THE UNIVERSITY OF ARIZONA

Mt. Graham Red Squirrel Monitoring Program

2019 Annual Report

Prepared by:

John L. Koprowski, Principal Investigator

Vicki L. Greer, Wildlife Biologist Sr.

Melissa J. Merrick, Asst. Research Scientist

Submitted 15 June 2020

photo credit: M. Merrick

EXECUTIVE SUMMARY

In 2019, the University of Arizona Mt. Graham Red Squirrel Monitoring Program (RSMP) continued efforts to document aspects of red squirrel population biology and food resources in the established study areas around the Mt. Graham International Observatory in the Pinaleño Mountains, Graham County, Arizona.

Four quarterly censuses (Mar, Jun, Sep, Dec) of all middens on or near monitored areas were conducted in 2018. From December 2018 to December 2019, the number of red squirrels on the monitored areas decreased, from 21 to 11. The number of occupied middens was fairly stable from March through September, but decreased in December.

Breeding chases were observed on or near the monitored areas in late March and mid-June. Females on or near the monitored areas were noted to be lactating or pregnant from mid-May through early September and 8 litters (16 juveniles total) were confirmed from mid-June through early September. One marked female was confirmed to have had 2 litters in 2019, the first in mid-June, then the second litter in late September.

Yearly seed production is reported as the mean number of 1000 *filled* seeds per hectare. The total seed crop in 2018 (one year delay due to methodology) was high, ranked 6 of 26 years of data since 1993. The 2018 overall mean seed crop was 2855.8 (1000 seeds/ha), larger than the 2017 overall mean seed crop, 68.9 (1000 seeds/ha), and the 2016 crop, 666.9 (1000 seeds/ha).

Overall annual mushroom production (sum of $\bar{x}$ wet weight for all areas) in 2019 was 140.1 kg/ha, smaller than in 2018 (250.1 kg/ha). The 2019 mushroom crop ranked 16 of 25 years since data collection began in 1994.

The proportion of squirrels that survived the winter of 2018-2019 (December 2018 to June 2019) in TR habitat was 90.9% (10 of 11 squirrels surviving); the highest percentage of overwinter survival (30 years of data). In SF habitat, overwinter survival, 50% (4 of 8 squirrels surviving), ranked 16th of 29 years of data. For comparison, survival from the previous winter, 2017-2018, was 50% (3 of 6 squirrels surviving) in TR habitat and 0% (0 of 2 squirrels surviving) in SF habitat. There were 4 marked squirrels on the monitored areas in December 2018 and all 4 survived to June 2019.

Table of Contents

List of Tables

List of Figures

List of Appendices

INTRODUCTION

The Mt. Graham red squirrel (*Tamiasciurus fremonti grahamensis*) is the southernmost subspecies of the wide-ranging red squirrel and is endemic to the Pinaleño (Graham) Mountains of southeastern Arizona (Hoffmeister 1986). A recent range-wide phylogeographic analysis of molecular genetic relationships determined that the southern Rockies population of red squirrels should be considered *Tamiasciurus fremonti* (Hope et al. 2016). Therefore, we use *Tamiasciurus fremonti grahamensis* throughout this annual report. Believed restricted to $\leq$ 12200 ha of mixed-conifer and spruce-fir forest at elevations > 2360 m (Hatten 2000), Mt. Graham red squirrels were federally protected as endangered in 1987 with critical habitat defined in 1990 and a recovery plan published in 1993 (United States Fish and Wildlife Service 1993). The University of Arizona's Mt. Graham Red Squirrel Monitoring Program (RSMP) was established in 1989 to meet the requirements of the Mount Graham International Observatory (MGIO) Management Plan (USDA Forest Service 1989) by monitoring the population of this endangered species in the highest peaks of the Pinaleño Mountains near the MGIO (32° 42' N, 109° 53' W). In 2019, the MGIO site consisted of three operating facilities, the Vatican Advanced Technology Telescope (VATT), the Sub-Millimeter Telescope (SMT), and the Large Binocular Telescope (LBT), a maintenance and generator building, and a 3.2 km access road (FR 4556). Herein, we report on the monitoring efforts from 1 January to 31 December 2019.

All use of terms *red squirrel* or *squirrel* refers to the Mt. Graham red squirrel unless otherwise noted.

Study Area

Four areas were defined in the vicinity of the MGIO to monitor red squirrel populations (Figure 1) and include two forest habitat types: transitional (TR) or mixed conifer forest and spruce-fir (SF) forest. The TR habitat, between 2680 m and 3050 m elevation, is composed of Engelmann spruce (*Picea engelmannii*), corkbark fir (*Abies lasiocarpa* var. *arizonica*), Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), southwestern white pine (*P. strobiformis*) and aspen (*Populus tremuloides*). The SF habitat, $\geq$ 3050 m elevation, is composed of Engelmann spruce and corkbark fir. In each habitat type, an area within 300 m of the telescope sites and access road was defined as the *construction* area (TRC, SFC). For comparison, a *non-construction* area beyond 300 m from the MGIO or the access road was defined in each habitat (TRN, SFN). The size of monitored areas has changed several times due to construction and fire events (Table 1).

METHODS

Red squirrels cache conifer cones in locations known as middens. Middens are easily recognized by presence of cached cones and piles of discarded cone scales. The RSMP defines a midden site as a circular area with 10 m radius surrounding the center of the primary cache site. Because red squirrels are territorial and generally solitary, counts of occupied middens provide a reasonably accurate estimate of population size (C.C. Smith 1968; Vahle 1978).

All known midden sites are marked with numbered metal tags, and black and orange striped flagging. During censuses or other monitoring duties, new activity areas that have the potential to become new middens are often located. Feeding sign, caching and squirrels are seen at these areas. Activity areas are assigned a temporary number and are revisited to assess sign and the presence of a squirrel during the next quarterly census. If conditions warrant, an activity area will be upgraded to a midden and added to the regular quarterly censuses. If no improvement occurs in the two quarterly censuses following initial location, the activity area is removed.

Red Squirrel Food Resources

Conifer Seed Production

The RSMP began collecting quantitative data in the early 1990s, to determine the abundance of major red squirrel food resources: conifer seeds (1993) and mushrooms (1994). Because seeds for a given year are not collected and analyzed until the following spring, seed data are delayed by one year. Seeds for the 2018 crop were collected in June 2019. Three 0.25 m^2 seed traps were randomly placed within a 10 m x 10 m plot at each location. Conifer seeds contained in each trap were separated by species and individually tested to determine the proportion of seeds that were “filled” (most likely to be viable). A filled seed leaves an oily spot on clean paper when squashed. This method is likely to underestimate total number of viable seeds because some seeds may have been preyed upon within the seed trap. Estimates of seedfall for each tree species were calculated as the average number of viable seeds from all three traps on each plot. Seeds of white pine and ponderosa pine are not readily dispersed by wind due to their large size. As a result, seed crops of these species are under represented in seed trap samples. Both species may be important local food supplies for red squirrels, but at present no reliable method exists to estimate size of seed crops.

Mushroom Production

As in previous years, mushrooms were collected from plots 1 m by 100 m (0.01 ha) at two week intervals during periods of mushroom production. Mushrooms (epigeous or above-ground fungi) are collected from late July or August through late September/early October each year. We alternate plot collection orientation (east-west or north-south) every five years in order to avoid possible impacts of long-term harvest on plots. Prior to beginning the alternating orientations, we collected mushrooms from both east-west and north-south plots in 2001 and detected no significant differences in weight, number, or diversity of mushrooms between the two orientations. Collections were restricted to genera of mushrooms used by red squirrels on Mt. Graham or in other regions (Table 2). Collected mushrooms

were separated by plot and genus, and weighed wet to the nearest 0.1 g. For most genera, dry weight was calculated by multiplying wet weight by a wet weight/dry weight ratio determined from previous samples on Mt. Graham. Dry weights were measured directly for genera with small numbers of specimens previously collected (n < 100).

