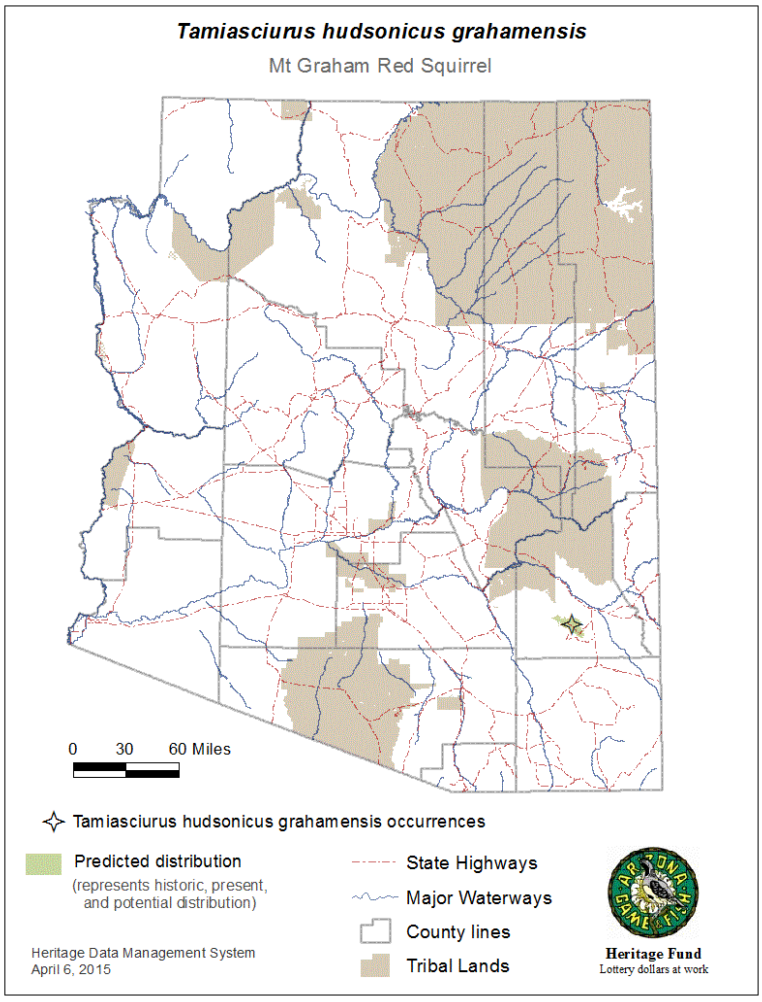
MOUNT GRAHAM RED SQUIRREL CONSERVATION GUIDELINES

INTRODUCTION

The Mount Graham red squirrel (*Tamiasciurus hudsonicus grahamensis*) is endemic to Arizona, occurring as an isolated population at higher elevations within the Pinaleño Mountains in Graham County (Fig 1). It is associated with old-growth coniferous forests with Engelmann spruce (*Picea engelmannii)*, corkbark fir (*Aibies lasiocarpa* var. *arizonica*), and Douglas fir (*Pseudotsuga menziesii*) being the preferred tree species. The suitable habitat of the Mount Graham red squirrel is entirely within the Safford Ranger District of the Coronado National Forest and management is the responsibility of the U.S. Forest Service (USFS).

