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Flying Squirrel Distribution and Habitat Use at Mount Rushmore National Memorial

Natural Resource Technical Report NPS/MORU/NRTR—2012/607

ON THE COVER
Flying squirrel at Mount Rushmore National Memorial.
Photograph by Daniel S. Licht

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Daniel S. Licht

National Park Service
231 E. St. Joseph St.
Rapid City, SD 57701

Christi Bubac

National Park Service
Mount Rushmore National Memorial
Building 31, Suite 1
Keystone, SD 57751

Jane Swedlund

National Park Service
Mount Rushmore National Memorial
Building 31, Suite 1
Keystone, SD 57751

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Abstract or Executive Summary

Mount Rushmore National Memorial (NMEM) is an iconic unit of the National Park Service because of the granite carving of four U.S. presidents. The carved mountain sits within a scenic ponderosa pine (*Pinus ponderosa*) forest that is ecologically valuable.

In 2010-11 a small mammal study was conducted to better understand the small mammal distribution and abundance within the park and the impacts of the forest thinning and fuel reduction on those species. One component of the study consisted of live-trapping northern flying squirrels (*Glaucomys sabrinus*). The objectives were to: 1) document the presence of flying squirrels within the park, 2) learn about the distribution and habitat use by flying squirrels, and, 3) better understand the impacts of forest thinning and fuel reduction to flying squirrels. To better interpret the live-trapping results motion-activated cameras were incorporated into the study.

Sixty-nine trap stations were established in the park; all in drainages as such sites were deemed most likely to support flying squirrels. The stations were categorized as being in forest stands that were un-thinned, partially thinned, or thinned. The un-thinned sites had no evidence of recent tree cutting or removal of downed woody material. The partially thinned habitat was along a power-line right-of-way where a limited amount of thinning occurred. The thinned sites were in forest stands that had recently had all trees less than 25 cm dbh removed as well as most downed woody material. The cut trees and woody material was chipped and spread across the forest floor.

There were 25 flying squirrel captures, some of which may have been recaptures, in 608.5 effective trap nights. Based on the capture rate of 4.1 animals per 100 effective trap-nights it appears that the park had a healthy flying squirrel population in 2010-11. Flying squirrels were captured in the Starling Basin, Grizzly Creek, and Lafferty Gulch drainages as well as the unnamed drainage that parallels a powerline near the junction of Highways 244 and 16. Flying squirrel capture-rates were 10.2 animals per 100 effective trap-nights in the un-thinned stands, 3.6 in the partially-thinned stands, and 0.4 in the thinned stands. Incidental captures (least chipmunks [*Tamias minimus*], red-backed voles [*Clethrionomys gapperi*], and deer mice [*Peromyscus maniculatus*]) ranged from 17.7 per 100 effective trap-nights in the un-thinned stands to 4.3 in the partially thinned and 0.4 in the thinned stands.

The motion-activated cameras detected 21.3 squirrels per 100 camera nights. During nights when both traps and cameras were operating at the same station the traps captured 2.4 squirrels per 100 effective trap-nights and the cameras detected 16.7 squirrels per 100 nights. The cameras documented several instances of a squirrel partially in a trap, yet a capture did not occur. Depending on the objectives, motion-activated cameras may be a more effective way to document flying squirrel presence and distribution.

Mount Rushmore NMEM must consider numerous factors when managing natural resources, including legal, policy, social, political, logistical, and aesthetic factors. Based on the results presented here, and the existing scientific literature, the park can best conserve flying squirrels by leaving woody material on the forest floor, by preserving snags, by maintaining a closed canopy, and by having a structurally complex mixed-age and mixed-composition forest.

Acknowledgments

We thank Bruce Weisman and Chris Holbeck for their support of the project. Dr. Dan Uresk of the U.S. Forest Service provided traps for the study. Gary Vequist purchased the motion-activated cameras. Robert Gitzen, Richard Stecher, Tom Juntti, and Andrew Licht assisted in checking the live-traps. Robert Gitzen, Chris Holbeck, Mike Bynum, Michael Prowatzke, Dan Swanson, and Cody Wienk provided informal comments on the manuscript. Dr. Dan Uresk and Dr. Marcia Wilson provided formal peer-review comments. Their comments made for a much stronger report; however, the recommendations and other statements in the manuscript are ours and may not reflect the viewpoints of others.

Introduction

The northern flying squirrel (*Glaucomys sabrinus*) is a well-known yet rarely seen species. It is renowned for its ability to glide long distances (Figure 1). However, little is known about the specie's status and ecology throughout much of its range due in large part to it being a non-game animal, an animal that is rarely viewed as a pest, and its nocturnal behavior.

Northern flying squirrels are generally most common in boreal and deciduous forests that have an old growth or late seral-stage structure. They tend to be more abundant in forests with increased structural complexity (Carey et al. 1999). Flying squirrel habitat is often characterized as a cool, moist, old, closed-canopy forest with lots of downed and decaying logs (Lehmkuhl et al. 2006). Hough and Dieter (2009*b*) developed a flying squirrel habitat model for the Black Hills that correlated squirrel abundance with higher precipitation, closer distance to a stream, presence of quaking aspen (*Populus tremuloides*), a northwest aspect, higher basal area of snags, and a higher density of live trees and snags compared to random habitats. They stated that squirrels in the southern drier portion of the Black Hills may be more limited to riparian areas. Duckwitz (2001) trapped flying squirrels at Wind Cave National Park in ponderosa pine (*Pinus ponderosa*) alliances; however, he noted that the sites may have been poor habitat based in part on the relatively large home ranges. Gabel et al. (2010) found that squirrel captures in the Black Hills were significantly correlated with the volume of downed wood and the number of snags.