Population Biology

Midden Occupancy

Census data were used to determine number and distribution of occupied middens on each monitored area. In March, June, September, and December 2019, all middens were visited at least once to determine occupancy. If a midden appeared to be occupied based upon feeding sign (cone scales, dried mushrooms, and conifer clippings) or caching, every attempt was made on subsequent midden visits to observe the resident and to determine its sex, age, and reproductive condition. In 2019, several animals on or near monitored areas were ear-tagged/radio-collared, further assisting census efforts.

All middens on the monitored areas were classified as either occupied, unoccupied, or possibly occupied, with each occupied midden representing one squirrel (except for females with dependent juveniles). A midden was considered unoccupied when no squirrel or squirrel sign was present. A midden was considered possibly occupied when red squirrel sign was found but sign was insufficient to clearly indicate occupancy and no squirrel was seen during subsequent observations. Possibly occupied middens were considered to be unoccupied when determining population size. Population size estimates are conservative and represent the minimum number known alive (Krebs 1966).

Overwinter Survival

Overwinter survival was estimated for squirrels on the monitored areas. During a complete census in December 2018, the number of occupied middens and the identity of resident squirrels were determined. December 2018 occupancy was then compared to occupancy for June 2019. For unmarked animals, a squirrel was considered to have survived winter if it was a resident of a midden in December and that same midden was found to be occupied by a squirrel of the same sex the following June. In addition, if the midden was listed as occupied based on sign or a squirrel of unknown sex was seen, this was also counted as a surviving individual. For marked squirrels, survival was generally known with a fair degree of certainty using available trapping and telemetry information.

Reproductive Activity and Success

In 2019, we recorded breeding condition of adult male and female squirrels, and litter size when observed. By examining the squirrel's condition through trapping efforts or binoculars, we determined reproductive status of females as non-reproductive (small unpigmented teats), reproductive (vulva visibly swollen or appearance of pregnancy), lactating (swollen, elongated teats with surrounding alopecia), recently lactating (elongated black tipped teats), or lactating in past seasons (small black

tipped teats). We determined reproductive status of male squirrels during trapping or visual assessment as testes non-scrotal (non-reproductive) or testes scrotal (reproductive).

Trapping and Marking

In accordance with permits issued by United States Fish and Wildlife Service Endangered Species (TE041875) and Arizona Game and Fish Department (SCL-2019: SP651773), using accepted methods (Koprowski 2002), we trapped red squirrels using wire-mesh box-type live traps (Tomahawk Co., model 201), baited with peanuts and/or peanut butter. Once captured, we transferred squirrels to a cloth-handling cone for marks and measurements. We tagged squirrels with small numbered metal ear-tags (National Band & Tag Co., style 1005-1) threaded with colored plastic washers (National Band & Tag Co., ⅜" diameter, style 1842) and affixed to ears for easy distance identification. Radio collars (Wildlife Materials Inc., model SOM2190) were fitted on some adult (collar weight < 7g). Squirrels were released at the capture site.

Mapping

All middens and most other physical features on the monitored areas were previously mapped using GPS with an accuracy of ± 5 m. Any new GPS data (middens, nests, etc.) were collected using Trimble GeoXM or GeoXT units or Garmin eTrex handheld units. Readings were taken within 5 m of the location center. Final GPS locations were based on an average from a minimum of 200 three-dimensional data points. Maps were produced using Arc-View 3.3 (ESRI 2002) and ArcMap 10.3 (ESRI 2015).

Weather Data

Weather data were summarized from the Western Regional Climate Center's RAWS station at Columbine, Arizona (32° 42' 14" N, 109° 54' 50" W), located about 2 km from the Biology Camp. https://wrcc.dri.edu/cgi-bin/rawMAIN.pl?azACOL
The station records air temperature, wind speed, wind direction, rainfall, relative humidity and other parameters. Data are averaged at 60 min intervals and minimum, maximum and mean values are recorded. Snow depth (cm) was recorded from three snow pole pairs located in SF habitat, and three snow pole pairs in TR habitat. Each pair consists of a pole in a clearing or canopy opening and a second pole nearby in the forest.

Statistical Analyses

All statistical analyses were conducted using standard tests found in IBM SPSS statistical software (Ver. 19, www.spss.com). Because sample sizes were sometimes small due to endangered status, significance for statistical tests was implied when $P \leq 0.05$ and potential biological significance was noted when $P < 0.10$.

RESULTS

Red Squirrel Food Resources

2018 Conifer Seed Production

Data collection for seed crops began in 1993 and yearly production is currently reported as the mean number of 1000 *filled* seeds per hectare. If years are ranked from highest (1) and lowest (26), the total 2018 seed crop was high, ranked 6 of 26 years of data since 1993. Corkbark-fir was the least abundant seed in 2018 and ranked 9 of 26. Douglas-fir was the most abundant seed in 2018, and ranked 4 of 26. The 2018 overall mean seed crop was 2855.8 (1000 seeds/ha), larger than the 2017 overall mean seed crop, 68.9 (1000 seeds/ha) and the 2016 crop, 666.9 (1000 seeds/ha). (Table 3, Figures 2a-c).

2019 Mushroom Production

Overall annual mushroom production (sum of $\bar{x}$ wet weight for all areas) in 2019 was 140.1 kg/ha, lower than in 2018 (250.1 kg/ha). The 2019 mushroom crop ranked 16 of 25 years since data collection began in 1994. Production was similar between the TR and SF habitats in 2019 as was seen in 2018 (Figure 3).

Population Biology

Midden Occupancy

Four quarterly censuses (Mar, Jun, Sep, Dec) of all middens on or near monitored areas were conducted in 2019 (Appendix A). From December 2018 to December 2019, the number of red squirrels on the monitored areas decreased, from 21 to 11. The number of occupied middens was fairly stable from March through September, but decreased in December. (Table 5, Figures 4 & 5, Appendices A & B).

Overwinter Survival

The proportion of squirrels that survived the winter of 2018-2019 (December 2018 to June 2019) in TR habitat was 90.9% (10 of 11 squirrels surviving); the highest percentage of overwinter survival (30 years of data). In SF habitat, overwinter survival, 50% (4 of 8 squirrels surviving), ranked 16th of 29 years of data. For comparison, survival from the previous winter, 2017-2018, was 50% (3 of 6 squirrels

surviving) in TR habitat and 0% (0 of 2 squirrels surviving) in SF habitat. There were 4 marked squirrels on the monitored areas in December 2018, and all of them survived to June 2019.

Overwinter survival may be overestimated because a midden may be occupied in the spring by a different squirrel of the same sex. Such a change in occupancy can not be detected among unmarked squirrels. However, this potential overestimate is minimal in recent years as many squirrels on the monitored areas are ear-tagged and radio collared for unique identification.

Reproductive Activity and Success

In 2019, two breeding chases were observed on the monitored areas in early March in the TR areas and one breeding chase was observed in the SFC area in mid-June (Appendix D-1). Based on information from census and trapping records, most resident adult males had testes scrotal throughout the year.

From mid-May through early September, several females seen or trapped during these months were found to be either pregnant or lactating. Direct evidence of 8 litters (16 juveniles emerged from natal nests) was documented on or near the areas during censuses or other activities. Litters were confirmed in mid-June through late September (Appendix D-2).

Trapping and Marking

In 2019, 15 squirrels (5 male, 10 female), on or near monitored areas, had radio-collars and/or colored ear tags (Appendix A). These animals were located several times each month using radio telemetry to track home ranges, reproduction and survival.

Mapping

All major features (middens, roads, trails, construction areas, etc.) have been mapped in years prior to 2019. New nests or habitat plots were GPS located and added to databases and maps. Fire severity information from USFS BAER team was overlaid on existing RSMP maps to aid in assessments of damage to study areas and middens (Figure 1).

