

Surveys for Forest Health and other Natural and Cultural Resources on Mica Mountain, Saguaro National Park, 2017-2019



Emily Fule, Kara O'Brien, Lauren Kramer, Don Swann, and Resource Management Staff

Summary

The Rincon Mountains cover most of the east district of Saguaro National Park and rise from the desert flats to over 8,600 feet at Mica Mountain. The absence of any road to the top has always made the high elevations much less accessible than other “Sky Island” mountain ranges in the region. In addition, because there is no commercial tree industry, forestry is not typically a priority at the park or with the National Park Service. Nevertheless, Saguaro has a long history of fire ecology research (Baisan and Swetnam 1990) and active fire management, as well as aerial forest health surveys conducted each summer by the US Forest Service (USFS). These efforts have provided a base level of knowledge of forest health and resiliency. Our study aimed to provide more precise and smaller-scale data about specific forest health indicators that could direct future resource and fire management decisions.

During the summer seasons of 2017-2019, Resource Management staff at Saguaro National Park conducted systematic mapping surveys of Mica Mountain. These surveys were focused on two main features: signs of bark beetle damage and dwarf mistletoe infestation. However, we also collected data on additional forest resources, cultural resources that NPS staff had not previously known about, and presence of water in drainages and springs. Surveyors consisted of NPS staff and interns trained to detect forest health concerns. Over the course of three seasons of surveys we discovered several new springs and many previously undocumented plants and cultural resources, while collecting a comprehensive dataset on riparian trees and forest health issues on Mica Mountain.

Our results indicate that the forest health of Mica Mountain is generally good. We detected bark beetle damage throughout the surveyed area but almost all damage was limited to fewer than 10 trees. This ground data matched well with USFS aerial data, indicating that there is not a more serious problem that the park had been unaware of. Dwarf mistletoe infestation was also widespread but generally mild with the exception of several small hotspots of severe infections. Unrelated to forest health but still significant were the numerous springs, riparian habitats, and valuable cultural artifacts discovered or rediscovered throughout the course of the surveys. While many high elevation areas in the Rincons remain to be surveyed, most are now too far from Manning Camp to visit on a single day trip from the cabin. Future work may include surveying areas on Rincon Peak or nearer to Grass Shack, Juniper Basin, Spud Rock, or Happy Valley campgrounds.

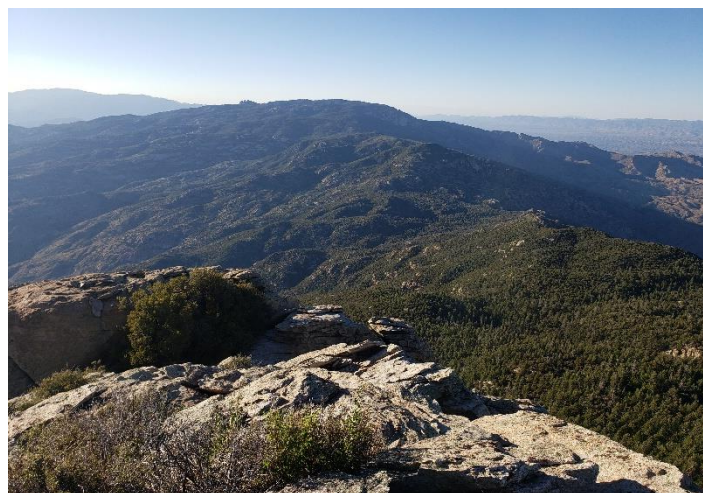


Fig 1. A view of Mica Mountain from Rincon Peak.

Introduction

Saguaro National Park consists of two distinct mountain ranges, a western district covering the Tucson Mountains and an eastern district covering the Rincon Mountains. The Tucson Mountains peak at around 4,700 feet, meaning that most of the western district is strictly desert habitat. The Rincons rise to over 8,600 feet at Mica Mountain, where pine forests cover the slopes and stands of Douglas fir and aspens can be found. In between the districts lies the city of Tucson, a major metropolis of half a million people (Figure 2).