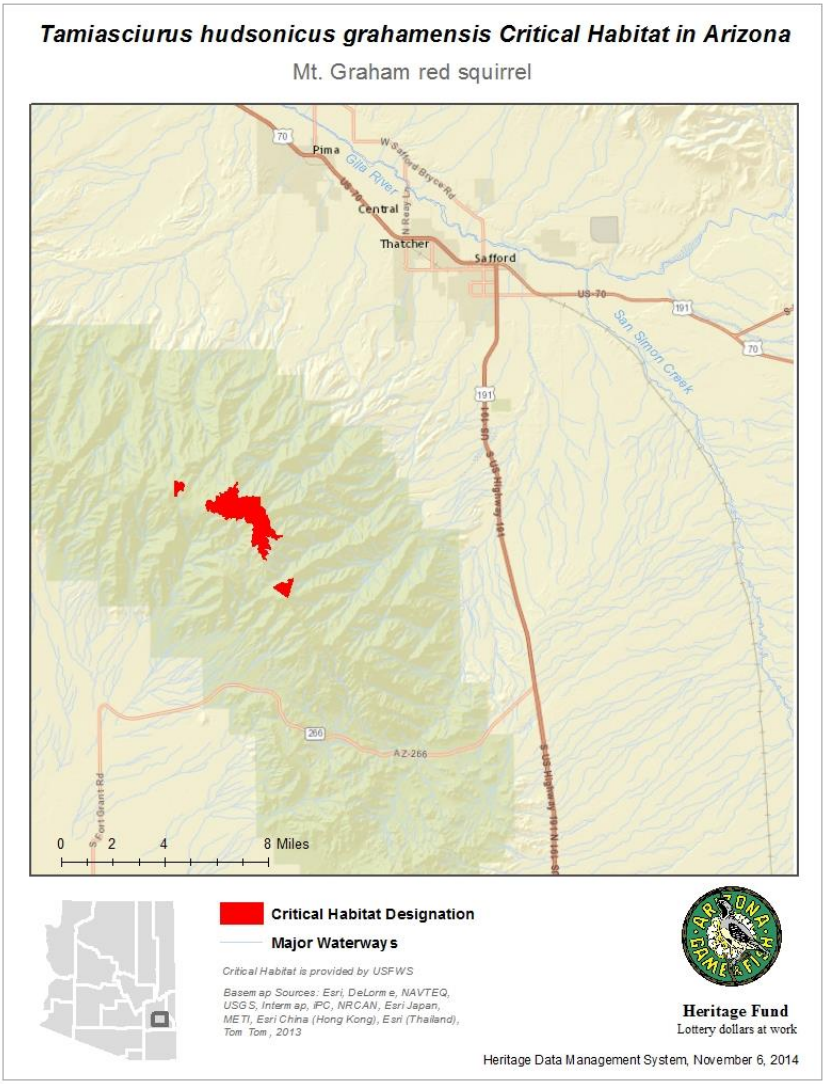
Figure 1. Distribution of Mount Graham red squirrel in Arizona.



The Mount Graham red squirrel occurs in an isolated mountain range in southeast Arizona where past logging greatly reduced the amount of available habitat to the point where it was thought to have been extinct in the 1950's until further sightings occurred in the 1970's (Wilson and Ruff 199). In 1987, the U.S. Fish and Wildlife Service (USFWS)

designated the Mount Graham red squirrel as endangered, pursuant to the Endangered Species Act of 1973. In 1990, approximately 1,900 acres (769 ha) of critical habitat was designated for the squirrel in three areas of the Coronado National Forest: Hawk Peak-Mount Graham Area, Heliograph Peak Area, and the Webb Peak Area (Fig 2). However, due to damage by insects, wildfire, and associated fire suppression activities, only approximately 277 acres (112 ha) of the designated critical habitat currently provides suitable habitat for the red squirrel (USFWS 2011). A recovery plan was originally approved in 1993. It has recently undergone its first revision in 2011 and this recent draft is available on the USFWS website. The Mount Graham red squirrel is also listed as a Species of Greatest Conservation Need by the State of Arizona.

Figure 2. Designated Critical Habitat for the Mount Graham red squirrel



Threats to the Mount Graham red squirrel which led to its listing in 1987 included its small population size and range, the loss of habitat from forest fires, development and road construction, and possible competition with the introduced tassel-eared (Abert's)

squirrel (*Sciurus aberti*). These threats continue today however they are compounded by more recent threats including continuing habitat loss due to multiple insect and parasite infestations, catastrophic wildfires, and fire suppression activities. These threats can be directly attributed to or exacerbated by continuing drought in southeast Arizona (USFWS 2011, 2013a).

GENERAL BIOLOGY

The Mount Graham red squirrel is a slightly smaller subspecies of red squirrel (*Tamiasciurus hudsonicus*) found exclusively within the Graham (Pinaleño) mountains. Red squirrels are small, arboreal (tree dwelling) rodents with a grayish-brown dorsum (topside), whitish colored venter (underside), large eyes and bushy tails. The Mount Graham red squirrel has a rusty or yellowish tinge along the back, a dark stripe that separates the darker colors from the lighter undersides in the summer (this line disappears in the winter), and white around the eyes. It is smaller than other Arizona red squirrels with an average total length of 13.3 in (331.5 mm), hind feet averaging 2 in (50.7mm) and an average adult weight of 8.3 ounces (236.4 grams) (Hoffmeister 1986, USFWS 2011, 2013a).