Weather Data

Weather data were collected from January - December 2019 from the Columbine RAWS weather station (TR habitat) due to several equipment failures at the biology camp weather station. The maximum average monthly temperature was 21.7 °C in July and the minimum average monthly temperature was -8.1 °C in February. The maximum total monthly rainfall was recorded in September, at 159.3 mm (Appendix E-1). Snow depth was recorded from six pairs of snow poles. The average ***accumulated*** snow depth from December 2018 - March 2019 ranged from 22.7 cm to 97.7 cm. For comparison, average accumulated snow depths from January 2017 - March 2018 ranged from 8.5 cm to 41.0 cm (Appendix E-2). Data on wind direction, wind speed, and humidity, were also collected (Appendix E-1).

RECENT PUBLICATIONS

Peer-reviewed Journal Articles - 2019

Chen, H. L. and J. L. Koprowski. 2019. Can we use body size and road characteristics to anticipate barrier effects of roads in mammals? A meta-analysis. Hystrix. 30:1-7. https://doi.org/10.4404/hystrix–00185-2018.

Derbridge, J.J. and J. L. Koprowski. 2019. Experimental removals reveal dietary niche partitioning facilitates coexistence between native and introduced species. Ecol Evol. 9:4065–4077. https://doi.org/10.1002/ece3.5036

Pereira Mendes, C. and J. L. Koprowski. 2019. Does caching strategy vary with microclimate in endangered Mt. Graham red squirrels? PLoS ONE14(11): e0224947. https://doi.org/10.1371/journal.pone.0224947

LITERATURE CITED

Buller, A. H. R. 1920. The red squirrel of North America as a mycophagist. Transactions of the British Mycological Society 6: 355-362.

ESRI 2002. ARC View 3.3. Environmental Systems Research Institute. Redlands, CA.

ESRI 2015. ARC Map 10.3. Environmental Systems Research Institute. Redlands, CA.

Froehlich, G. F. 1990. Habitat use and life history of the Mt. Graham red squirrel. Thesis, University of Arizona, Tucson, USA.

Hatten, J. R. 2000. A pattern recognition model for the Mount Graham red squirrel. Technical Report 160. Arizona Game and Fish Department, Phoenix, USA.

Hoffmeister, D. F. 1986. Mammals of Arizona. University of Arizona Press and Arizona Game and Fish Department, Tucson, USA.

Hope, A.G., Malaney, J.L., Bell, K.C., Salazar-Miralles, F., Chavez, A.S., Barber, B.R. & Cook, J.A. (2016) Revision of widespread red squirrels (genus: *Tamiasciurus*) highlights the complexity of speciation within North American forests. Molecular Phylogenetics and Evolution, 100, 170–182.

Koprowski, J. L. 2002. Handling tree squirrels with an efficient and safe restraint. Wildlife Society Bulletin 30: 101-103.

Krebs, C. J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. Ecological Monographs 36: 239-273.

Smith, C. C. 1968. The adaptive nature of social organization in the genus of three *(sic)* squirrels *Tamiasciurus*. Ecological Monographs 38: 31-63.

Smith, M. C. 1968. Red squirrel responses to spruce cone failure in interior Alaska. Journal of Wildlife Management 32: 305-317.

States, J. S. 1990. Mushrooms and Truffles of the Southwest. University of Arizona Press, Tucson, USA.

United States Fish and Wildlife Service. 1993. Mount Graham red squirrel recovery plan. United States Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Uphoff, K. C. 1990. Habitat use and reproductive ecology of red squirrels (*Tamiasciurus hudsonicus*) in central Arizona. Thesis, Arizona State University, Tempe, USA.

USDA Forest Service. 1989. Mount Graham International Observatory Management Plan. Coronado National Forest, Tucson, USA.

Vahle, J. R. 1978. Red squirrel use of southwestern mixed coniferous habitat. Thesis, Arizona State University, Tempe, USA.

Table 1. Changes in size of study areas due to construction and fire events, University of Arizona Red Squirrel Monitoring Program, Pinaleño Mountains, Graham County, Arizona. All area measures are in hectares.

	Transition habitat		Spruce-fir habitat		
Event and Date	Construction [1]	Non-construction	Construction	Non-construction	All Areas
September 1989	85.19	20.86	88.28	104.81	299.14
LBT Site Expansion 1993	85.19	20.86	100.42	104.81	311.28
After Clark Peak Fire April 1996	51.12	20.85	75.90	104.81	252.68
After Nuttall Fire July 2004	51.12	19.81	58.49	34.14	163.56
After Frye Fire June/July 2017 [2]	50.18	19.74	56.02	32.99	158.93

1 Construction areas are ≤ 300 m from Mt. Graham International Observatory or access road. Non-construction areas are sites outside this boundary established for comparison.

2 Area sizes were reduced by the number of hectares within each perimeter classified as Severe soil burn by USFS BAER team assessments. Many middens in areas classified as Moderate soil burn had locally heavier damage. However, as the damage was scattered throughout these areas, they were not removed from the total size.

Table 2. Mushroom genera known to be food resources of Mt. Graham red squirrels (*Tamiasciurus fremonti grahamensis*), collected from the food resource plots on University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

Genus	Source
Amanita	Buller 1920, M.C. Smith 1968
Auricularia	Monitoring Program personal observations
Boletus	Buller 1920, C.C. Smith 1968, M.C. Smith 1968
Clavaria	M.C. Smith 1968
Clitocybe	Monitoring Program personal observations
Cortinarius	C.C. Smith 1968, Froehlich 1990, Uphoff 1990
Gastroid sp.	Monitoring Program personal observations, States 1990
Hydnum	C.C. Smith 1968, M.C. Smith 1968
Lactarius	Buller 1920, C.C. Smith 1968
Leccinum	Monitoring Program personal observations
Lycoperdon	Monitoring Program personal observations
Pholiota	C.C. Smith 1968
Ramaria	Monitoring Program personal observations
Russula	M.C. Smith 1968, C.C. Smith 1968
Suillus	C.C. Smith 1968

Table 3. Mean *filled* conifer seed production, 2018, on University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. The percent column represents the proportion of each seed species on an individual area (proportions add across rows).

		Corkbark fir		Douglas-fir		Engelmann spruce	
Area/Habitat	# plots	$\bar{x}$ 1000 seeds/ha	%	$\bar{x}$ 1000 seeds/ha	%	$\bar{x}$ 1000 seeds/ha	%
TRC	4	313.1	22.5	893.2	64.3	183.3	13.2
TRN	2	153.2	41.1	86.6	23.2	133.2	35.7
SFC	1	853.2	78.0	0.0	0.0	240.0	22.0

Table 4. Mean annual mushroom production, 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona

Area/Habitat	# transects	$\bar{x}$ wet weight ± SE (kg/ha)
TRC	4	53.0 ± 14.4
TRN	3	28.9 ± 6.0
SFC	1	58.2 ± 0.0
TR Habitat	7	44.0 ± 10.9

Table 5. Number and percent of available middens occupied by Mt. Graham red squirrels (*Tamiasciurus fremonti grahamensis*), 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

	June			December		
Area/Habitat	# middens	# occupied	% occ	# middens	# occupied	% occ
TRC	39	7	18.0	39	6	15.4
TRN	35	7	20.0	35	4	11.4
SFC	20	5	25.0	20	1	5.0
SFN	6	1	16.7	6	0	0.0
TR Habitat	74	14	18.9	74	10	13.5
SF Habitat	26	6	23.0	26	1	3.9
TR + SF	100	20	20.0	100	11	11.0

Table 6. Overwinter survival of Mt. Graham red squirrels (*Tamiasciurus fremonti grahamensis*), 2018 - 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

	Number of Squirrels	Number of Squirrels Surviving	
Area/Habitat	Dec 2018	Jun 2019	% Survival
TRC	7	6	85.7
TRN	5	4	80.0
SFC	6	3	50.0
SFN	2	1	50.0

Figure 1. Map of study areas, December 2019 University of Arizona Red Squirrel Monitoring Program, Pinaleño Mountains, Graham County, Arizona. Soil burn severity data is from the USFS BAER assessment team.

