

**The Impact of Climate Change on Archaeological Resources in Arizona: Harnessing  
Citizen Science through the Arizona Site Stewardship Network**

**Arizona Department of Parks**

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## **Introduction:**

This project addresses the emerging challenges that climate change presents for the preservation of archaeological sites. The study used data generated by citizen scientists to assess the correlation between illegal looting, vandalism, and other negative impacts at archaeological sites and climatic fluctuations. Specifically, the study addresses the questions of when and where negative impacts occur at archaeological sites in Arizona, and if those impacts correlate with seasons, temperature, or precipitation.

### *The Site Steward Program:*

The study relied on the extraordinary efforts of approximately 800 citizen volunteers who collected monitoring data from 870 archaeological sites across the state of Arizona in an effort to offset the deleterious impacts of illegal looting, vandalism, and reckless damage to archaeological sites. This enormous effort is due to the success of the Arizona Site Steward Program (ASSP), a program facilitated by the Arizona State Parks Department that trains volunteers to assist in the preservation of archaeological sites for federal and state land-managing agencies. The site stewards work with land managers to monitor archaeological sites. Site stewards agree to visit selected archaeological sites, often located in remote and rugged backcountry settings, to look for evidence of illegal looting, vandalism and negative impacts from recreation (for example damage from ATVs). Site stewards record the results of these visits into a database managed by Arizona State Parks.

The ASSP was established in response to the widespread looting and vandalism of Arizona's irreplaceable archaeological resources. In 1985, then Governor Bruce Babbitt charged the Governor's Archaeology Advisory Commission (GAAC) with developing a stewardship-type program in Arizona. The Law Enforcement Subcommittee of the GAAC quickly focused on establishing a volunteer Stewards program, with monitoring sites for vandalism as its primary purpose. Working with the Arizona State historic Preservation Office and a committee of GAAC members, the Commission formally approved the establishment of the Arizona Site Stewards Program on June 5, 1986.

Now in the year 2016, the program celebrates its 30<sup>th</sup> anniversary. Since the program's inception, the ASSP has trained more than 2,000 volunteer stewards located throughout the State of Arizona, who monitor, document, and report damages to cultural sites and properties for 38 federal, state, non-profit, and private land managers. In the year 2015 alone, 646 volunteers logged over 26,000 hours visiting sites across 26 regions in Arizona.

In the year 2010, the ASSP implemented an online database for recording a standardized set of attributes observed at looted, vandalized, or otherwise negatively impacted archaeological sites. This new technology created a digital reservoir where the thousands of site visits and vandalism reports could be logged for research and analysis.

### *Project Goals:*

Between the years 2010 and 2014, approximately 800 volunteer site stewards completed 25,642 site visits to 971 archaeological sites. This effort generated an enormous data set. This study used the resulting data to address three primary questions: when and where do negative impacts to archaeological sites occur, and do they correlate with seasonal changes?

This project used site condition data collected by the ASSP volunteers and compared the data to fluctuations in temperature, precipitation, and season. Recent research indicates that high seasonal temperatures associated with climate change will reduce recreation on public lands during the summer, and may extend visitation during the winter, or vice versa depending on the area (Loomis and Crespi 1999, Mendelsohn and Markowski 1999, Morris and Walls 2009, Richardson and Loomis 2004, Scott et al. 2005). Shifts in regional climate conditions may impact rates of human-caused site damage. This study sought to understand the current relationship between the climate, human behavior, and site damage, to be used as a reference for future preservation planning.

### *Methods:*

This study used the ASSP database to analyze the results of thousands of site visits and vandalism reports. The data for the project relied on reports logged between the years 2010 and 2014. Within this timeframe, 33,840 activities were logged, 25,642 of which represent site visits.

Attributes recorded by the site stewards can be categorized into three broad and overlapping categories: illegal looting, vandalism, and recreation. Looting can be evidenced by the presence of illegal digging including potholes, probe holes, exposed human remains, and use of mechanical equipment like backhoes. Looters also attempt to remove entire petroglyph boulders from the sites, often assisted by use of mechanical equipment or tools for chiseling. Vandalism at archaeological sites is widespread and is often evidenced by paintball splatter, graffiti or scratching on petroglyph panels, evidence of damage from bullets (for example using a petroglyph for target practice), rearranging/moving/damaging masonry from standing structures, and downing fences to enter protected archaeological sites illegally. Archaeological sites also suffer from the impacts of general recreation or backcountry use. These impacts can be more innocent, or perhaps result from poor etiquette, or reckless behavior. The negative impacts from recreation recorded by site stewards include ATV tracks, moved boulders, artifact collection piles, evidence of camping including fire pits and trash, moved boulders, and foot prints.

Phase I of the research began with downloading the 25,642 site visit reports and 848 vandalism reports generated between 2010 and 2014. An additional data set including information on 1,697 highly sensitive, or considered to be at-risk archaeological sites, was provided by the State Parks Department and partner land managing agencies. This data set required significant reformatting in order to be compatible with Geographic Information Systems software. The coordinates for 300 select archaeological sites were obtained from the Arizona State Museum. Finally, monthly climate data from the National Oceanic and Atmospheric (NOAA) from 30 weather stations found throughout Arizona were downloaded. These data included the mean monthly temperature in Fahrenheit (MNTM) and the total precipitation amount for the month (TPCP).

Phase II entailed the creation of a relational Access database to facilitate the analysis. This involved reformatting significant amounts of data, and retrieving Arizona State Museum site numbers for over 400 archaeological sites. The new relational database facilitated one-to-many relationships between archaeological sites, site visits, and vandalism reports.

Phase III: Using spare-money from the grant, the research team scanned 450 paper vandalism reports and their associated photos for permanent curation with the Digital Archaeological Record (t-dar), helping to

preserve and curate the legacy site steward data generated in the 1980s, 1990s, and 2000s, prior to the development of the digital database.

Phase IV entailed spatial analysis. Site visit and vandalism report tables were exported from the newly created Access database and imported into ArcGIS software for spatial analysis. Specifically, this phase plotted the location of looting, vandalism, and negative-impact recreation occurrences, and analyzed whether spatial trends existed.

Phase V: Analysis revealed that the most active site steward regions included the Tucson and Prescott regions, each of which generated thousands of reports. Both of these regions also experience a higher than expected frequency of vandalism and looting. Due to the excellent samples provided, the Tucson and Prescott regions were selected for a more detailed analysis. Site reports were analyzed according to date. Sites that were visited by a site steward at least once every three months were included in the sample. Sites that failed to meet this standard were excluded from the sample. This level of scrutiny allowed the researcher to narrow instances of vandalism, looting, and recreation to a three-month timeframe, enabling comparisons with seasonal fluctuations. Most visits within the sample occurred monthly.

Phase VI: The selected sample of vandalism reports from the Tucson and Prescott regions were analyzed separately and compared. The researcher categorized each report as looting, vandalism, or recreation. Reports were assigned two or more of these categories if necessary. Because these categories are subjective and can overlap, the following criteria were applied:

*Looting:* Potholes, probe holes, mechanical equipment/trenching, petroglyph thief, surface collecting (only if found in association with other looting), collection piles (only if found in association with other looting).

*Vandalism:* Petroglyph target, sign target, graffiti, paintball (only if found with other vandalism), fencing downed, rearranging of features.

*Recreation:* Trash found on site, human tracks (if found in the absence of looting or vandalism), collection piles and surface collecting (if found in the absence of looting), ATV tracks, fires made on site, unauthorized visitor (if found in the absence of vandalism and looting), new roads or trails, shrines built.

The three codes were assigned to vandalism reports and quantified by month. Yearly summaries were displayed in histograms by category. These histograms were compared to line graphs displaying the mean monthly temperature (MNTM) and total precipitation amount of the month (TPCP) for each region. Climate data were downloaded from the closest weather stations to the vandalism reports, and were obtained from plotting the coordinates of the weather stations in GIS. Monthly climate data from the years 2010-2014 were downloaded from: Tucson International Airport, and Prescott Love Field. Both weather stations were within a 50-mile radius or less of the analyzed vandalism reports. Finally, scatter plots comparing looting, vandalism, and recreation against monthly precipitation and mean temperature were generated in order to analyze whether correlations existed.

## **Spatial Analysis**

The spatial analysis focused on where negative impacts occur. Of the 1,697 sites included in the ASSP database, 870 were visited at least once. The project was able to obtain the coordinates for 583 of these visited sites (67%). It's important to note that these numbers vary from the vandalism reports in the below climate analysis, which includes an exhaustive sample of all vandalism reports, regardless of whether they could be associated with coordinates.

Spatial analysis revealed that a negative impact (looting, vandalism, recreation) was present at 210 sites (36% of the sites with coordinates). Overall, only 83 sites (14%) showed evidence of illegal looting (potholes, probe holes, ect.) across all of Arizona. Figure 1 shows the distribution of negatively impacted sites while Figure 2 shows the distribution of looted sites. As seen on the figures, large areas of Arizona are missing data, and not surprisingly, negative impacts tend to cluster in the areas with the most data. Three dense concentrations of negative impacts are apparent on the figures: the Tucson area, the Prescott area, and Northeastern Arizona.

A closer analysis of these “hot spots” was able to illuminate areas with the highest frequencies of negative impacts. The area around Tucson showed the heaviest evidence of looting. Within a 45-mile buffer around the centerpoint for the city of Tucson, looting was present at 21 out of 67 sites (31 percent). When compared to the 13% looting average for all of Arizona, this number is particularly high. Prescott showed the second highest rate of looting. A 45-mile buffer around Prescott found that 18 of the 105 sites were looted (17%). The third highest concentration of looting occurred in northeastern Arizona, where a 45-mile buffer found 15 of the 192 (~7%) visited sites showed at least one instance of looting.

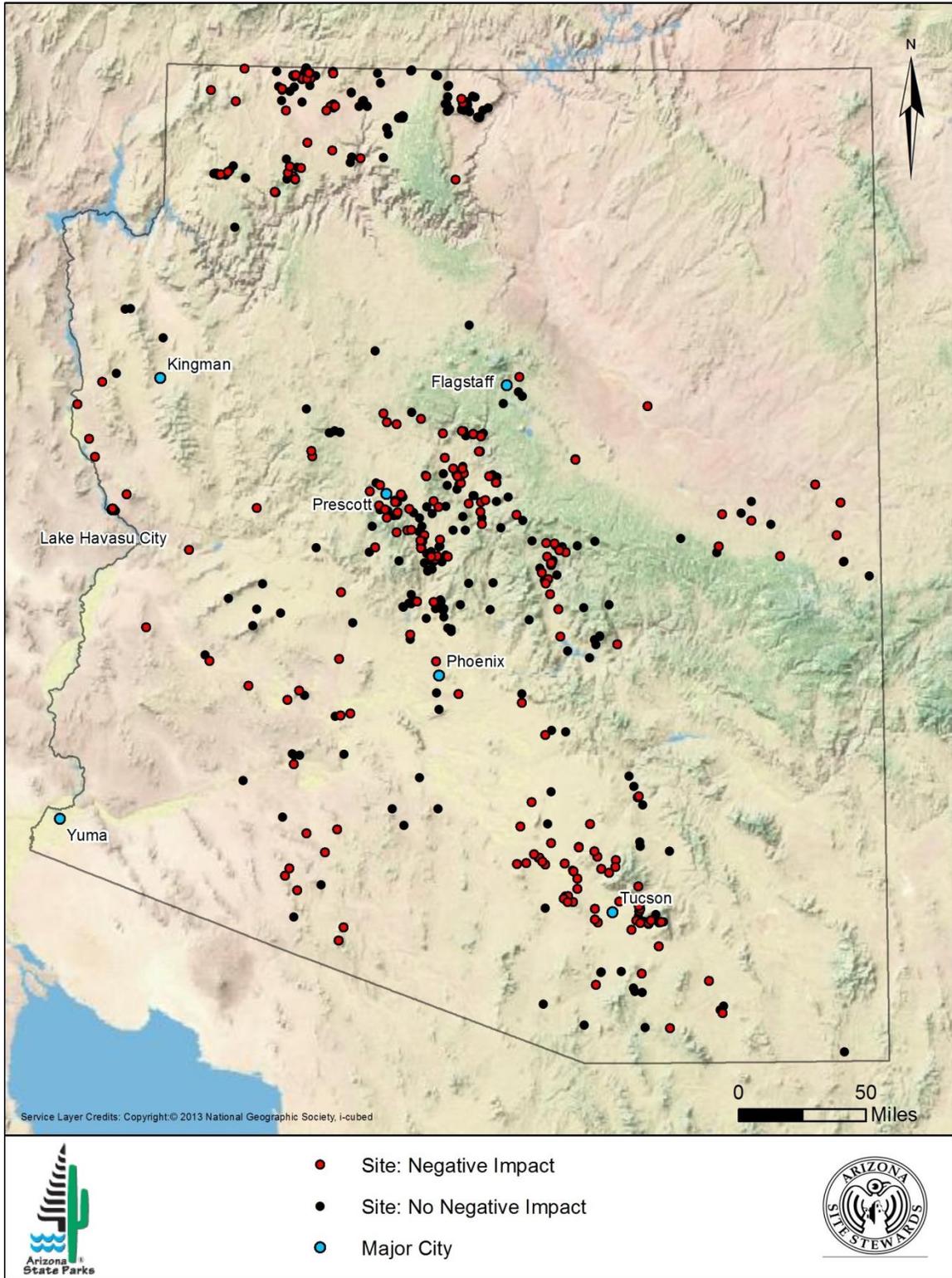


Figure 1. Distribution of archaeological sites showing positive and negative occurrences, from 2010-2014.

