The Fort Valley Experimental Forest, Ponderosa Pine, and Wildlife Habitat Research

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Abstract—*Wildlife research at the Fort Valley Experimental Forest began with studies to determine how to control damage by wildlife and livestock to ponderosa pine (*Pinus ponderosa*) reproduction and tree growth. Studies on birds, small mammals, and mule deer (*Odocoileus hemionus*) browsing were initiated in the early 1930s and 1940s but these were short term efforts to develop control techniques. While researchers at Fort Valley and other study areas expressed a need for more information on forest wildlife, there was no major effort in this direction until 1962 when the Rocky Mountain Forest and Range Experiment Station established the first Wildlife Research Work Unit in Arizona on the Arizona State University campus in Tempe. In cooperation with state and federal agencies, research was started on non-game birds, wild turkey (*Meleagris gallopavo*), and effects of forest manipulation on mule deer and elk (*Cervus elaphus*) habitat. A major long-term focus was on the ecology and management of the Abert's squirrel (*Sciurus aberti*) and its relation to management of ponderosa pine.*

Results of research from several state and federal agencies confirm that squirrels need a certain size, density, and arrangement of ponderosa pine to survive and reproduce. In turn, there is evidence that squirrels and other small animals recycle nutrients that contribute to the health of ponderosa pine. The Abert's squirrel and other small rodents have not caused damage to the extent predicted by foresters in the early 1900s and both are part of an ecosystem that has been functioning for thousands of years. It appears, from what we now know, discounting dramatic climate change, that future generations will continue to enjoy both the Abert's squirrel and ponderosa pine for another several thousand years.

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Figure 1. Abert's squirrel.

Introduction

When the Fort Valley Experimental Forest was established in 1908 the research mission was to study the natural regeneration, growth, mortality and methods of cutting ponderosa pine (*Pinus ponderosa*). Although a concern existed by foresters that wildlife, particularly the Abert's squirrel (Figure 1, *Sciurus aberti*), was inflicting severe damage to ponderosa pine natural regeneration there was no mission or direction by the Forest Service to include wildlife as a research emphasis.

Cox (in Taylor 1927) suggested that animals that feed on ponderosa pine seed might become so numerous as to endanger its existence as part of the forest. In California, Bowles (in Taylor 1927) estimated that hundreds of thousands of dollars of damage is done annually to Douglas-fir (*Pseudotsuga menziesii*) by the western gray squirrel (*Sciurus griseus*) and G.A. Pearson (1950) stated that the Abert's squirrel could become the most destructive of all animals in the pine forests of the Southwest.

Pioneering Efforts

Wildlife studies that occurred from 1908 until 1960 on the Fort Valley Experimental Forest and surrounding National Forests were mostly to determine who (rodents, birds) were doing what (eating seeds, roots, live twigs, etc) to whom (ponderosa pine). The following summaries provide insight into the first efforts of early researchers to obtain information on selected animals, and from field observations by G.A. Pearson (1950) during his study on the management of ponderosa pine.

Birds and Rodents

Because rodents and birds had been suggested as obstacles to successful regeneration of ponderosa pine, a series of plots designed to exclude small rodents and birds was established near the FVEF headquarters. Results of the study showed

that seedlings germinated on study plots did not survive except for those that were completely protected (Taylor and Gorsuch 1932). Vertebrates implicated in the disappearance of seedlings were the golden-mantled ground squirrel (*Spermophilus lateralis*), Steller's jay (*Cyanocitta stelleri*) and northern flicker (*Colaptes auratus*). The gray-collared chipmunk (*Eutamias cinereicollis*) and white-footed mouse (*Peromyscus maniculatus*) may also have killed seedlings.

