feeding on hypogeous fungi (1 *Russula*, 1 truffle, 1 unknown), 3 feeding on cones (2 corkbark fir, 1 unknown), and 1 feeding on an unknown food item.

Interactions with Red Squirrels—In mixed-conifer forest, Abert's squirrels were observed in red squirrel middens (within 10 m of the central cone-scale pile) on 169 occasions, 53 were observed near middens (<30 m from the edge of the midden), and 102 were observed >30 m away from middens. Similarly ($\chi^2 = 4.61$, $df = 2$, $P = 0.10$), in spruce-fir forest, 89 Abert's squirrels were observed in red squirrel middens, 41 were observed near middens, and 44 were observed away from red squirrel middens. We observed red squirrels chasing Abert's squirrels from the vicinity of middens on 49 occasions in mixed-conifer forest and on 25 occasions in spruce-fir forest; on only 1 occasion did we see an Abert's squirrel chase a red squirrel.

Five observations of Abert's squirrels taking food from red squirrel middens were recorded during 3 years. In mixed-conifer forest, an Engelmann spruce cone, a Douglas-fir cone, and 3 cones of unknown species were taken, with 1 squirrel taking 2 cones within a 20-minute period. One Engelmann spruce cone was taken from a red squirrel midden in spruce-fir forest.

DISCUSSION—Use of mixed-conifer and spruce-fir forests by Abert's squirrels on Mount Graham suggests that they were not merely transitory individuals. Not only did we see many moving through the study area, but we also observed foraging, feeding, mating chases,

and nest building. This is the first record known to us of an Abert's squirrel building a nest outside a forest dominated by ponderosa pine. Furthermore, Abert's squirrels of varying age class, sex, and reproductive status were observed in both forest types. Abert's squirrels also were observed using the resources in these forests, including mushrooms, Engelmann spruce cones, and cones and cambium of Douglas-fir trees, but none were seen foraging or feeding on ponderosa pines. On Mount Graham, Abert's squirrels do not seem to be ponderosa pine obligates (Keith, 1965; Hall, 1981; Brown, 1984).

Whether Abert's squirrels compete with the endangered Mount Graham red squirrel for resources is unknown; however, Abert's squirrels seem to use some of the same habitats and resources as the Mount Graham red squirrel. We observed Abert's squirrels taking cones from middens, and we saw red squirrels chasing Abert's squirrels away from middens. A similar pattern of resource use exists in other portions of their range, where Abert's squirrels seem to revisit red squirrel middens (Hall, 1981) and are known to remove cones from red squirrel larderhoards (Ferner, 1974). Because red squirrels are larderhoarders and Abert's squirrels are scatterhoarders, red squirrels typically have smaller home ranges than Abert's squirrels (Brown, 1984; Koprowski, 1998). Therefore, the resources immediately around a red squirrel midden might be more valuable to a red squirrel than to an Abert's squirrel in the same area. Time spent defending middens against Abert's squirrels and competing with them for resources could be, as Minckley (1968) indicated, detrimental to red squirrels. On Mount Graham, however, red squirrels aggressively chased Abert's squirrels away from middens, suggesting that the larger Abert's squirrels might not be socially dominant in territories of red squirrels. Yet with the population of Mount Graham red squirrels declining and the negative impacts of introduced species on native species being documented worldwide (Manchester and Bullock, 2000; Pimentel et al., 2001; Simberloff, 2001), the possibility of resource competition between these 2 tree squirrels should not be dismissed. More research is needed to determine the ecology of Abert's squirrels on Mount Graham, includ-

ing their demography, spatial and temporal patterns, and impact on red squirrels.

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