The food resources used by flying squirrels are generally most abundant in structurally complex old growth forests (Smith 2007). Flying squirrels specialize in feeding on fungi found in snags and downed and decaying logs, making them one of very few extant fungivores. They are even capable of feeding on toxic mushrooms. Gabel et al. (2010) found hypogeous (i.e., underground) fungi in 78-98 % of flying squirrel scats collected in summer over a 2-year period in the Black Hills. *Rhizopogon* was the most frequently observed fungi, making up about 97% of the spores found in the scat. Plant material was found in 8% or less of the scats and animal material was negligible. Carey et al. (2002) found more truffle diversity in legacy (i.e., un-thinned) than in thinned forests in the Pacific Northwest, including truffle species important to flying squirrels.

Figure 1. Northern flying squirrel gliding.

High quality habitat for northern flying squirrels generally includes abundant large snags and trees for shelter (Carey et al. 1997). Hough and Dieter (2009*c*) found that flying squirrels in the Black Hills use a variety of tree species for summer daytime nesting including both live and dead trees; however, nest trees were characterized as being older, taller, and larger than non-nesting trees. They also found that 68% of the daytime summer nests were in cavities with the remainder being drays (a nest of leaves, twigs, and other material supported by branches). All of the live-tree cavities used by flying squirrels in their study were associated with aspen and paper birch (*Betula papyrifera*). All of the drays were associated with live conifers and were located near the top of the tallest trees. Duckwitz (2001) found that all of the cavity sites used by four flying squirrels at Wind Cave National Park were in ponderosa pine; he speculated that such cavities were made by woodpeckers.

Hough and Dieter (2009*a*) found that flying squirrel home ranges in the Black Hills were 11 ha for males and 7 ha for females using a 100% minimum convex polygon. They observed that home ranges in the southern and central Black Hills were actually smaller than ranges in the northern Black Hills (7 ha versus 14 ha), even though squirrel densities were higher in the latter. They speculated that the smaller ranges in the more xeric southern Black Hills were the result of squirrels being limited to the relatively cooler and wetter drainages. Duckwitz (2001) found a mean home range of 5 ha for four female flying squirrels at Wind Cave National Park using a 95% minimum convex polygon. Hough and Dieter (2009*a*) noted that flying squirrel home ranges in the Black Hills fell in the "middle of the range for other study areas."

In some portions of its range the northern flying squirrel's association with old growth or late seral stage forests may be putting it at risk as such forest types are being lost to logging, landscape fragmentation, and other impacts (Weigl 2007) or modified to meet other forest objectives (Lehmkuhl et al. 2006). Two subspecies of the northern flying squirrel, the Carolina northern flying squirrel (*G. s. coloratus*) and Virginia northern flying squirrel (*G. s. fuscus*), are listed as endangered under the Endangered Species Act. The subspecies found in the Black Hills, *G. s. bangsi*, is not listed under the Endangered Species Act; however, it is geographically isolated from other flying squirrel populations (King 1951) with the next closest population being in Park County, Wyoming (i.e., the Yellowstone Ecosystem). Kiesow (2008) reaffirmed this geographic isolation through genetic analyses and Kiesow et al. (2011) determined that the species had low genetic variability due to the isolation. The U.S. Forest Service lists the Black Hills flying squirrel as a Species of Local Concern (U.S. Forest Service 2008) and NatureServe and the State of South Dakota lists the specie as imperiled (South Dakota Game, Fish and Parks 2011).

Mount Rushmore National Memorial (NMEM), located in the Black Hills of South Dakota, is primarily comprised of ponderosa pine forest; however, there are several drainages in the park that support a more boreal habitat comprised of Black Hills spruce (*Picea glauca*), paper birch, and quaking aspen. Large portions of the park, including the drainages, have little or no history of logging and still contain many large snags and old-growth structure and conditions. Symstad and Bynum (2007) determined that 66% (344 ha) of the park was covered by old-growth forest and that 29% of the park had no evidence of tree harvesting. These old growth and unlogged stands within the park are regionally and ecologically important as old growth forests are a rare resource in the Black Hills (Spiering and Knight 2005, Symstad and Bynum 2007). The old growth conditions in the park suggest that the park may support a healthy flying squirrel population; however, no scientific studies had been conducted on flying squirrels at the park.

From approximately 2000 to 2008 the Black Hills experienced a severe drought and a series of relatively mild winters. Partly due to these conditions a mountain pine beetle (*Dendroctonus* *ponderosae*) epidemic occurred throughout the region. The epidemic threatened to invade the park, killing the pine trees that are deemed important for the visitor's visual experience. The mountain pine beetle epidemic was also viewed as increasing the risk of a wildfire. Therefore, in 2010 the park initiated thinning and cleaning of the forest (National Park Service 2010).

In the summer and fall of 2010-11 a small mammal project was conducted at the park in an effort to better understand the impacts of the proposed forest management practices (i.e., removing small trees and cleaning the forest floor) on small mammal biodiversity. The initial focus and approach was to use live-traps to document the presence and abundance of least chipmunks (*Tamias minimus)*, mice, voles, and other ground-dwelling small mammals in treated and non-treated areas. The study was subsequently expanded to document the presence and distribution of flying squirrels in the park. The squirrel study was then modified to include trapping in un-thinned, partially-thinned, and thinned forest stands within the park. To better interpret the trapping results, and their effectiveness in capturing flying squirrels, motion-activated cameras were co-located with some of the traps.