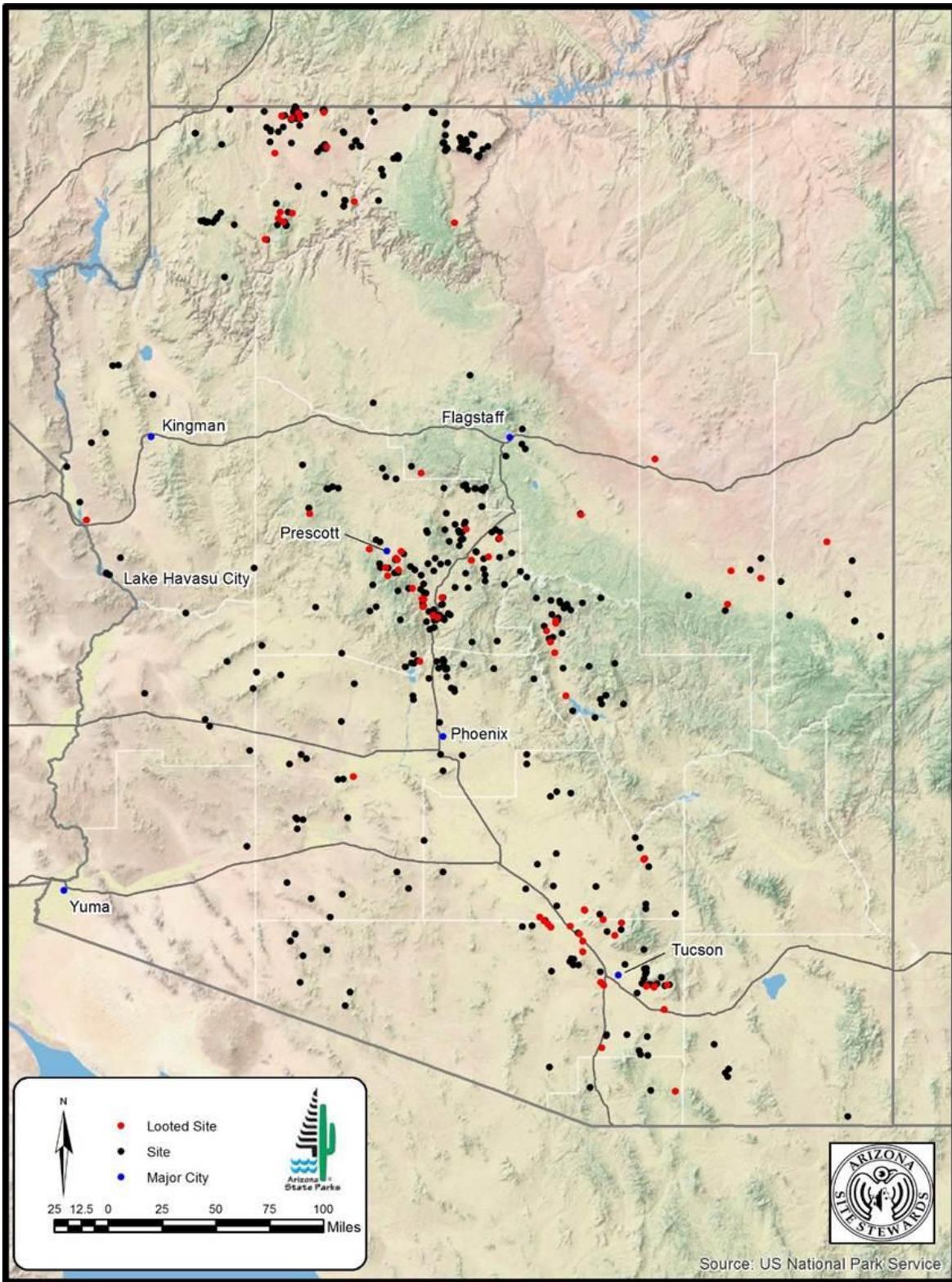


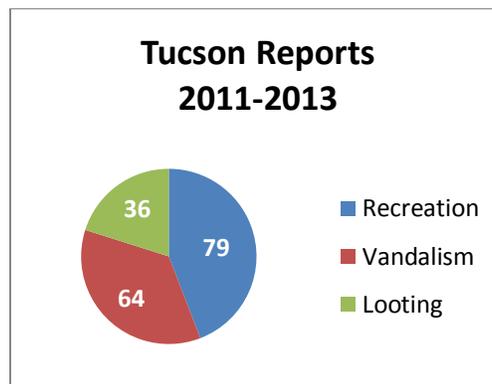
Figure 2. Distribution of looted and non-looted archaeological sites from 2010-2014.

## Climate Analysis

The second phase of the study addressed the questions of when negative impacts occur, and whether they correlate with seasons, temperature, or precipitation. The Tucson and Prescott areas, which by far provided the most generous samples, were analyzed separately then compared.

### Tucson Area Climate Analysis

Between the years 2010 and 2014, site stewards completed 4,962 site visits of 84 sites in the Tucson region. Of these visits, 232 reports of negative occurrences were filed covering 53 sites, or 63% of the sites. Eliminating sites that were not visited at least once every three months, 179 negative occurrences remained. These negative occurrences were classified as looting, vandalism, recreation, or multiple categories (Figure 3).



**Figure 3.** Breakdown of negative report occurrences.

### *Tucson Climate Data*

The following figures provide the climate data for the Tucson region.

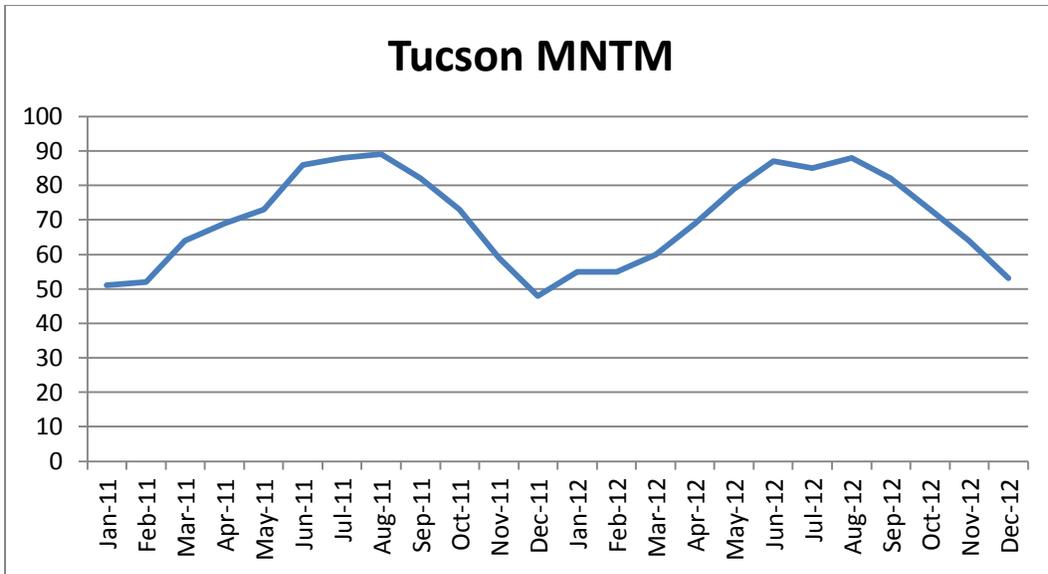


Figure 4. Mean monthly temperature 2011-2012.

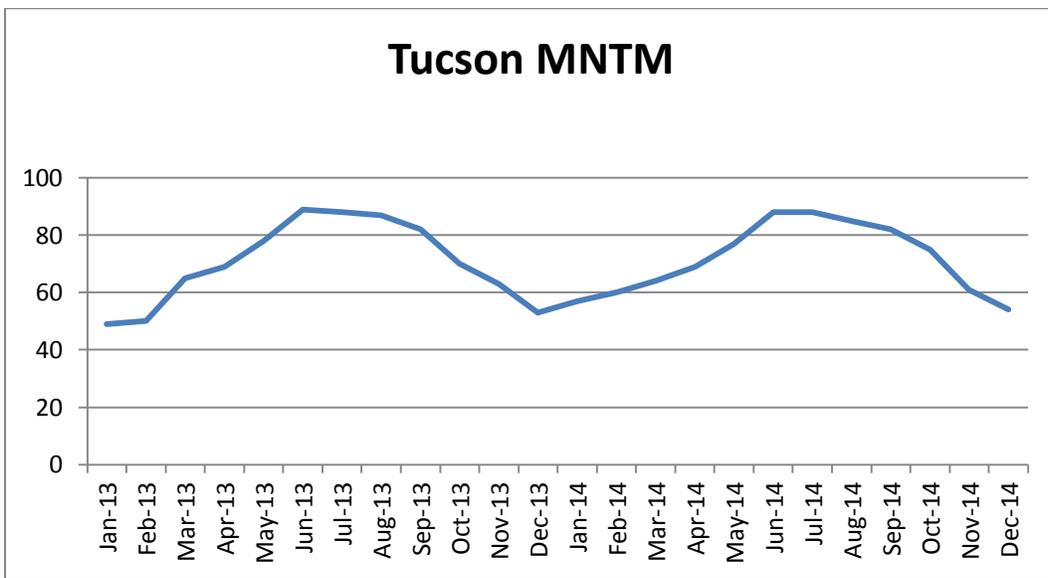


Figure 5. Mean monthly temperature 2013-2014.

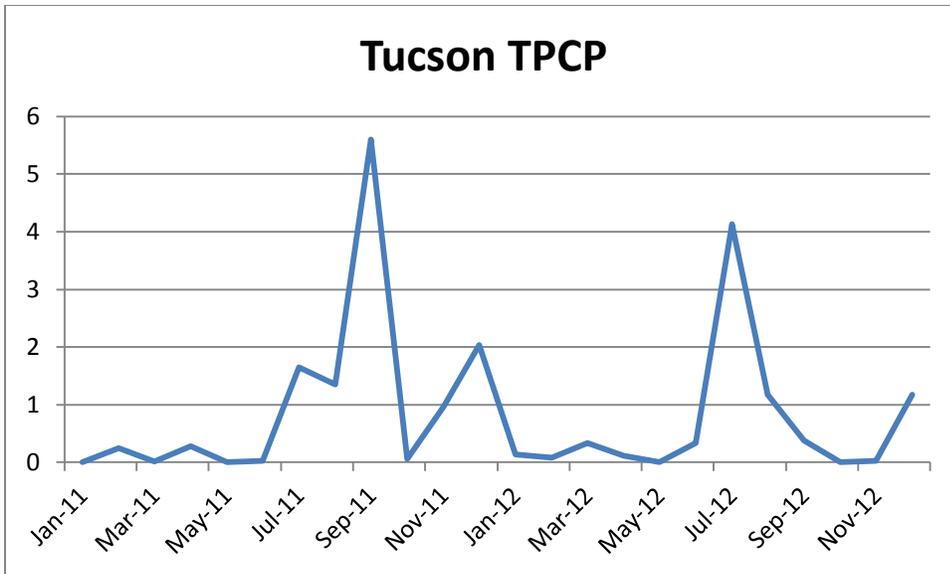


Figure 6. Total monthly precipitation, 2011-2012.

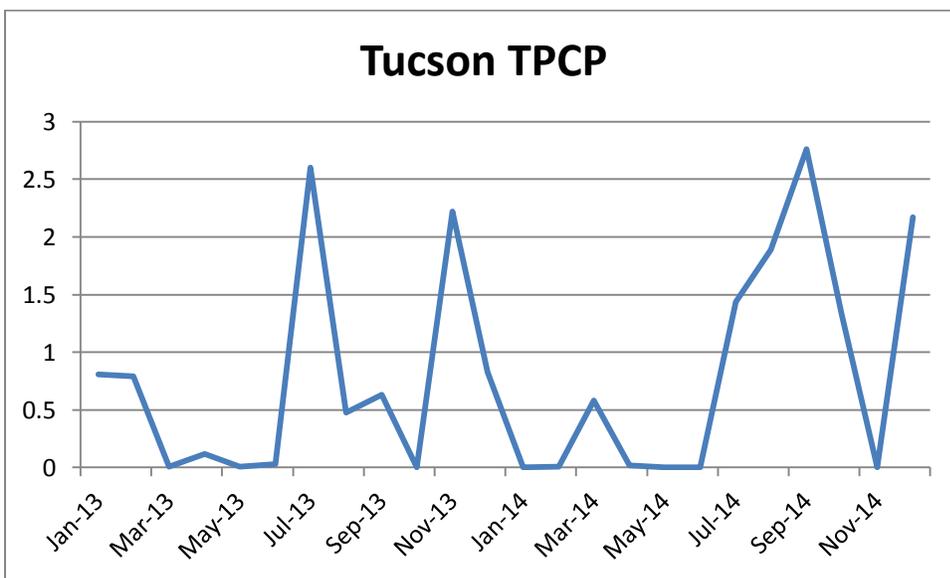


Figure 7. Total monthly precipitation, 2013-2014.

### *Tucson Looting*

The following figures summarize Tucson looting data. Of the 36 occurrences in the sample, looting occurs most frequently in the months of January, February, March, and December, and is least likely to occur in May and August. Looting decreases during the summer between mean temperatures of 55 and 90. The scatter plots show that most looting occurs between 45 and 65 degrees, while the least looting occurs between 65 and 90 degrees. Precipitation occurs primarily in the summer when looting is down. As a result, looting occurs primarily during months with 0 and .75 inches of rainfall (which is the majority of the year).

