Implementing Rapid Assessment of the Trail Environments of Arid Regions:

Indicator Development and Implementation Scenarios

by

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ABSTRACT

As part of the effort to streamline management efforts in protected areas worldwide and assist accountability reporting, new techniques to help guide conservation goals and monitor progress are needed. Rapid assessment is recognized as a field-level data collection technique, but each rapid assessment index is limited to only the ecoregion for which it is designed. This dissertation contributes to the existing bodies of conservation monitoring and tourism management literature in four ways: (i.) Indicators are developed for rapid assessment in arid and semi-arid regions, and the processes by which new indicators should be developed is explained; (ii.) Interpolation of surveyed data is explored as a step in the analysis process of a dataset collected through rapid assessment; (iii.) Viewshed is used to explore differences in impacts at two study sites and its underutilization in this context of conservation management is explored; and (iv.) A crowdsourcing tool to distribute the effort of monitoring trail areas is developed and deployed, and the results are used to explore this data collection's usefulness as a management tool.

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DEDICATION

For Steve, without whom

this dream would never have come true.

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INTRODUCTION

1.1: Introduction

Heritage management, tourism management, and resource conservation are fields of growing interest across many disciplines in academia, as well as within the government and public sectors (c.f. Clark 2002, Schwartza, Stewarta and Backlundb 2012, Anthony 2007, Deacon 2006, Hall and McArthur 1993a, McArthur and Hall 1993). Protected areas cover over 12% of the Earth's land surface, and that amount continues to grow (Ervin 2003a, Soutullo, De Castro and Urios 2008, Dudley 2009). The actual amount and type of protected land varies by country and region, with some parks created to preserve a natural resource and others being converted from private land at the behest of its owners (Uddhammar 2006, Holland 1996, Schwartza et al. 2012).

In the United States, much of the body of protected land is land that is less than ideal for other purposes (Scott et al. 2001b). As a result, a good deal of U.S. government-protected land falls in the southwestern region of the country and is comprised of the Sonoran, Great Basin, and Mojave Deserts, as well as other semi-arid regions (Schwartza et al. 2012). These arid and semi-arid regions also coincide with some of the faster-growing parts of the country (Sibly and Hone 2002).

As populations continue to expand in the desert southwest and other arid regions, pressure for human recreational use of wild land becomes another concern for managers of these protected spaces grows. There are ranges of recreational use, from formal trail networks for hiking, biking, and horseback riding to full recreational facilities including picnic areas and bathrooms (c.f. McArthur and Hall 1993, Moore and Polley 2007, Draper 2000). A balance must be struck between satisfying the desires of tourists and maintaining the integrity of the resources and environment within the park (Uddhammar 2006). Additional considerations may be necessary if the park contains spaces or objects with religious or historical meaning to a group of people, if the area contains a nonrenewable resource, or if protected or endangered species of plants or animals are found within its boundaries (Morris 2003, Scott et al. 2001b).

A framework to help direct management efforts as effectively as possible offers the foundation for monitoring methodologies in protected areas (Hockings, Stolton and Dudley 2000). In this framework , techniques that provide quick and dirty assessments of protected areas worldwide are described and a call for the development of such techniques is made. In order to gather accurate information about an environment's condition, it is important to tailor the methodology to the specific environment it seeks to maintain (Ervin 2003a). Therefore, although these rapid assessment data collection techniques already exist for some fragile environments such as rainforests (c.f. Courrau 1999), wetlands (c.f. Fennessy, Jacobs and Kentula 2007), and mountainous areas (c.f. Ervin 2003b), these implementations cannot be used as the starting point for rapid assessment techniques in other, different environments.

Arid and semi-arid environments are sensitive to disturbances that lead to land degradation, such as off-trail anthropogenic activity (Okin, Murray and Schlesinger 2001), which other environments may be able to absorb more effectively. Current methods of assessing disturbance to desert environments are limited by scale and available technology. Some methodologies, such as the tool developed by Allen (2009) to monitor long-term anthropogenic impact of the Upper Sonoran Lifestyle, focus on measurements over a small scale (<2 meters) and may require the use of specialized equipment or training. Others methodologies for measuring impact in a desert environment rely on remotely-sensed imagery to allow for a broad assessment over a large area (Shupe and Marsh 2004).

This dissertation seeks to fill the gap between micro-scale and large-scale data collection techniques in an arid environment. This is accomplished through the development of a rapid assessment index as described in the framework outlined by Hockings et. al (2000) that is designed specifically for an arid environment and supported by a literature review. Implementation schemes for conservation monitoring and for tourism management are tested in the field and the results are discussed in the context of management considerations.

1.2: Dissertation Format

This dissertation contains a total of five chapters, with the three middle major chapters each written as a separate journal manuscript. The three middle chapters link together systematically with an objective of laying a foundation for future rapid assessment efforts in dryland preserves. The first sub-objective requires the development, testing and refinement of a rapid assessment strategy. The second sub-objective develops through fieldwork completed by the author and assistants and then analyzes a spatially dense data set — to help better understand the sorts of information that can be extracted from rapid assessment research. The third sub-objective explores the possibility of using less skilled individuals to gather a large data set through crowdsourcing.