Methods

Live-trapping

To document the presence, distribution, and habitat use of flying squirrels at Mount Rushmore NMEM a series of seven trap-lines, each comprised of 9-10 traps, were established within the park. All trap-lines were located within quaking aspen drainages as such habitats likely provide the best conditions for flying squirrels in the southern Black Hills (Hough and Dieter 2009*b*).

Four of the trap-lines (Lafferty Gulch, Grizzly Creek, Upper Starling Basin, and Lower Starling Basin) were placed in habitats that had no noticeable thinning of trees or removal of downed woody material (Figure 2). These areas were characterized by having lots of structural diversity, a high percentage of snags, and large amounts of decaying logs on the forest floor (Figure 3). One trap-line (Powerline) was placed parallel and adjacent to a powerline right-of-way. Trees had been removed from the right-of-way for purposes of maintaining the powerline, but the abutting forest was mostly un-thinned and woody material was present on the forest floor. Two trap-lines (Chipped Area East and Chipped Area West) were placed in a drainage that had been thinned and cleared in early November 2011 for purposes of preventing a potential mountain pine beetle infestation and for fuel reduction. The sawn trees and downed woody material were run through a chipper with the chips strewn across the forest floor (Figure 4). The thinned stand was in the same drainage as two of the un-thinned lines, but was further up the drainage and may have had different squirrel densities prior to the thinning. However, the thinned stand included numerous quaking aspen (a species excluded from the thinning operation) and standing and sawn snags, suggesting the site had potential for squirrels prior to the thinning.

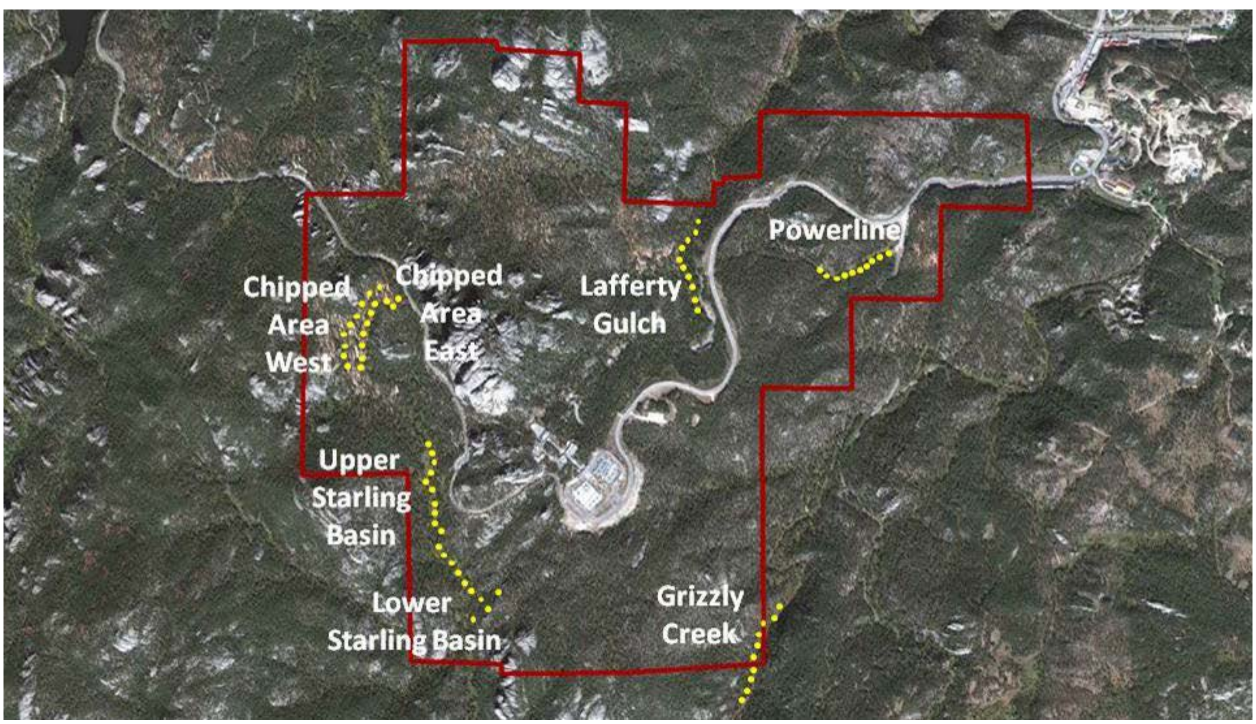

Figure 2. Map of flying squirrel trap-lines at Mount Rushmore NMEM.

Figure 3. Flying squirrel trap in un-thinned habitat in the Lower Starling Basin trap-line. Note the structural and compositional complexity and the downed woody material.

Figure 4. Flying squirrel trap affixed to an aspen tree in the Chipped Area East trap-line. Note the lack of down woody debris and the wood chips on the forest floor.

Within a line the traps were placed about 50 m apart. Sherman[1] live-traps were affixed to trees with no preference given to tree species or status (i.e., live or dead) or other characteristics other than the tree being large enough to properly support the trap. The traps were attached to the trees approximately 1.5 m above the ground by running a wire through the trap and around the tree (Figure 5). A bait mixture of rolled oats, peanut butter, and sunflower seeds was placed inside the trap at the back end and smaller portions were placed on top of the trap and near the base of the tree. A small amount of insulation was placed in the back of the trap for purposes of reducing capture mortality due to hypothermia.

Traps were checked daily as early in the morning as possible, typically around sunrise. Animals were handled and restrained without the use of immobilizing drugs (Figure 6). Trapped animals were weighed and their sex determined. Females were inspected for evidence of lactation. The animals pelage was inspected for purposes of determining age class (young-of-the-year or adult: Villa et al. 1999); however, the method is subjective and the information was not used in any analysis. A small number of animals were marked with a permanent ink marker or by clipping a small patch of hair on a portion of their body or tail. However, due to the small sample size the marking effort was not used in the analysis of the capture data.