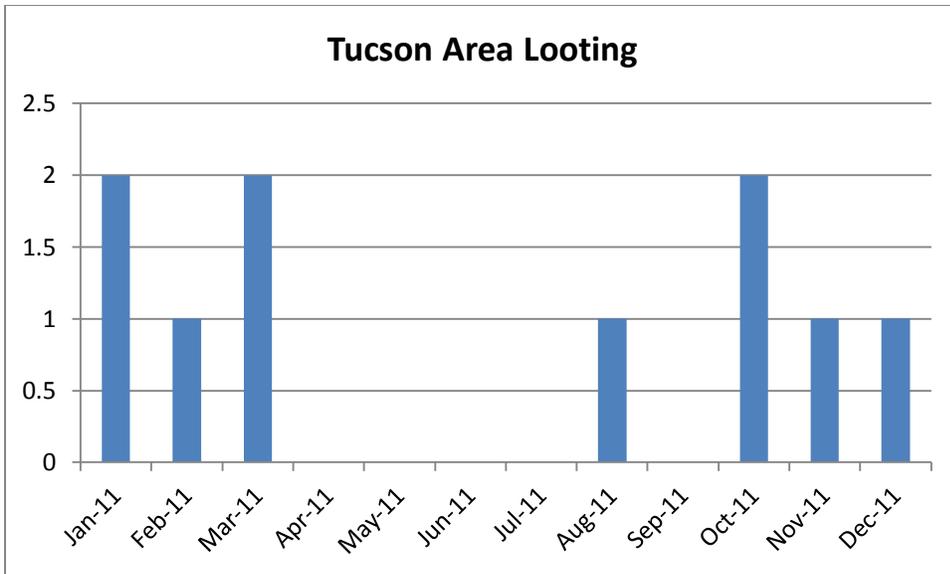


Figure 8. Tucson Region looting 2011

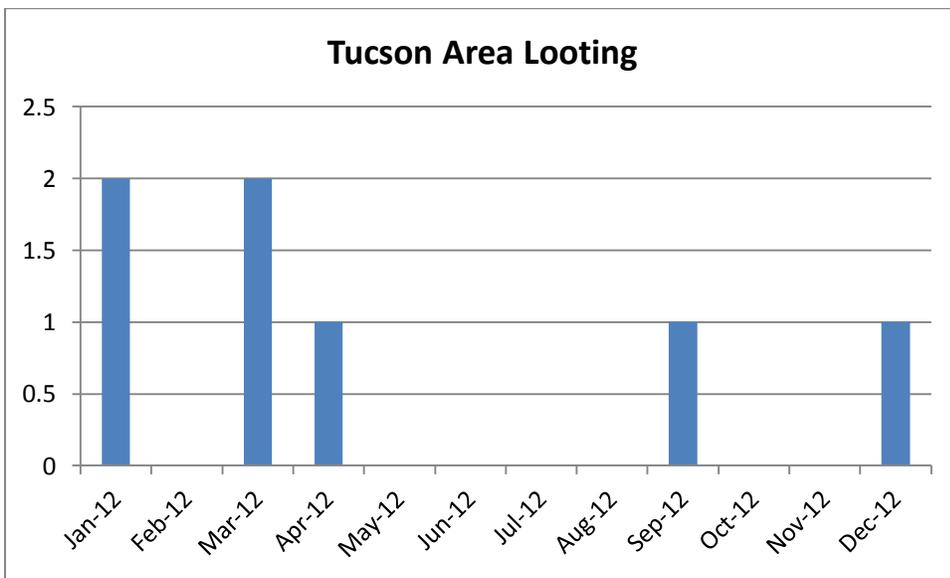


Figure 9. Tucson Area looting 2012

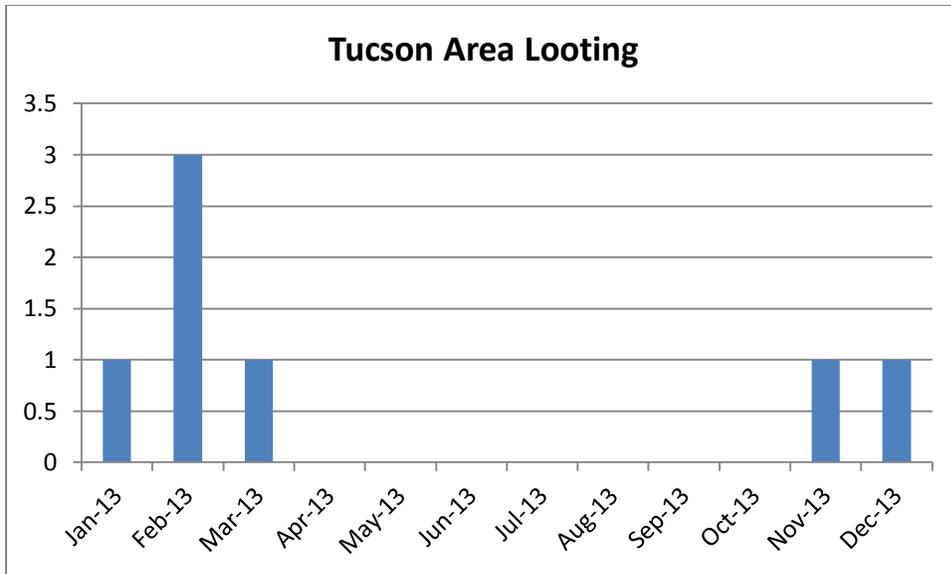


Figure 10. Tucson Area Looting 2013

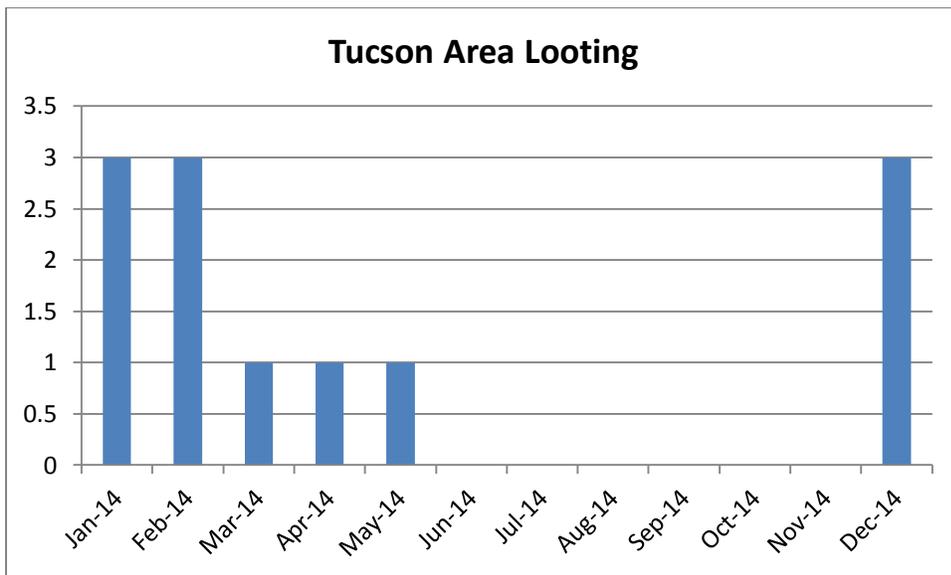


Figure 11. Tucson Area Looting 2014.

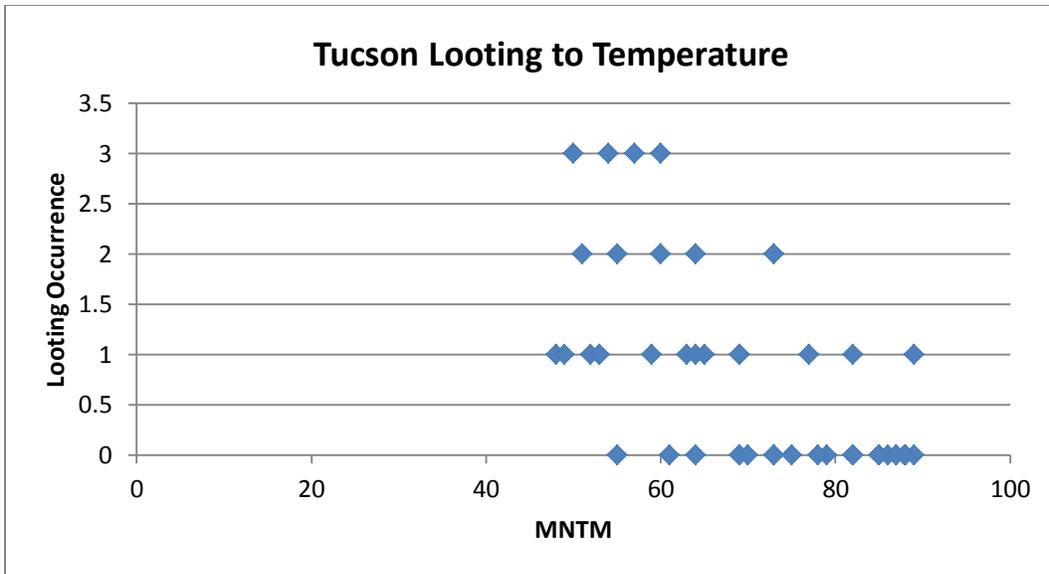


Figure 11. Scatter plot of looting occurrences per month to mean monthly temperature.

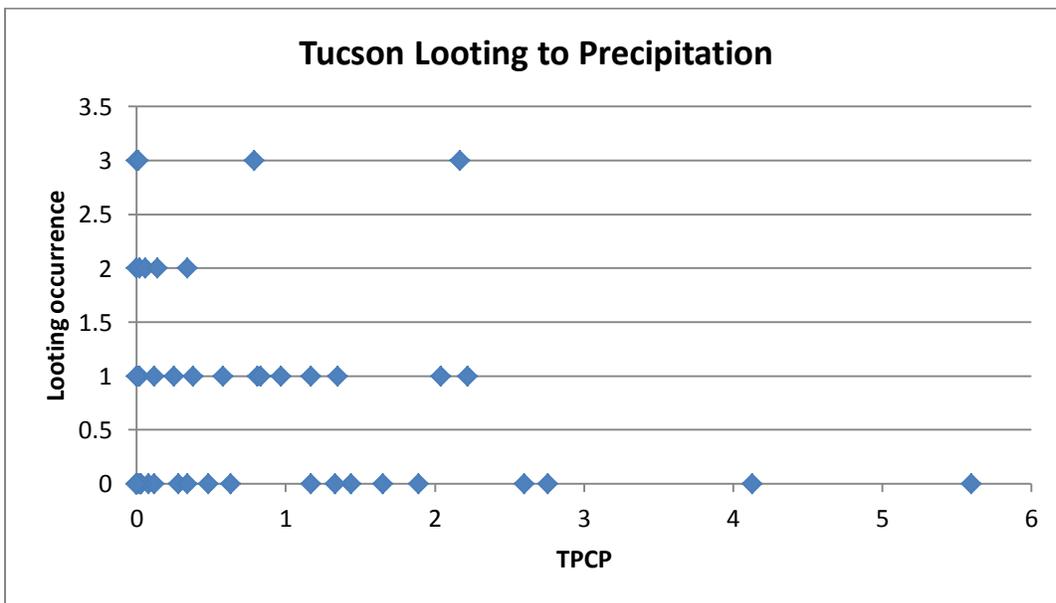


Figure 12. Scatter plot of looting occurrences per month to total precipitation per month.

### *Tucson Vandalism*

The following figures summarize Tucson vandalism data. Of the 64 occurrences, most occur in the winter, followed by a moderate spring, a significant drop off in the summer, and a slight pick-up in the fall. Vandalism is most common in January and February, followed by March and April, and November and December. Vandalism tends to occur between months with mean temperatures ranging from 45 to 70 degrees, with significant decreases between 75 and 85 degrees. Most vandalism occurs during months with precipitation less than 2 inches (the majority of the non-summer months). Like the looting data, vandalism decreases in the summer when precipitation increases, creating a negative correlation between looting and precipitation.

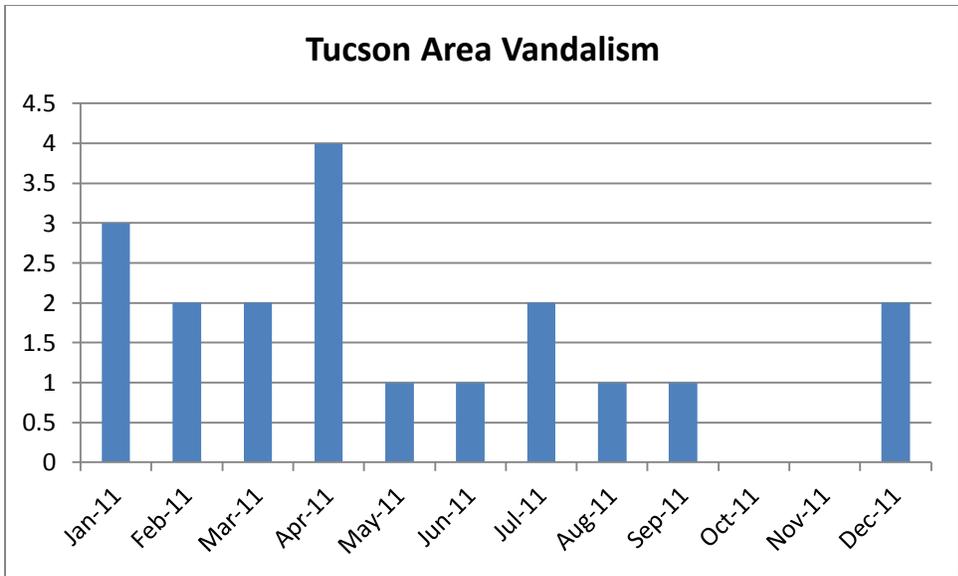


Figure 13. Monthly Vandalism Occurrences.

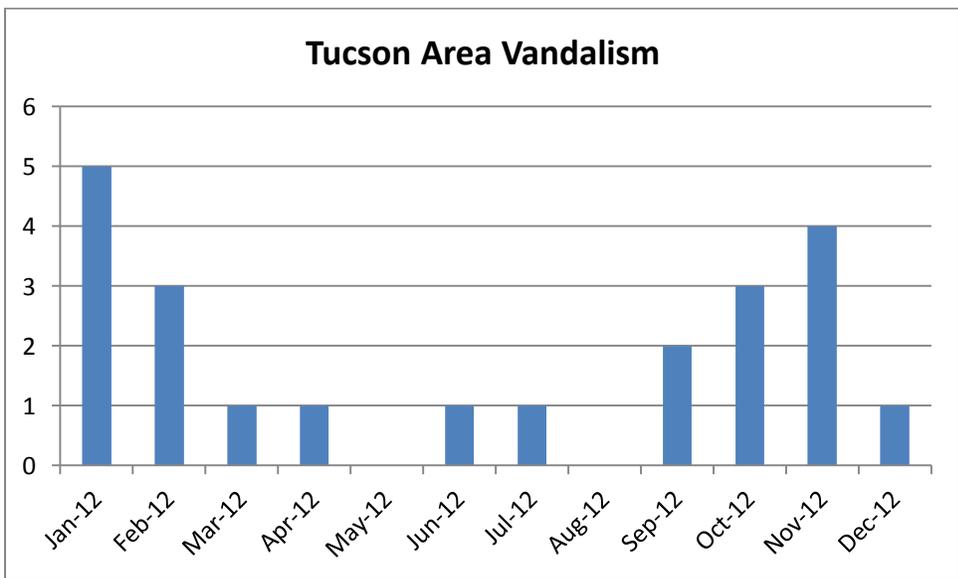


Figure 14. Monthly Vandalism Occurrences.

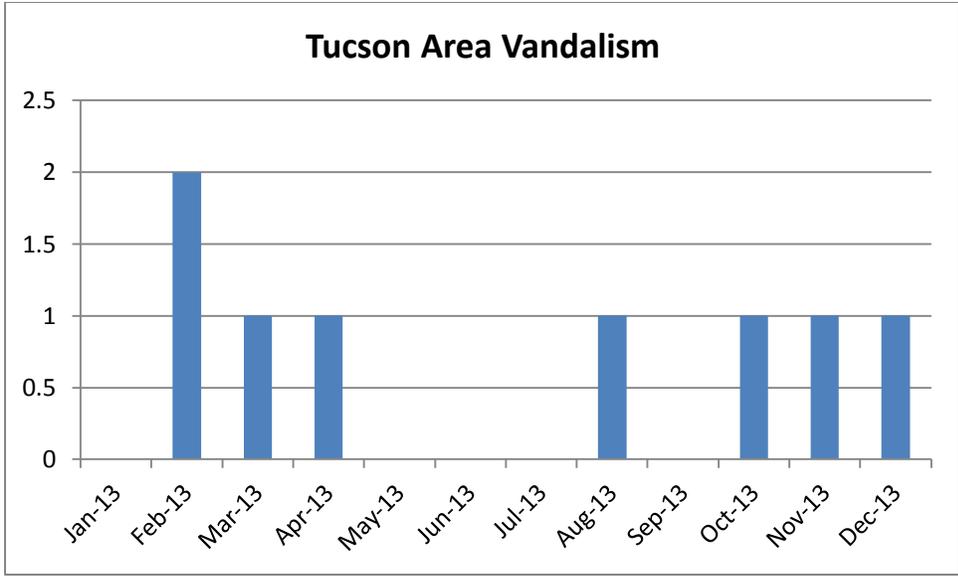


Figure 15. Monthly Vandalism Occurrences.

