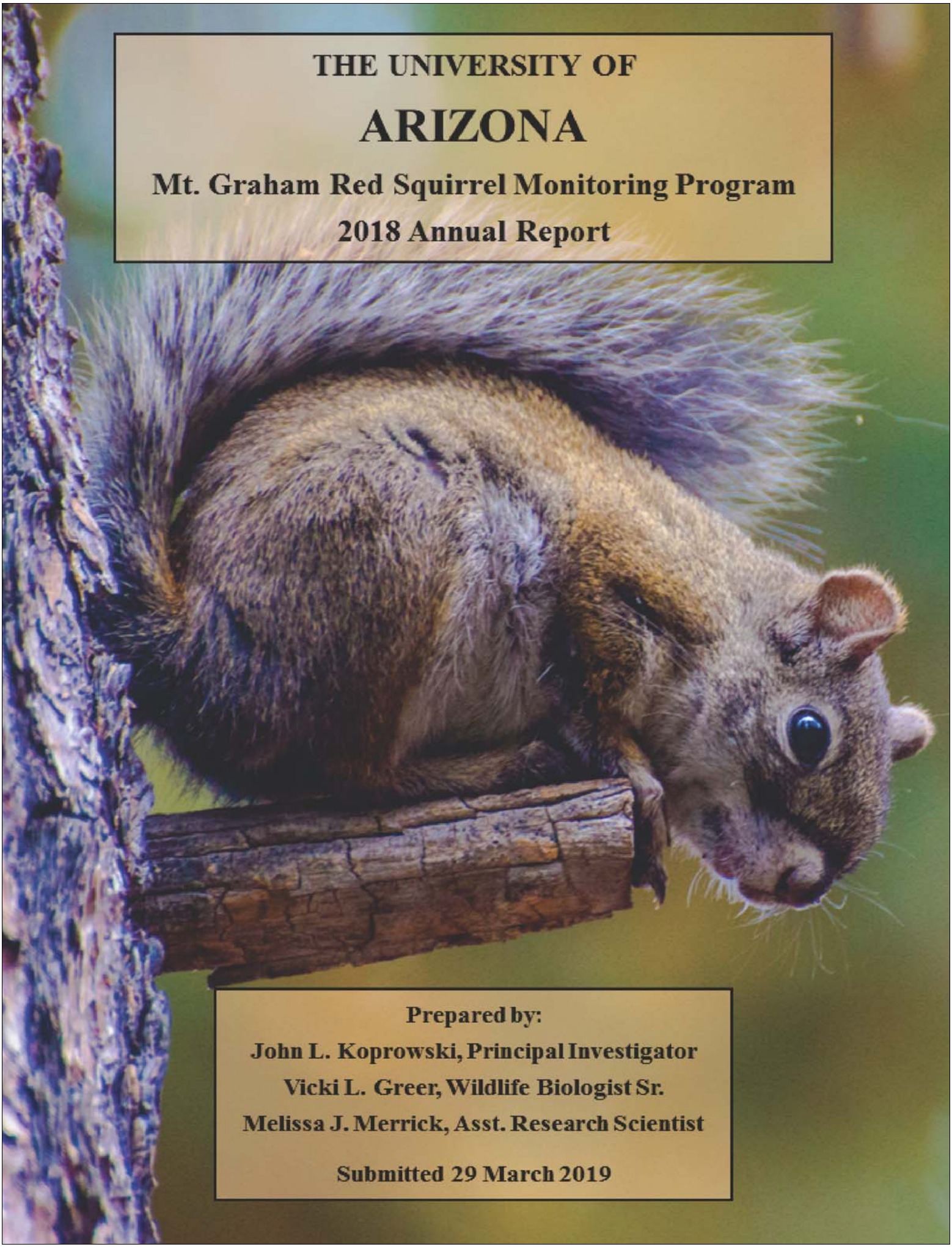

THE UNIVERSITY OF ARIZONA

Mt. Graham Red Squirrel Monitoring Program

2018 Annual Report

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EXECUTIVE SUMMARY

In 2018, 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 2017 to December 2018, the number of red squirrels on the monitored areas increased, from 7 to 21. Increases were seen in all study areas, even in the small patches of unburned forest in spruce-fir (SF) habitat remaining after the Frye Fire in 2017.

Breeding chases were observed on or near the monitored areas in late March and late May. Females on or near the monitored areas were noted to be lactating or pregnant from late April through early September and 5 litters (9 juveniles total) were confirmed from early June through early September.

Yearly seed production is reported as the mean number of 1000 *filled* seeds per hectare. The total seed crop in 2017 (one year delay due to methodology) was low, ranked 23 of 25 years of data since 1993. The 2017 overall mean seed crop was 68.9 (1000 seeds/ha), smaller than the 2016 overall mean seed crop, 666.9 (1000 seeds/ha), and the 2015 crop, 164.7 (1000 seeds/ha).

Mushroom sample collection resumed in 2018, following no collection in 2017 due to the Frye Fire. Overall annual mushroom production (sum of $\bar{x}$ wet weight for all areas) in 2018 was 250.1 kg/ha, slightly larger than in 2016 (244.1 kg/ha). The 2018 mushroom crop ranked 10 of 24 years since data collection began in 1994.

The proportion of squirrels that survived the winter of 2017-2018 (December 2017 to June 2018) in transition (TR) habitat was 50% (3 of 6 squirrels surviving) and in SF habitat overwinter survival 0% (0 of 2 squirrels surviving). For comparison, survival from the previous winter, 2016-2017, was 57.1% (20 of 35 squirrels surviving) in TR habitat and 27.3% (3 of 11 squirrels surviving) in SF habitat. There were 3 marked squirrels on the monitored areas in December 2017, and by June 2018, 2 were known alive with 1 confirmed mortality (remains and collar found in January 2018).

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 2018, 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 2018.