Analysis of small mammal live-trapping data is confounded by the use of single-capture traps. Once a trap is sprung, whether it misses an animal, captures a non-target species, or captures a target species, the trap is no longer operational and available for captures. This situation can bias analysis of catch-per-unit effort. To account for potential biases due to sprung traps we counted nights where the trap was sprung and was empty or contained an animal, either a flying squirrel or a non-target, as 0.5 of a trap-night (Beauvais and Buskirk 1999). We do not report the results of statistical tests of different capture rates between sites, i.e., un-thinned, partially-thinned, and thinned stands. Such analysis was deemed inappropriate due to uncertainties about the pre-treatment similarities between the stands and other confounding factors.

Motion-activated Cameras

Six Reconyx[2] cameras (four model HC500 and two model PC800) were deployed next to live-traps #5-10 on the Grizzly Creek line (see Appendix A) from September 30 to November 2, 2010 for purposes of better understanding trap captures, false triggers, and animal activity at the trap. The cameras were affixed to a tree approximately 2 m from the live-trap and facing the open door of the trap (Figure 5). The cameras used the default settings of: day and night operation (using an infra-red flash in low-light conditions), highest sensitivity for the motion sensor, and 3 images spaced 1 second apart each time the motion sensor detected a movement. There was no delay between activations meaning that if the sensor detected an animal at the end of the 3-image sequence the cycle would start again. The cameras stamped each image with the date, time, and ambient temperature. Multiple images of the same species <30 minutes apart were treated as one animal visit whereas images $\geq$ 30 minutes apart were counted as two different visits.

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[1] Use of Sherman live-traps, a brand name, does not constitute an endorsement of the traps.
[2] Use of Reconyx cameras, a brand name, does not constitute an endorsement of the cameras.

Figure 5. Flying squirrel trap affixed to tree and motion-sensing camera (red arrow) in background.

Results

Live-trapping Results

There were 25 flying squirrel captures in 608.5 effective trap nights (Table 1). Some captures may have been recaptures. Based on the capture rate of 4.1 animals per 100 effective trap-nights it appears that the park had a very healthy flying squirrel population in 2010-11. Squirrels were captured in the Starling Basin, Grizzly Creek, and Lafferty Gulch drainages as well as an un-named drainage that parallels the powerline near the junction of Highways 244 and 16.

Figure 6. Captured northern flying squirrel in handling cone.

Flying squirrel capture-rates were 10.2 per 100 effective trap-nights in the un-thinned stands, 3.6 in the partially-thinned stand, and 0.4 in the thinned stand (Figure 7). Incidental captures included least chipmunks, red-backed voles (*Clethrionomys gapperi*), and deer mice (*Peromyscus maniculatus*). Combined capture rates for the three non-target species were 17.7 per 100 effective trap-nights in the un-thinned stands, 4.3 in the partially thinned stand, and 0.4 in the thinned stand.