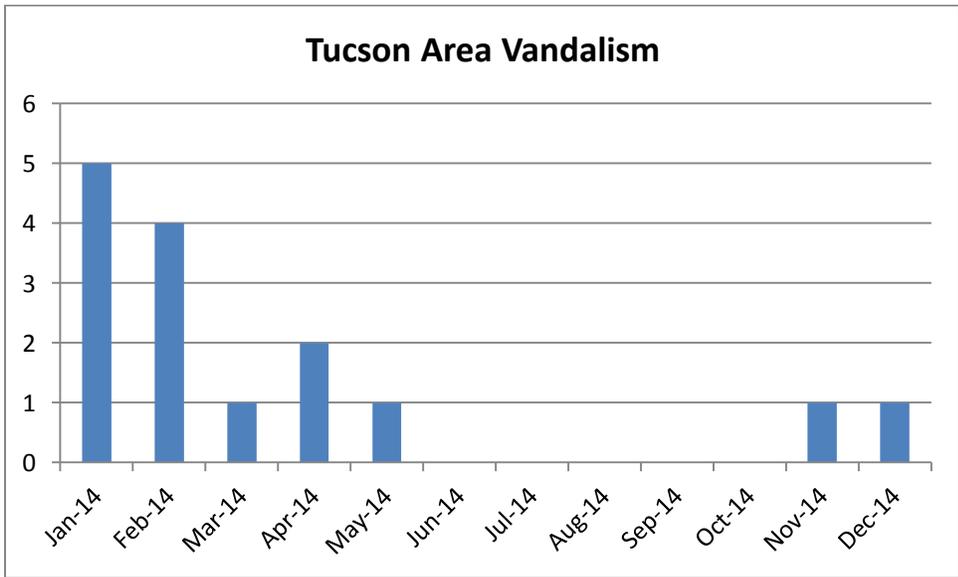


Figure 16. Monthly Vandalism Occurrences.

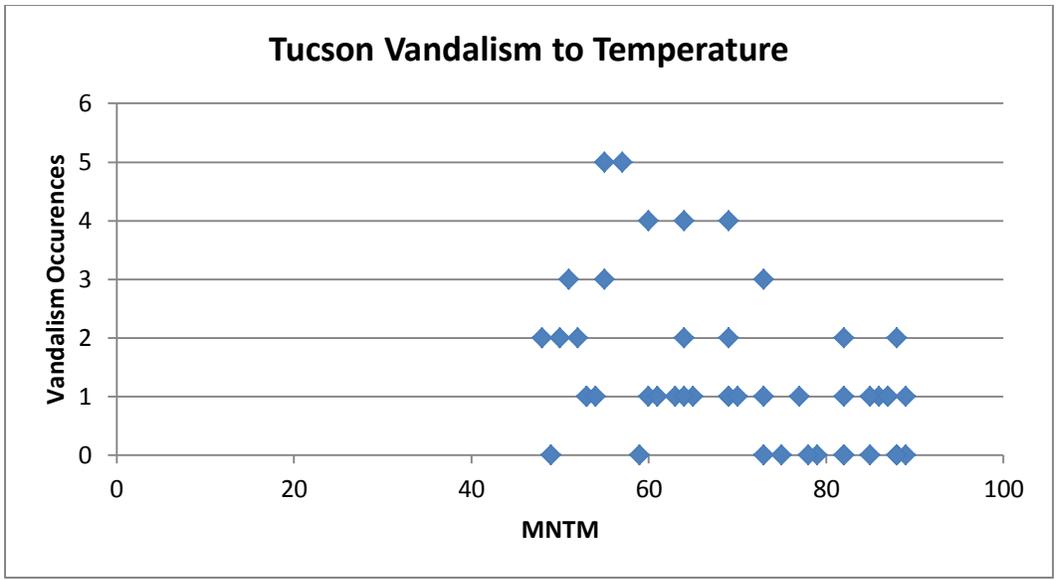


Figure 17. Scatter plot of vandalism occurrences to mean monthly temperature.

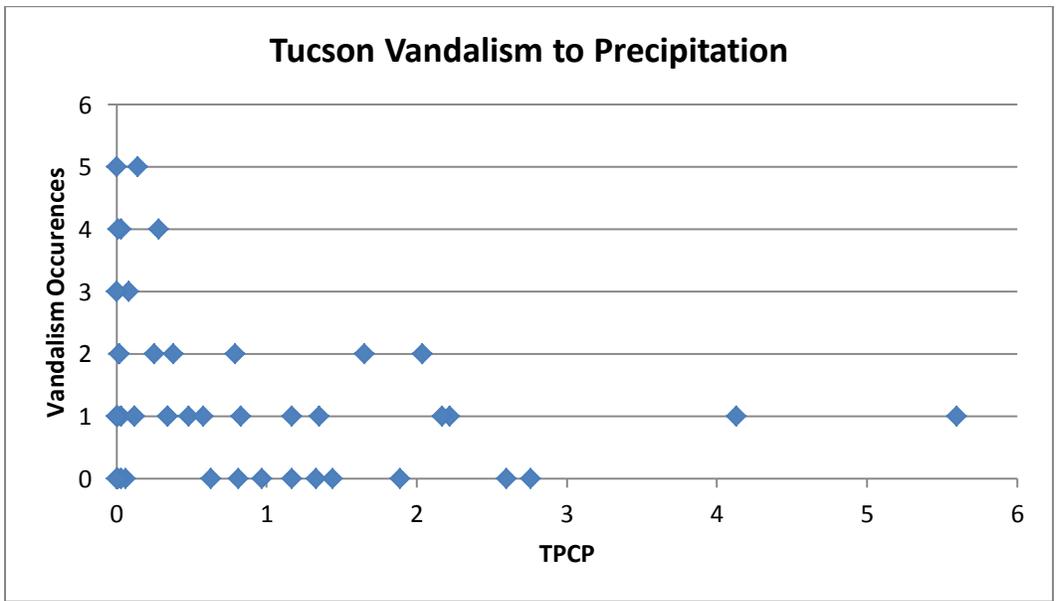


Figure 18. Scatter plot of vandalism occurrences to total monthly precipitation.

*Tucson Recreation:*

The following figures summarize the recreation data. Recreation occurs more frequently and is less predictable than looting and vandalism. Like looting and vandalism, recreation occurs most frequently in January and February, followed by March and July. Likewise, most recreation occurs between months with mean temperatures of 55 and 75 degrees and drops off significantly during months ranging between 75 and 85 degrees. Like the other Tucson occurrences, recreation tends to occur during months with less than one inch of precipitation (the majority of the non-summer year).

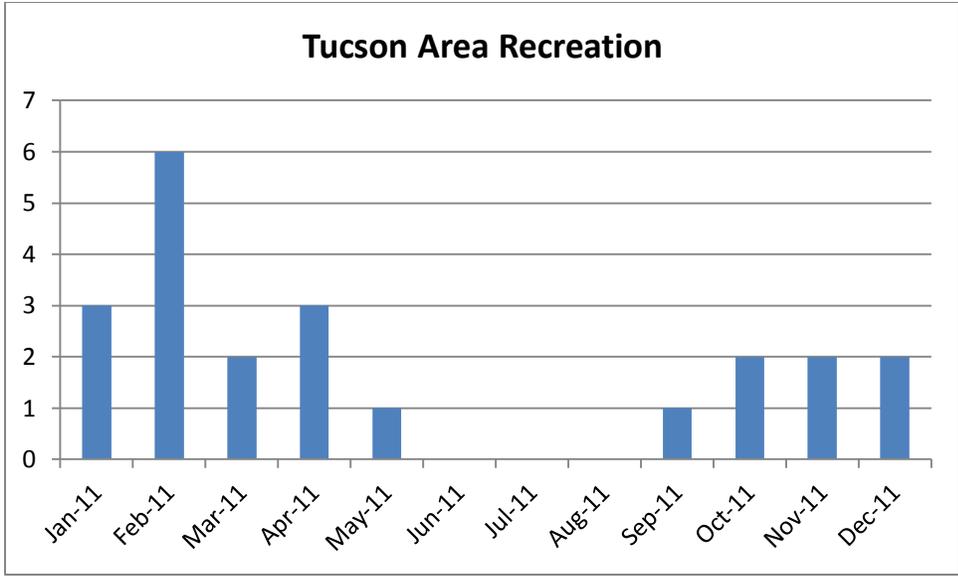


Figure 19. Monthly recreation occurrences.

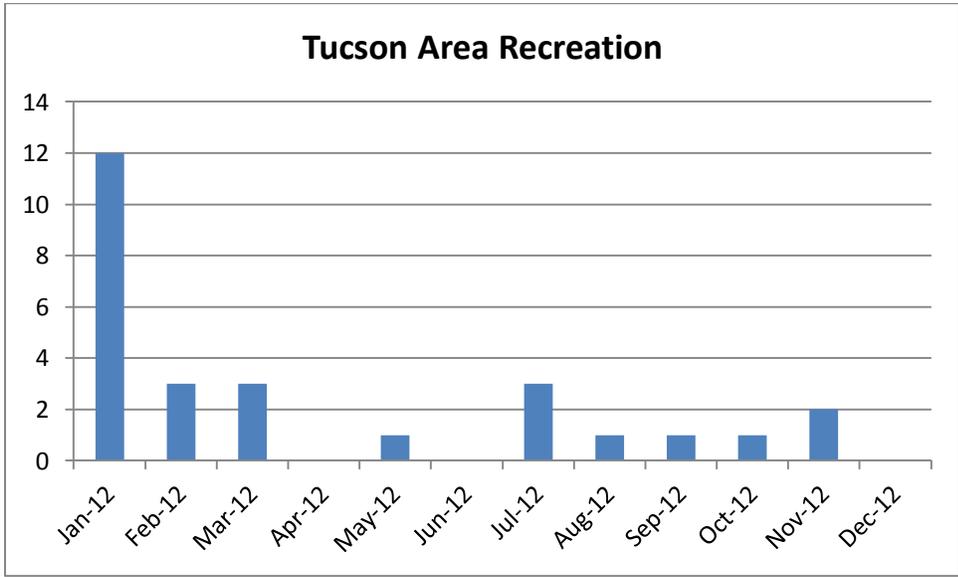


Figure 20. Monthly recreation occurrences.

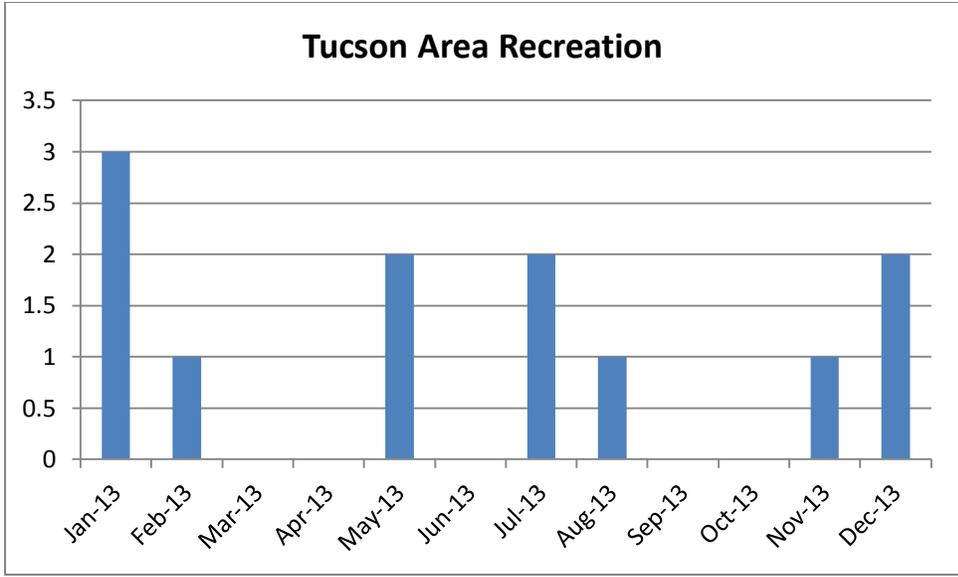


Figure 21. Monthly recreation occurrences.

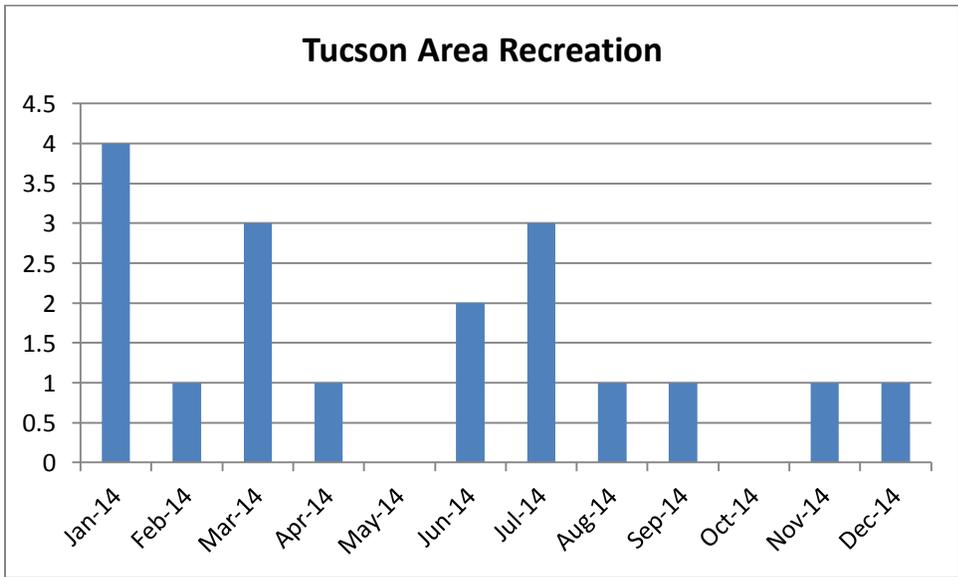


Figure 22. Monthly recreation occurrences.