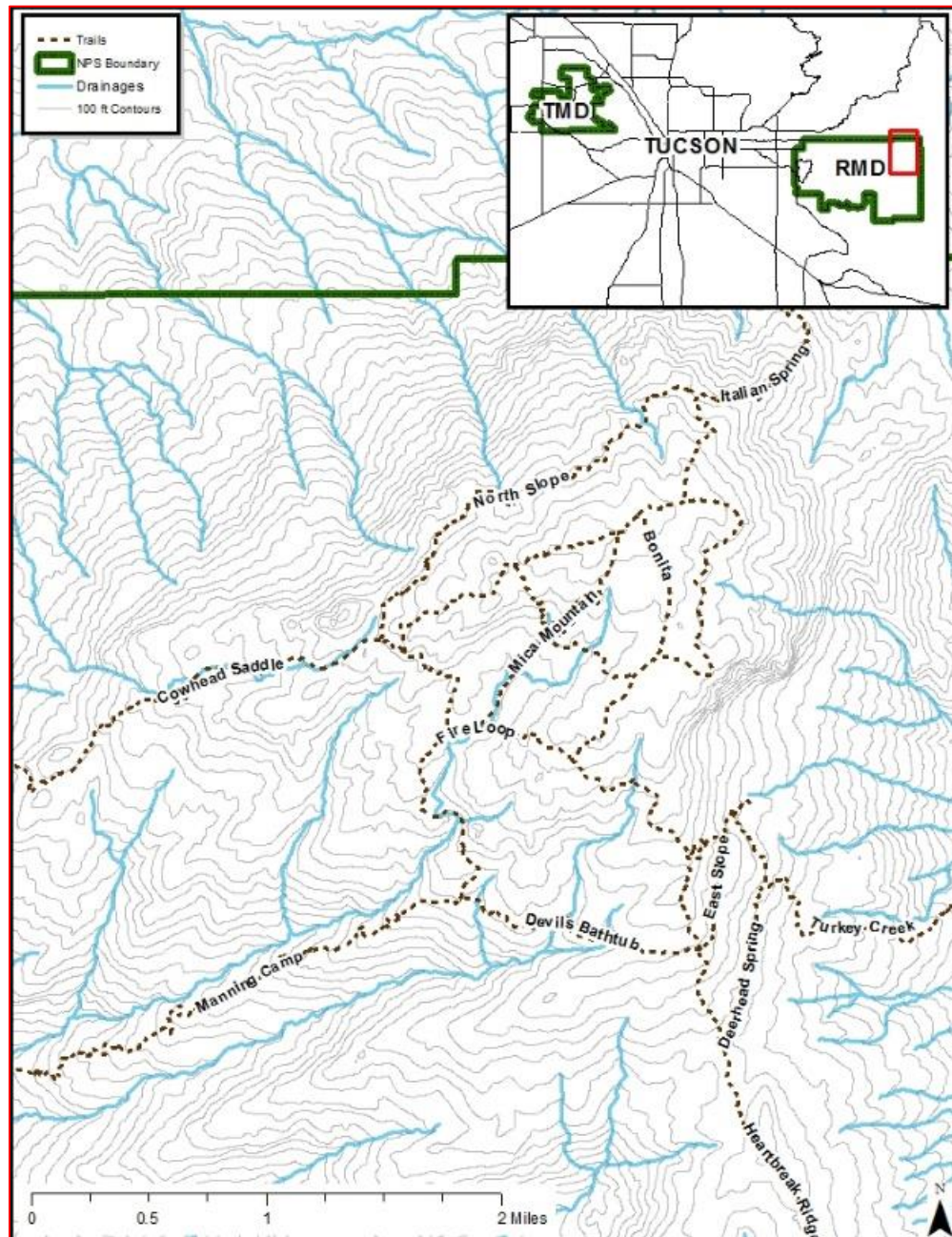


Figure 2. Location map of high elevation area in Rincon Mountain District of Saguaro National Park in southern Arizona with inset showing the two park districts in relation to Tucson.

The Rincon Mountains are a northern “Sky Island” range adjacent and biologically connected to the Santa Catalina Mountains. The Sky Island region of the southwestern U.S. and northwestern Mexico is known for exceptional biological diversity, including species from the Sierra Madre, Rocky Mountains, Sonoran Desert, and Chihuahuan Desert biogeographic provinces. Biotic communities at different elevations include Sonoran desertscrub, semi-desert grassland, oak savannah, pine-oak forest and woodland, and pine and mixed conifer forest (Figure 3). The Rincons also contain riparian forest and riparian woodland in canyon bottoms, scattered wet and dry meadows at higher elevations, and perennial springs and spring-fed rock pools (*tinajas*). With no roads into the mountains and only a few remote trails, this district has remained less affected than other nearby mountain ranges by this growing city. Some threats, however, are undeterred by the remoteness of the range. As temperatures have increased in recent decades, the Rincons face warmer winter and summer temperatures (Gonzalez 2013), decreased snow pack, earlier springs and later winters, and potential changes in plant and animal communities.



Fig 3. Above left, the desert flats of the Tucson Mountain District. Right, pine forest below Reef Rock (about 7500 feet) on Mica Mountain in the Rincon Mountain District.

These climatic changes may be contributing in part to region wide increases in tree mortality associated with native bark beetles. In 2011, the USFS documented 41.7 million acres of bark beetle mortality across the Western U.S., which they attributed to a combination of warmer temperatures and increased water stress. In 2018, over 3,700 acres in southern Arizona alone showed signs of bark beetle damage (USFS 2019). In addition to bark beetles and climate change, pine forests face threats from a variety of native parasites, including Southwestern Dwarf Mistletoe (*Arceuthobium vaginatum*). These threats can also build on one another. Water stress makes trees less able to fight off bark beetles, while an existing mistletoe infestation can be made fatal with the addition of bark beetles.

Previously, monitoring or assessment of forest health conditions in the high elevations of the Rincon Mountains have been conducted either through annual aerial monitoring by the US Forest Service or the park’s fire ecologists and managers with a focus on specific wildfires. These surveys have provided a base level of data but were often quite general, or only specific within a relatively small area. From 1970s to the 1990s Saguaro National Park (then still a National Monument), employed a progressive

approach to fire management that encouraged natural fires to burn and supplemented them with prescribed burns. Since then, due to a variety of national and local factors including diminishing funds for proactive fire management, Saguaro has transitioned to greater suppression of natural wildfires and less frequent prescribed burns (Pyne 2012). However, active fire management still occurs and in 2019 the park conducted a prescribed fire on Mica Mountain.

Our current study on Mica Mountain is the first attempt to collect forest health data, specifically regarding bark beetles and dwarf mistletoe, from ground based systematic mapping surveys. These surveys during spring and summer of 2017, 2018, and 2019 provided a comprehensive data set of not only forest health measures but also cultural resources, springs, and riparian habitats. We also set bark beetle traps in 2017 and ground-truthed USFS aerial forest health data. These data have provided invaluable insights already; several plant species new to the park's official flora list were found at springs and riparian habitats discovered during these surveys (see Beckman 2020). We also hope that these data can help inform fire management and, because the surveys are repeatable, provide a benchmark for evaluating future forest health conditions.

Methods

Systematic surveys. We recorded forest health parameters during systematic surveys of the high elevations of Mica Mountain in the Rincon Mountain District of Saguaro National Park (Figure 4). Surveyors were trained park biological technicians and interns who had to first hike to Manning Camp, a semi-primitive campsite located about 9.5 miles and 5000 ft in elevation from the nearest trailhead. We developed a training guide and provided on-site training in the Rincons so that all surveyors would be able to recognize basic forest health parameters, especially signs of bark beetle infestations including red needles, pitch tubes, and exit holes, as well as dwarf mistletoe, riparian trees, and certain rare plants.

Systematic surveys were conducted with surveyors following either east-west or north-south transects using a Trimble Juno GPS unit. Transects were 20 meters apart; surveyors were assigned a GPS coordinate and were instructed to cover areas between them and the surveyor on either side. All data was recorded in a geodatabase (developed at SNP by Lauren Kramer) loaded into the GPS unit. When diseased trees were encountered, we recorded type of infestation (bark beetles or other); signs of infection (e.g., red needles, pitch tubes, exit holes, etc.), severity of infection (low, medium, or high), tree species, and number of trees infected. In addition to forest health parameters we also recorded targeted rare and invasive plants, cultural resources, and water resources. At 100 m intervals, we recorded forest characteristics, including degree of mistletoe infection. At each location we selected the nearest mature (approximately 0.3 m DBH) ponderosa or Arizona pine to the north, and used the Hawksworth (1926) 6-class Mistletoe Rating System to determine the degree of infestation. In this system, the tree is divided into thirds, and the degree of mistletoe infection in each third is rated from 0 (no mistletoe), 1 (<50% of branches infected), or 2 (>50% of branches infected), and the ratings are totaled for the whole tree so that the tree is rated from 0-6. In addition, at these 100-m interval stops we recorded forest type, substrate (rock or soil), soil depth, and presence or absence of pocket gopher holes as an indicator of soil type and depth and because gophers are an ecologically important mammal in this forest environment.