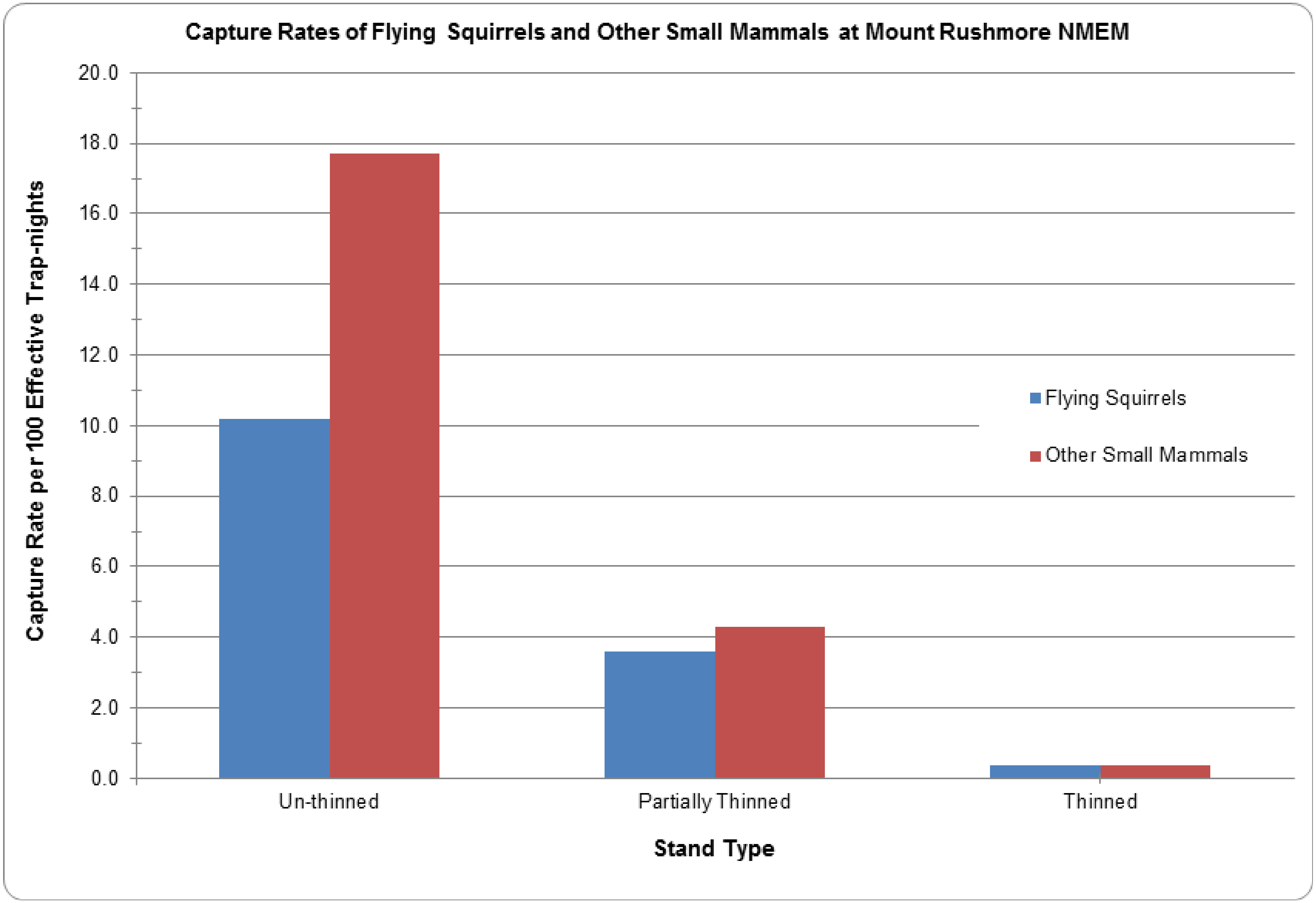

Figure 7. Capture rates of flying squirrels and other small mammals by stand type.

Table 1. Number of captures by trap-line, species, and captures per hundred effective trap-nights (in parentheses).

Trapline	Dates[1]	Total Trap Nights	Effective Trap-nights[2]	Flying Squirrel	Chipmunk	Deer Mouse	Red-backed Vole
Un-thinned Sites							
Lafferty Gulch	Aug. 4-12, 2010	50	25.5	3 *(11.8)*	2 *(7.8)*	4 *(15.7)*	0 *(0.0)*
Upper Starling Basin	Aug. 12-26, 2010	60	40.0	9 *(22.5)*	0 *(0.0)*	9 *(22.5)*	2 *(5.0)*
Lower Starling Basin	Aug. 30 – Sept. 9, 2010	60	54.5	3 *(5.5)*	2 *(3.7)*	1 *(1.8)*	0 *(0.0)*
Grizzly Creek	Sept. 29 – Nov. 2, 2010	80	66.5	4 *(6.0)*	9 *(13.5)*	4 *(6.0)*	0 *(0.0)*
Sub-total		**250**	**186.5**	**19 (*10.2*)**	**13 (*7.0*)**	**18 (*9.7*)**	**2 (*1.1*)**
Partially Thinned Site							
Powerline	Sept. 27 – Nov. 2, 2010	**158**	**139.5**	**5 *(3.6)***	**6 *(4.3)***	**0 *(0.0)***	**0 *(0.0)***
Thinned Sites							
East Chipped Area	Nov. 8-11, 2010 and Jul. 12 – Aug. 11, 2011	146	143.5	0 *(0.0)*	0 *(0.0)*	0 *(0.0)*	0 *(0.0)*
West Chipped Area	Nov. 8-11, 2010 and Jul. 12 – Aug. 11, 2011	142	139.0	1 *(0.7)*	0 *(0.0)*	1 *(0.7)*	0 *(0.0)*
Sub-total		**288**	**282.5**	**1 (*0.4*)**	**0 (*0.0*)**	**1 (*0.4*)**	**0 (*0.0*)**
Total		**696**	**608.5**	**25 (*4.1*)**	**19 (*3.1*)**	**19 (*3.1*)**	**2 (*0.3*)**

[1] Lines were not run all nights during this period, e.g., lines were closed on weekends, holidays, and inclement weather.

[2] Excludes nights where trap was stuck or bait was gone but trap was not triggered. Trap-nights where the trap was sprung, whether it captured an animal or not, counted as 0.5 nights.

Motion-activated Camera Results

Six motion-activated cameras were deployed at the traps to test the effectiveness of the traps in catching flying squirrels (Figure 8). The motion-activated cameras detected 23 squirrels, or 21.3 squirrels per 100 camera nights. During nights when both traps and cameras were operating at the same station the traps captured 2.4 squirrels per 100 effective trap-nights and the cameras detected 16.7 squirrels per 100 nights.

The cameras documented several instances of a flying squirrel partially in a trap yet a capture did not occur. Traps were routinely inspected for their trigger sensitivity and adjusted when necessary. In spite of that, one plausible explanation for why the traps did not close is that their sensitivity was not suitable for squirrels. Another explanation is that the flying squirrel never actually touched the trigger pan.

The motion-sensor cameras provided additional information that traps cannot provide, such as the time of the visit. Peak visitation was within 1-2 hours after sunset. After that period visitation was relatively uniform until about 2 hours before sunrise at which time no squirrels visited the traps (Figure 9).

Figure 8. Flying squirrel near trap. In the next image the trap door was shut. The squirrel was removed the next morning. However, in several cases squirrels were photographed near trap entrances, but no capture occurred.

Incidental Observations

In September of 2010 a flying squirrel was observed around 2200 near the Resource Manager's office (R. Gitzen, pers. obs.). The site was not in a drainage and the stand did not contain the more boreal-like habitat where flying squirrels were captured in this study, suggesting that some flying squirrels may be present in the park in the relatively open stands of ponderosa pine.

One trap had both a flying squirrel and a deer mouse in it. The most likely explanation for this dual capture is that the mouse was inside the open trap when the flying squirrel tried to enter and sprung the trap. However, this is speculation and little more can be said about this event other than it was unusual and noteworthy.