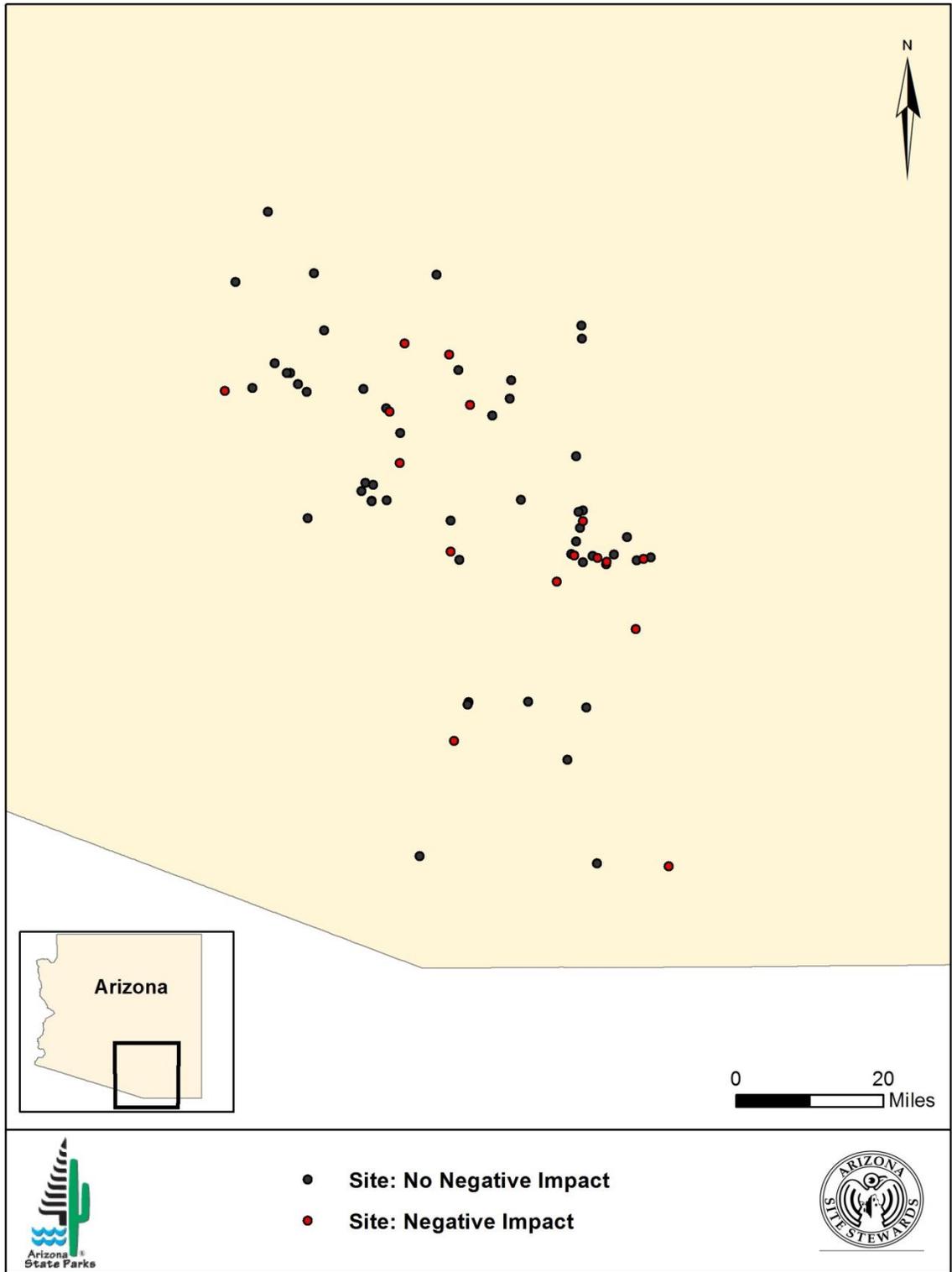
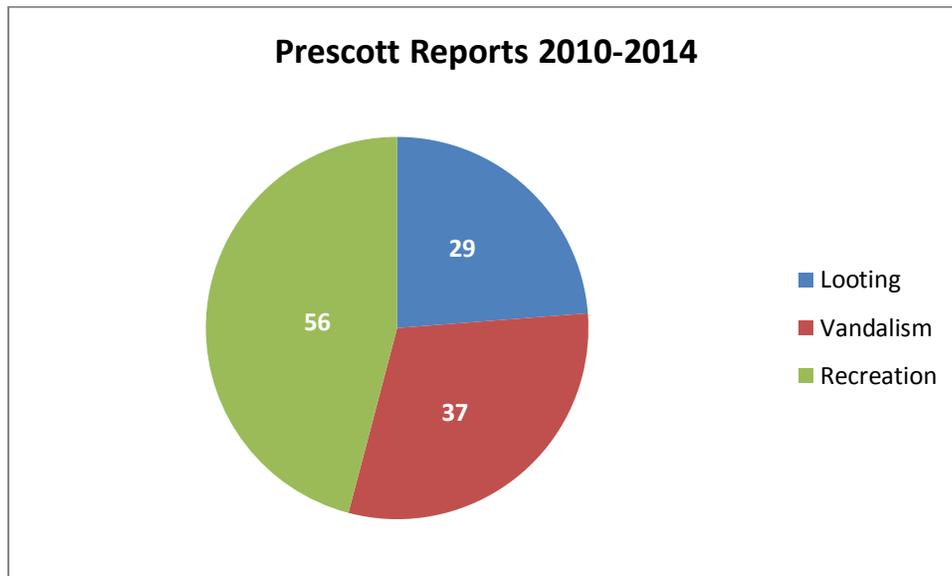


Figure 25. Tucson Area Impacts.

### Prescott Area Climate Analysis

Between the years 2010 and 2014, site stewards completed 2,389 site visits of 66 sites in the Prescott region. Of these visits, 122 reports of negative occurrences were filed. Eliminating sites that were not visited at least once every three months, all 122 negative occurrences remained. These negative occurrences were classified as looting, vandalism, recreation, or multiple categories (Figure 26).



**Figure 26.** Breakdown of negative report occurrences.

#### *Prescott Climate Data*

The following figures provide the climate data for the Prescott region.

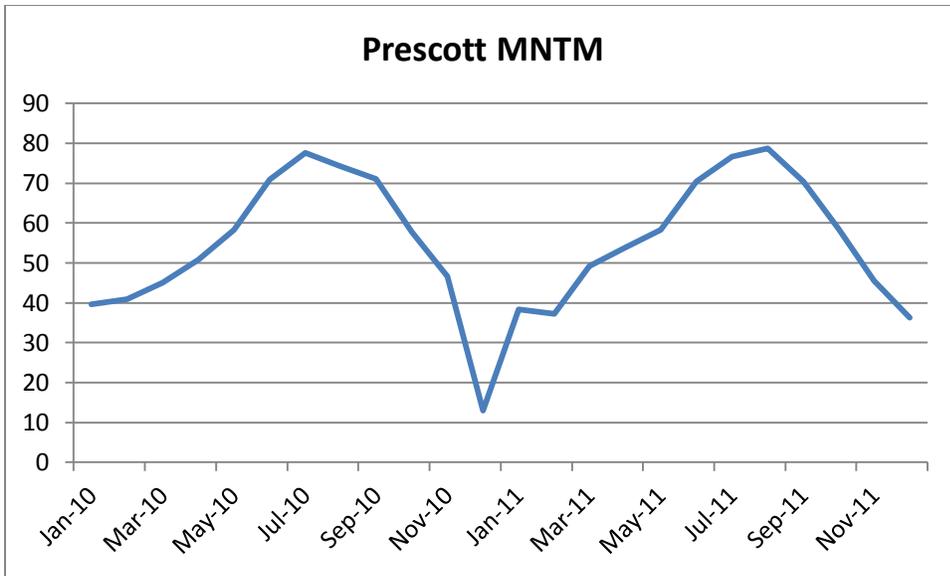


Figure 27. MNTM 2010-2011

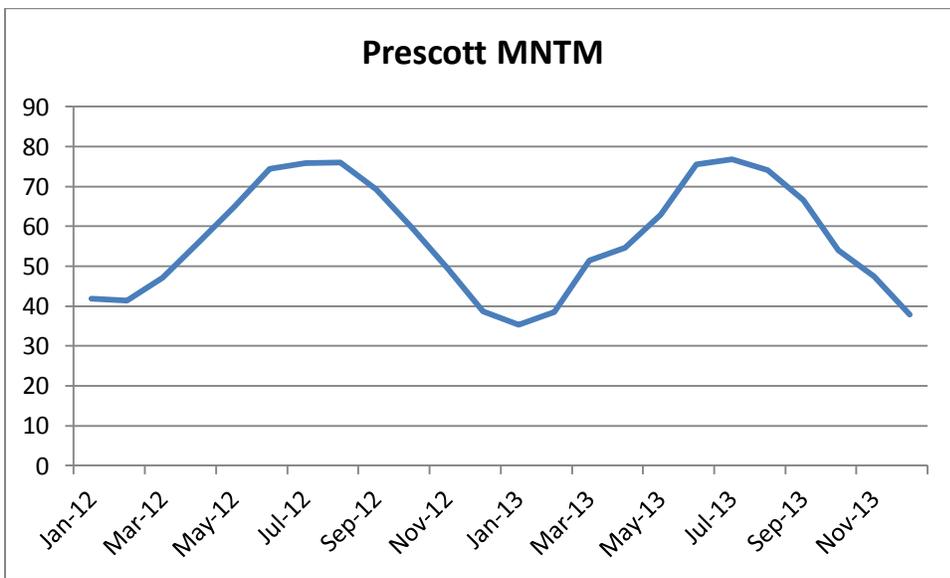


Figure 28. MNTM 2012-2013

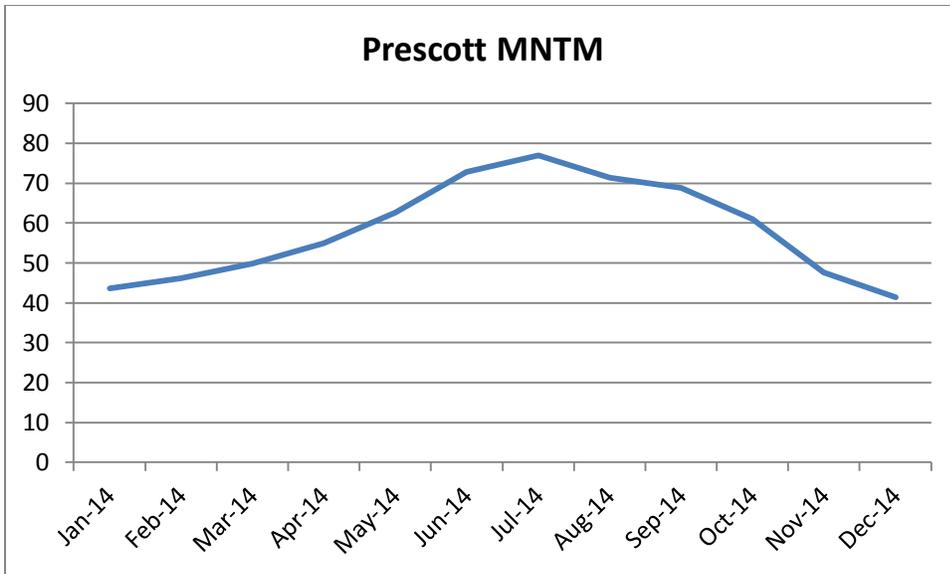


Figure 29. MNTM, 2014.

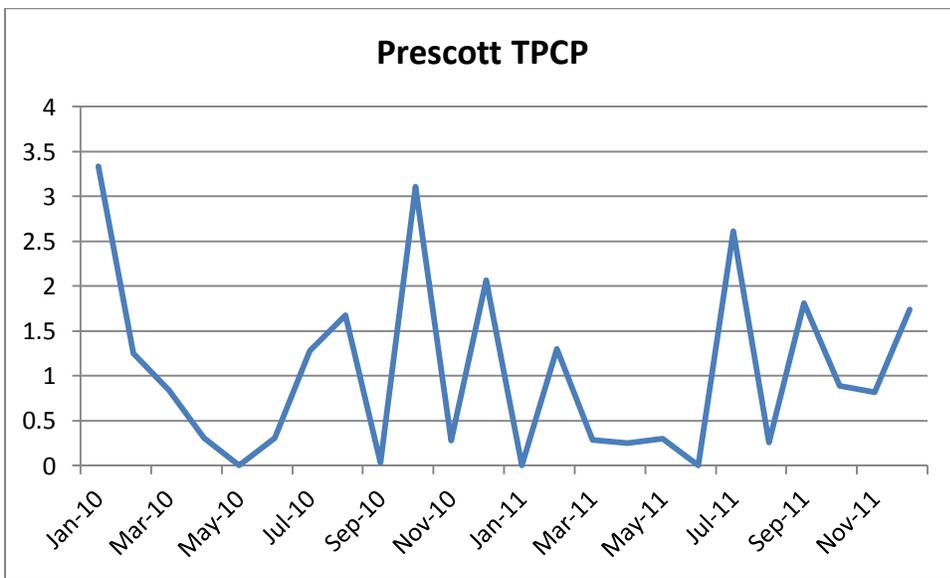


Figure 30. TPCP, 2010-2011.

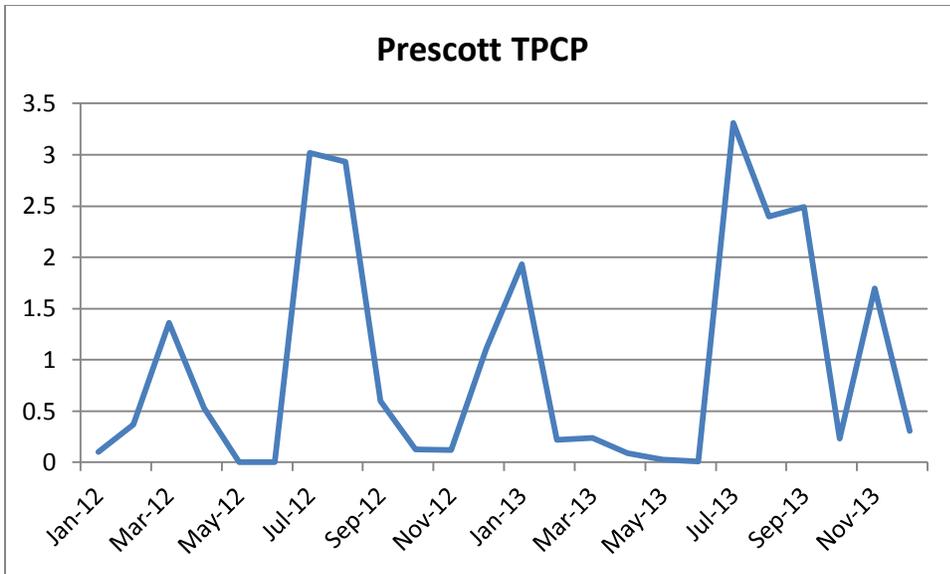


Figure 31. TPCP, 2012-2013.