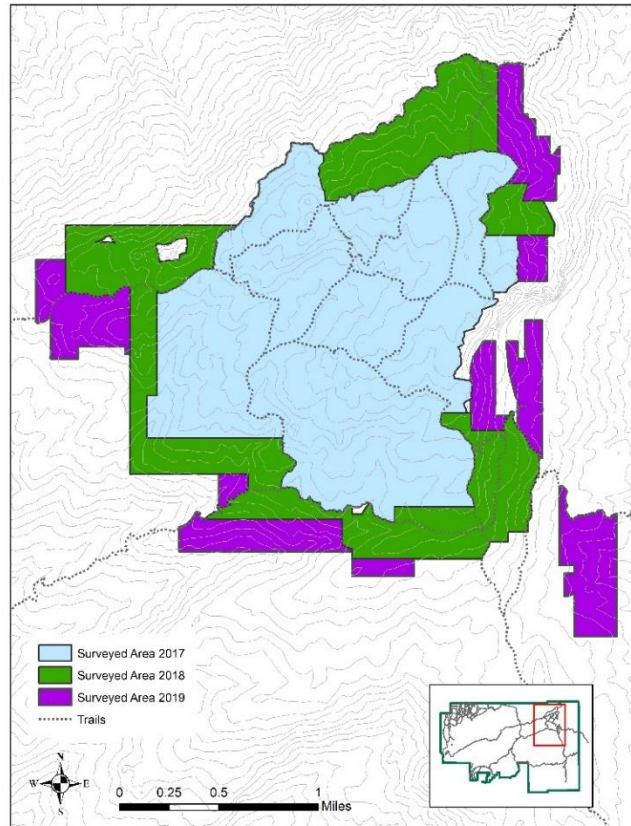


Fig. 4. Details the survey area by year. As the unsurveyed areas became further from Manning Camp and often steeper with denser vegetation, our ability to survey as large of areas was limited.

Water Revisits

We recorded the presence or absence of water in areas where water had been detected on prior surveys. The revisits were conducted prior to the summer monsoons to assess which drainages and individual pools still had water by mid-summer. The revisits were not part of the systematic surveys and were usually completed as a separate project. Each data collection consisted of visiting a previously mapped point and confirming the presence or absence of water using the Trimble Juno GPS data. Flow, depth, and substrate were also recorded on each date where water was present at the site.

Results

Bark Beetles

Bark beetles have the capacity to pose a significant threat to the pine and fir forests of the Rincons. So far, Saguaro National Park has avoided serious mortality attributed to bark beetles but we have seen significant fluctuations in year to year mortality, most likely due to annual precipitation levels. Even one year with moderate precipitation drops seems to make trees more vulnerable to bark beetle

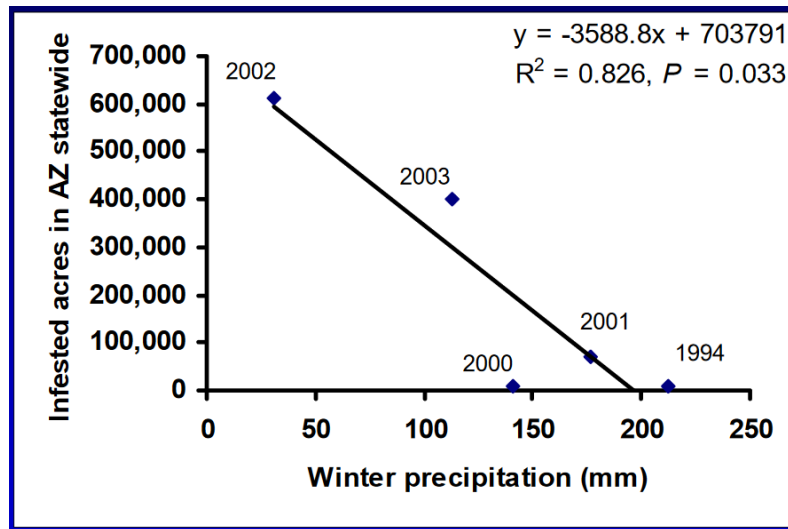


Fig 5. From the US Forest Service, bark beetle mortality is strongly correlated with precipitation levels across the state of Arizona (Wagner et al, 2004).

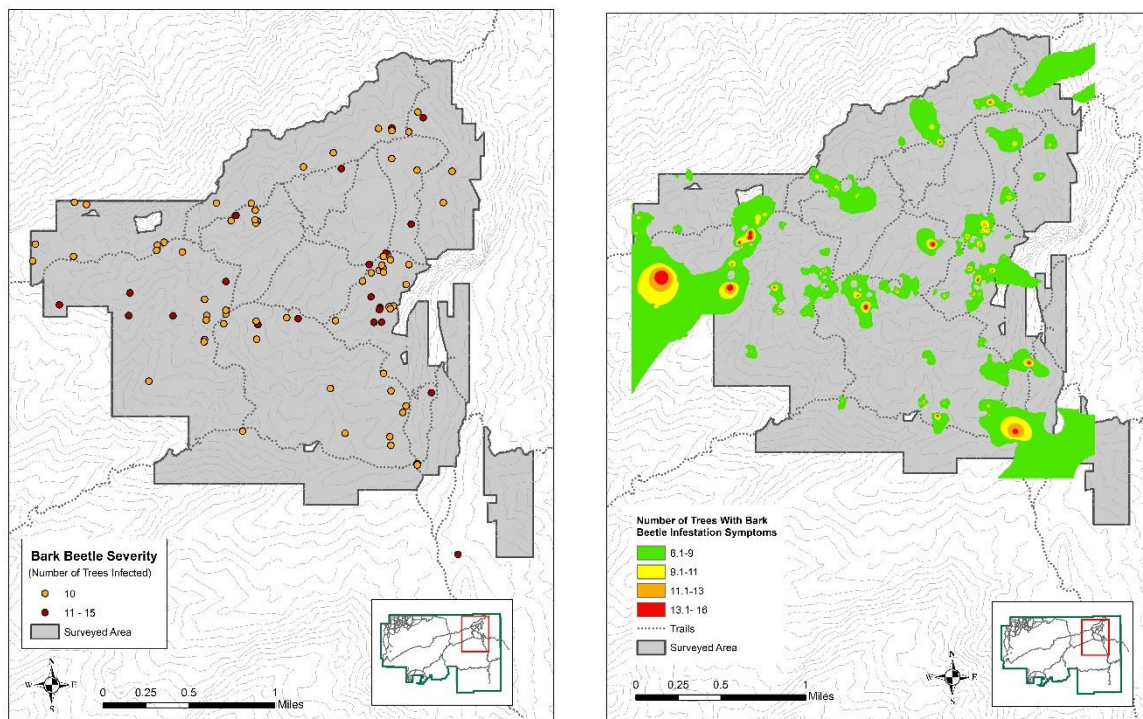


Fig 6. On the left, areas of more significant bark beetle infestation, where at least 10 or more trees showed signs of bark beetle damage. On the right, an IDW surface raster showing only areas with 6 or more trees affected. IDW (Inverse Distance Weighted) rasters analyze the twelve nearest points to any given point and extrapolate to form a continuous surface. This can help show hotspots more clearly but can also “create” areas whose values are misleading. The spread of bark beetle infected trees on Mica Mountain do not appear to show a clear geographical pattern. Data shown above is from 2017-2019.

infestation and less able to effectively fend them off (Figure 5). Significant winter precipitation in late 2018 and early 2019 appear to have decreased the overall mortality due to bark beetles, especially the mortality seen from the aerial surveys conducted by the US Forest Service (Aerial Detection Survey, 2019). Our surveys found a scattering of bark beetle infected trees but no single infestation affected more than 15 trees (Figure 6).