Taylor and Gorsuch (1932) suggested that reproduction of ponderosa pine in the Southwest depends on a generous seed crop and favorable rains the following year—a combination which occurs only at intervals, but when a positive season happens, regeneration takes place in spite of all obstacles. A major conclusion of the Taylor and Gorsuch exclosure study was that under natural conditions seed-eating rodents and birds have little or no detrimental effect on the long-term establishment of ponderosa pine or other trees. They also stated that their information does not justify control operations on birds or rodents, nor should conclusions from isolated investigations be extended too far.

Pearson (1950) continued to believe that during light or moderate seed years the seeds are largely consumed by rodents and it is only in exceptionally good years that the remaining seed is likely to be adequate for regeneration. He stated that in dense stands this may not be serious and may perform a useful service by eliminating surplus stems, but where the stand is already deficient every kill or deformed seedling represents a loss. In addition to small rodents the larger jack rabbits (*Lepus* spp.) eat pine needles and buds in winter. Fortunately, they are not abundant in pine and higher forest types but their numbers have increased noticeably during the past 30 years (Pearson 1950).

A forked tree is a common result of porcupine (*Erethizon dorsatum*) activity that was reported for ponderosa pine at Fort Valley (Pearson 1950). Porcupines girdle the stems of seedlings and saplings near the ground. As the trees increase in size the porcupines transfer their activities to the upper portion of the trunk. Young trees from 4 to 12 inches in diameter are often deformed and become "wolf trees" to such degree as to render them worthless for lumber. Effective control of porcupines is by poisoning and shooting as complementary measures. Pearson (1950) encouraged forest staff to carry shotguns and "kill the creatures."

Deer Browsing

Injury to ponderosa pine from browsing seedlings was observed at Fort Valley during the late summer of 1925 and 1926 (Pearson 1950). Livestock (cattle and sheep) and browsing game animals (deer) as well as tip moths, caused the most injury to seedlings older than three years, whereas rodents were largely responsible for cutting off tops of the younger seedlings. In a range-timber study to determine the effects of browsing, Cooperrider (1938) found that mule deer (*Odocoileus hemionus*), in contrast to the other animals studied, may destroy terminal buds soon after shoot elongation begins in spring. On parts of the experimental forest where deer congregated, shoots were browsed in May during the early stages of growth before livestock were on these ranges.

Deer tended to concentrate on areas where grazing by domestic livestock is light (Pearson 1950). On two areas lightly stocked with domestic animals since 1930, browsing increased noticeably and so did the number of deer. In 1944 both areas

were unused by domestic animals, but browsing by deer continued. Pearson emphasized the importance of proper stocking by both deer and domestic livestock. He suggested that the best control measure for damage to ponderosa pine by deer is reduction of their numbers through regulated hunting.

Abert's Squirrel

At Fort Valley, Pearson (1950) found that twig cutting on ponderosa pine was the most injurious activity of the Abert's squirrel during winter months. He stated that removal of twigs from the lower branches would not be serious but squirrels prefer active shoots from the upper portion of the crown, especially the terminal and the upper laterals. Besides loss of foliage, removal of these stems automatically destroys most of the first-year cones. Pearson stated that saplings and poles suffer most because of the loss of terminal shoots that retards height growth and may deform the bole. Although squirrel activity has been noticeable during the past 30 years, it is only in the last decade that damage has attained such proportions as to be a cause of concern (Pearson 1950).

At the request of G.A. Pearson, the Fish and Wildlife Service and Arizona Game and Fish Department initiated a project on the Abert's squirrel to: (1) reduce the population of squirrels by hunting, trapping and relocating and, (2) secure quantitative data about squirrel populations (Trowbridge and Lawson 1942). Some of the general findings were: (1) cut and sparsely timbered lands have less than one-half as many squirrels per unit area as stands of virgin ponderosa pine; (2) approximately three squirrels per hour could be harvested under all conditions of weather, forest type, and hour of the day; and (3) squirrel activity was most pronounced during the morning hours.