The first article executes the necessary steps to create a field collection methodology that meets the suggested Level I guidelines for a rapid assessment strategy (Hockings et al. 2000). The Desert Impact Assessment (DIA) index is developed by creating a collection of indicators that measure disturbance in a desert environment (Hockings et al. 2000, Moore and Polley 2007). These indicators are each recorded individually and measured using an ordinal scale that does not require any specialized equipment or expert knowledge of the area (Salafsky and Margoluis 1999, Tear et al. 2005, Hockings 2003, Acar and Sakici 2008). The iterative process undertaken to refine indicators based on information gathered in the field is discussed. This article will be submitted to the *Journal of Arid Environments*.

The second article analyzes a dataset compiled using the DIA index developed in the first article. A case study is conducted at Petrified Forest National Park, Painted Desert, Arizona. This case study surveys three of the park's seven trails using stratified random sampling and 15 meter stops (Schwartza et al. 2012, Bakus et al. 2006, Hedley and Buckland 2004). The ordinal data are interpolated at each study site using inverse distance weighting and the results are discussed with respect to management implications (Ly, Charles and Degre 2011, Sun et al. 2009). The surveyed points also establish a baseline condition at all three trails that can be used to support future analysis over time (Pauly 1995, Salafsky and Margoluis 1999, Tear et al. 2005). This article will be submitted to *Environmental Management*.

The third article revisits the core indicators identified in the first article of this dissertation. The DIA index is designed to be executed using a systematic field sampling methodology such as the one discussed in the second article. This is a powerful tool, but the indicators of impact used in the DIA index can be utilized in other ways as well (Couvet et al. 2008, Manning 2001, Moore and Polley 2007, Timko 2008). The ordinal scale is replaced by a categorical scale of “present” and “not present”, and the collection methodology is adjusted to so that it can be accomplished by users of the trail (Turner 2006, Schwartza et al. 2012, McPherson et al. 2005). A case study of this distributed “crowdourced” data collection methodology is conducted at Tempe Butte Preserve in Tempe, Sonoran Desert, Arizona and the results are analyzed from a management perspective. This article will be submitted to *Heritage Management*.

Finally, a concluding chapter summarizes the findings from all three papers and discusses the theoretical and practical contributions to the fields of environmental monitoring and heritage and tourism management.

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Chapter 2

DEVELOPING A RAPID ASSESSMENT INDEX FOR ARID ENVIRONMENTS THROUGH ITERATIVE FIELD RESEARCH

2.1: Introduction

During the second half of the twentieth century, local and national conservation efforts evolved into a worldwide undertaking as governments increasingly recognized the importance of preserving landscapes supporting biodiversity (Parrish, Braun and Unnasch 2003a, Soutullo et al. 2008). Many conservation strategies set aside large protected areas in order to maintain an entire ecosystem, in contrast to only addressing individual preservation goals (Hockings 2003, Bruner et al. 2001). Between 1975 and 2000, the amount of protected area worldwide more than doubled to over 10% of the Earth's land surface, with much of the protected land selected to preserve sizeable areas from as much anthropogenic impact as possible (Ervin 2003a). The amount of area under preservation continues to increase, albeit at a somewhat slowed pace (Andam et al. 2008, Tear et al. 2005).

As the amount of protected area worldwide increased, nature-based tourism grew commensurately (Moore and Polley 2007, McArthur and Hall 1993). Tourist visitation in protected areas provides income to those areas that are consistently under-funded (Bruner et al. 2001, Hockings 2003). Protected areas often feature attractions and amenities designed to attract tourists (c.f. Bushell et al. 2003), although inviting tourism into protected areas can cause for concern among some activist groups (Hall and McArthur 1993b, Rai and Sundriyal 1997).

Opening protected areas to visitation is often mandated by the public and private funders who establish those areas, but the tourism that results can cause unforeseen managerial problems (Deacon 2006, Moore and Polley 2007, Rai and Sundriyal 1997, Uddhammar 2006). Physical impact due to human visitation cannot be avoided, particular in popular areas that experience heavy traffic (Bruner et al. 2001, Loubser 2001). The more visitation allowed, the more at-risk an area becomes for the destruction of the very natural resources it protects. A number of natural and anthropogenic causes can contribute to this, including: unofficial foot traffic, trash, vandalism, increased rates of erosion, damage to vegetation, and more. (Okin et al. 2001, Deluca et al. 1998, McArthur 1993).

In order to address these and other problems related to human interaction with a preserved environment, a plethora of techniques designed to identify and in some cases quantify anthropogenic impact are being implemented in protected areas around the world (c.f. Ewan, Ewan and Burke 2004, Fennessy et al. 2007, Hockings 1998, McArthur and Hall 1993). Many of these methods of impact reduction are designed specifically to accommodate a single site's particular quirks without consideration for wider implementation in similar regions. All of these plans, however, are merely stopgap measures to collect information about anthropogenic impact rather than to address the underlying problems caused by human traffic (Clark 2002, Deacon 2006, Loubser 2001, McArthur 1993).