In 2017, we set bark beetle traps at four locations (Figure 7) with the support of USFS entomologist Monica Gaylord and Manning Ranger Tony Palmer. The Four Corners region yielded the highest, while the Mica Mountain and Bonita/Fire Loop traps caught the fewest. As of 2020 the beetles had still only been identified to genus (*Dendroctonus* and *Ips*). That same year we also ground-truthed the 2017 aerial USFS Forest Health data to confirm the accuracy of their bark beetle damage assessment. We found their data to be accurate (the aerial data regarding which trees were damaged by bark beetles matched what we saw on the ground) but also found small areas that were infected that the USFS had not been able to detect from the air.

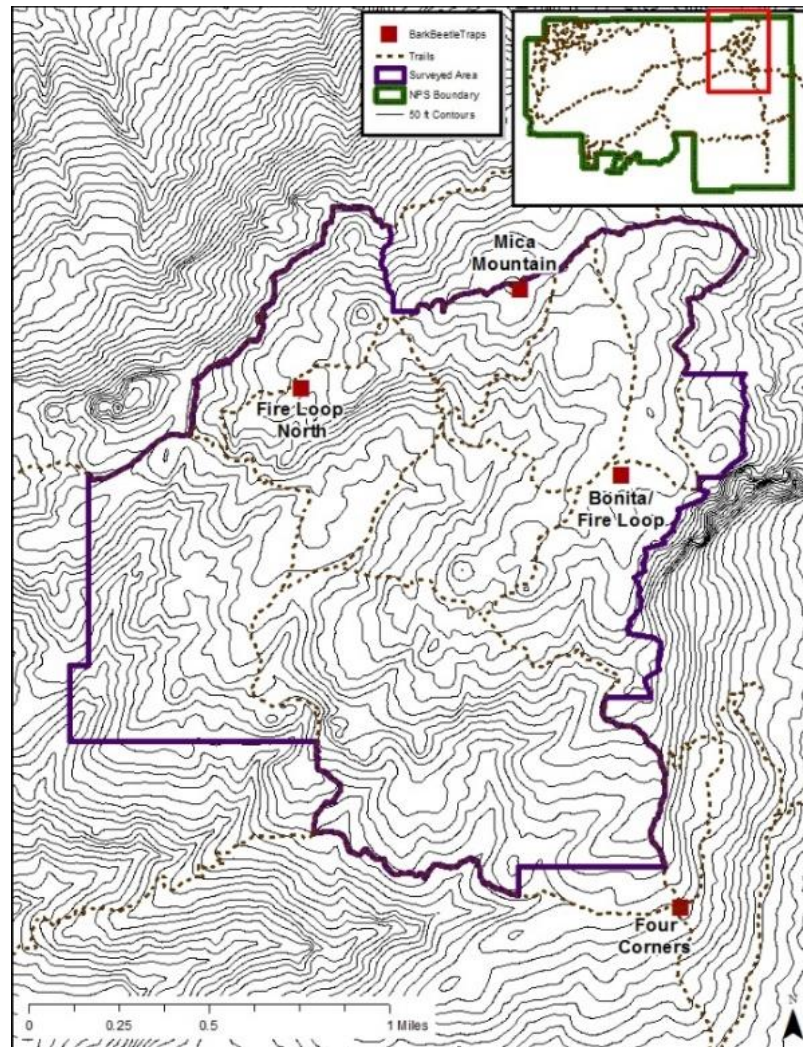


Fig 7. Location of bark beetle traps on Mica Mountain, 2017

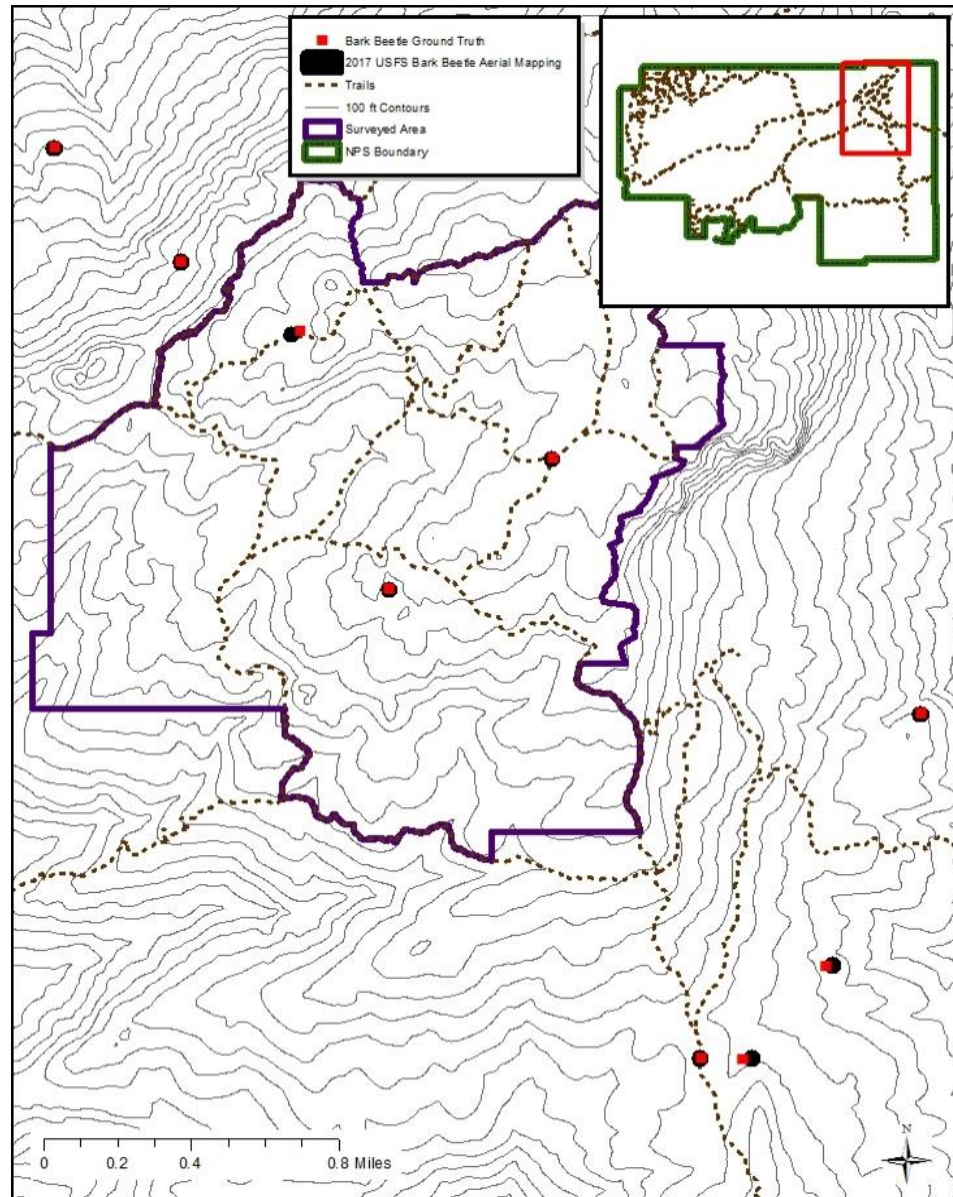


Figure 8. Results of ground visits to areas determined to be of high bark beetle infestations based on US Forest Service aerial surveys from 2017. Red dots indicate ground surveys from 2017 and green areas indicate aerial mapping results from same year. We confirmed bark beetle activity at all areas mapped by air.

Dwarf Mistletoe

Dwarf mistletoe (Figure 9) is a parasitic plant that can cause fatal infections in several pine species. Possibly due to their explosive seed dispersal techniques, but possibly due to habitat, it is common to find pockets or hotspots of infection surrounded by unaffected trees. Dwarf mistletoe can result in slower growth in infected trees, reduced seed viability, mortality, and an increased susceptibility to bark beetle infestation. While lightly infected trees can survive several decades or more, heavily infested trees have mortality rates of 95% or higher within 5 years, with mortality slightly