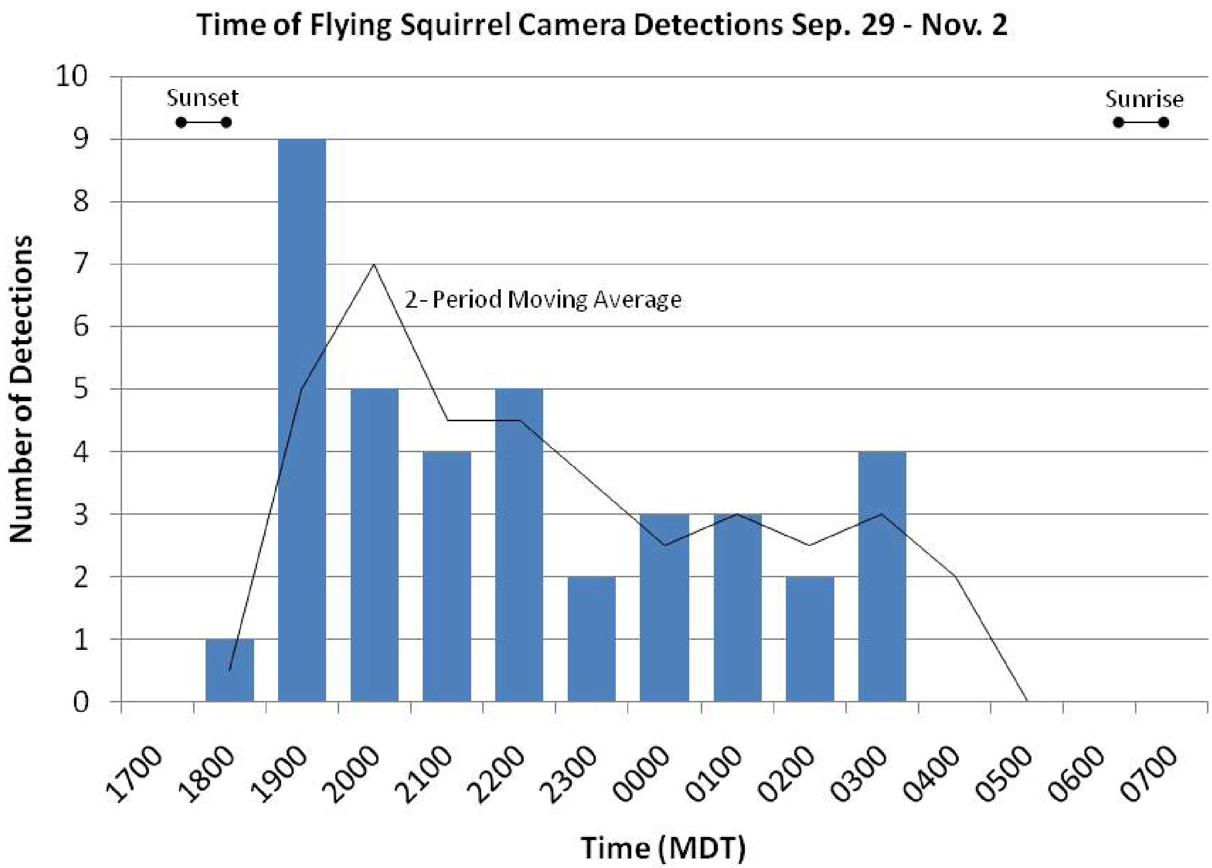

Figure 9. Time of flying squirrel visitation to traps based on motion-activated cameras.

While monitoring traps on the Upper Starling Basin trap-line the senior author observed tracks that appeared to be pine marten (*Martes americana*). A motion-sensing infra-red video camera was deployed at the site. The camera documented a pair of martens (Figure 10). The information is relevant to this study as martens are predators of flying squirrels and relatively rare in the Black Hills.

On August 20, 2010 a flying squirrel was captured and released on the Upper Starling Basin trap-line. As was typical of all the squirrel releases the animal quickly climbed the nearest tree. The animal rested in the upper branches of the tree for approximately 15 minutes at which time the squirrel glided to a nearby paper birch and quickly went to a grid of red-naped sapsucker (*Sphyrapicus nuchalis*) holes. The squirrel began feeding at the holes (Figure 11). At one point a red-naped sapsucker landed on the tree trunk near the holes, but quickly flew off when the flying squirrel moved. The squirrel fed for approximately 5 minutes before climbing to the top of the tree and then gliding to another tree, at which time the field personnel left the site.

Figure 10. Pine marten documented with an infra-red camera in the Starling Basin area. Martens are predators of flying squirrels.

On November 7, 2010 a red-backed vole was observed by the senior author at the Chipped Area West trap-line as the area was being thinned and chipped. The time was mid-day and the vole was observed for several minutes as it moved about 20 m in a zig-zag route. It is unusual to see a vole for such a long period of time without it disappearing under cover, but all of the woody cover and structure on the forest floor had been removed just a few hours prior by the thinning and chipping operation.

Figure 11. Flying squirrel feeding on sap at sapsucker holes following its release from a trap.

Discussion

This study documented that flying squirrels are present at Mount Rushmore NMEM. The capture-rates suggest that flying squirrels occur in relatively high density in the park, especially in the drainages that have not been thinned of trees and cleared of downed woody material. For example, the capture rate in the un-thinned stands at the park was 10.2 squirrels per 100 effective trap-nights whereas the capture rate in mature forests in the Cascade Range in eastern Washington was 3.0 squirrels per 100 trap-nights (Lehmkuhl et al. 2006).