[1 map redacted]

Figure 2a. Corkbark fir (*Abies lasiocarpa* var. *arizonica*) seed fall, 1993 - 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. **Scales are different for figures 2a-c**.

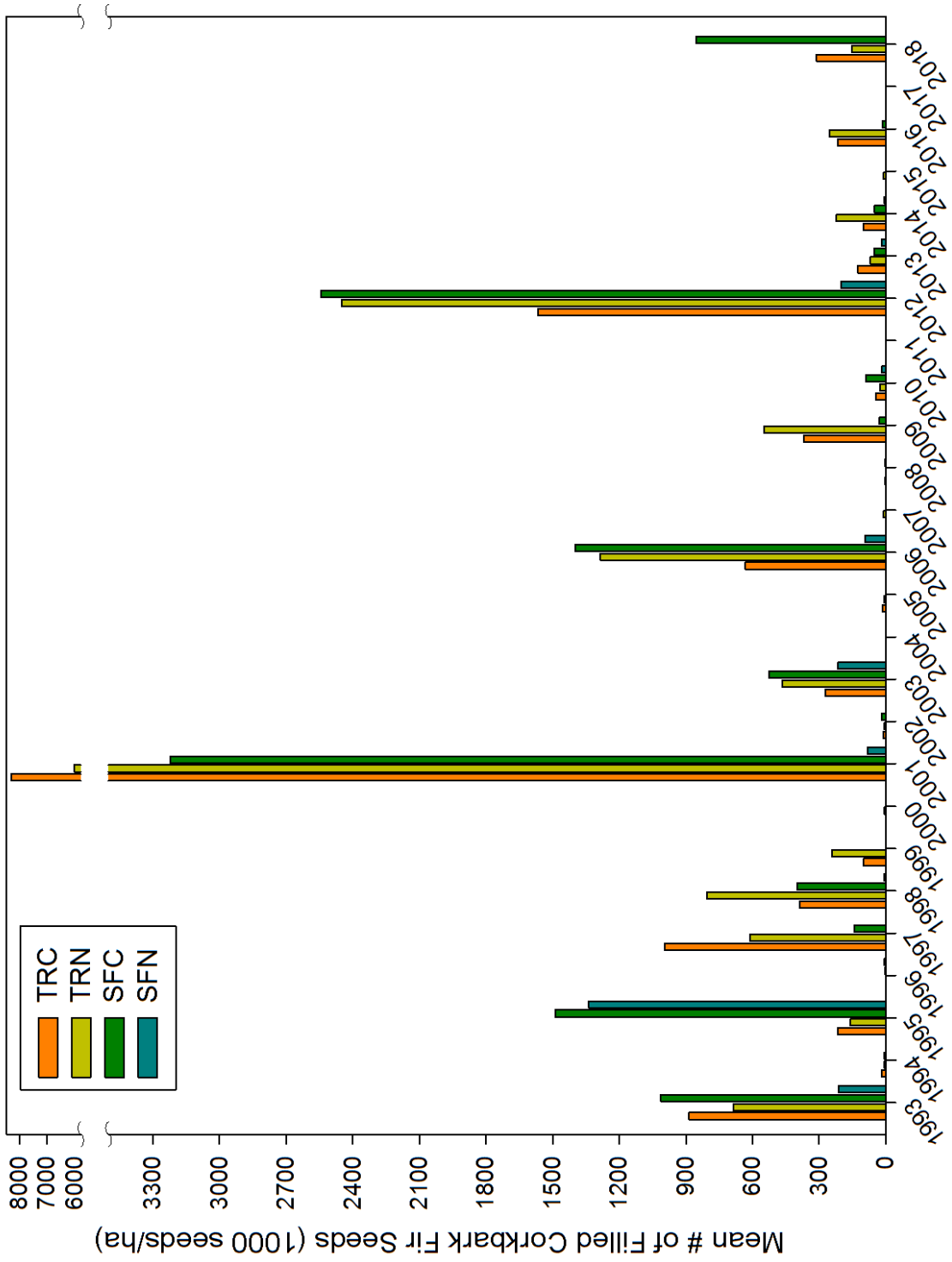


Figure 2b. Douglas-fir (*Pseudotsuga menziesii*) seed fall, 1993 - 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. **Scales are different for figures 2a-c.**

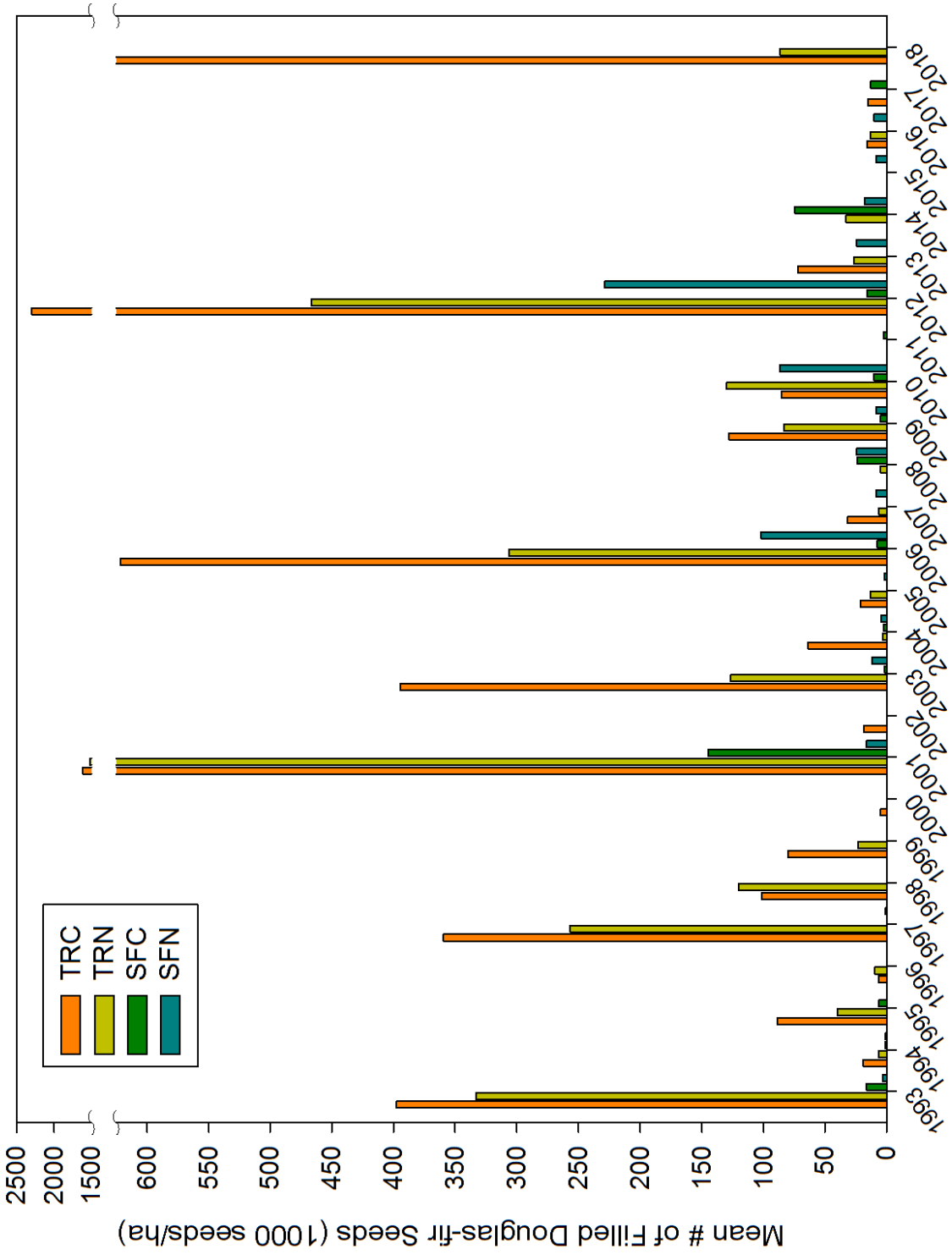


Figure 2c. Engelmann spruce (*Picea engelmannii*) seed fall, 1993 - 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. **Scales are different for figures 2a-c.**