dependent on size (dbh). Widespread infestations can cause negative effects on a forest-wide level as well, including fewer large diameter trees and increased stand openings (Saguaro National Park, 2013). Dwarf mistletoe is controlled in pine forests mainly through natural or prescribed wildfires and species-specific thinning.

Our surveys found widespread dwarf mistletoe presence as well as several hotspots of infestation on Mica Mountain (Figure 10). Most infections were classified as a 3 or lower on the Hawksworth scale (moderate or lower). Hotspots occurred southwest of Manning Cabin close to the Manning Camp trail as well as Mica Meadow and areas around the Northern Fire Loop. These data could be useful in determining future areas for prescribed burns.

We also analyzed mistletoe severity as it related to aspect and slope. Using only data points that scored the trees as a 4 or higher on the Hawksworth scale, we found severe dwarf mistletoe infections appeared more often on western facing slopes (about 35%, compared to south (23%), east (18%), north (13%), or flat slopes (9%)). This pattern is not simply due to there being a higher number of data points taken on westward facing slopes. Temperature might play a small role: western facing slopes tend to be slightly warmer than eastern ones (due to sunlight hitting the slopes later in the day when the air temperature is already warmer) and southern slopes are warmer than northern slopes in the winter months.



Figure 9. Southwestern dwarf mistletoe (*Arceuthobium vaginatum subsp. cryptopodeum*).

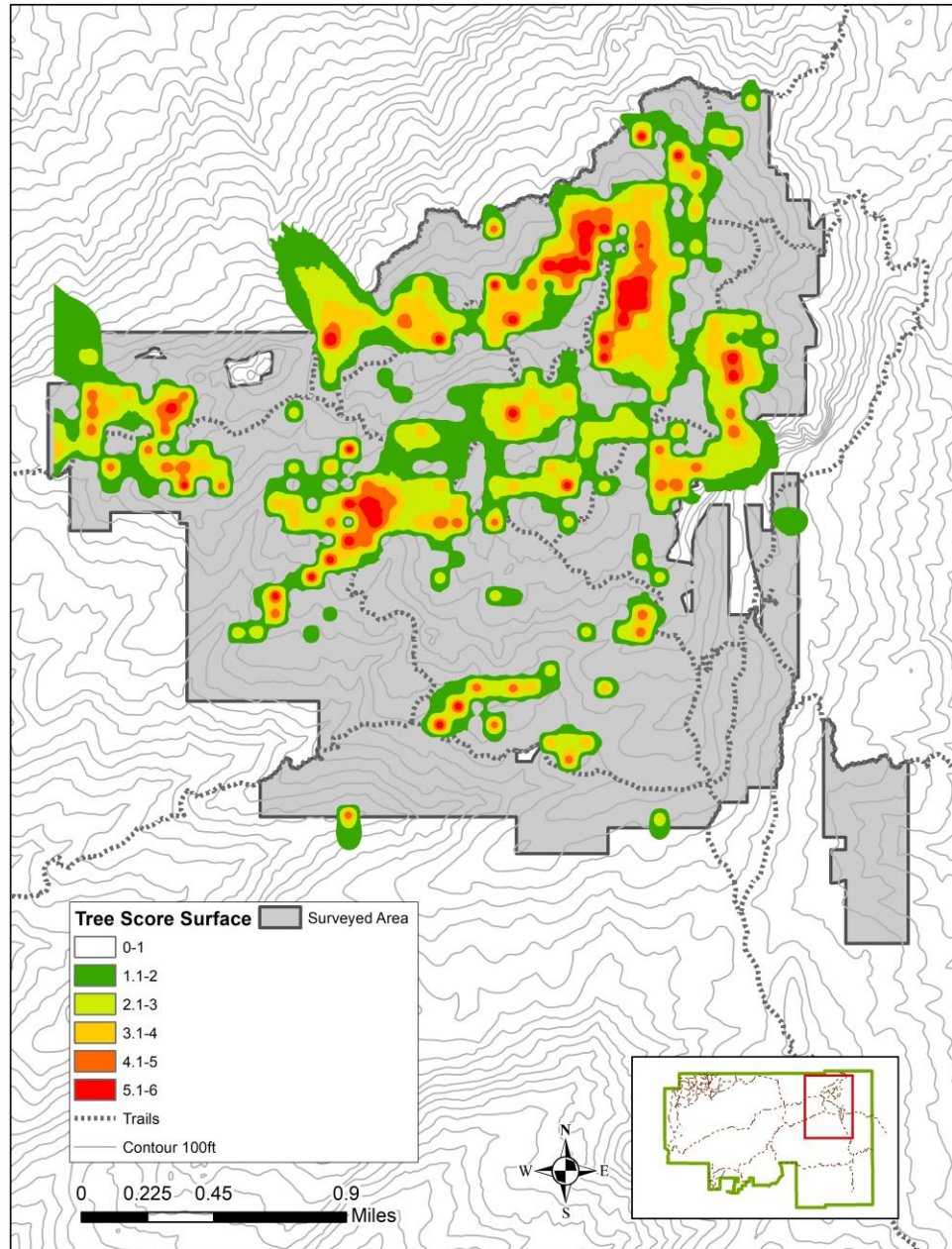


Figure 10. Mistletoe infection was classified according the Hawksworth Scale, ranging from 1 (mild) to 6 (severe). The above map shows an interpolated view of mistletoe infection across Mica Mountain, highlighting areas with more severe infestations.