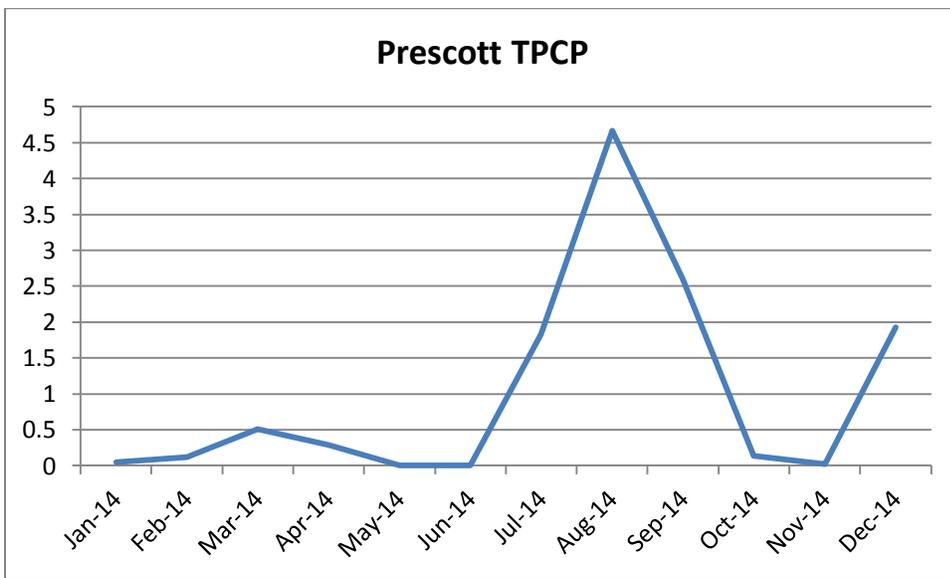


Figure 32. TPCP, 2014.

### *Prescott Looting*

The following figures summarize Prescott looting data. 29 instances of looting occurred at 12 sites. Looting occurs most frequently in March, April, and December, with the heaviest occurrences between December and May, when the temperature is gradually increasing. Generally, looting occurs between months with mean temperatures of 40 to 60 degrees, and drops between 70 and 80 degrees. Instances tend to cluster between 0 and 1.5 inches of precipitation (which is the minority of the year), resulting in a negative correlation between looting occurrences and precipitation.

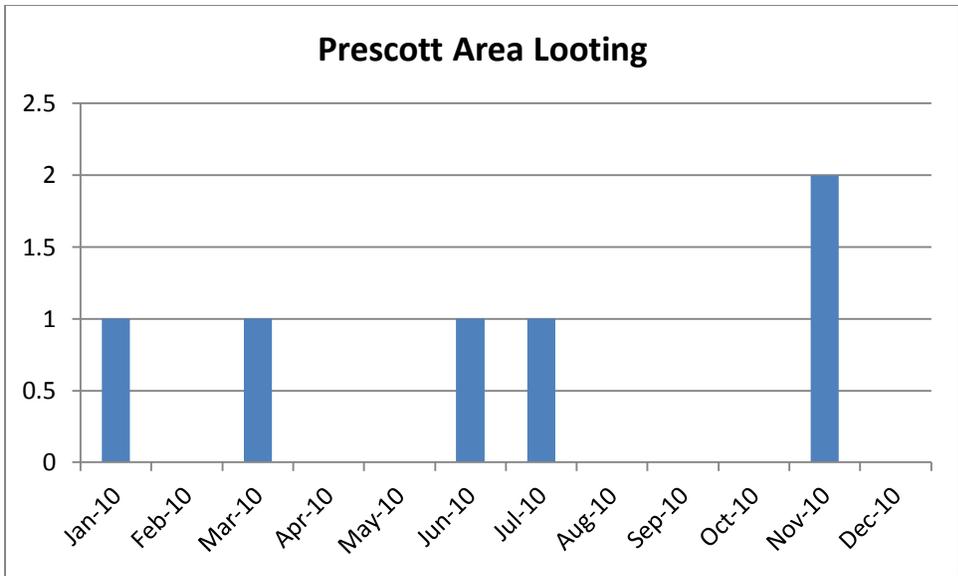


Figure 33. Monthly looting occurrences.

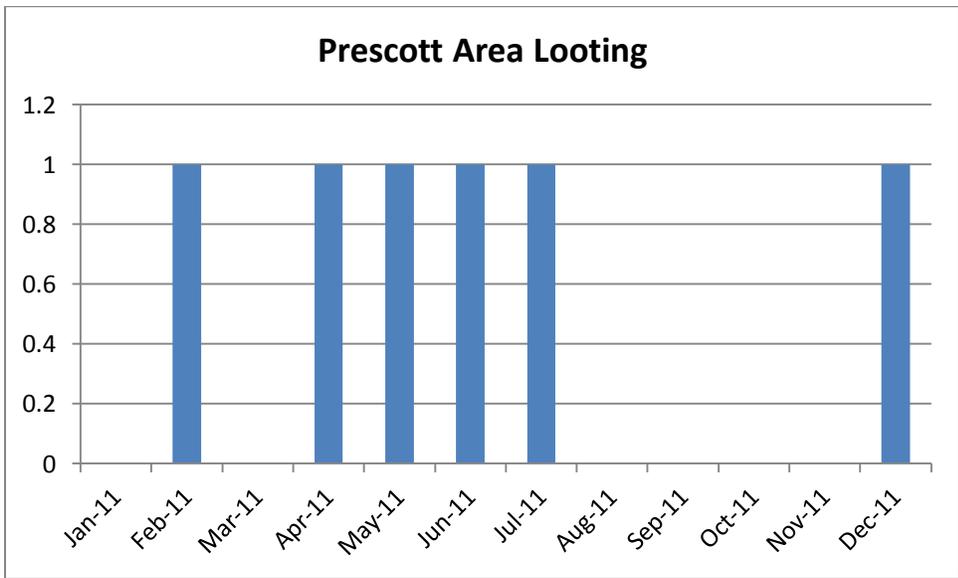


Figure 34. Monthly looting occurrences.

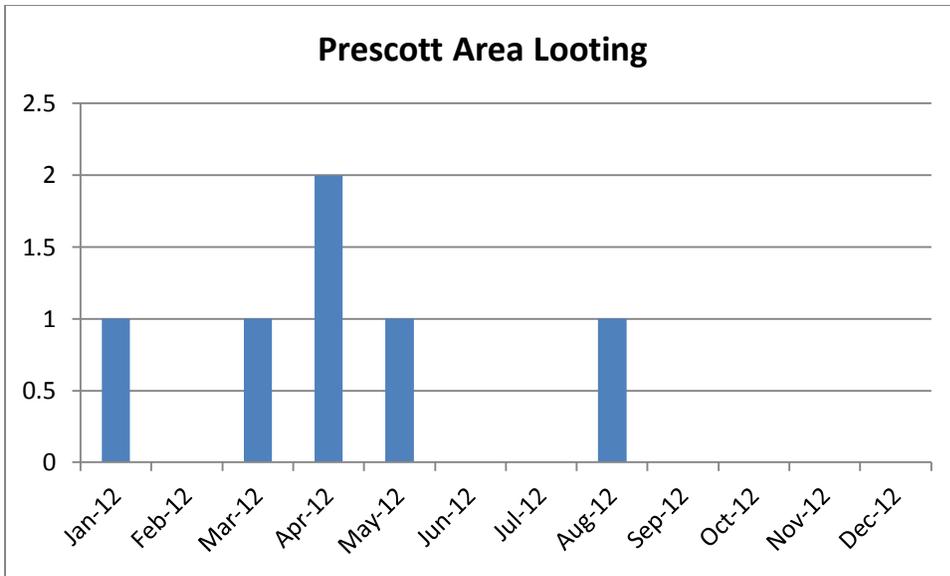


Figure 35. Monthly looting occurrences.

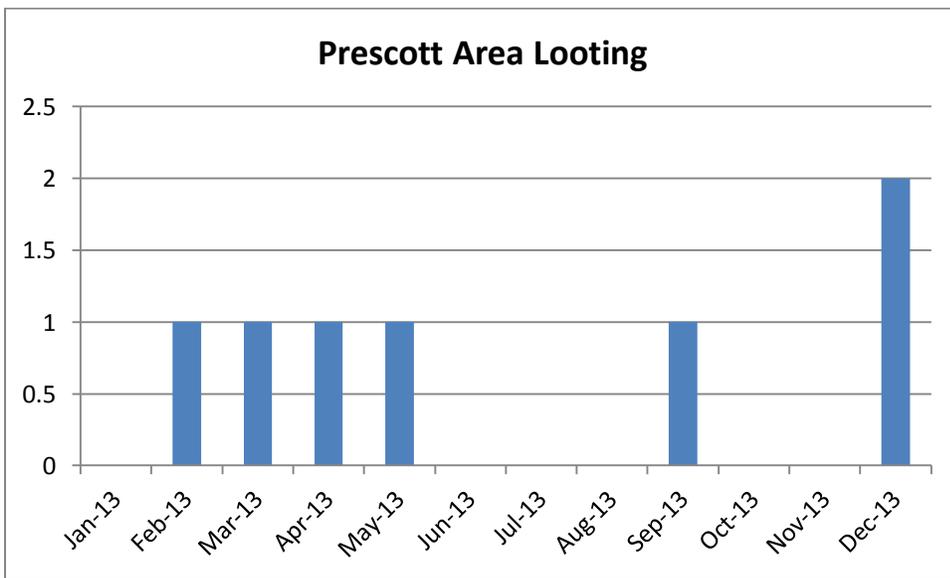


Figure 36. Monthly looting occurrences.

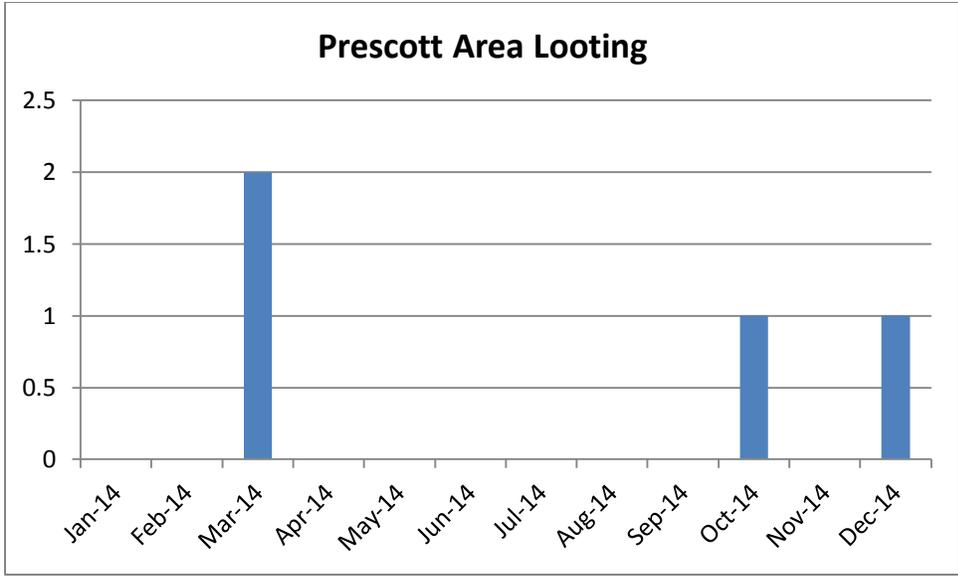


Figure 37. Monthly looting occurrences.

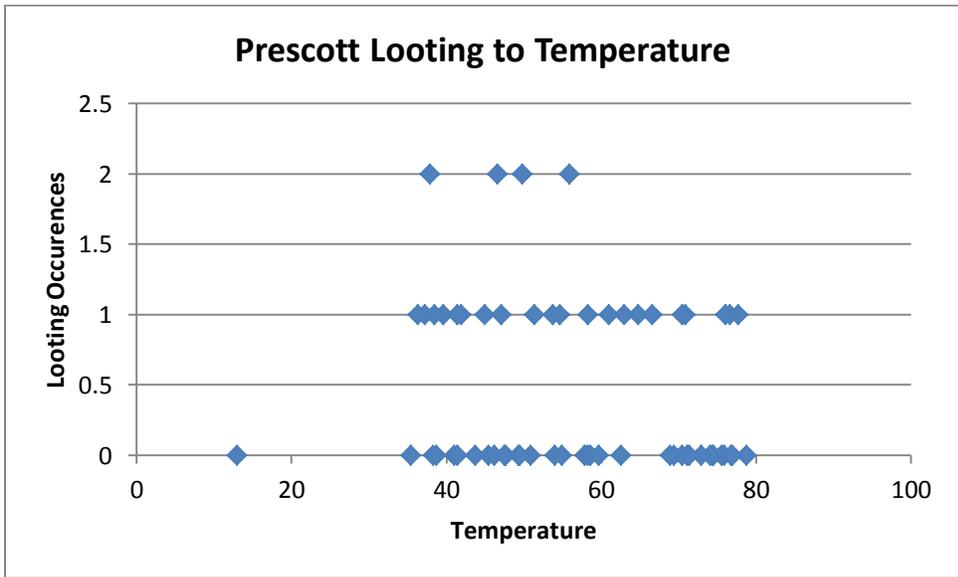


Figure 38. Scatterplot, looting to temperature.



### *Prescott Vandalism*

The following figures summarize the Prescott vandalism data. In Prescott, unlike Tucson, vandalism is the most frequent negative impact. Most vandalism occurs in April, July, and November, although July 2011 is an outlier year with a large number of occurrences. January and February are scant months, followed by upticks in the spring, decreases in the summer, and higher occurrences in the fall. Most vandalism occurs between mean temperatures of 40 and 70 degrees (most of the year). Vandalism does not appear to correlate with temperature, but instead to seasons. Scatter plots show a negative correlation with precipitation, indicating that the most vandalism occurs during the driest months. This trend was unexpected. Prescott's precipitation fluctuates highly compared to Tucson's precipitation. To this point, recreation has seemed to be more related to season and temperature than precipitation.