Hough and Dieter (2009*b*) developed a resource selection model for flying squirrels in the Black Hills. The model determined that northern flying squirrels in the Black Hills used habitats with higher precipitation, closer distance to a stream, more aspen, northwest aspect, higher basal area of snags, and a higher density of live trees and snags than randomly available habitats. Carey et al. (1999) associated higher flying squirrel abundance with increasing forest complexity and old growth conditions and Carey (1995) stated that thinned and heavily managed forests were poor habitat for flying squirrels in the Pacific Northwest. Lehmkuhl et al. (2006) found more flying squirrels in young or mature mixed-conifer forests than in open ponderosa pine forests in eastern Washington and that thinning might reduce flying squirrel densities at the stand level. Due to the sequence of events in 2010-11 the flying squirrel study described here was not integrated with the forest thinning operation; had that happened a more robust study design could have been developed and statistical tests conducted between un-thinned and thinned stands.

The motion-sensing cameras documented flying squirrels at a greater rate than did the traps. They also documented other species such as mice and voles. For purposes of documenting small mammal presence the cameras may be a more efficient tool, providing that the expected species can be clearly identified via photographs. The cameras require fewer person-hours to operate, provide information on diel activity patterns, do not cause capture-related mortalities and injuries, and can document non-target species that could not be captured by traps. However, live-traps are still needed for small mammal mark-recapture studies, studies of the animal's condition (e.g., weight, reproductive status), and where species cannot be identified by photographs. Also, live-traps are less expensive in terms of equipment costs (but that needs to be weighed against the labor costs).

Figure 12. A downed log that has been sawn into sections. A small mammal had been using the log as a nest.

Based on the camera stations the peak flying squirrel activity was shortly after dusk. No animals were detected in the two hours before sunrise. This suggests that most flying squirrels captured in traps were in the traps at least 2 hours prior to release and the majority may have been in the traps 8-11 hours before release. Yet, no flying squirrels were found dead in the traps. The absence of in-trap mortalities may be attributed to the fact that the trapping ceased when night-time temperatures approached freezing.

A flying squirrel was observed feeding on birch sap from sapsucker holes shortly after its release. The popular literature states that flying squirrels do feed at sapsucker holes, but the scientific literature is scant on documentation regarding this. The use of sap would not be captured in diet studies that rely on scat analysis and would be difficult to observe visually due to the nocturnal nature of the animals. As far as we know this is the first hard evidence in the peer-reviewed scientific literature for such an event.

The northern flying squirrel is a species of management concern in the Black Hills and therefore should, in our opinion, be a high conservation priority for Mount Rushmore NMEM. Based on the results here and the scientific literature maintaining a structurally complex, compositionally diverse, closed-canopy forest with lots of down woody material will best conserve flying squirrels. That should also benefit predators of flying squirrels. A pair of martens was documented at the park in September of 2010 using motion-sensing cameras. The fact that two martens were observed suggests either a mated pair or reproduction in or near the park.

Conserving flying squirrels can help conserve pine martens and other predators. Yet the role and importance of flying squirrels may go well beyond providing prey for carnivores. Studies suggest that flying squirrels play a critical role in maintaining and enhancing the health of a forest by spreading fungi spores through their excrement (Carey et al. 2002, Weigl 2007, Gabel et al. 2010). The growing fungi form associations with tree roots, greatly increasing their surface area and the tree's absorption of water and minerals. Gabel et al. (2010) described this as an "important 3-way mutualistic relationship" between squirrels, fungi, and trees. It's conceivable that were it not for flying squirrels, and the role that they play in distributing fungi spores, that many trees might grow poorly and forest health would be diminished.

Figure 13. A cut and sectioned snag in the Chipped Area West trap-line. Such snags should be left uncut and intact for flying squirrels. Sectioning and breaking apart large downed woody material desiccates the material making it less suitable for fungi.

Management Recommendations

This study documents that northern flying squirrels are present at Mount Rushmore NMEM and that they may be relatively abundant in the drainages, especially in those forest stands that have not been thinned of trees and cleared of down woody debris. Based on our results, observations, and the scientific literature (especially Weigl [2007], Smith [2007], and Hough and Dieter [2009*a*]), we provide the following management recommendations for conserving flying squirrels at the park. We recognize that these recommendations for flying squirrels need to be weighed against other park objectives.

1. Leave large trees of all species, including live, decadent, and dead trees, as they provide nest cavities, drays, fungi, and eventually become large downed woody material.

2. Leave woody debris on the forest floor, especially large decaying logs. Do not section or break apart downed logs. Such debris is needed for truffles, mushrooms, and other fungi and also provides shelter for small mammals.

3. Manage for structural and compositional complexity and diversity of the forest stands.

4. Manage for a closed-canopy forest. A closed canopy maintains a shaded, cool, and moist understory that promotes fungi.

5. Prevent hot fires as such fires can eliminate downed woody material, reduce structural diversity, and destroy fungi and other food resources.

6. Use adaptive management principles when manipulating forest habitats to better understand impacts to flying squirrels. Specifically, establish control and treatment sites and conduct pre- and post-monitoring of squirrel abundance, behavior, and other characteristics.

7. Periodically monitor the flying squirrel population within the park, perhaps by replicating the methods and sites used in this study.