Red squirrels are highly territorial and will create and defend nests and food storages within their territories (USFWS 2013b). They are also very vocal, the noisiest of all squirrels, often noisier than any other mammals that inhabit the same forests. Their presence is often made known by their variety of sounds including "cherrs", chatters, screeches, squeaks, whistles, growls, barks, and the drumming of their hind feet. Their characteristic chatter is a territorial call used as the first line of defense in protecting their occupied area, nests, and food supply while the bark is an expression of aggression towards intruders (Hoffmeister 1986, Wilson and Ruff 1999).

Population size and composition are influenced by many factors; however, red squirrel demography may be influenced by the closed-cone seed crop more than any other single variable. The stored seed crops likely influence the length of the breeding season, the number of adult females that bear two litters, pre-implantation embryo losses, the number of adult yearling females that breed, the longevity of adults, dispersal, changes in diet, and possibly the average, long-term density of the population (USFWS 2011).

Reproduction

Breeding occurs from February through early April. Courtship is a noisy affair consisting of chasing, chattering and a "buzzing" noise that sounds similar to that of a cicada (Wilson and Ruff 1999). One litter is produced in the spring although, in Arizona, some red squirrels may produce two litters: one in the spring and one in the summer (Hoffmeister 1986). Onset of breeding may be related to the quality and quantity of the spring bud crop on conifers, However, this is not well understood. Females have only one day of fertility in which they are receptive to males each breeding season and will chase all intruders away at other times. Gestation lasts 33-35 days. Litter size and the number of squirrels that breed can vary widely from year to year and may also be related to seed crop availability. The average litter size for red squirrels ranges from two to five,

however Mount Graham red squirrels, on average give birth to fewer young than other red squirrels. The young are born blind and helpless and will remain in the nest for about 40 days. After seven to eight weeks, they will be completely weaned and independent. First reproduction for both male and female red squirrels occurs after their first winter and after the second winter, all squirrels are considered adults. Red squirrels may live up to 10 years although a 3-5 year lifespan is more typical (Wilson and Ruff 1999, USFWS 2011).

Movement

The home range size of Mount Graham red squirrels, where they spend up to 95 percent of their time, tends to be from 3 to 10 times greater than the range size of other red squirrel populations. Koprowski et al. (2008) suggest that this discrepancy may be due to the poor habitat quality on Mt. Graham compared to other locations since territory size in red squirrels appears to be directly related to the energy required by the squirrel that holds the territory. Territory size increased during years of food shortage as well as in marginal habitat (Koprowski 2005). Home range averages 8.9 acres (3.62 ha) overall for the subspecies. The average dispersal distance for red squirrels is 1,916 ft (670 m) and the maximum recorded distance a red squirrel has been found from its midden is 3,028 ft (1,009 m; USFWS 2013b), however, edge habitats appear to be avoided (Koprowski 2005). Males and females have similar home ranges during most of the year until the summer when the home range for both sexes increase, however the increase is larger for males than females (Koprowski et al. 2008).

HABITAT REQUIREMENTS

See page 16 of USFWS (2011) Draft recovery plan for detailed plant association information.

The Mount Graham Red Squirrel occurs entirely within the 35km long and 20km wide Pinaleño Mountains located in southeastern Arizona. This mountain range has an extensive high-elevation plateau supporting one of the southernmost spruce-fir forests in North America. The squirrels inhabit approximately 19,768 acres above 8,000 ft (2,438 m) elevation within these montane conifer forests. Within the highest elevations of their habitat there is predominantly Engelmann spruce (Picea engelmanii) and corkbark fir (Abies lasiocarpa var. arizonica) while the lower elevations are dominated by Douglas fir (Pseudotsuga menziesii) with white fir (Abies concolor) and Mexican white pine (Pinus strobiformis) also mixed (USFWS 2010, 2011, 2013a).

Red squirrels are restricted to mature forests due to their heavy reliance on tree seeds for food and adequate cover foliage (Koprowski 2005). They require a forest to produce reliable and adequate conifer cone crops and a microclimate suitable for storage of closed cones; conditions that are met in mature to old-growth stands with closed canopies. The full forested canopy further facilitates arboreal travel and some protection for aerial predation. Mixed-conifer forests also allow for several available species in case one tree species' cone crop fails. Other important elements that increase the quality of habitat are downed logs, snags, and interlocking branch networks. These habitat characteristics

provide Mount Graham red squirrels with adequate access to food resources, perching sites, storage and nesting sites, runways that allow cone retrieval in the winter, and escape routes for avoidance of predators. Within the Pinaleño Mountains, an area is considered suitable habitat for the Mount Graham red squirrel if it is within the mixed conifer, ecotone, and spruce-fir series AND it is above 9,000 ft (2,744 m). Or, if the area is below 9,000 ft (2,744 m) then it is higher than 7,720 ft (2,353 m) elevation, is on a north or east aspect, and has less than a 45-degree slope (USFWS 2011).