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). Prior to the Frye Fire in summer 2017, there were 20 seedfall plots distributed among the monitored areas. Following the fire, several plots had the overstory damaged or destroyed, or seed traps filled with ash and debris in areas of ground fire. Most of the plots lost were in the SF habitat. Only 4 plots provided useable samples from the 2017 crop; these were collected in June 2018. Because seeds for a given year are not collected and analyzed until the following spring, seed data are delayed by one year. 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. The mushroom plots are located at the seedfall plots, so also experienced damage from the Frye Fire in 2017. We were able to collect samples from 7 plots on the monitored areas in 2018, as areas with lighter ground fires had some

recovery in the understory. Mushrooms (epigeous or above-ground fungi) are collected from late July 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 2018, 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 2018, 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 2017, the number of occupied middens and the identity of resident squirrels were determined. December 2017 occupancy was then compared to occupancy for June 2018. 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 2018, 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-2018: SP611944), 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. Locations were differentially corrected using base station (Continuously Operating Reference Station, CORS-COT1, Tucson, Arizona). 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

2017 *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 (25), the total 2017 seed crop was low, ranked 23 of 25 years of data since 1993. However, due to damage to seedfall plots from the Frye Fire in summer 2017, useable samples were collected only from 3 plots in the TR habitat and 1 plot in the SF habitat. So comparisons to seed crops in other years should be made with caution. Corkbark fir was not present in 2017 samples. Engelmann spruce was the most abundant seed in 2017 and ranked 21 of 25. Douglas-fir was the least abundant seed in 2017, and ranked 23 of 25. The 2017 overall mean seed crop was 68.9 (1000 seeds/ha), smaller than the 2016 overall mean seed crop, 666.9 (1000 seeds/ha) and the 2015 crop, 164.7 (1000 seeds/ha). (Table 3, Figures 2a-c).

2018 *Mushroom Production*

Overall annual mushroom production (sum of $\bar{x}$ wet weight for all areas) in 2018 was 250.1 kg/ha, slightly larger than in 2016 (244.1 kg/ha). No mushrooms were collected following the Frye Fire in 2017. The 2018 mushroom crop ranked 10 of 24 years since data collection began in 1994. Production was similar in TR and SF habitats in 2018 as compared to 2016 (Figure 3).

Population Biology

Midden Occupancy

Four quarterly censuses (Mar, Jun, Sep, Dec) of all middens on or near monitored areas were conducted in 2018 (Appendix A). From December 2017 to December 2018, the number of red squirrels on the monitored areas increased, from 7 to 21. Increases in occupied middens were seen

in all areas, even in the small patches of SF habitat that remained following the Frye Fire (Table 5, Figures 4 & 5, Appendices A & B).

Overwinter Survival

The proportion of squirrels that survived the winter of 2017-2018 (December 2017 to June 2018) in TR habitat was 50% (3 of 6 squirrels surviving); the 21st lowest percentage of overwinter survival (29 years of data). In SF habitat, overwinter survival, 0% (0 of 2 squirrels surviving), ranked 28th of 28 years of data. For comparison, survival from the previous winter, 2016-2017, was 57.1% (20 of 35 squirrels surviving) in TR habitat and 27.3% (3 of 11 squirrels surviving) in SF habitat. There were 3 marked squirrels on the monitored areas in December 2017, and by June 2018, 2 were known alive, with 1 confirmed mortality (remains and collar found in January 2018).

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 2018, one breeding chase was observed on the monitored areas in late May and one chase was seen on nearby study areas indicating breeding activity during late March (Appendix D-1). Based on information from census and trapping records, most resident adult males had testes fully scrotal March through early September and again in December.

From late April through early September, several females seen or trapped during these months were found to be either pregnant or lactating. Direct evidence of 5 litters (9 juveniles emerged from natal nests) was documented on or near the areas during censuses or other activities. Litters were confirmed in early June through early September (Appendix D-2).

Trapping and Marking

In 2018, 6 squirrels (4 male, 2 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 2018. 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 2018 from the Columbine RAWS weather station (TR habitat) due to several equipment failures at the biology camp weather station. From available data, maximum temperature recorded was 26.7 °C in July and the minimum temperature recorded was -21.1 °C in January. The maximum average monthly temperature was 22.1 °C in June and the minimum average monthly temperature was -5.1 °C in January (Appendix E-1). The maximum total monthly rainfall was recorded in August, at 150.1 mm (Appendix E-1). Snow depth was recorded from six pairs of snow poles. The average ***accumulated*** snow depth from January 2018 - March 2018 ranged from 8.5 cm to 41.0 cm. For comparison, average accumulated snow depths from December 2016 - April 2017 ranged from 0.0 cm to 65.0 cm (Appendix E-2). For comparison, average accumulated snow depths for the previous winter (November 2015 - April 2016), ranged from 0.0 cm to 98.9 cm. Data on, wind direction and speed, and humidity, were also collected (Appendix E-1).

RECENT PUBLICATIONS

Peer-reviewed Journal Articles - 2018

Goldstein, E. A., M. J. Merrick, and J. L. Koprowski. 2018. Low survival, high predation pressure present conservation challenges for an endangered endemic forest mammal. Biological Conservation 221:67-77.

Hale, S. L., V. L. Greer,. J. L. Koprowski, and N. Ramos-Lara. 2018. Microsciurus santanderensis (Rodentia: Sciuridae). Mammalian Species 50:166-169.

Hale, S. L., and J. L. Koprowski. 2018. Ecosystem-level effects of keystone species reintroduction: a literature review. Restoration Ecology. DOI: 10.1111/rec.12684.

Hefty, K. L. and K. M. Stewart. 2018. Novel location data reveal spatiotemporal strategies used by a central-place forager. Journal of Mammalogy. DOI:10.1093/jmammal/gyy019.

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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, **2017**, 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). After the Frye Fire in summer 2017, many of the seed plots on the study areas were burned or impacted (ash and mud filled seed traps). Data from the remaining plots is presented below, but should be considered with caution when comparing to other years, due to small number of plots.

		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	3	0.0	0.0	15.6	36.9	26.7	63.1
SFC	1	0.0	0.0	13.3	50.0	13.3	50.0

Table 4. Mean annual mushroom production, **2018**, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. In the summer of 2017, the Frye Fire damaged or destroyed the habitat at 13 of the 20 mushroom plots on the study areas. Most of plots lost were in the SF habitat.