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Appendix A. Trap Locations and Descriptive Characteristics

Trapline name and trap ID	UTM Zone, Easting, and Northing (NAD 83)	Tree Species Trap was Attached to and Nearby Trees/Shrubs	Management Practice
Lafferty Gulch			
1	13 T 624691 4859945	not recorded	Un-thinned
2	13 T 624660 4859987	not recorded	Un-thinned
3	13 T 624660 4860049	not recorded	Un-thinned
4	13 T 624635 4860079	not recorded	Un-thinned
5	13 T 624613 4860122	not recorded	Un-thinned
6	13 T 624591 4860155	not recorded	Un-thinned
7	13 T 624600 4860213	not recorded	Un-thinned
8	13 T 624646 4860235	not recorded	Un-thinned
9	13 T 624664 4860265	not recorded	Un-thinned
10	13 T 624678 4860313	not recorded	Un-thinned
Upper Starling Basin			
1	13 T 623541 4859337	not recorded	Un-thinned
2	13 T 623556 4859289	not recorded	Un-thinned
3	13 T 623561 4859257	not recorded	Un-thinned
4	13 T 623547 4859204	not recorded	Un-thinned
5	13 T 623545 4859154	not recorded	Un-thinned
6	13 T 623559 4859122	not recorded	Un-thinned
7	13 T 623535 4859081	not recorded	Un-thinned
8	13 T 623539 4859033	not recorded	Un-thinned
9	13 T 623552 4858994	not recorded	Un-thinned
10	13 T 623572 4858967	Pole oak – oak/hazelnut	Un-thinned
Lower Starling Basin			
1	13 T 623528 4858923	Pole spruce – spruce	Un-thinned
2	13 T 623550 4858907	Pole spruce – spruce	Un-thinned
3	13 T 623607 4858961	Pole oak – oak/pine	Un-thinned
4	13 T 623629 4858854	Large pine – pine/spruce/oak	Un-thinned
5	13 T 623668 4858823	Pole pine – pine/hazelnut	Un-thinned
6	13 T 623687 4858783	Pole pine – pine/spruce	Un-thinned
7	13 T 623759 4858748	Large pine – pine/spruce	Un-thinned
8	13 T 623724 4858660	Large pine – pine/oak	Un-thinned
9	13 T 623788 4858691	Pole pine – pine/aspen	Un-thinned
10	13 T 623855 4858810	Pole pine – pine/aspen	Un-thinned

Grizzly Creek

Trapline name and trap ID	UTM Zone, Easting, and Northing (NAD 83)	Tree Species Trap was Attached to and Nearby Trees/Shrubs	Management Practice
1	13 T 625089 4858660	Pole pine – pine/oak	Un-thinned
2	13 T 625047 4858596	Pole pine – pine/oak	Un-thinned
3	13 T 625007 4858554	Pole oak – oak/spruce	Un-thinned
4	13 T 624988 4858502	Large pine – pine/spruce	Un-thinned
5	13 T 624983 4858447	Pole oak – oak/pine/aspen	Un-thinned
6	13 T 624954 4858405	Large pine – pine/oak/spruce	Un-thinned
7	13 T 624954 4858359	Pole oak – oak/spruce	Un-thinned
8	13 T 624937 4858324	Large birch – birch/spruce	Un-thinned
9	13 T 624922 4858287	Pole birch – birch	Un-thinned
10	13 T 624945 4858249	Pole pine – pine/spruce/birch	Un-thinned
Powerline			
1	13 T 625516 4860234	Large aspen – aspen/pine/spruce	Partially Thinned
2	13 T 625482 4860205	Large pine – pine	Partially Thinned
3	13 T 625436 4860182	Pole oak – oak/aspen/pine	Partially Thinned
4	13 T 625396 4860139	Pole aspen – aspen	Partially Thinned
5	13 T 625366 4860084	Pole oak – oak	Partially Thinned
6	13 T 625356 4860047	Large oak – oak	Partially Thinned
7	13 T 625314 4860019	Large oak – oak	Partially Thinned
8	13 T 625298 4859976	Pole pine – pine	Partially Thinned
9	13 T 625277 4859930	Pole oak – oak	Partially Thinned
10	13 T 625230 4859904	Pole pine – pine	Partially Thinned
Chipped Area East			
1	13 T 623412 4859920	Pole pine – pine	Thinned and Chipped
2	13 T 623364 4859948	Pole pine – pine	Thinned and Chipped
3	13 T 623334 4859960	Pole pine – pine	Thinned and Chipped
4	13 T 623302 4859951	Pole pine – pine	Thinned and Chipped
5	13 T 623282 4859906	Pole pine – pine	Thinned and Chipped
6	13 T 623273 4859880	Pole pine – pine	Thinned and Chipped
7	13 T 623259 4859834	Pole pine – pine	Thinned and Chipped
8	13 T 623267 4859755	Large pine – pine	Thinned and Chipped
9	13 T 623255 4859749	Large aspen - aspen	Thinned and Chipped
10	13 T 623235 4859710	Large pine – pine	Thinned and Chipped

Chipped Area West

Trapline name and trap ID	UTM Zone, Easting, and Northing (NAD 83)	Tree Species Trap was Attached to and Nearby Trees/Shrubs	Management Practice
1	13 T 623223 4859683	Large pine – pine	Thinned and Chipped
2	13 T 623220 4859678	Large pine – pine	Thinned and Chipped
3	13 T 623211 4859720	Large pine – pine	Thinned and Chipped
4	13 T 623218 4859784	Large pine – pine	Thinned and Chipped
5	13 T 623189 4859798	Large pine – pine	Thinned and Chipped
6	13 T 623192 4859851	Large pine – pine	Thinned and Chipped
7	13 T 623220 4859870	Large pine – pine	Thinned and Chipped
8	13 T 623254 4859920	Pole pine – pine	Thinned and Chipped
9	13 T 623288 4859979	Large pine – pine	Thinned and Chipped

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U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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