Nest Site Component

Nests are important for thermoregulation, cone and fungal storage, and avoidance of predators (Koprowski 2005). Nests may be constructed in natural hollows or abandoned cavities made by other animals in a tree hollow, hollow snag, downed log, or they may be built of bolus grasses among understory branches of a sheltered canopy. If cavities are limited, nests may also be constructed of leaves and underground burrows will be used. Mount Graham red squirrels appear to favor cavity nests over bolus nests (dreys). In the Pinaleño Mountains where snags are important for cone storage as well as nest location, both nests and stored cones have been found in the same log or snag. However, a squirrel nest can range anywhere from 0 to 2,000 ft (610 m) away from a midden.

Food Component

The Mount Graham red squirrel's diet consists largely of conifer seeds from closed cones, but also includes mushrooms, pollen (pistillate cones) and cone buds, cambium from conifer twigs, bones, and berries and seeds from broadleaf trees and shrubs. Each food is generally used seasonally. The squirrels will eat pollen and buds in the spring, fungi in the spring and late summer, closed cones low in lipids in the early summer, while closed cones high in lipids are stored for use in the winter. Female squirrels will also eat bones during lactation (USFWS 2011).

Red squirrels extensively harvest seed-bearing cones in the fall, just before the cones mature, and store them (along with other food items) in caches called middens. During the winter, red squirrels depend heavily on these caches of food. Usually associated with logs, snags, stumps, or a large living tree, middens are located in damp, shady places, in areas with high canopy closure near food sources. This type of placement allows specific moisture levels to be maintained within the midden, creating prime storage conditions for cones and other food items, such as mushrooms, acorns, and bones. Cones stored in damp places will not open and thus retain their seeds until they are dug up and opened by the squirrel. Middens are often the focal point of an individual's territory and may contain one to two years of cone resources, and are thus heavily guarded (USFWS 2011, 2013a). The scales of the cones are stripped away as the seeds are eaten and this, along with cone cores and pine needles, forms the large piles of debris that make up the midden, which may be as large as 15 feet or more across and a foot or more deep (Hoffmeister 1986, Wilson and Ruff 1999).

Because middens are critical to the survival of red squirrels, quality habitat must provide microclimates of cool, moist conditions optimal for cone storage near and at the base of large, mature, old growth conifers. The presence of large-diameter snags and dead and

down logs is also essential to provide cover and safe travel routes, especially in the winter when open travel across the snow may leave them more exposed to predation. This is demonstrated in surveys in the spruce-fir and mixed forests of Arizona where midden sites exhibit high canopy closure, high foliage volume, numerous decadent logs, many standing snags, and high stem density (USFWS 2011).

Habitat Limitations and Loss

Old growth trees can range between 100 to 300 years in age and thus are not easily replaced when lost. The specific requirements of the old growth trees are increasingly difficult to meet due to drought, epidemics caused by insect species that have devastated the spruce-fir ecosystem, disease damage, catastrophic stand-replacing wildfires, and fire suppression activities, all of which may be exacerbated by climate change. The loss of trees directly reduces the squirrel's opportunities for foraging, nesting, and dispersal. Along with direct loss of habitat, stand replacing agents such as harvest, fire and tree mortality leads to fragmentation which is one of the primary landscape features that appears to limit red squirrel use of forest landscapes because the squirrels appear to avoid edge habitats (USFWS 2011).

Wildfire:

Catastrophic wildfire currently poses the greatest threat to all remaining habitat for the red squirrel. A legacy of fire suppression, livestock grazing, and logging has reduced the role of natural fire and caused the forests to become dense and filled with dead and down trees. This has resulted in a shift in the fire regime from short-interval, low-intensity ground fires to infrequent but larger, high-intensity crown fires. Engelmann spruce and corkbark fir are both fire-intolerant species. Douglas-fir, ponderosa pine, and southwestern white pine are fire-resistant. An accumulation of young smaller fire-intolerant species at lower elevations along with increased density has created a continuous canopy cover as well as an accumulation of vertical fuels. This creates a ladder for fire to reach the canopy and the forests no longer provide a fire buffer for the fire-intolerant spruce-fir forest at the higher elevations. Two such crown consuming fires occurred in 1996 and 2004 which reduced the red squirrel population through the loss of habitat and middens as well as direct mortality (USFWS 2011, 2013b).