Slope analysis revealed a slightly higher prevalence of mistletoe on slopes less than 15 degrees (flatter slopes). About 75% of trees that scored as 4 or higher on the Hawksworth scale lay on slopes less than 15 degrees whereas about 50% of the total collected data, a more representative sample of the whole study area, lay on slopes less than 15 degrees. In other words, trees with higher amounts of mistletoe infection were found more often on flatter slopes.



Fig 11. A view of healthy mixed conifer forests from the North Slope.

Riparian Trees

During our systematic surveys we recorded the location of three different riparian tree species of interest whenever we encountered them (Figure 12). These included alder species (*Alnus spp*), box elder maples (*Acer negundo*), and willow species (*Salix spp*). These species are important for different reasons and monitoring their populations in the future will be an important indicator of overall forest health. Riparian areas in general play vital roles in ecosystems and are usually the most biologically productive and diverse regions in a given landscape.

Alders play an important role in nitrogen fixing in the soil through their relationship with the bacteria *Frankia alni*. These bacteria live in fist sized nodules in the alder's roots and fix nitrogen in the soil in return for sugars. This relationship helps increase soil fertility both for the individual tree and the surrounding plants and fungi. Willow and box elder populations could prove as benchmarks for how severely climate change is affecting the Rincons. Willows and box elders are both dioecious species, meaning a species with different male and female organisms such as humans. A 2016 literature review (Hultine et al, 2016) concluded that dioecious plant species in particular may be at significant risk from increased aridity due to climate change. Their review found that female box elder maples have increased resource demands compared to males due to their fruit-producing capacities. These higher resource demands make female trees more sensitive to fewer resources than their male counterparts and could create a population with vastly more male then female trees in a less arid future. This would be due to an increase in female mortality as well as a decrease in the growth and gas exchange abilities of the surviving female trees.

Regardless of reproductive biology, riparian trees are valuable resources for wildlife, and are likely to be impacted with diminishing snowpack and increased temperatures in the future. Monitoring the population dynamics of willows and box elders could be a valuable tool in the future for gauging the impacts of climate change and increased aridity on Mica Mountain.

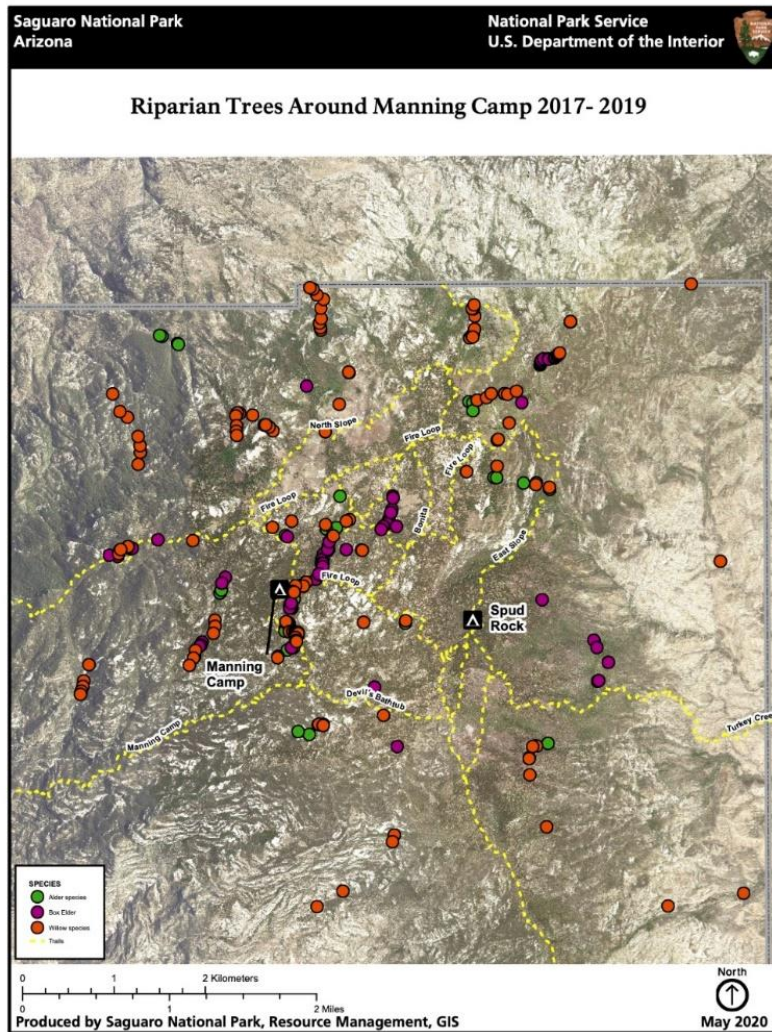


Fig 12. This map shows the location of several types of riparian trees of interest. These include alder species (*Alnus* species, in green), box elder maple trees (*Acer negundo*, in purple) and willow species (*Salix* species, in orange).

Aspen inventory

As a part of systematic surveys, we discovered and mapped several new aspen groves. Aspen groves are a storage system for soil water, serve as natural fire breaks, and provide habitat for vulnerable species (Kitchen et. al 2019). The north slope of Mica Mountain has many small clusters of aspens that cannot be seen from trails and can only be observed through systematic surveys. After we found them, we mapped the perimeter of many of the groves. This will serve as base data so that the groves may be remapped in the future and we can determine any significant changes. Aspen are believed to be declining throughout the west and Sudden Aspen Decline (SAD) has been observed in northern Arizona. During 2017-2019 we mapped about 19 acres of aspen groves, not including 13 additional points taken where aspen occur but have not yet been mapped (Figure 13). These data will help direct efforts to conserve Saguaro National Park's aspen groves and the critical habitat they provide to many of our high elevation species.