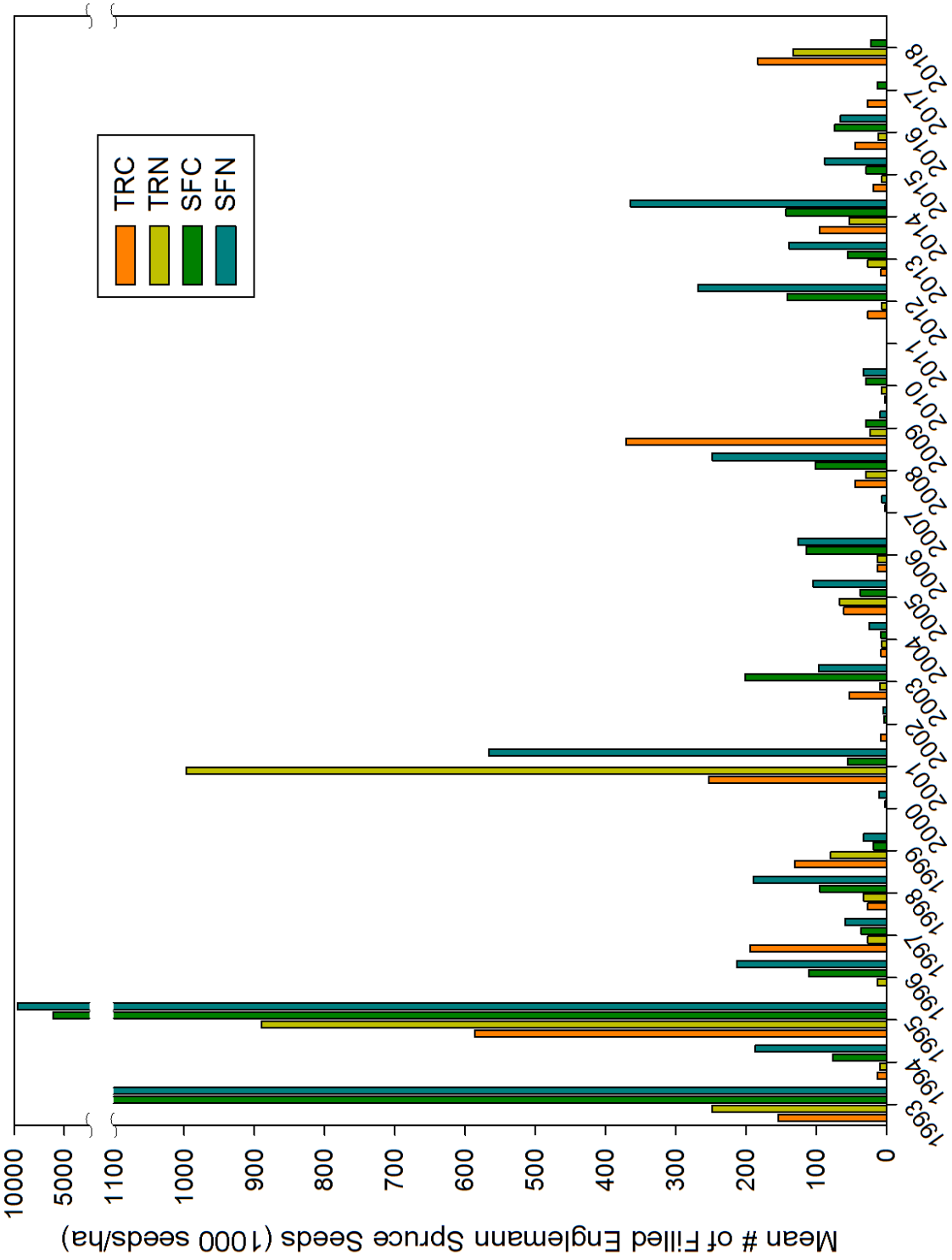


Figure 3. Mushroom crops by habitat, 1994 - 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona

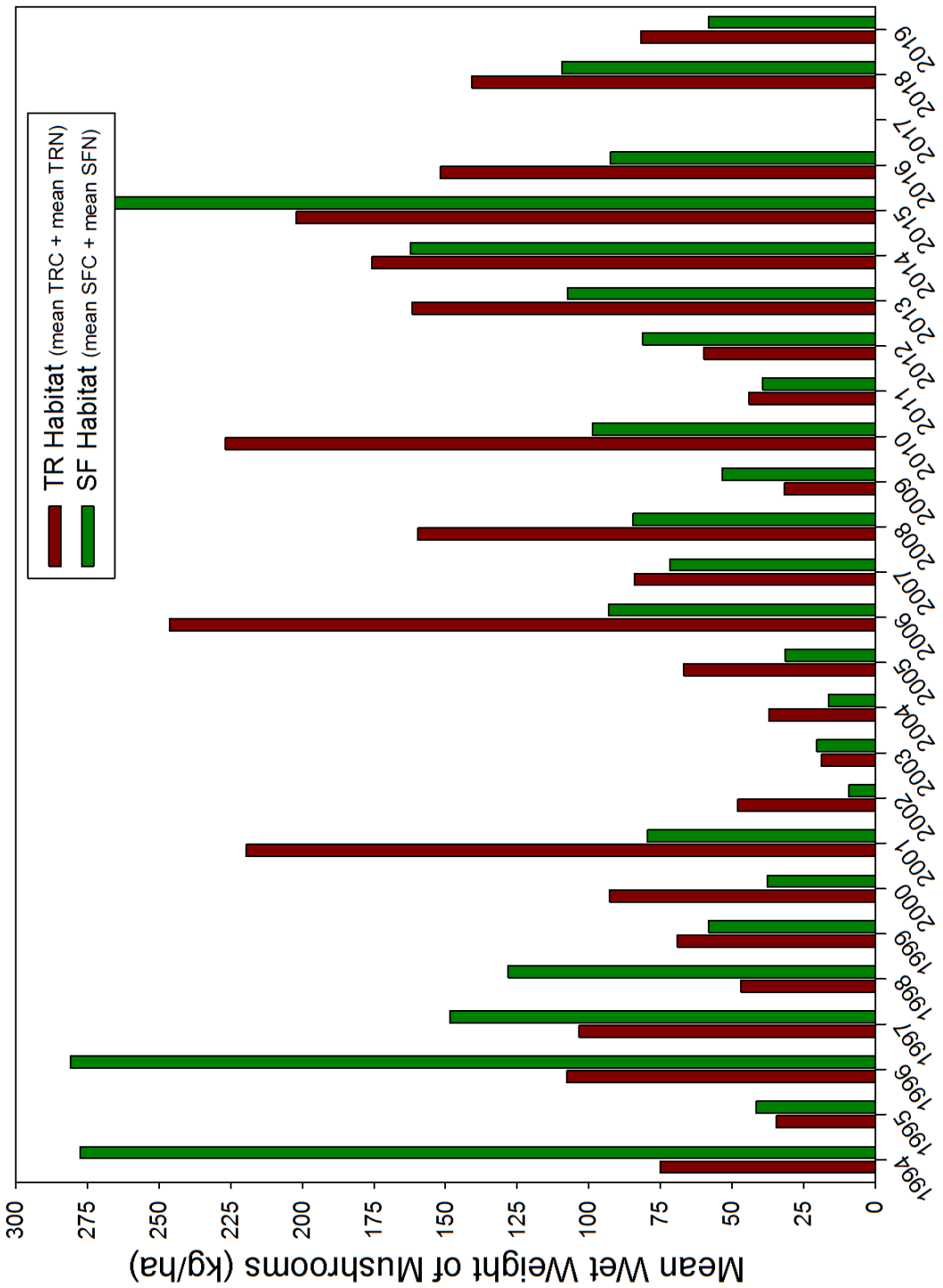


Figure 4. Quarterly Mt. Graham red squirrel (*Tamiasciurus fremonti grahamensis*) populations (including juveniles), March 2015- December 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