Silviculture projects such as the Pinaleño Ecosystem Management (PEM) project and the Pinaleño Ecosystem Restoration Project (PERP) which aim to control the establishment, growth, composition, health, and quality of forests help reduce the threat of catastrophic wildfire and may set the forest on a trajectory towards conditions that will allow a return to low-intensity fire cycles without risk of catastrophic fire damage (USFWS 2013b). Koprowski (2005) suggests that "management that maintains a diversity of successional stages in a temporal and spatial distribution that permits movement and use by squirrels is likely to enable long-term persistence within the native disturbance regime" and that these projects should manage for biological legacies, decadence, and variable stem densities such as those suggested by Carey (1995, 2001). To promote arboreal squirrel populations, Carey (1995) recommended the retention of 20 large (> 50 cm DBH) snags per ha in Douglas-fir forests. Carey (2001) also suggests that the use of variable-density thinning along with the retention of biological legacies and management of decadence

could possibly accelerate the biocomplexity in second-growth forests that will actually mimic that of old natural forests.

Insects and Disease:
The threat of wildfire is compounded by the added pressures of insect and disease outbreaks that lead to the loss of squirrel habitat. Progressive insect infestations have defoliated and killed trees in both the spruce-fir and mixed conifer forests. Engelmann spruce and corkbark fir populations located at the highest elevations of the Pinaleño Mountains were severely depleted by recent catastrophic outbreaks of *Nepytia janetae*, spruce beetle, western balsam bark beetle, and spruce aphid. Engelmann spruce and corkbark fir populations have also faced an increase in armillaria root disease activity. This may be directly related to the increased availability of food substrate from the increased spruce and fir mortality due to insects. Armillaria appears to be infecting species weakened by drought and defoliators but may also spread to relatively healthy trees as well. Within the mixed-conifer forest, bark beetles and defoliators interact with each other and other stressors such as drought, root disease, and dwarf mistletoes to cause mortality in the Douglas-fir, southwestern white pine, and spruce trees (USFWS 2013b). According to Koprowski et al (2005), insects reduce the basal area and stem densities of live stems, while increasing number and basal area of standing dead stems, resulting in a decline in two major foods: fungi and tree seeds. An increase in wildfire potential and a decline in the red squirrel population in the due to habitat loss and decreased cone crops has been directly associated with these outbreaks (USFWS 2011).

Drought:
Arizona is experiencing a severe multi-year drought that may last several more years. This combined with a rise in mean annual temperatures compound to increase the outbreak of insects and exacerbate wildfires (USFWS 2013b).

Non-Native Species:
The Mt. Graham red squirrel faces the loss or reduction of food sources due to the apparent dietary and territory competition with the introduced Abert's squirrel (*Sciurus aberti aberti*) (USFWS 2011).

Rocky Mountain elk (*Cervus Canadensis nelson*) are another non-native species that can severely impact the growth of tree seedlings and saplings in other parts of Arizona. Tree species most impacted by elk include aspen, Douglas-fir, white fir, and subalpine fire and Engelmann spruce. Repeated browsing of young conifers by elk results in bushy elongated shrubs with limited height growth, which is not conducive to the long-term viability of red squirrels. Although this has not yet become a widespread issue for the Mount Graham red squirrel, elk populations if allowed to grow in the Pinaleño Mountains may have the potential to negatively affect red squirrel habitat if this continues (USFWS 2011).

Human Factors:
One of the threats facing the Mt. Graham red squirrel is loss of habitat due to human factors such as disturbance, conversion to roads, trails, and/or recreation sites, and permitted special uses (USFWS 2013b). These activities can lead to fragmentation of

forest habitats and direct loss of habitat through the removal of vegetation. Management practices that eliminate or thin forests, disrupt necessary microclimates for red squirrels, or that fragment forests leading to negative edge effects are likely to be detrimental in the short term. However, moderate timber harvest and prescribed thinning may be compatible with the management of squirrels (Koprowski 2005).