Area/Habitat	# transects	$\bar{x}$ wet weight ± SE (kg/ha)
TRC	4	37.2 ± 8.4
TRN	3	103.5 ± 24.5
SFC	1	109.4 ± 0.0
TR Habitat	7	65.6 ± 16.9

Table 5. Number and percent of available middens occupied by Mt. Graham red squirrels (*Tamiasciurus fremonti grahamensis*), 2018, 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	38	3	7.9	38	7	18.4
TRN	33	1	3.0	34	6	17.6
SFC	18	1	5.6	20	6	15.0
SFN	4	0	0.0	6	2	33.3
TR Habitat	71	4	5.6	72	13	18.1
SF Habitat	22	1	4.5	26	8	30.8
TR + SF	93	5	5.3	98	21	21.4

Table 6. Overwinter survival of Mt. Graham red squirrels (*Tamiasciurus fremonti grahamensis*), 2017 - 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

	Number of Squirrels	Number of Squirrels Surviving	
Area/Habitat	Dec 2017[1]	Jun 2018	% Survival
TRC	4	3	75.0
TRN	2	0	0.0
SFC	2	0	0.0
SFN	0	0	--

[1] There were only 3 known squirrels on the TRC area in Dec 2017, however a marked female (ID 1218), that had been missing since Sep 2017, was found at a new midden in March 2018. So she was alive in Dec 2017, just not known at the time.

Figure 1. Map of study areas, December 2018 University of Arizona Red Squirrel Monitoring Program, Pinaleño Mountains, Graham County, Arizona. Soil burn severity data is from the USFS BAER assessment team.

[Map redacted]

Figure 2a. Corkbark fir (*Abies lasiocarpa* var. *arizonica*) seed fall, 1993 - 2017, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. **Scales are different for figures 2a-c**.

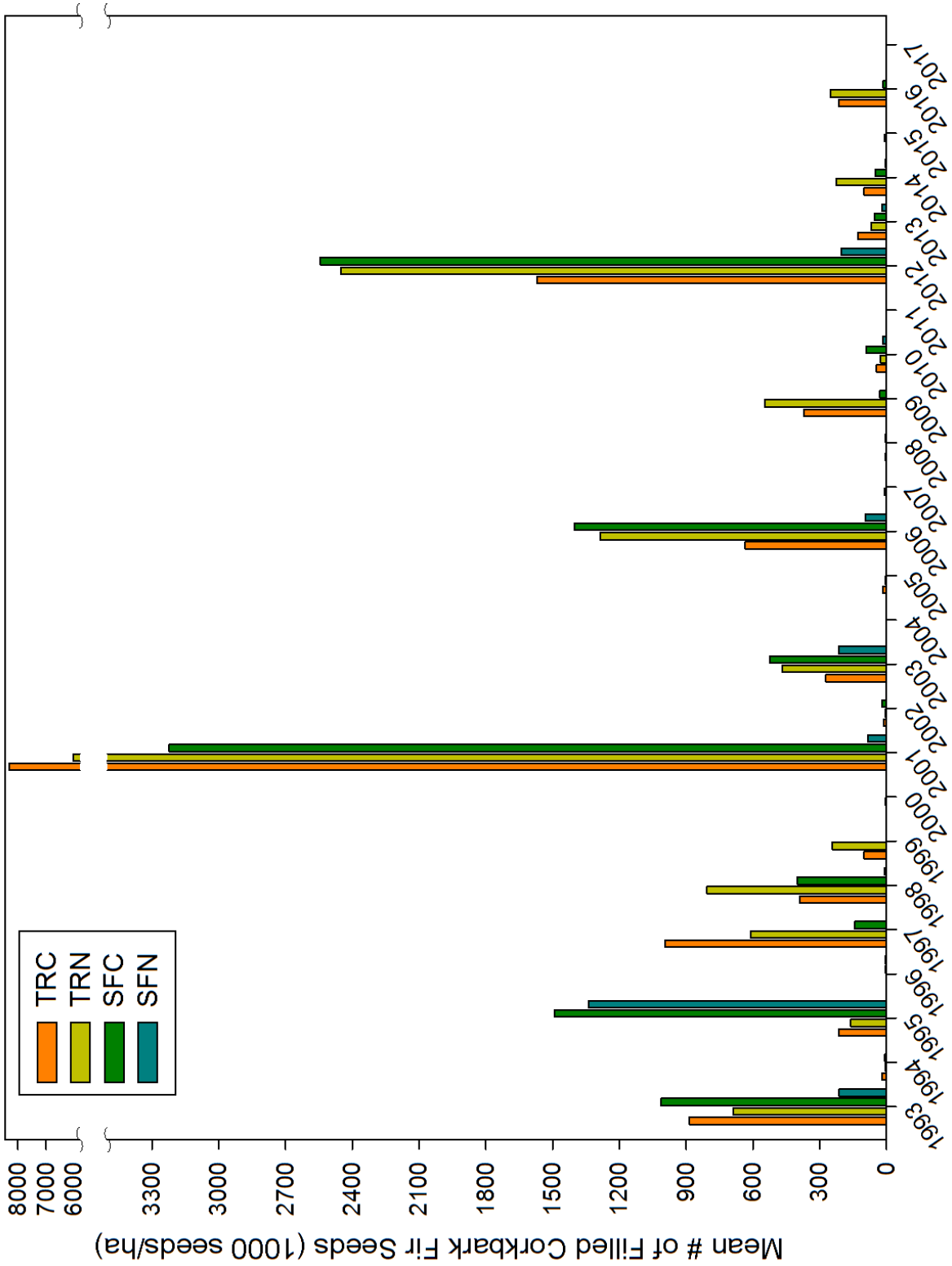


Figure 2b. Douglas-fir (*Pseudotsuga menziesii*) seed fall, 1993 - 2017, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. **Scales are different for figures 2a-c.**