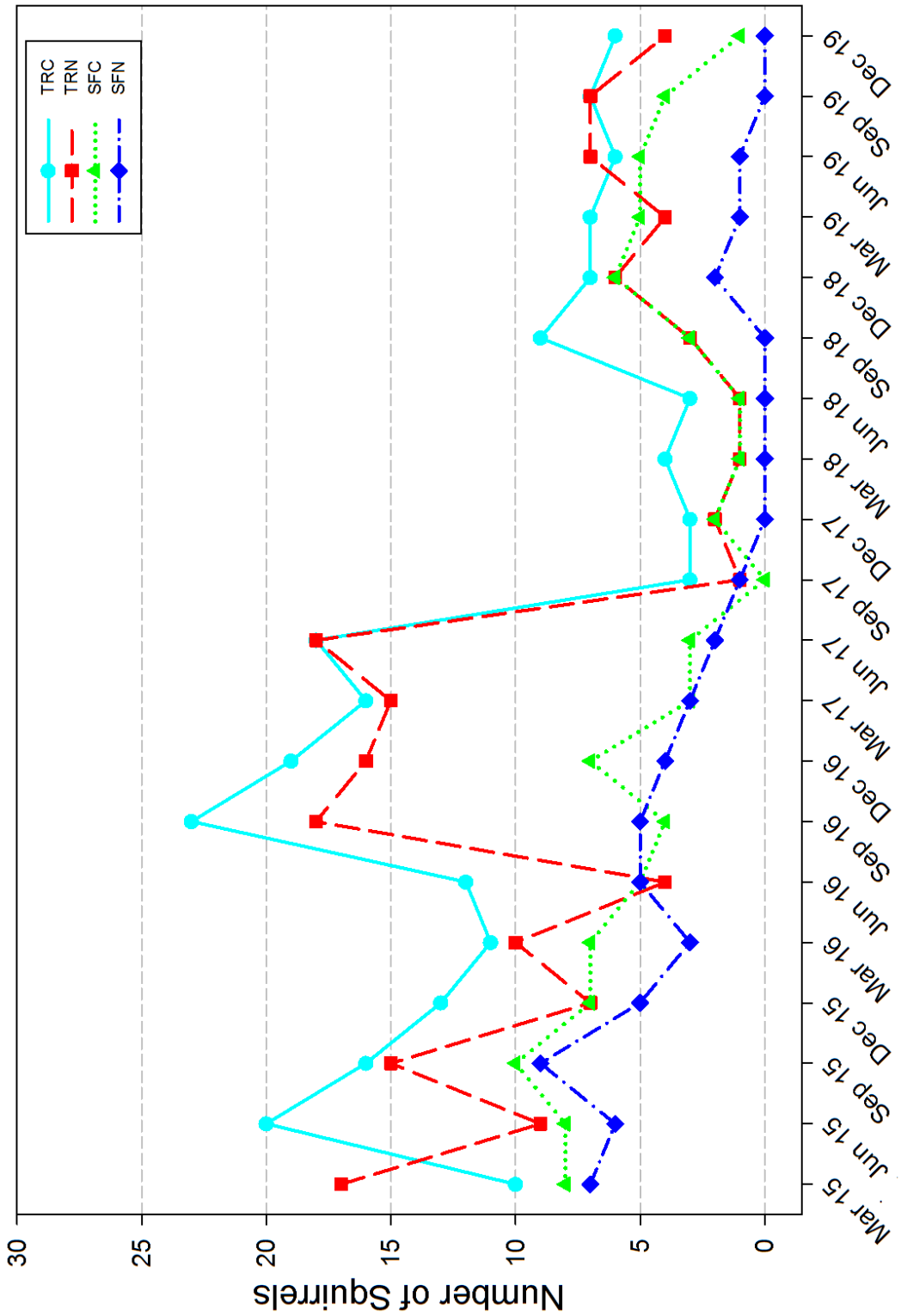
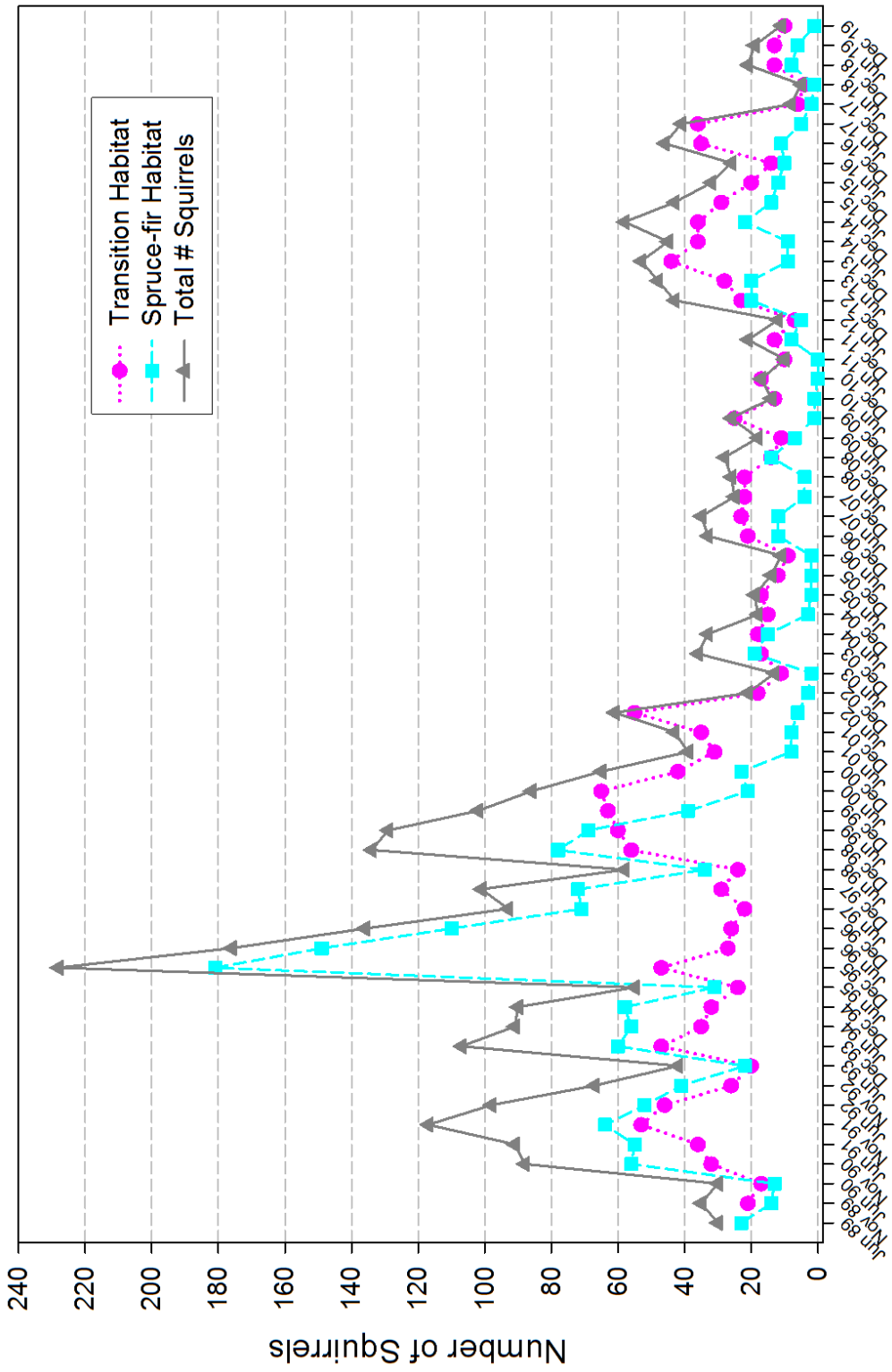


Figure 5 Summer and winter Mt. Graham red squirrel (*Tamiasciurus fremonti grahamensis*) populations (including juveniles), by habitat, June 1989 - December 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.