The Need for Research

"Where is the forest biologist?" asked E. N. Munns (1926) in an article in the Journal of Forestry. He stated that wildlife research from a forest point of view had not yet been undertaken except from the standpoint of control. A year later, also in the Journal of Forestry, the need for research and more information by managers was expressed by Taylor (1927) when he was making the case that publications about silviculture were relatively numerous, but one must search to discover information on forest biology even though the problems of forest production are fundamentally biological.

> *The forest is a community of specialized living organisms, including certain plants and animals. The trees, to which so large a percentage of research is irected, are but one expression of the life in this community. The grass, weeds, and browse are others, and the birds, mammals, insects, reptiles, and lower animal forms are still others. In order to secure the best results in production of trees we must acquire a scientific knowledge of the predominant organisms, throughout the entire forest biota (Taylor 1927).*

Research on wildlife as more than destructive agents changed after forester Aldo Leopold published his textbook on Game Management in 1933. The following year, the Fish and Wildlife Coordination Act was enacted. In 1936 the Forest Service hired Dr. Homer Shantz as the first Director of Wildlife Management. President Roosevelt signed the Federal Aid in Wildlife Restoration Act into law in 1937. While most of the concerns about damage to ponderosa pine by birds and mammals could not be addressed at Fort Valley, they were later incorporated into studies that were to become part of the Forest Service's research mission particularly after the passage of the Multiple-Use Sustained-Yield Act of 1960.

Southwestern Ponderosa Pine

Silviculture of southwestern ponderosa pine (Schubert 1974) was published to update Pearson's work (1950). The report continued Pearson's classification of birds, small mammals, deer, elk (*Cervus elaphus*) and sheep as damaging agents to ponderosa pine. Schubert and Adams (1971) determined that loss could be reduced by direct seeding and using a nonpoisonous chemical (*Thiram*) as a repellent or by covering the seeds with soil. An option to reduce damage to seedlings is by spraying them with *Thiram* (Dietz and Tigner 1968, Heidmann 1963). While damage to cone production by the Abert's squirrel has an adverse impact it may not be significant (Larson and Schubert 1970). In his ending summary, Schubert repeated Taylor's (1927) comment that we need to know how ponderosa pine and other plants and animals reproduce, grow, and interact with each other and with the physical environment.

A New Direction

The first Forest Service wildlife research project in Arizona was implemented in 1962. Dr. Hudson G. Reynolds was transferred from the Santa Rita Experimental Range to the campus of Arizona State University in Tempe to be the Project Leader with a new problem statement:

> *To determine the effects of management practices on the habitat and populations of forest wildlife such as deer, elk, turkey (*Meleagris gallopavo*), nongame birds, and squirrels.*

As a result of an increased research effort by the Forest Service, in cooperation with state and federal agencies, there is now considerable wildlife information available for managers to use in the ecosystem management, planning, and decision-making process for National Forests. Some examples of research completed from 1962-1975, which focused primarily on the ponderosa pine ecosystem, show the depth and breadth of research on wildlife in Arizona:

- use by deer, elk and cattle (Reynolds 1966),
- thinning, clear cutting, and reseeding affect on deer and elk use (Pearson 1968),
- foliage use by birds (Balda 1969),

- roost tree characteristics for Merriam's turkey (Boeker and Scott 1969),
- a treatment prescription for improving big game habitat (Clary 1972),
- response of deer and elk to watershed treatments (Neff 1972),
- reproductive biology and food habits of Abert's squirrels (Stephenson 1974),
- Abert's squirrel cover requirements (Patton 1975), and
- food selection of small rodents (Goodwin 1975).

While the studies listed were in progress, others were added to the research program in ecosystems adjacent to ponderosa pine. These included the effects of grazing on riparian habitat, management of cavity nesting birds, habitat requirements of endangered birds and fish, and development of habitat models for forest wildlife species.