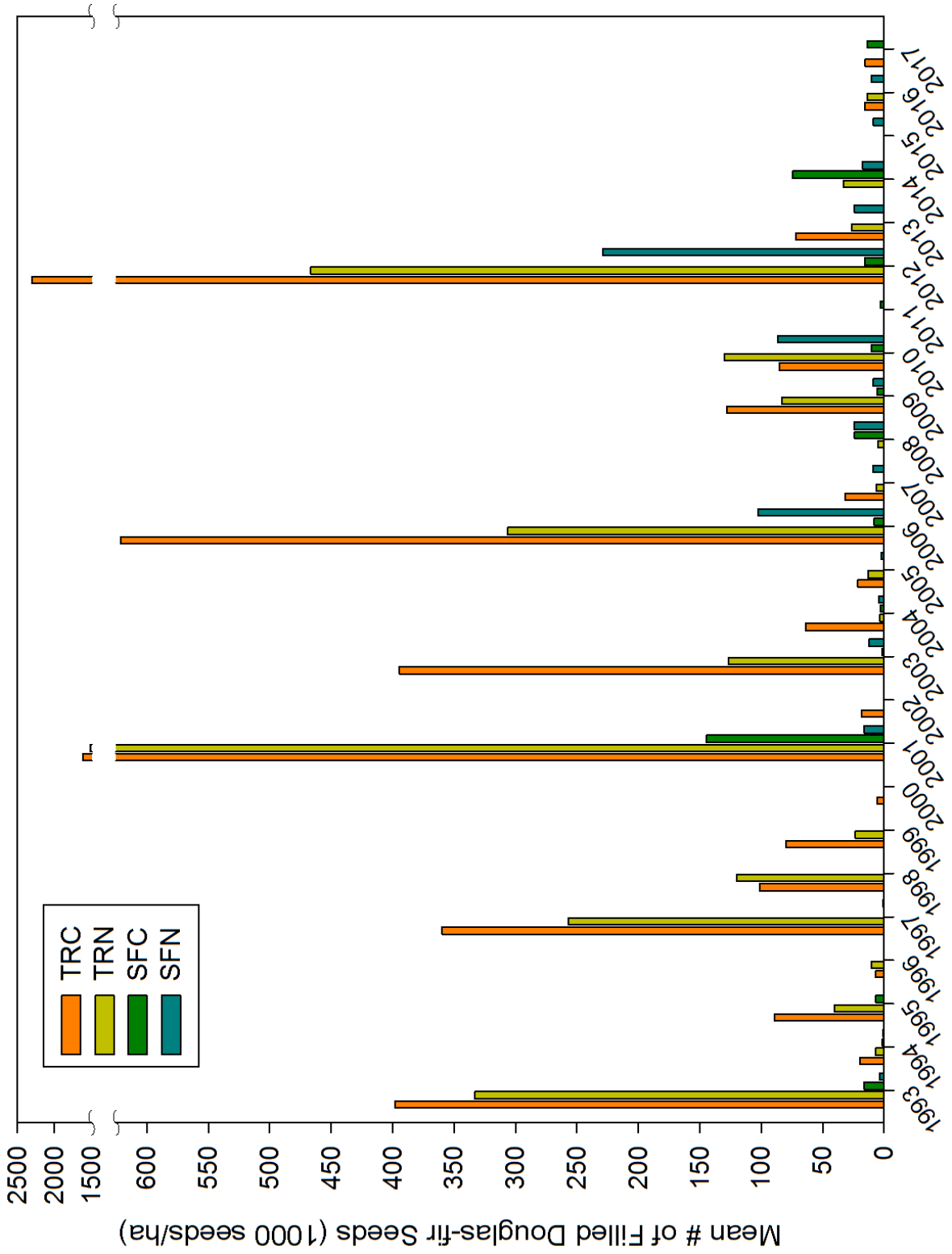


Figure 2c. Engelmann spruce (*Picea engelmannii*) seed fall, 1993 - 2017, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. **Scales are different for figures 2a-c.**