Appendix A: Midden occupancy records, 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

KEY

For Midden Numbers:

###^{89*}	Midden Number$^{\text{'Year Found'}}$ '*' following year indicates a newly established midden

For Monthly Occupancy cells:

N	not occupied
P	possibly occupied, red squirrel sign found but unsure of residency
Y	occupied, red squirrel sign indicates resident
S	occupied, red squirrel sighted
♀	occupied, adult female red squirrel
♂	occupied, adult male red squirrel
J	occupied, juvenile red squirrel sex unknown
SA	occupied, subadult red squirrel
♀ (R/R RC 101)	squirrel is tagged (letters indicate ear tag colors - left ear/right ear, numbers indicate RSMP animal ID) [B = blue, G = green, M = metal, O = orange, P = pink, R = red, Y = yellow, W = white n = none, -- = rip] [RC = radio collar] [tag shape is round unless noted: sq = square, tr = triangle]
NAT	squirrel is naturally marked - ear notch, short tail, etc.
-	midden not checked, no data
♀L	adult female red squirrel, lactating
♀+'#'	adult female red squirrel with "#" juveniles

Transition Construction Area (TRC), 2019				
Midden	Mar	Jun	Sep	Dec
1118[89]	N	N	N	P
1121[89*]	N	N	N	N
1127[14*]	Y	P	♂ (Osq/Osq 1242)	P
1128[15*]	Y	♀ (R/W RC 1235)	♀ (R/W RC 1235)	♀ (O/Y RC 1247)
1129[18*]	N	P	S	N
1133[19*]	new midden	♀ (Y/W 1241)	N	N
1134[91*]	N	N	N	N
1144[91*]	N	N	N	N
1146[91*]	N	N	N	N
1147[91*]	N	N	N	N
1149[91*]	N	N	N	N
1151[91*]	N	N	N	N
1154[92*]	N	N	N	N
1156[93*]	N	N	N	N
1160[96*]	S	♂ (Y/G RC 1233)	P	P
1161[96*]	N	N	N	N
1163[98*]	N	N	N	P
1164[98*]	♂ (G/G RC 1229)	♀ (P/P RC 1218) + 3J	♂ (Ysq/Ysq RC 1244)	♂ (Ysq/Ysq RC 1244)
1165[98*]	N	N	N	N
1172[90*]	N	N	N	N
1173[99*]	P	N	N	N
1174[99*]	N	N	N	N
1175[99*]	N	N	N	N
1177[99*]	N	N	N	♂
1182[02*]	N	N	N	N
1183[04*]	N	N	N	N
1185[05*]	N	N	N	N
1186[05*]	N	N	N	N
1187[05*]	N	N	N	N
1188[10*]	N	N	N	N
1189[10*]	N	N	N	N
1190[10*]	♀ (P/P RC 1218)	P	♀ (P/P RC 1218) + 2J [1]	♀ (Y/P RC 1246)
1191[10*]	♂ (Bsq/Bsq RC 1230)	♂ (Bsq/Bsq RC 1230)	♂ (Bsq/Bsq RC 1230)	♂ (Bsq/Bsq RC 1230)
1192[11*]	♀ (B/O RC 1220)	♀ (B/O RC 1220)	♀ (B/O RC 1220) + 1J [2]	S

Transition Construction Area (TRC), 2019				
Midden	Mar	Jun	Sep	Dec
1193[12*]	N	N	N	N
1194[13*]	N	N	N	N
1195[13*]	N	N	N	N
1196[13*]	N	N	N	N
1197[13*]	N	N	N	N
# Mid	38	39	39	39
# Occ	7	6	7	6
% Occ	18.4%	15.4%	17.9%	15.4%
# Sq	7	6 + 3J	7 + 3J	6

1 Female 1218 was confirmed to have 2 different litters in 2019, 3 Juveniles in June, and 2 Juveniles in September.

2 3 Juveniles were seen with female 1220 in late August.

Transition Non-Construction Area (TRN), 2019				
Midden	Mar	Jun	Sep	Dec
2202[89]	N	N	N	N
2204[89]	N	N	N	N
2205[89]	N	N	N	N
2209[89]	N	N	N	P
2210[90]	N	Y	N	N
2211[90*]	N	N	N	♀ (P/W RC 1243)
2215[90*]	N	N	N	N
2216[90*]	N	N	N	N
2217[90*]	N	N	N	N
2218[91*]	Y	♀ (R/Y RC 1239)	Y	N
2220[91*]	N	N	N	N
2222[91*]	N	N	N	N
2223[91*]	Y	♂	♂	♂
2224[93*]	N	N	N	N
2226[95*]	N	N	N	N
2227[95*]	S	♀ (O/O RC 1236) + 3J	♀ (O/O RC 1236)	♀ (O/O RC 1236)
2230[96*]	N	N	N	N
2233[96*]	N	N	N	N
2235[98*]	N	N	N	N
2236[98*]	N	♂	Y	N
2237[98*]	N	N	N	N
2238[98]	N	N	N	N
2239[98]	N	N	N	N
2244[99*]	N	N	N	N
2245[99*]	N	N	N	P
2248[99*]	N	N	N	N
2250[00*]	N	N	N	N
2251[00*]	N	N	N	N
2255[11*]	N	N	N	N
2256[12*]	N	N	N	N
2257[13*]	N	N	N	N

Transition Non-Construction Area (TRN), 2019				
Midden	Mar	Jun	Sep	Dec
2260[14*]	N	N	S	N
2262[17*]	N	N	P	N
2263[18*]	Y	♀ (Nat rip/B 1240) + 1J [1]	♀ (Nat rip/B 1240)	N
2264[19*]	new midden	♀ (P/W 1243)	♀ (P/W 1243) + 1J [1]	♂ (G/G RC 1229)
# Mid	34	35	35	35
# Occ	4	7	7	4
% Occ	11.8%	20.0%	20.0%	11.4%
# Sq	4	7 + 4J	7 + 1J	4

1 There were likely at least 2 juveniles in each litter for females 1240 and 1243, but could not be 100% confirmed.

Spruce-Fir Construction Area (SFC), 2019				
Midden	Mar	Jun	Sep	Dec
3019[96*]	N	N	N	N
3020[96*]	Y	♂	S	N
3330[95*]	N	N	N	N
3031[99*]	N	N	N	N
3033[12*]	N	N	N	N
3037[17*]	N	♀	♀	Y
3038[18*]	N	N	N	P
3039[18*]	N	Y	P	P
3040[18*]	Y	♀	Y	N
3312[95*]	N	♀	♀	P
3314[95*]	N	N	N	P
3315[95*]	N	N	N	N
3347[95*]	N	N	N	N
3357[86]	N	N	N	N
3363[86]	N	N	N	N
3364[86]	S	N	N	P
3365[86]	S	N	N	N
3366[86]	N	N	N	N
3367[87]	Y	N	N	N
3382[91*]	N	N	N	N
# Mid	20	20	20	20
# Occ	5	5	4	1
% Occ	25.0%	25.0%	20.0%	5.0%
# Sq	5	5	4	1

Spruce-Fir Non Construction Area (SFN), 2019				
Midden	Mar	Jun	Sep	Dec
4026[09*]	N	N	N	N
4028[14*]	N	N	N	N
4030[18*]	N	N	N	N
4031[18*]	Y	Y	P	N
4417[95*]	N	N	N	N
4465[90*]	N	N	N	N
# Mid	6	6	6	6
# Occ	1	1	0	0
% Occ	16.7%	16.7%	0%	0%
# Sq	1	1	0	0