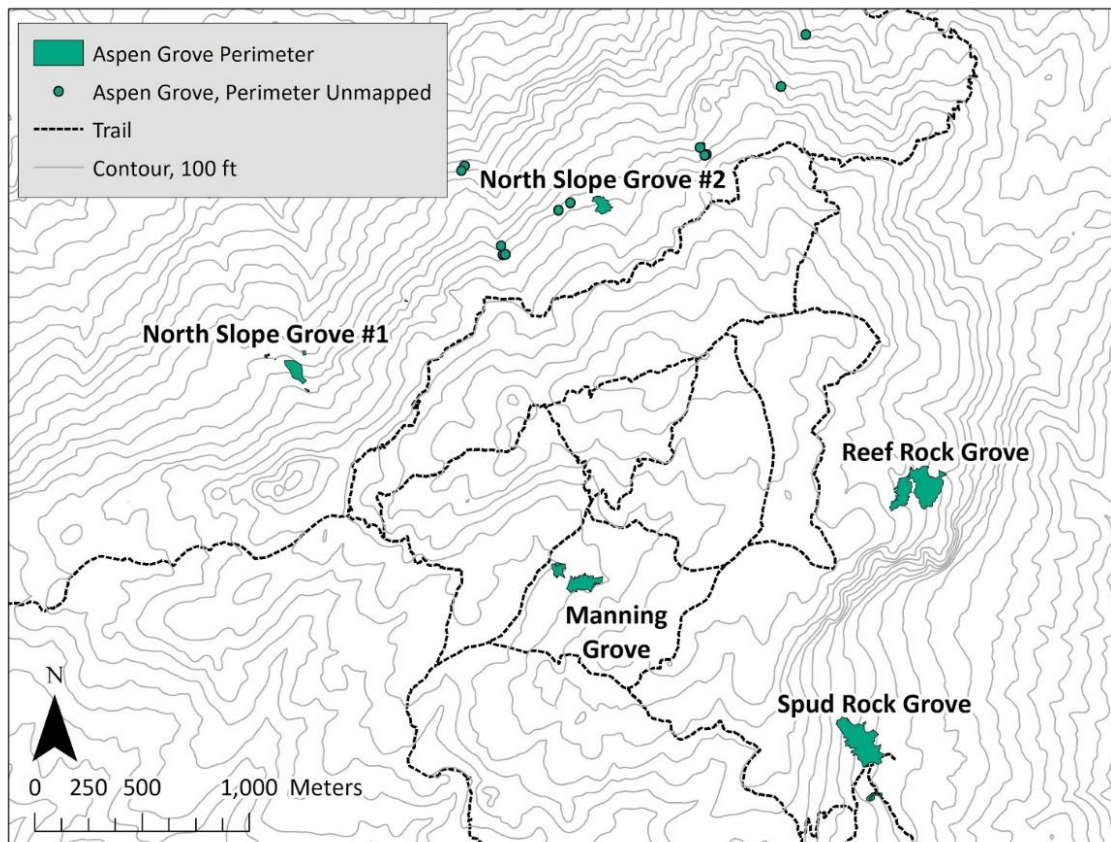


Fig 13. Aspen groves on Mica Mountain.

Water Revisits

We conducted water revisits in 2019 from May until July due to the late start of that year's summer monsoon season. Sites were visited as often as possible but due to the varying accessibility of each point, some were visited more than others. Crews also devoted time to searching for and conducting inventories of known and newly discovered springs. We found a number of new springs that did not appear on any historic maps, including (to our surprise) some of the most productive springs in the Rincon Mountains including the tentatively named Scarlet, Cabin, and Bullrush Springs (Figure 14-15). We also relocated Art's Spring, which had been incorrectly mapped. We added our spring inventories to the Spring Stewardship Institute database (<https://springstewardshipinstitute.org/>). At these springs we also discovered several exciting new plant species (Beckman 2020). Spring results will be published separately following another round of water revisits in 2020. One of the more significant results of our work will be a published guide to springs in the Rincons that can be used by hikers to locate water during dry periods. Currently, hikers often run out of water in the high country despite the fact that water is close by, but simply not known to them, and we believe that releasing this information will improve safety and make it easier for campers.



Fig 14. Left, the beginning of a prolific re-discovered spring, named in 2019 as Bullrush Spring. This spring, located in a drainage adjacent to Turkey Creek, remained flowing throughout the entire dry season of 2019. Right, staff and interns conduct a spring assessment in 2019 at Cabin Spring, another prolific new spring.

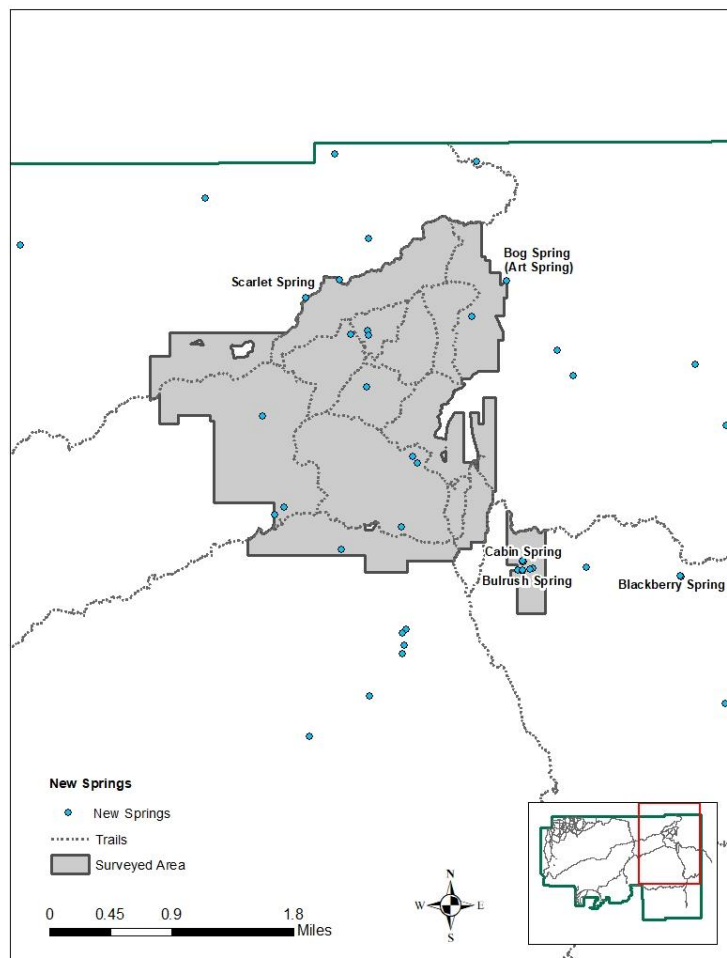


Fig 15. A map showing all known springs on Mica Mountain with prominent newly-found springs labelled.

Soil Depth, Gopher Burrows, and Invasive Plants

At each point where we collected mistletoe data (every 100 meters along a specific transect) we also collected data on soil depth and gopher holes using a 36-inch soil probe (Figure 16). Deeper soil holds more water and nutrients and can support larger and deeper root systems. Deeper soil also heats up slower than shallow soil and reaches its peak heat later in the day, allowing for less evaporation of soil moisture. Gopher burrows created by native pocket gophers were used as an additional indicator of soil depth and soil health, as gopher burrows help to aerate soils (Jones et al 2004).