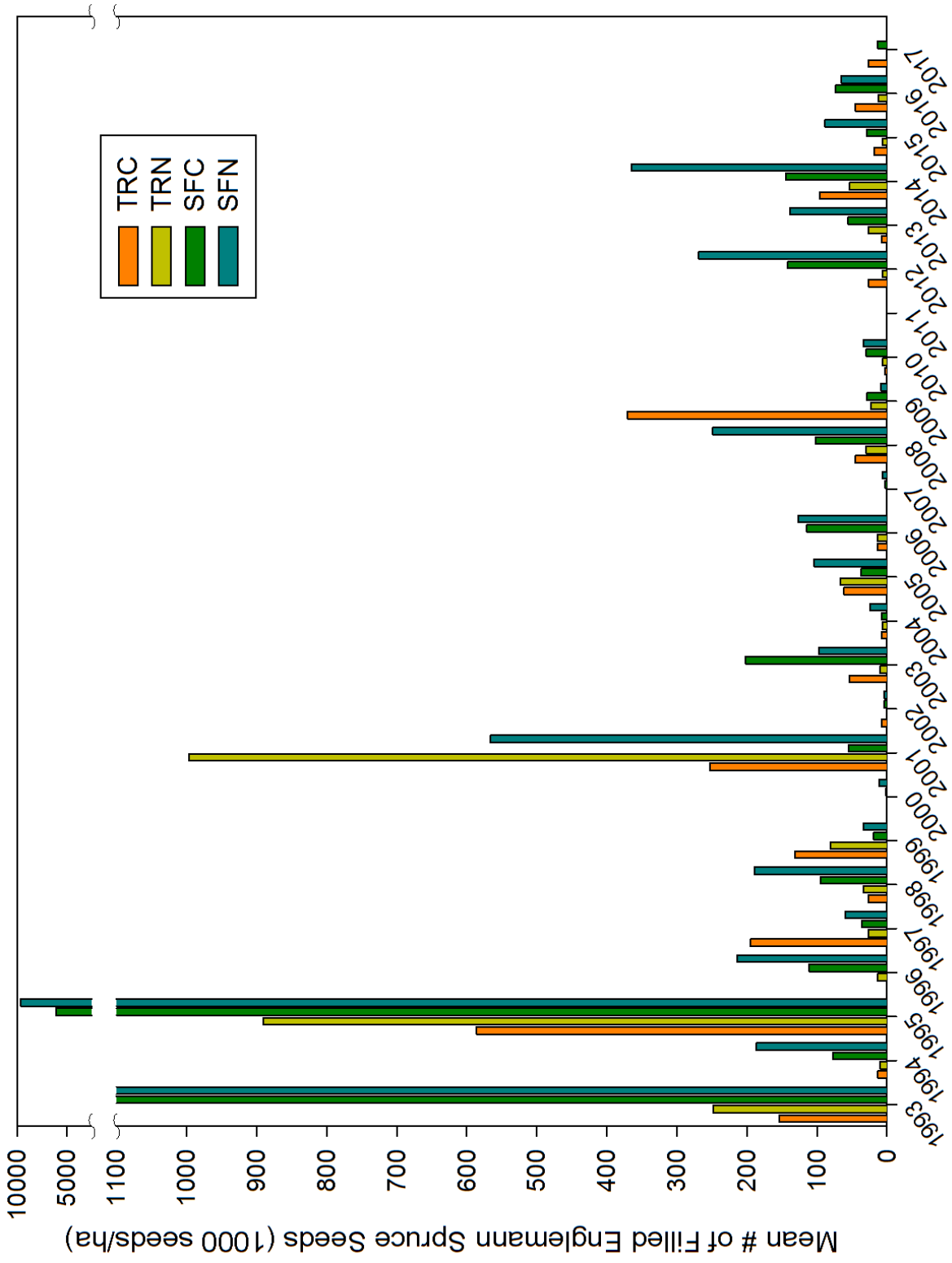


Figure 3. Mushroom crops by habitat, 1994 - 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona. In the summer of 2017, no mushrooms were collected due to the Frye Fire. After the fire, habitat at 12 of the 20 mushroom plots on the study areas was damaged or destroyed. Most of the plots lost were in the SF habitat.

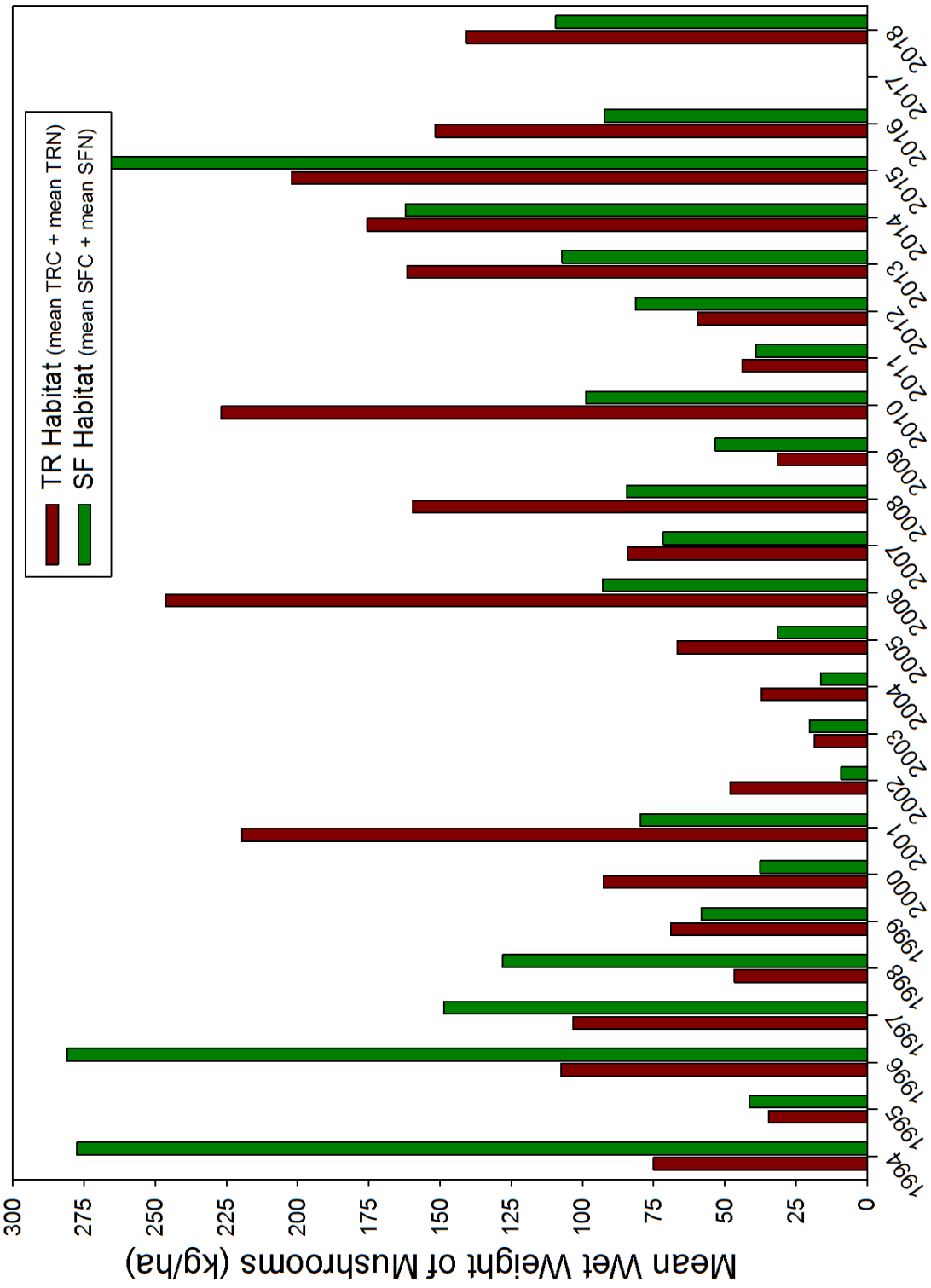


Figure 4. Quarterly Mt. Graham red squirrel (*Tamiasciurus fremonti grahamensis*) populations (including juveniles), March 2014- December 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