Ponderosa Pine and the Abert's Squirrel

Although much of the concern about the damage inflicted to ponderosa pine by Abert's squirrel activity was reduced by the time of Schubert's (1974) publication, there was still a need to continue research to fully document the relationship of the Abert's dependence on ponderosa pine for survival particularly as it related to timber harvesting. A summary of research findings from 1965 to 2006 will indicate the state of knowledge of Abert's squirrel ecology as we know it today.

The present distribution of Abert's squirrel is believed to have resulted from the disappearance of ponderosa pine from low elevations because of changes in climate (McKee 1941). The Abert's squirrel did not adapt to other vegetation types and over thousands of years moved upward with the receding pine forest. The geographic range of Abert's squirrels is the same as the range of ponderosa pine in Arizona, New Mexico, Colorado, and Utah (Figure 2). Ponderosa pine is used both for food and cover provided by density and size of trees (Keith 1965, Farentinos 1972, Patton 1975, 1985) and changes in these two forest characteristics can affect squirrel populations (Patton 1977, 1984, 1985).

A considerable amount of research has been devoted to descriptions of habitat used by Abert's squirrels and to provide guidelines to maintain their habitat under different management regimes. As a result, good squirrel habitat to provide both food and cover can be described as: a stand density averaging 120 to 160 trees per acre with an average diameter of 12 to 15 inches. An important part of this size and density configuration is the interlocking of nest-tree crowns in a zone from 30 to 50 feet in the canopy (Figure 3). The interlocking feature provides protection for the nest site and many escape routes from predators. More recent studies have used remotely sensed data of canopy cover, basal area, and tree density to develop landscape models for predicting the effects of forest management practices on squirrel populations (Prather et. al. 2006).

Environmental factors of predation by raptors, severe winters, and poor cone crops keep the Abert's population in balance (Keith 1965, Stephenson and Brown 1980). Winter survival of the Abert's squirrel in central Arizona has been found to be inversely related to duration of snow cover (Dodd et. al. 2003). Snow cover as a factor influencing squirrel mortality had previously been identified by Stephenson and Brown (1980).

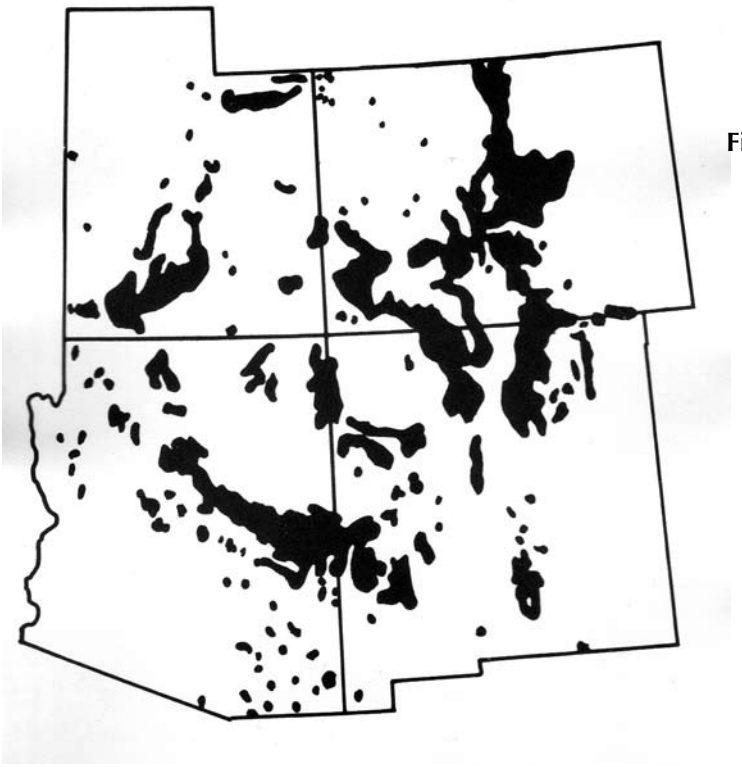

Figure 2. Distribution map of ponderosa pine and the Abert's squirrel in Arizona, New Mexico, Colorado, and Utah.