Practices that restore conditions of cool moist ground microclimates, promote cone crop productivity and regularity, and ensure quality mature forest habitat over broad areas while avoiding fragmentation will promote the long-term persistence of the Mount Graham red squirrel (Koprowski 2005). Programs such as PERP (summarized in Appendix B of the Recovery Plan, USFWS 2011) have initiated forest restoration in order to protect the existing Mount Graham red squirrel habitat and key ecosystem components in the Pinaleño Mountains. PERP outlines the optimal characteristics of Mount Graham red squirrel midden and foraging habitat as three desired conditions: Forest structure should consist of a nearly continuous multi-layered forest with overhead canopy closure greater than 80 percent; Basal area of live and dead trees of at least 65 m2/ha (275 ft2/ac) with groupings of 0.031 ha (0.078 ac) of large dominant trees greater than or equal to 40 cm (16 in) diameter at breast height (dbh) associated with greater than or equal to 5 to 8 logs and 1 to 2 standing snags greater than or equal to 40 cm (16 in) dbh; Snags 10 to 15 per ha (4 to 6 snags/ac) that are greater than or equal to 40 cm (16 in) dbh. Logs, as many as possible, need to be maintained, especially those in the latter stages of decay.

MONITORING

Habitat

Aerial and satellite imagery methods with resolution to detect forest stage and general forest composition can be used to assess available habitat and the spatial distribution or continuity of habitats (Koprowski 2005). Koprowski (2005) suggests that any systems used to monitor habitat quality should include approaches to assess and track insect damage and other related forest health issues and that ground truthing which incorporates important biotic features such as biological legacies, management for decadence, and snags would provide even finer scale inventory of existing and potential habitat. The Mount Graham Red Squirrel pattern recognition model developed by Hatten and discussed in Appendix C of the Recovery Plan (2011) is a simple tool for identifying Mount Graham red squirrel habitat based upon spectral and structural characteristics of the forest canopy and can detect changes in habitat among years. This model employs a 19,768 acre (8,000 ha) boundary surrounding all areas in the Pinaleño Mountains within which Mount Graham red squirrel habitat could potentially exist. Within this boundary, areas are considered habitat if they meet the following conditions: They are within the mixed conifer, ecotone, and spruce-fir series AND they are above 9,000 ft (2,744 m). Or, if they are below 9,000 ft (2,744 m), then they meet the following criteria: They are above 7,720 ft (2,353 m) elevation, they are on a north or east aspect, and they have less than a 45-degree slope. Further information on the protocol for monitoring habitat and

areas under management to become habitat can be found in Appendix C of the Draft Recovery Plan (USFWS 2011).

Populations

Since the red squirrel is highly territorial, the concept of one squirrel per midden is widely accepted thus the number of occupied middens is used to determine a rough estimate of the abundance of squirrels in an area. Occupancy of a midden is inferred from signs of recent caching and digging and from the condition of midden material even when squirrels are not directly observe. Fall surveys tend to provide more reliable data, as red squirrels are caching cones in their middens for the upcoming winter, and therefore midden occupancy is usually easier to detect. Personnel visit a proportion of middens each year to determine their occupancy. This method results in very tight confidence intervals (high precision) but accuracy of the population estimate is dependent upon knowing where all the middens are located. The ruggedness of the Pinaleño Mountains makes mountain-wide surveys difficult and can lead to an underestimation of the population. New methods include satellite imagery and GIS (USFWS 2011, 2013a). Further information on surveying and monitoring, including sampling design, survey procedures, locating middens, and the protocol for determining the population estimate can be found in Appendix A of the Draft Recovery Plan (USFWS 2011).

KEY THREATS

Destruction, modification or curtailment of habitat by:

- Catastrophic wildfire
- Insects and pathogens
- Climate Change
- Human Development
- Indirect effects from non-native squirrels and ungulates

HABITAT MANAGEMENT GUIDELINES

1. Forest structure should consist of a nearly continuous multi-layered forest with overhead canopy closure greater than 80 percent

2. Basal area of live and dead trees of at least 65 m2/ha (275 ft2/ac) with groupings of 0.031 ha (0.078 ac) of large dominant trees greater than or equal to 40 cm (16 in) diameter at breast height (dbh) associated with greater than or equal to 5 to 8 logs and 1 to 2 standing snags greater than or equal to 40 cm (16 in) dbh (Mannan and Smith 1991)

3. Snags 10 to 15 per ha (4 to 6 snags/ac) that are greater than or equal to 40 cm (16 in) dbh. Logs, as many as possible, need to be maintained, especially those in the latter stages of decay.

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