As part of our surveys, we trained the crew look for a suite of potential high elevation invasive plants. We found remarkably few invasives, to our great surprise. In fact the contrast in invasive plants at high elevations in the Rincons compared to the nearby Santa Catalina Mountains is remarkable, with many very prominent invasives in the Catalinas either completely absent (e.g., mullein,) or very localized (e.g., cheat grass). The probable reason for these differences is the lack of a road and residences in the Rincons compared to a very busy highway and many private homes in the Santa Catalinas.

Cultural Resources

Our surveys detected many cultural artifacts and structures throughout Mica Mountain. While a few of these were known, most were not. Among the new findings were a cave shelter with prehistoric Hohokam pottery and stone tools and a historic structure near a large spring on the East Slope. Old fencing, and other historic items were also found in various locations (Figure 17-18). An archeological team surveyed both the cave and the historic structure and further analysis may occur. These finds highlight the importance of these surveys as the items are culturally quite significant and unique.

We also collected data on rebar and other metal tags associated with past research projects in the Rincons. Many of these tags are associated with tree-ring studies, others with fire effects plots, and others are unknown. We hope to match rebar with previous scientific studies to re-create plots for repeat studies.

Discussion

Forest health surveys conducted from 2017 to 2019 in the high elevations of Saguaro National Park provided park managers with a wealth of data and new discoveries. NPS staff and interns worked for three seasons to collect data on bark beetles, dwarf mistletoe, perennial water sources, and cultural resources. Our results showed widespread but not severe bark beetle damage that mostly corresponded with aerial forest health surveys conducted by the USFS. Bark beetle traps set in 2017 with the assistance of the USFS caught beetles of two species and confirmed the existence of small hotspots near the Four Corners region and off the East Slope and Switchback trails. Overall however, bark beetle infections have not been found in significant numbers and only small areas have seen severe damage.

We found dwarf mistletoe to be both more prevalent and more severe on average than bark beetle damage. Several large hotspots were found, including southwest of Manning Cabin, parts of Mica

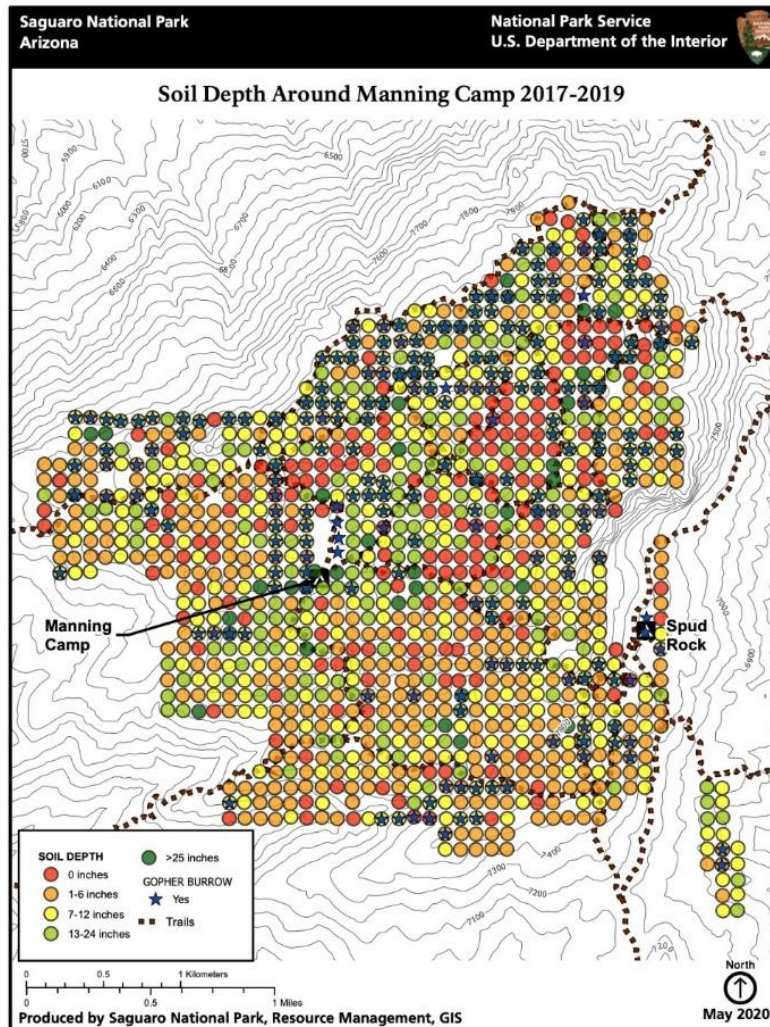


Fig 16. Stars indicate the presence of gopher burrows, while green points indicate deeper soils.



Fig 17. Left- a rock fireplace found in 2019. Park staff found several fire structures and abandoned fire rings throughout Mica Mountain. Right- the remains of a firefinder, a device used by scouts to determine the angle and distance of a wildfire. This item is likely hand-punched and was found near an old fire lookout on Mica Mountain.



Fig 18. Left, artifacts found near cabin ruins on the East Slope. Right, a rebar stake.

Meadow and areas around the Northern Fire Loop. We were able to correlate more severe infections with westward and southern facing slopes, as well as flatter slopes. These findings could help determine the locations of future prescribed burns in the Rincons.

Our new cultural and natural discoveries are perhaps the most exciting. Pre-historic shards and historic structures were the biggest finds, but new cultural resources were found throughout the study area. These discoveries have already begun to reshape what we know of the history of Mica Mountain. Newly discovered springs and riparian habitats have been important as well. Our park botanist was able to document several plant species in these areas that were either thought to be extirpated or were never before documented in the Rincons at all. These areas provide new information about the geology, hydrology, and general ecology of these mountains.

It is our hope to continue these systematic surveys into 2020 and beyond. With much of the accessible parts of Mica Mountain surveyed, we are now looking to Rincon Peak or the Grass Shack region to continue our efforts. Rincon Peak in particular presents several new challenges given its steepness and lack of amenities but we hope to continue collecting data on forest health issues throughout the Rincons.

Acknowledgments

We are very appreciative for support for this project from the Friends of Saguaro National Park for financial support for this project. Thank you to Bob Newton and Fred Stula.



Fig 19. A balloon caught on a tree, found during our systematic surveys. Over three seasons crews found dozens of mylar and rubber balloons scattered throughout Mica Mountain.

We are grateful for expert assistance from a number of individuals with the US Forest Service, particularly entomologist Amanda Grady, who provided consistent encouragement and conducted a great training for us in Tucson in May with forest pathologist Nick Wilhelmi. We also thank USFS entomologist Monica Gaylord, who provided traps, bait, and great advice on bark beetles. We also received helpful training from Leslie Prewitt and Christopher Griggs from the Coronado National Forest.

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