Off-Area Midden Occupancy, 2019				
Midden	Mar	Jun	Sep	Dec
TRC Area				
5103[99*]	N	N	N	N
5104[99*]	N	N	N	N
5119[89*]	N	N	N	N
5120[89*]	N	N	N	N
5158[12*]	N	N	N	N
TRN Area				
5200[93*]	N	N	N	N
5203[00*]	N	♂ (G/G RC 1229)	♂ (G/G RC 1229)	N
5221[91*]	N	N	N	N

Appendix B. Mt. Graham red squirrel (*Tamiasciurus fremonti grahamensis*) populations (including juveniles at maternal middens), March 2015 - December 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

Date	TRC	TRN	SFC	SFN	TOTAL
Mar 2015	10	17	8	7	42
Jun 2015	17 + 3 Juv	9	8	6	40 + 3 Juv
Sep 2015	16	15	10	9	50
Dec 2015	13	7	7	5	32
Mar 2016	11	10	7	3	31
Jun 2016	12	4	5	5	26
Sep 2016	19 + 4 Juv	18	4	5	46 + 4 Juv
Dec 2016	19	16	7	4	46
Mar 2017	16	15	3	3	37
Jun 2017	18	14 + 4 Juv	3	2	37 + 4 Juv
Sep 2017	3	1	0	1	4
Dec 2017	3	2[1]	2	0	7[1]
Mar 2018	4	1	1	0	6
Jun 2018	3	1	1	0	5
Sep 2018	6 + 3J	3	3	0	12 + 3J
Dec 2018	7	6	6	2	21
Mar 2019	7	4	5	1	17
Jun 2019	6 + 3J	7 + 4J	5	1	19 + 7J
Sep 2019	7 + 3J	7 + 1J	4	0	18 + 4J
Dec 2019	6	4	1	0	11

Appendix C: Quarterly occupancy maps for Mt. Graham red squirrels (*Tamiasciurus fremonti grahamensis*), March, June, September, and December 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

[12 maps redacted]

Appendix D-1: Breeding Chases Observed - 2019

Breeding chases observed on or near the University of Arizona Red Squirrel Monitoring Program study areas in 2019. Information on breeding chases in other areas of the Pinaleño Mountains is included here to provide a general time frame for red squirrel breeding activity.

Date	Location	Notes
9 Mar 19	1190 - TRC	Female 1218 and 6 males were observed in a breeding chase. Marked males 1224 and 1229 and 4 unmarked males were observed.
9 Mar 19	2227 - TRN	Marked male 1232 was observed in this midden for most of the day, there was on and off chasing of the resident unmarked female.
17 Jun 19	3037 - SFC	One unmarked female was observed with 2 unmarked males chasing her.

Appendix D-2: Litters and reproductive status observed in 2019 on or near University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. Only litters on the monitored areas during census months are counted in the quarterly population totals (see Appendix A).

Mother ID	Midden/Nest	Date Litter 1st Seen	Notes
1218	1164 - TRC	13 Jun 19	3 juveniles
1218	1190 - TRC	20 Sep 19	2 juveniles [1]
1220	1192 - TRC	7 Aug 19	3 juveniles
1228	8694 - Grant Hill	5 Sep 19	3 juveniles
1235	1128 - TRC	12 Jun 19	1 juvenile [2]
1236	2227 - TRN	27 Jul 19	1 juvenile
1237	8076 - ST	13 Jun 19	2 juveniles [3]
1243	2264 - TRN	6 Sep 19	1 juvenile [4]
Total	8 litters		16 juveniles

1 Female 1218 was confirmed to have 2 separate litters in 2019.

2 There were likely at least 2 juveniles in female 1235's litter, as predated remains of a juvenile were found at the base of the maternity nest.

3 On 13 June, small juvenile seen just poking head out of nest. Two juveniles were seen foraging with female 1237 as late as 27 July 19.

4 There may have been a second juvenile in female's 1243's litter, but not confirmed.

Appendix E. Weather information, 2019, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

E-1: Monthly weather summaries

E-2: Accumulated snow depths

The weather summary data is from the RAWS (remote automated weather station) site at Columbine Ranger Station, Mt. Graham, Coronado National Forest. The Raws station is located approximately 2 km north of the biology camp at a similar elevation.

https://wrcc.dri.edu/cgi-bin/rawMAIN.pl?azACOL

Appendix E-1: Monthly weather summaries - 2019, Columbine Ranger Station RAWS.

	Mean Wind Direction	Mean Wind Speed	Maximum Wind Gust	Average Air Temperature					Average Relative Humidity			Precip.
Date	m/s	Deg	m/s	Deg C					%			mm
	Ave.	Vector Ave.	Max.	Ave.	Ave. Daily Max.	Max.	Ave. Daily Min.	Min.	Ave.	Max.	Min.	Total
Jan-19	1.59	197.10	17.43	-0.88	6.36	15.00	-6.81	-14.43	55.99	99	4	63.75
Feb-19	2.81	215.60	18.78	-3.43	1.81	10.56	-8.06	-16.10	68.93	100	5	113.80
Mar-19	2.55	214.80	24.14	1.78	8.05	15.00	-3.69	-13.88	50.66	99	4	37.08
Apr-19	2.33	223.40	20.56	5.06	10.89	18.33	-0.50	-6.11	47.46	97	7	11.68
May-19	2.55	215.00	16.99	5.89	11.77	17.78	0.66	-4.44	48.07	97	15	4.83
Jun-19	1.85	212.70	14.31	13.55	20.41	25.56	6.28	2.78	34.16	92	9	4.32
Jul-19	1.12	79.53	13.41	15.55	21.65	25.00	10.11	6.67	53.99	98	18	105.40
Aug-19	0.75	65.61	10.73	14.94	21.34	25.56	9.37	7.22	65.37	99	19	111.30
Sep-19	1.50	192.20	16.54	11.43	16.98	22.78	6.80	1.11	72.34	98	17	159.30
Oct-19	1.90	204.10	16.99	6.86	13.67	16.67	1.11	-7.22	43.9	97	2	10.67
Nov-19	1.52	192.20	23.25	2.61	9.13	17.78	-2.02	-9.99	59.8	98	1	134.60
Dec-19	1.90	203.90	13.86	-0.95	4.82	16.67	-5.70	-14.99	57.41	99	4	82.55

Appendix E-2: ***Accumulated*** snow depths on the monitored areas for Winter 2018 - 2019. Snow pole data are collected opportunistically when biologists are on Mt. Graham.

Snow Depth Summary

Snow Year Year	*Month*	*Habitat*	*Location*	*Avg Depth (cm)*	*Min Depth (cm)*	*Max Depth (cm)*	*Avg. % Cover*	*# of Readings for Avg.*
2018-2019								
2018	Dec	Spruce-fir	Clearing	27.2	23.5	32	100.0	3
2018	Dec	Spruce-fir	Forest	28.3	28	28.5	100.0	2
2018	Dec	Transition	Clearing	28.0	25	33	100.0	3
2018	Dec	Transition	Forest	22.7	15	34	100.0	3
2019	Jan	Transition	Clearing	63.7	54	70	100.0	3
2019	Jan	Transition	Forest	54.7	34	79	100.0	3
2019	Feb	Transition	Clearing	97.7	75	110	100.0	3
2019	Feb	Transition	Forest	83.3	60	120	100.0	3
2019	Mar	Spruce-fir	Clearing	64.0	39	89	100.0	2
2019	Mar	Spruce-fir	Forest	93.3	74	105	100.0	3
2019	Mar	Transition	Clearing	72.3	45	87	100.0	3
2019	Mar	Transition	Forest	57.3	39	89	100.0	3
	Averages for Snow Year			57.7	42.6	73.0	100.0	***Sum # Readings***
			Std Dev	26.51				34
			SE of Mean	4.55				