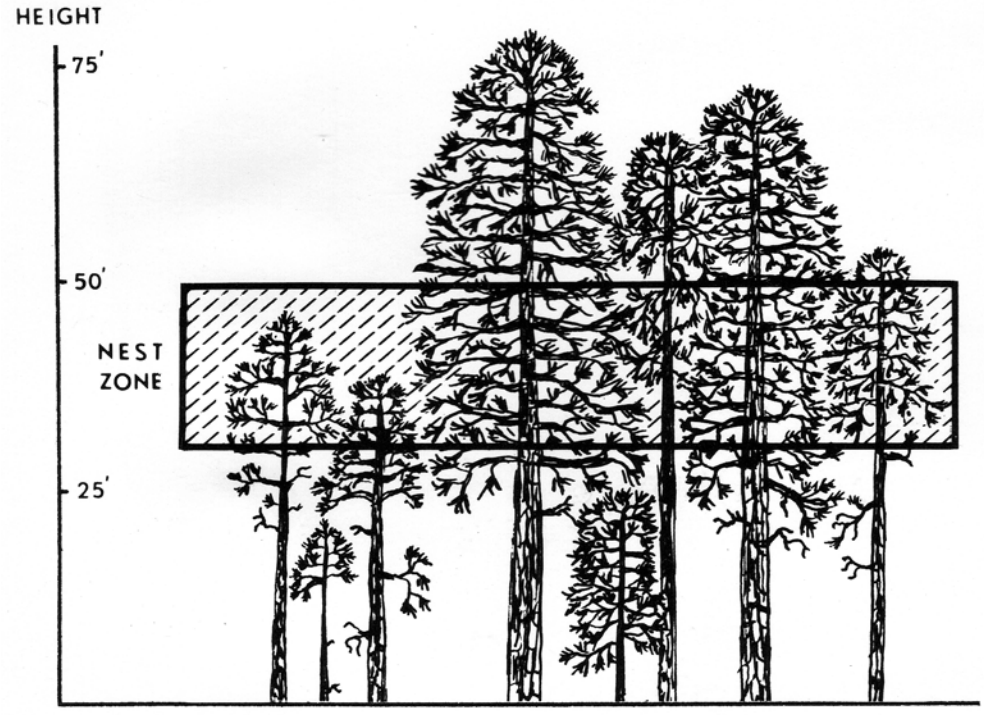

Figure 3. Abert's squirrel nest zone in ponderosa pine.

Although there is some indication that squirrels prefer certain trees for feeding, Hall (1981) could not validate this difference in his chemical analyses of ponderosa pine on the Kaibab National Forest. Nutritional value of ponderosa pine twigs had four to six percent protein and seven percent fat in the Beaver Creek Watershed on the Coconino National Forest in September (Patton 1974). This indicates that a diet of inner bark in winter months without other food could put squirrels in a weak condition for survival.

There is no doubt that squirrels, especially when populations are high, have the potential of consuming large amounts of inner bark from twigs and seeds from cones. From these activities there is also a loss of green needles and in one instance the litter was 71.7 lb/ac. for a 13.8 ac. study area (Allred and Gaud 1994). Calculated nitrogen in ponderosa pine stands that is returned to the forest floor was 5.3 lb/ac. compared with areas where there is no squirrel feeding activity (Skinner 1976).

Evidence exists for a rest-rotation process in feed tree selection. In a five-year study on 1,390 permanently identified pine trees on the Coconino National Forest, 56 percent were used one in four years, 29 percent were used two in four years; 13 percent were used three in four years; and only two percent were used in all four years (Ffolliott and Patton 1978). This finding is contrary to the "year-after-year" use reported by Larson and Schubert (1970). In addition to using pine products for food the Abert's squirrel is known to be a major consumer of truffels (Stephenson 1975).