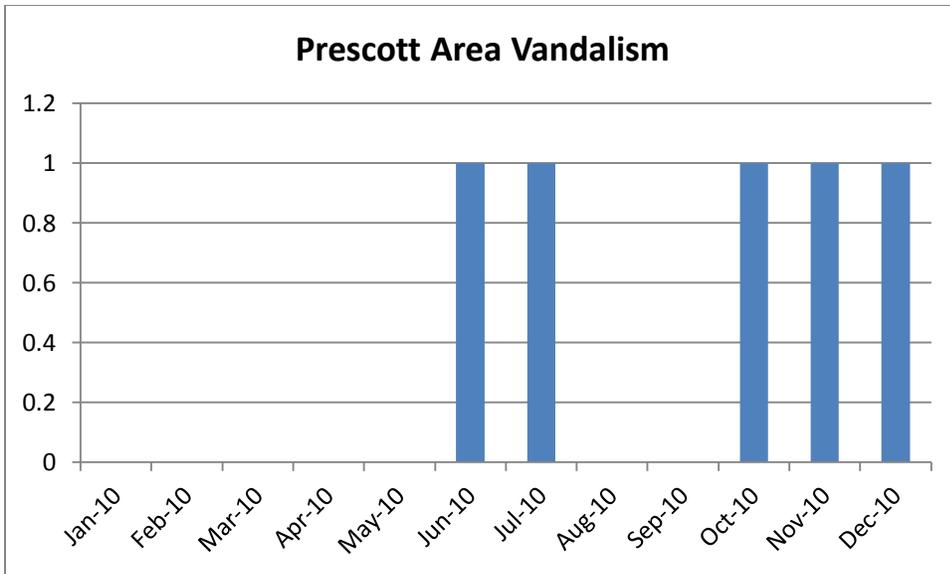


Figure 40. Monthly vandalism occurrences.

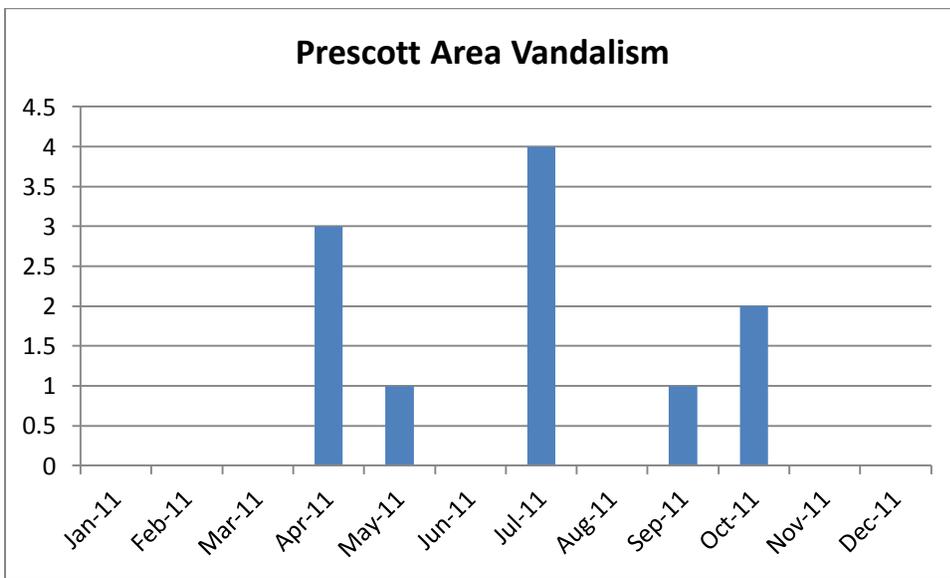


Figure 41. Monthly vandalism occurrences.

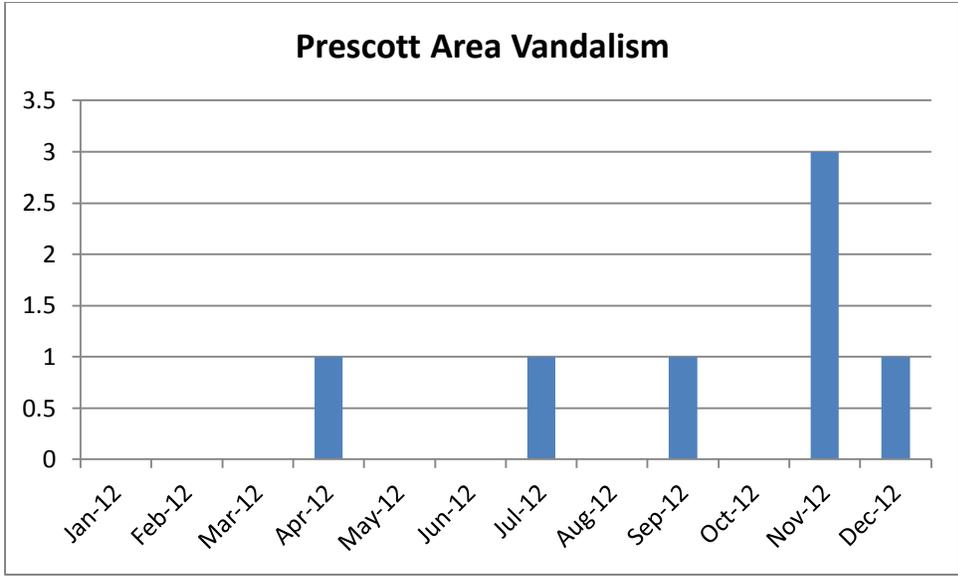


Figure 42. Monthly vandalism occurrences.

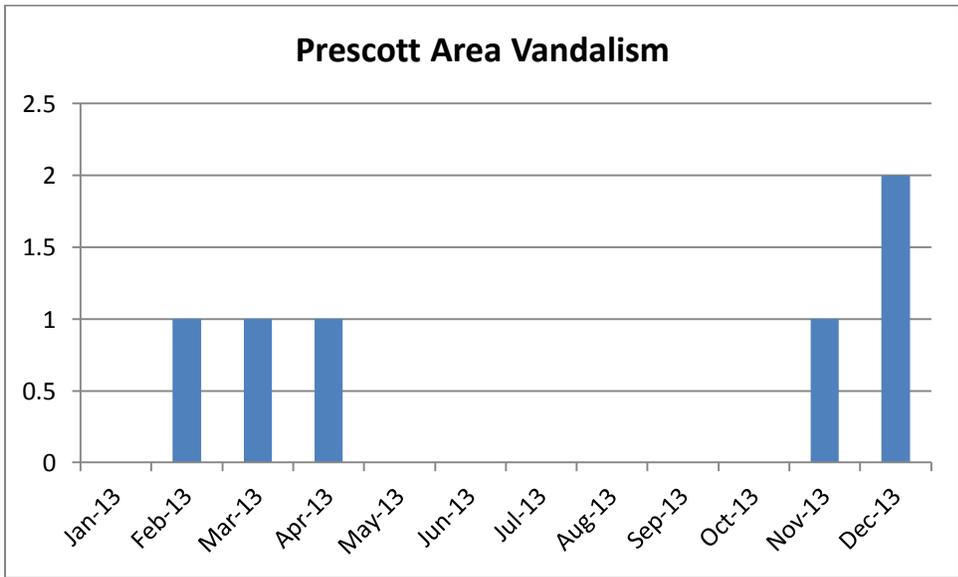


Figure 43. Monthly vandalism occurrences.

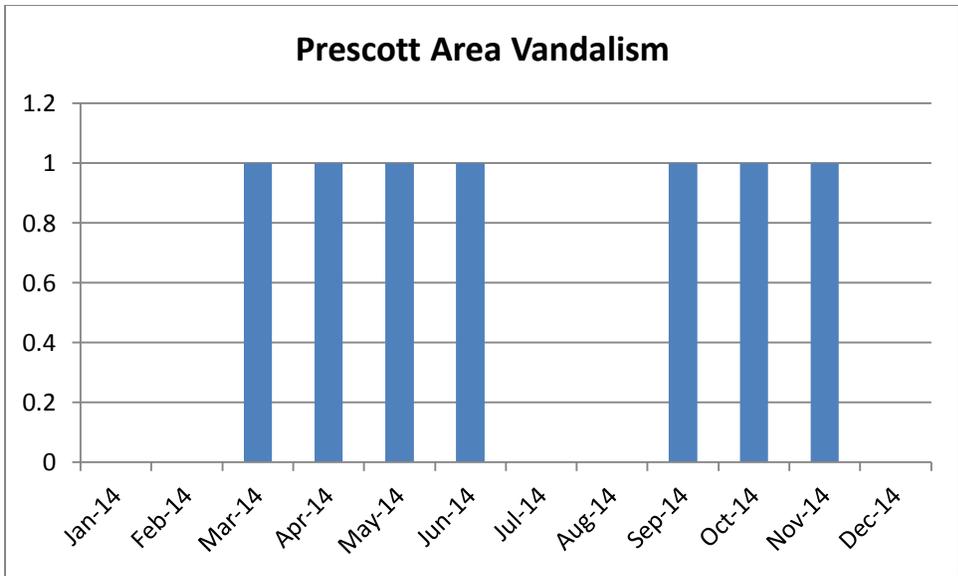


Figure 44. Monthly vandalism occurrences.

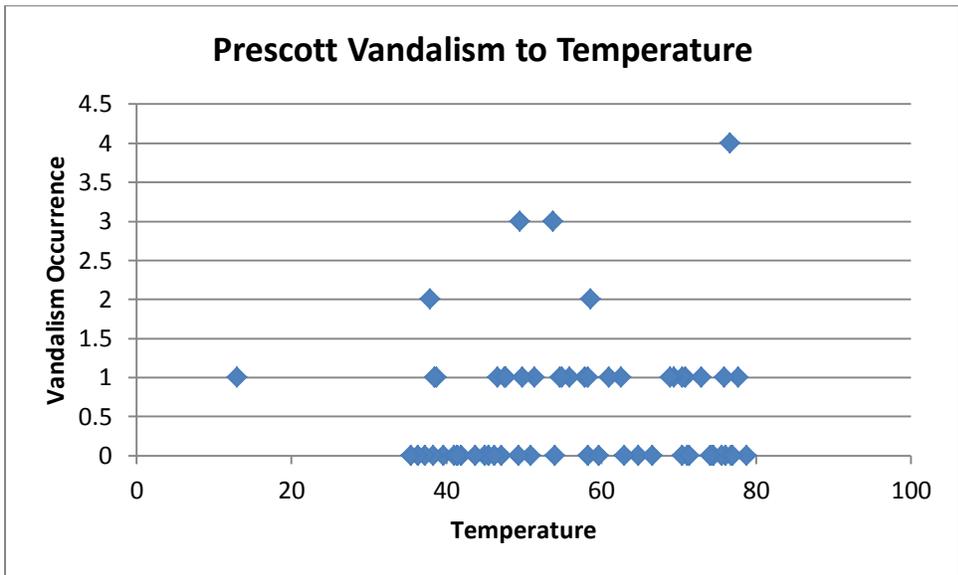


Figure 45. Scatterplot, vandalism to temperature.



### *Prescott Recreation*

The following figures summarize the Prescott recreation data. Of the 37 instances between 2010 and 2014, recreation was found most frequently in January, February, March, and May. Generally, recreation is frequent in the winter and spring, slower in the summer, with a slight pickup in the fall. These instances occur between 40 and 80 degrees (a range indicative of most of the year). Months with the highest frequencies of recreation tend to range between 40 and 60 degrees, creating a slightly left-skewed scatterplot. The scatterplot of recreation to precipitation is also slightly left-skewed, indicating that like vandalism, recreation tends to occur during drier times (less occurrences during summer monsoon season).

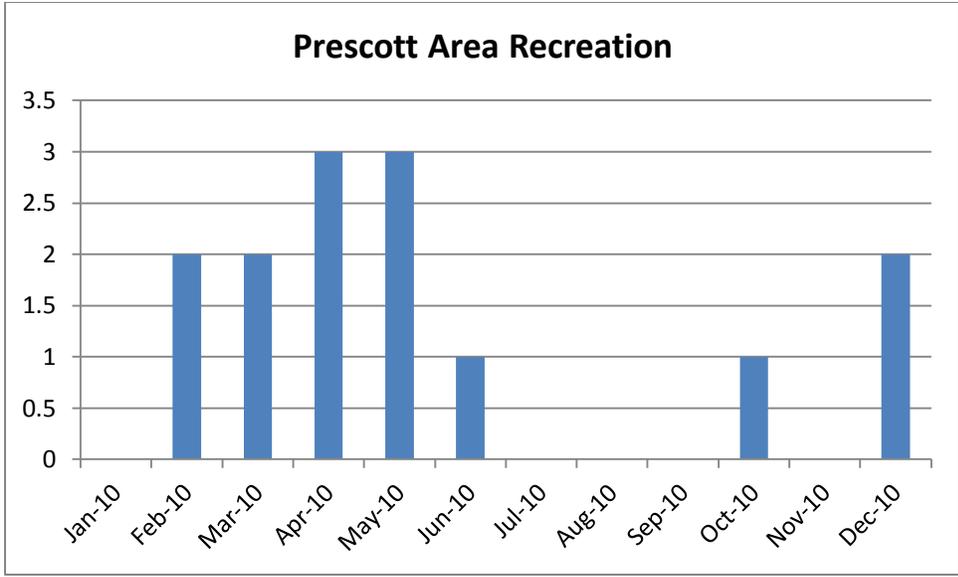


Figure 47. Monthly Recreation Occurrences.

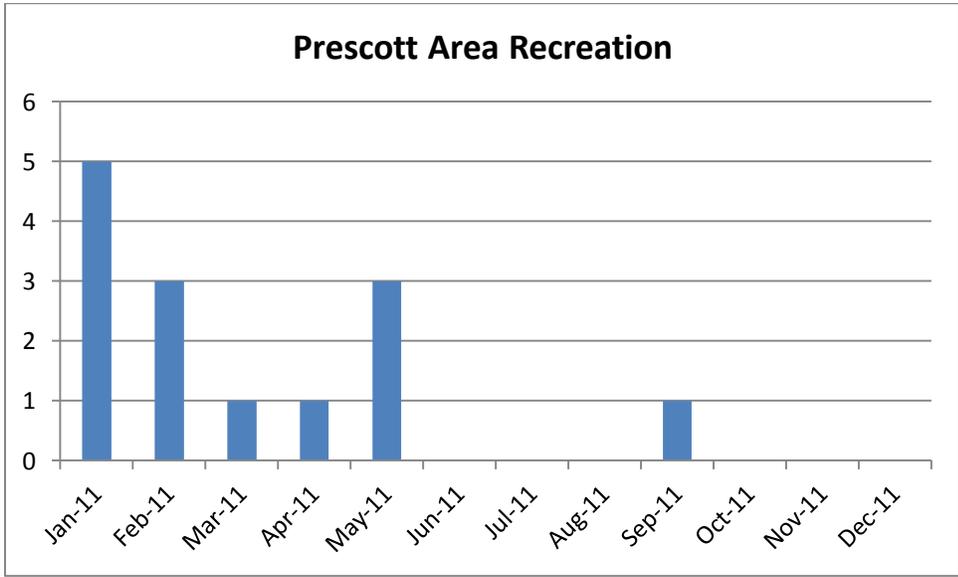


Figure 48. Monthly Recreation Occurrences.