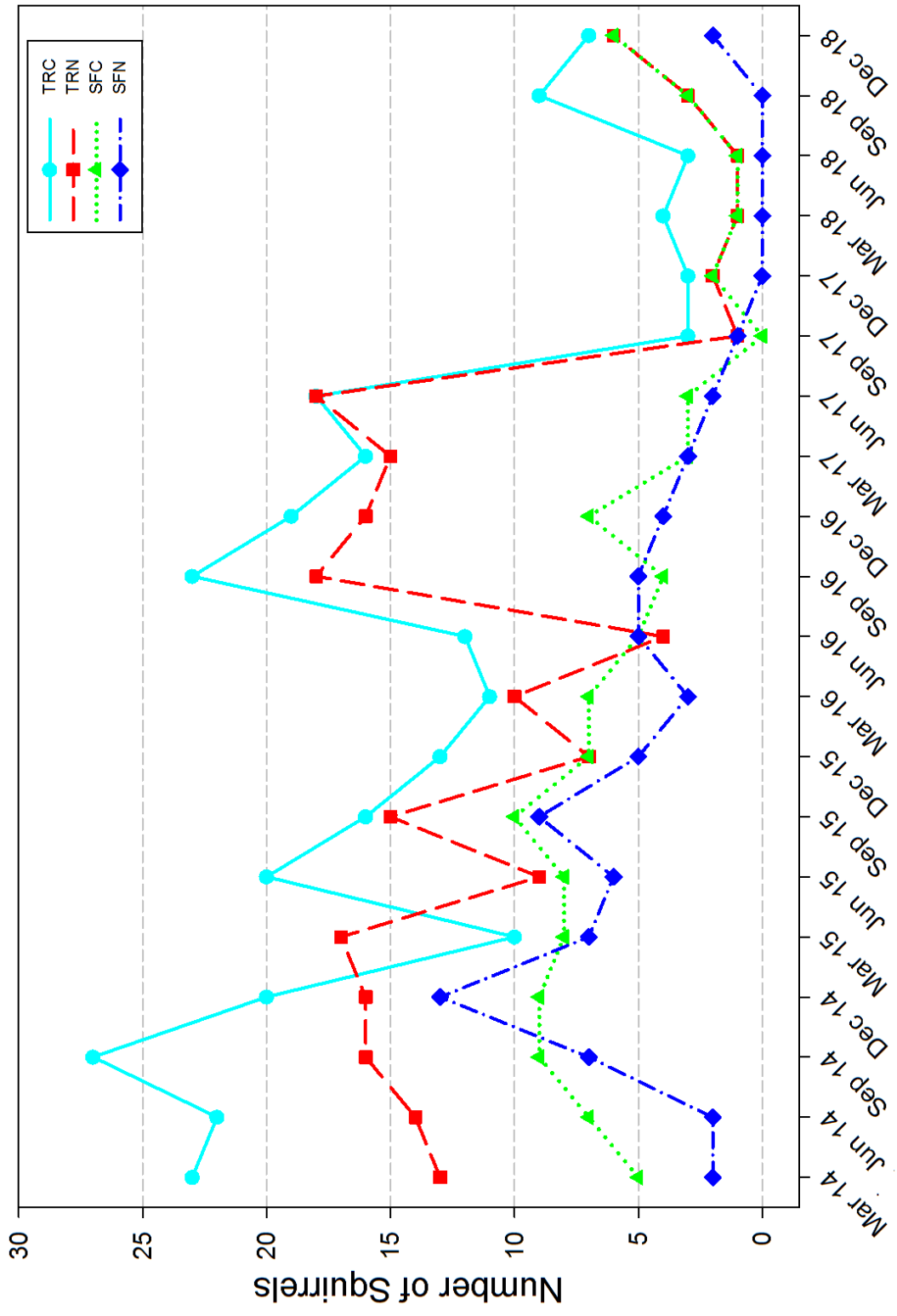
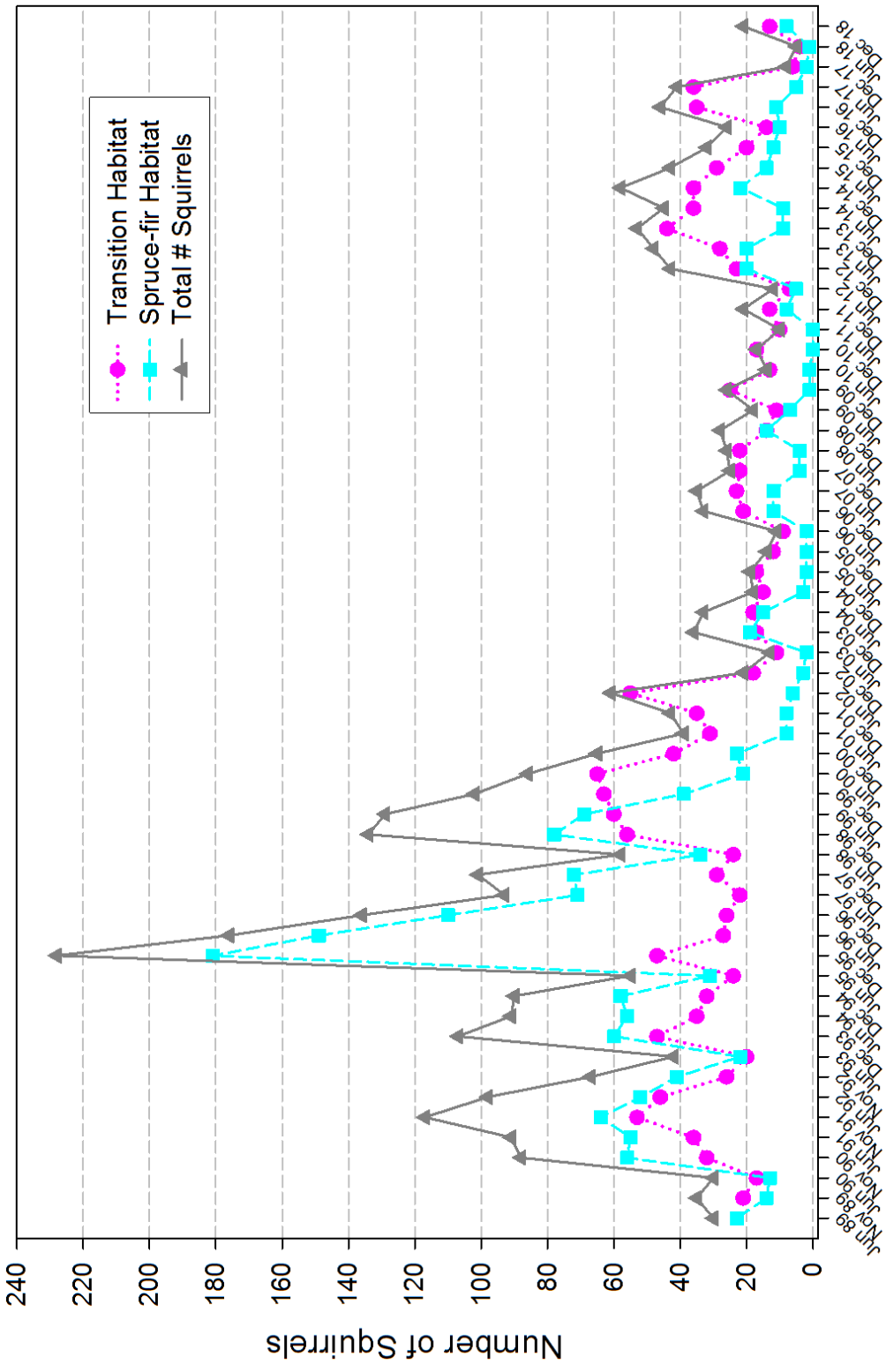