Subterranean mushrooms are primarily associated with intermediate to mature pine stands with high canopy densities (States 1985). While foraging squirrels excavate pits to get the mycorrhizal fruiting bodies there also is a soil tilling effect that tends to create traps for moisture, helps in nutrient redistribution, and inoculates pine roots with mycorrhizal spores (Figure 4, Allred and Gaud 1999). Studies to determine squirrel use of different fungi species showed a higher use in August than in January or April and fungal content in the diet was positively related to basal area of tree species (Dodd et al. 2003).

The first estimate of the Abert's squirrel's home range and space requirements was made in ponderosa pine stands at Fort Valley (Trowbridge and Lawson 1942). Using travel distance between captures of marked animals as a radius, the approximate home range was 18 acres. In the Beaver Creek Watershed, squirrels were tagged with radio collars to determine movement and nest tree use (Patton 1975a). The home range varied from 10 to 85 acres and squirrels used two to six nests. The longest distance recorded for travel by one squirrel away from a nest site was approximately four miles as determined by radio tracking. On the Apache-Sitgeaves National Forest at one study site a nest tree was used for ten years and maintained with new material each year (Figure 5, Patton 1975a). Studies on nest tree selection (Snyder and Linhart 1994) on the Fort Valley Experimental Forest indicate that tree chemistry is involved in selecting nest trees over other trees.

Pogany and Allred (1993) and Allred and Pogany (1996) suggested that Abert's squirrels have more than one breeding season each year. The maximum amount of sperm in males occurred through March and April with sperm still in the *vas deferens* as late as June (Pogany and Allred 1995). Data resulting from eight years of trapping squirrels on the Kaibab National Forest were used to develop a life table to document the survival and mortality of a cohort from 1973 to 1980 (Patton 1997). From an original population of 58 squirrels, 26 remained in year two, 14 in year three, 10 in year four, 5 in year five, and 2 in year six when the study ended (Table 1).

Figure 4. Hole dug by Abert's squirrel hunting for mushrooms, Coconino National Forest. USDAFS photo by D.R. Patton.

Figure 5. Abert's squirrel nest in ponderosa pine, Coconino National Forest. USDAFS photo by D.R. Patton.

Table 1. Composite life table for the Abert's squirrel (author's original data).

Age	Frequency	Survival	Mortality	Mortality rate	Survival rate
0-1	58	1000	552	0.552	0.448
1-2	26	448	207	0.462	0.538
2-3	14	241	69	0.286	0.714
3-4	10	172	86	0.500	0.500
4-5	5	86	52	0.605	0.395
5-6	2	34	34	1.000	

The Fort Valley Influence

Located within the 1.8 million acre Coconino National Forest, the influence that Fort Valley had on setting a direction for Forest Service Research extended beyond the Experimental Forest boundary. The research effort on ponderosa pine was fortuitous because it was not just an important timber resource—it also contains habitat for over 300 wildlife species. The idea expressed by Taylor (1927) that we must have knowledge of the entire forest biota to understand the production of trees was an early projection of the current direction of ecosystem management by the U.S. Forest Service—it just took a long time to happen. In the meantime knowledge began to accumulate that animals are part of the nutrient cycling and energy flow process which makes forests function as ecological systems.

If the damage to ponderosa pine were as great as first predicted (Cox, Bowles (in Taylor 1927), Pearson 1950), then we would not have ponderosa pine today at Fort Valley or the national forests surrounding Flagstaff. Ponderosa pine with its animal components, including the Abert's squirrel, has functioned as an ecosystem for thousands of years. It appears, from what we now know, discounting dramatic climate change, that future generations will continue to enjoy both the Abert's squirrel and ponderosa pine for another several thousand years.

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We owe a debt of gratitude to the people that came before us for their contributions to science and society. While many are no longer with us, their work lives on in manuscripts, in journals, symposium proceedings, books and government publications. And finally, several of us owe much of our research career to a tassel-eared tree squirrel that uses ponderosa pine for food and cover.

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