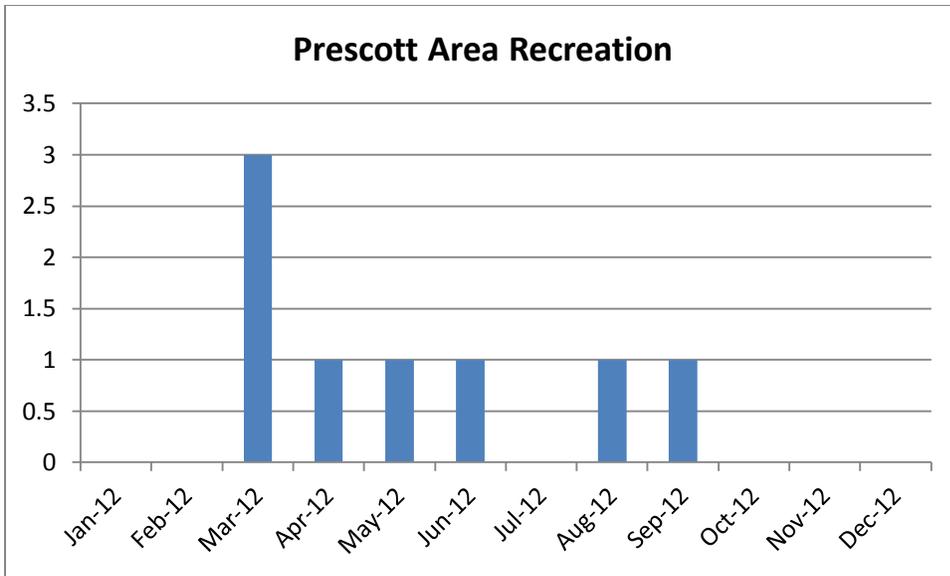


Figure 49. Monthly Recreation Occurrences.

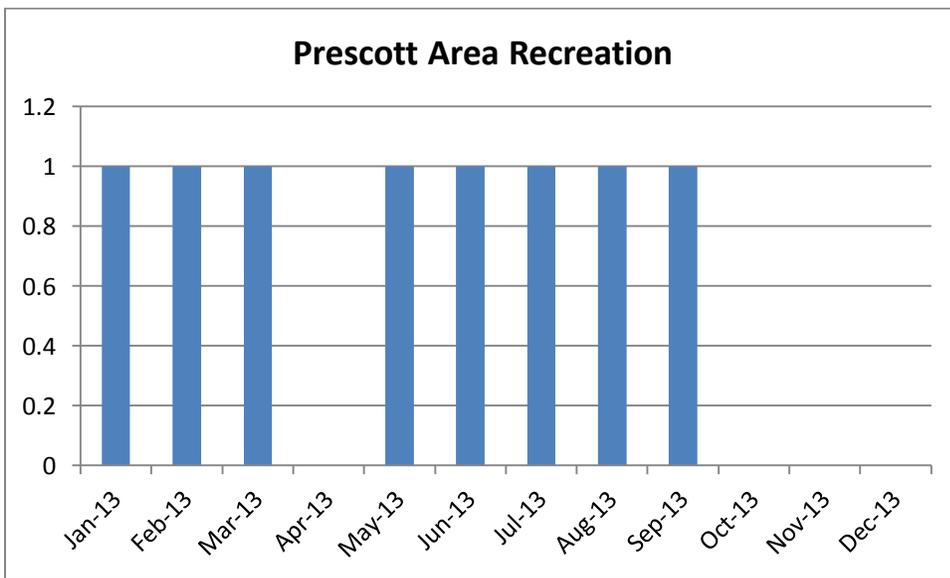


Figure 50. Monthly Recreation Occurrences.

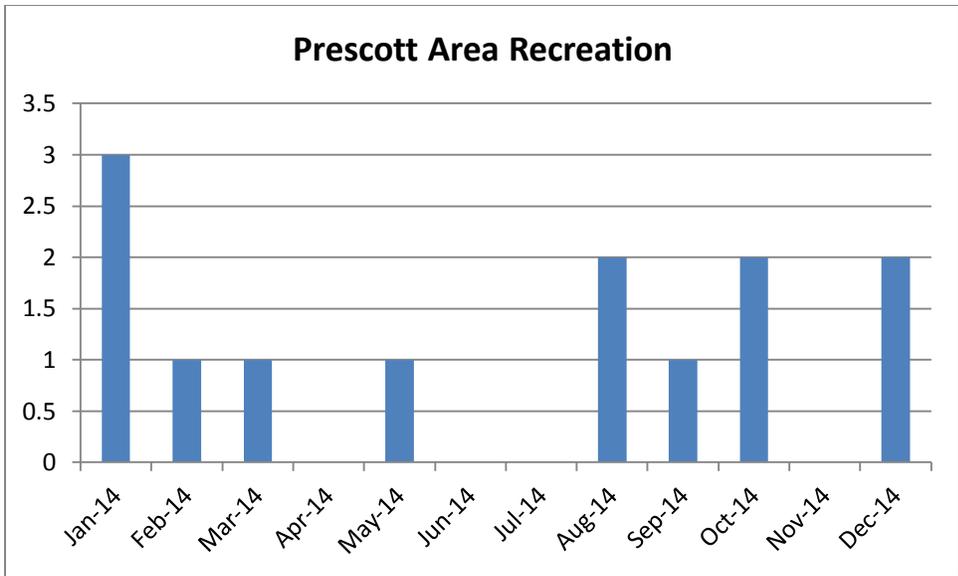


Figure 51. Monthly Recreation Occurrences.

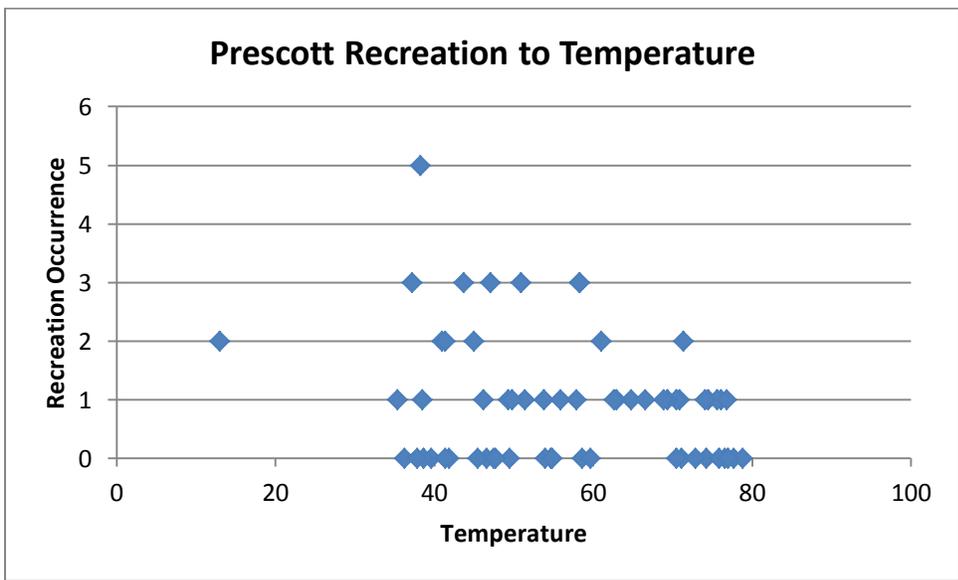


Figure 52. Scatterplot of recreation to temperature.



### *Prescott Region Conclusion*

As with the Tucson data, the Prescott data show somewhat similar distributions for looting, vandalism, and recreation. Activities are less predictable in the Prescott region (likely due to the lack of extreme heat). Unlike in Tucson, Prescott's monthly rates between looting, recreation, and vandalism vary. Negative impacts drop off less significantly in the summer than in Tucson. The analysis suggests a negative correlation between precipitation and negative impacts, with frequencies of looting, vandalism, and recreation increasing during the driest months. Unlike the Tucson region, the Prescott region categories vary between each other. Looting occurs most frequently in the first half of the year. Vandalism occurs most frequently in April and November, resulting in strong spring and fall numbers. Recreation occurrences increase in the winter and spring, drops off in the summer, and increase again in the fall.

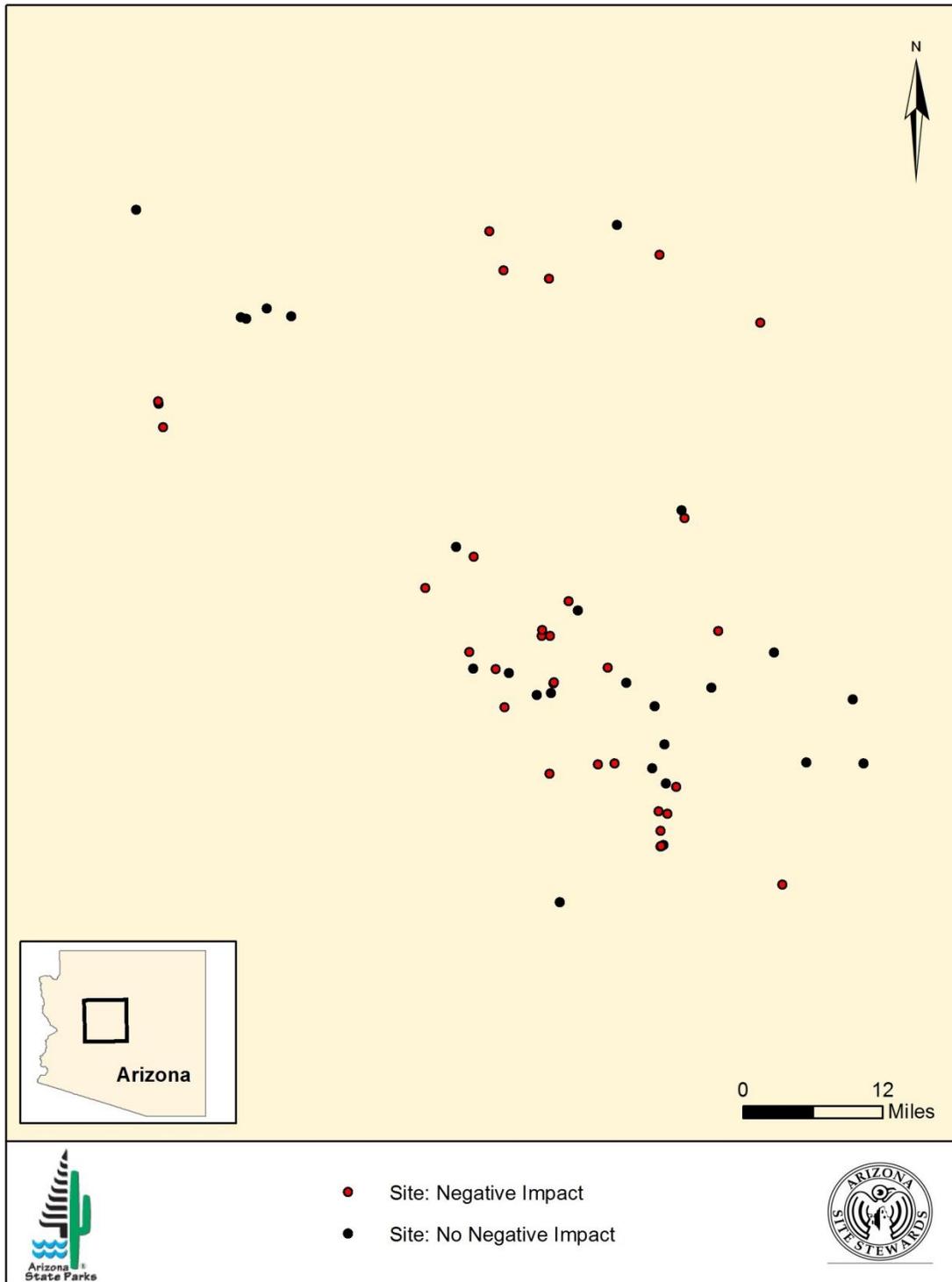


Figure 54. Distribution of Prescott Region Archaeological Sites.

## Conclusion

Across Arizona, negative impacts from either looting, vandalism, or recreation are present at 36 percent of the 583 sites (with coordinates) visited between 2010 and 2014. Most of these negative impacts result from recreation and vandalism. Only 13 percent of the sites (with coordinates) across Arizona show evidence of clear illegal looting. Spatial analysis of these impacts revealed three clear hot spots centered around Tucson, Prescott, and northwestern Arizona. Within these hot spots, the Tucson region experiences the highest frequencies of looting, vandalism, and recreation. 31 percent of Tucson region sites showed at least once instance of illegal looting. Prescott showed the second highest rate of looting. A 45-mile buffer around Prescott found that 18 of the 105 sites were looted (17%). The third highest concentration of looting occurred in northeastern Arizona, where a 45-mile buffer found 15 of the 192 (7%) visited sites showed at least one instance of looting.

Due to the high number of volunteer site visits, the Prescott and Tucson regions were selected for additional study. The vandalism reports for sites visited a minimum of once every three months (most were visited at least once a month) between these two regions were compared to mean monthly temperatures and total monthly precipitations. Between the two regions, months with higher instances of looting tend to range in temperature between 40 and 70 degrees, with a somewhat left skewed, negative correlation between temperature and looting occurrence. Looting occurrences increase as temperatures drop, at least until mean temperatures reach 40 degrees. In Tucson, looting occurs most frequently in January and February, followed by March. In Prescott, looting occurs most frequently in January, February, March, May, August, and September, with significant decreases in June and July. Between the two regions, looting occurs most frequently in the winter. Vandalism occurs most frequently in April and November for the Prescott region, and January, February, March, April, November, and December for the Tucson region. Both trends indicate that vandalism occurs during the cooler times of the year across regions. Recreation occurs most frequently in January and February in the Prescott region, and in January, February, and March in the Tucson region.

Both regions exhibit high instances of negative recreational impacts to archaeological sites in the winter. Because most precipitation occurs during the hot summer months, a left-skewed negative correlation is present between looting, vandalism, and recreation occurrences across both regions. In Prescott, where precipitation is more variable on a month to month basis, this negative correlation still upholds.

The analysis shows that archaeological sites are negatively impacted during cooler, drier, and more moderate times of the year when backcountry recreation is more comfortable. These results, while not surprising, can assist land managers in planning for the preservation of at-risk archaeological sites. Whether this trend will continue as the climate changes is speculative, but in general, land managers can anticipate that negative human-caused impacts to archaeological sites will occur during the most “comfortable” times of the year.

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