Figure 5 Summer and winter Mt. Graham red squirrel (*Tamiasciurus fremonti grahamensis*) populations (including juveniles), by habitat, June 1989 - December 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.



Appendix A: Midden occupancy records, 2018, 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), 2018				
Midden	Mar	Jun	Sep	Dec
1118[89]	♂ (O/O RC 1161)	♂ (O/O RC 1161)	♀ (P/P RC 1218) + 2J	P
1121[89*]	N	N	N	N
1127[14*]	Y	N	S	P
1128[15*]	P	N	N	S
1129[18*]	♀ (P/P RC 1218)	♀ (P/P RC 1218)	N	S
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*]	N	N	N	♂
1161[96*]	N	N	N	N
1163[98*]	N	N	N	N
1164[98*]	N	P	♂ (O/O RC 1161)	♂ (G/G RC 1229)
1165[98*]	N	N	N	N
1172[90*]	N	N	N	N
1173[99*]	N	N	N	N
1174[99*]	N	N	N	N
1175[99*]	N	N	N	N
1177[99*]	N	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	S	N
1190[10*]	N	N	N	♀ (P/P RC 1218)
1191[10*]	N	N	S	♂ (Bsq/Bsq RC 1230) N
1192[11*]	♀ (B/O RC 1220)	♀ (B/O RC 1220)	♀ (B/O RC 1220) + 1J	♀ (B/O RC 1220)
1193[12*]	N	N	P	N

Transition Construction Area (TRC), 2018				
Midden	Mar	Jun	Sep	Dec
1194[13*]	P	N	N	N
1195[13*]	N	N	N	N
1196[13*]	N	N	N	N
1197[13*]	N	N	N	N
# Mid	38	38	38	38
# Occ	4	3	6	7
% Occ	10.5%	7.9%	15.8%	18.4%
# Sq	4	3	6 + 3J	7

Transition Non-Construction Area (TRN), 2018				
Midden	Mar	Jun	Sep	Dec
2202[89]	N	N	N	N
2204[89]	N	N	P	N
2205[89]	N	N	N	N
2209[89]	N	N	N	N
2210[90]	N	N	N	N
2211[90*]	♂ (G/G RC 1222)	P	N	N
2215[90*]	N	N	N	N
2216[90*]	N	N	N	N
2217[90*]	N	N	N	N
2218[91*]	N	P	♂	S
2220[91*]	N	N	N	N
2222[91*]	N	N	N	N
2223[91*]	NC [1]	♀	♀	S
2224[93*]	N	N	N	N
2226[95*]	N	N	N	N
2227[95*]	N	N	♀	♀
2230[96*]	N	N	N	N
2233[96*]	N	N	N	N
2235[98*]	N	N	N	N
2236[98*]	N	P	P	♀
2237[98*]	N	N	N	S
2238[98]	N	N	N	N
2239[98]	N	N	N	N
2244[99*]	N	N	N	N
2245[99*]	N	N	N	N
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), 2018				
Midden	Mar	Jun	Sep	Dec
2260[14*]	N	P	P	N
2262[17*]	N	N	P	N
2263[18*]	new midden			♀ NAT (rip left ear)
# Mid	33	33	33	34
# Occ	1	1	3	6
% Occ	3%	3%	9.1%	17.6%
# Sq	1	1	3	6

1 The immediate area around midden 2223 was burned in the 2017 Frye Fire. In May 2018, a shift just north of the old tag tree area was located with a resident female and abundant signs. This midden was included in censuses thereafter.

Spruce-Fir Construction Area (SFC), 2018				
Midden	Mar	Jun	Sep	Dec
3019[96*]	N	N	N	N
3020[96*]	S	P	S	S
3330[95*]	N	N	N	N
3031[99*]	N	N	N	N
3033[12*]	N	N	N	P
3037[17*]	N	P	N	S
3038[18*]	new midden	S	P	N
3039[18*]	new midden		S	S
3040[18*]	new midden			S
3312[95*]	N	N	S	N
3314[95*]	N	N	N	N
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]	N	N	N	P
3365[86]	N	N	N	S
3366[86]	N	N	N	N
3367[87]	N	N	N	S
3382[91*]	N	N	N	N
# Mid	17	18	19	20
# Occ	1	1	3	6
% Occ	5.8%	5.6%	15.8%	30%
# Sq	1	1	3	6

Spruce-Fir Non Construction Area (SFN), 2018				
Midden	Mar	Jun	Sep	Dec
4026[09*]	N	N	N	N
4028[14*]	N	N	N	P
4030[18*]	new midden			♀
4031[18*]	new midden			S
4417[95*]	N	N	N	N
4465[90*]	N	N	N	N
# Mid	4	4	4	6
# Occ	0	0	0	2
% Occ	0%	0%	0%	33.3%
# Sq	0	0	0	2

Off-Area Midden Occupancy, 2018				
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	P	N
5203[00*]	N	N	N	N
5221[91*]	N	N	N	N

Appendix B. Mt. Graham red squirrel (*Tamiasciurus grahamensis*) populations (including juveniles at maternal middens), March 2014 - December 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

Date	TRC	TRN	SFC	SFN	TOTAL
Mar 2014	23	13	5	2	43
Jun 2014	19 + 3 Juv	14	7	2	42 + 3 Juv
Sep 2014	21 + 6 Juv	16	9	7	53 + 6 Juv
Dec 2014	20	16	9	13	58
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

1 Occupancy number differs from 2017 Annual report (3 on TRN, 8 total) due to correction in the table discovered after publication.

Appendix C: Quarterly occupancy maps for Mt. Graham red squirrels (*Tamiasciurus grahamensis*), March, June, September, and December 2018, University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

[12 maps redacted]

Appendix D: Reproductive success of Mt. Graham red squirrels (*Tamiasciurus fremonti grahamensis*), 2018 on or near[1] University of Arizona Red Squirrel Monitoring Program study areas, Pinaleño Mountains, Graham County, Arizona.

D-1: Mt. Graham red squirrel breeding chases on or near the study areas.

D-2: Mt. Graham red squirrel litters seen on or near the study areas.

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1 Reproductive success notes for squirrels at middens ≥ 100 m from study area boundaries are included for anecdotal information only. Litters at these middens are not counted in population totals for the Monitoring Program study areas.

Appendix D-1: Breeding Chases Observed - 2018

Breeding chases observed on or near the University of Arizona Red Squirrel Monitoring Program study areas in 2018. 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
24 Mar 18	9088 - Grant Hill	Marked males 1201, 1223, and an unmarked male were chasing and buzz calling at marked female 1209 in her midden.
29 May 18	1192 - TRC	Marked male 1161 was observed in this midden, chasing resident marked female 1220. These squirrels co-nested together the same night. Male 1161's home midden is about 275 meters from midden 1192.

Appendix D-2: Litters and reproductive status observed in 2018 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	1118 - TRC	6 Sep 18	2 juveniles
1220	1192 - TRC	6 Sep 18	1 juvenile
1225	8079 - E of TRC area	10 Sep 18	2 juveniles
1203	8696 - Grant Hill	4 Jun 18	1 juvenile
unmk	517 - N of Columbine cabins	11 Sep 18	3 juveniles
Total	5 litters		9 juveniles

Appendix E. Weather information, 2018, 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 - 2018, 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-18	1.33	172.40	16.09	1.24	8.82	16.11	-4.43	-12.77	41.47	100	4	10.16
Feb-18	2.01	217.90	16.09	0.01	5.36	15.56	-4.34	-13.88	57.9	100	7	127.50
Mar-18	2.45	216.30	14.31	2.19	7.76	14.44	-2.78	-13.32	50.63	100	6	13.97
Apr-18	2.63	215.80	18.33	7.26	13.69	17.78	1.11	-7.22	29.55	99	6	0.00
May-18	2.60	206.50	16.54	10.57	17.51	22.22	4.05	-5.56	27.61	95	8	0.25
Jun-18	1.82	214.00	12.07	15.00	22.13	26.11	7.78	2.22	35.57	100	7	67.82
Jul-18	0.97	121.00	12.96	14.88	21.08	26.67	9.70	4.44	67.82	100	10	135.10
Aug-18	0.79	114.40	10.28	13.74	20.43	25.56	8.35	4.44	75.63	100	27	150.10
Sep-18	0.80	118.80	8.49	12.05	18.89	21.67	6.50	3.89	66.26	100	23	109.70
Oct-18	2.08	212.90	13.86	5.21	9.93	17.22	1.60	-3.89	81.1	100	16	125.50
Nov-18	1.67	204.00	15.65	1.61	7.94	14.44	-3.46	-8.89	46.86	100	3	0.00
Dec-18	1.77	216.30	14.75	-1.02	4.98	13.89	-5.57	-21.10	58.16	100	3	42.67

Appendix E-2: ***Accumulated*** snow depths on the monitored areas for Winter 2017 - 2018. Snow pole data are collected opportunistically when biologists are on Mt. Graham. In December 2017, only a light dusting of snow was present. By April 2018, little to no snow remained on the monitored areas.

Snow Depth Summary

Snow Year Year	*Month*	*Habitat*	*Location*	*Avg Depth (cm)*	*Min Depth (cm)*	*Max Depth (cm)*	*Avg. % Cover*	*# of Readings for Avg.*
2017-2018								
2018	Jan	Transition	Clearing	9.8	0	13	85.0	6
2018	Jan	Transition	Forest	8.5	0	23	82.5	6
2018	Feb	Transition	Clearing	25.3	19	34	100.0	3
2018	Feb	Transition	Forest	18.3	15	22	100.0	3
2018	Mar	Spruce-fir	Clearing	40.0	35	45	100.0	3
2018	Mar	Spruce-fir	Forest	41.0	35	48	100.0	3
2018	Mar	Transition	Clearing	29.5	27	32	100.0	2
2018	Mar	Transition	Forest	26.0	17	35	100.0	2
		Averages for Snow Year		24.8	18.5	31.5	95.9	***Sum # Readings***
			Std Dev	12.24				
			SE of Mean	2.31				28