Concerns about simplifying the process of creating and working towards conservation goals prompted a call for the development of an international management framework, fulfilled by Hockings and others (2000). This framework serves as the foundation for a plethora of methods aimed at assessing management effectiveness (c.f. Parrish et al. 2003a, Timko 2008), as well as others that are meant to measure conservation goals (c.f. Bruner et al. 2001, Tear et al. 2005).

Despite their potential upsides, many of the proposed methodologies do not translate into real world application. Many of these methods require the use of specialized equipment or computer programs, or other steep investments to be carried out (Loubser 2001, Hockings 2003). Management plans that rely on these and other time-heavy methodologies can be problematic from many perspectives, particularly when senior park managers are not necessarily trained or ready to put their trust in the technology required to use the programs, and when many junior park managers lack the experience required to implement the programs properly (Garrett 2007).

The family of rapid assessment strategies represents a type of methodology that is increasingly popular in light of the aforementioned challenges. Developed in response to the time and money constraints faced by many parks, rapid assessment strategies are characterized by their quick-and-simple approach to gathering information about an area, typically without the need for specialized equipment or training (c.f. Stohlgren et al. 1997, Triantafilis, Huckel and Odeh 2002, Ervin 2003b). Creating site-specific management plans with clear preservation goals, and monitoring protected areas to ensure that those goals are being met are vital steps towards a successful conservation effort (Deacon 2006, Ervin 2003a). Rapid assessment data collection provides an excellent tool to add to a park manager's repertoire in order to achieve these goals.

This paper evaluates a newly proposed rapid-assessment technique designed for use in arid and semi-arid environments. Simple to learn and easy to carry out in the field without specialized equipment or time-consuming stops, the Desert Impact Assessment (DIA) method informs on anthropogenic and natural impacts to a preserve setting. The methods section explains the development of the technique, followed by field tests conducted in two separate case studies: South Mountain Municipal Park in Phoenix, Sonoran Desert, Arizona and Petrified Forest National Park, Colorado Plateau semi-arid Arizona. This initial research reveals that DIA can provide insight useful to park management in these arid park settings.

2.2: Method Development and Testing

2.2.1: Determining rapid assessment indicators

The indicators of preserve condition derive from a variety of rapid assessment methods found in the literature (Dudley 2009, Hockings et al. 2000). These factors are combined in an index that meets the criteria for level one framework as defined by the World Commission for Protected Areas, and follows published evaluation guidelines (Hockings et al. 2000). Since the index presumes use by volunteers, selected factors must be visually assessed with minimal training not requiring specialized equipment, even at the expense of the precision found in alternative available measures (Allen 2009, Courrau 1999). Volunteers are encouraged to use their best judgment in addition to the guidelines provided by the written guidelines (Hockings 2003).The first iteration of the index includes the following factors:

1. *Weathering*. A brief visual inspection for visual signs of recent physical weathering within an approximate 3m radius of the survey site. Indicators can include pieces of rock broken off larger rock faces or mass wasting activity, and evidence of recent landslide activity (McArthur and Hall 1993, Okin et al. 2001).

2. *Erosion*. A brief visual inspection for visual signs of recent erosion within an approximate 3m radius of the survey site. Indicators can include evidence of

sediment movement, overland flow, and rills and gullies (Leopold, Wolman and Miller 1995).

3. *Amount of trash*. A visual assessment of the quantity of trash within a 3m radius of the survey site, measured as an approximate percentage of ground cover. Park management regularly cleans up areas that show signs of heavy anthropogenic misuse; in order to direct these efforts as effectively as possible, managers must be notified of areas in need of attention (Arbogast 2009, Moore and Polley 2007).

4. *Type of trash*. A visual assessment of whether or not the trash within a 3m radius of the survey site biodegrades. Coupled with the "amount of trash" indicator, this information allows park management to direct cleanup efforts more effectively (Arbogast 2009).

5. *Mature vegetation density*. A visual assessment of mature vegetation cover within a 3m radius of the survey site, measured as an approximate percentage. Significant change in mature vegetation density or a notable replacement of perennial vegetation with annual vegetation can read to higher rates of wind erosion and susceptibility to fire damage (Okin et al. 2001, Shupe and Marsh 2004).

6. *Mature vegetation damage*. A visual assessment of damage to mature vegetation within a 3m radius of the survey site. Damage to mature vegetation can be indicative of anthropogenic and natural impact (Okin et al. 2001).

7. *Trails*. A visual assessment of the presence or absence of footpaths and trails. Assigning a value by width helps distinguish between unauthorized trail spurs and officially maintained park trails (Arbogast 2009).

8. *Vandalism*. A visual assessment of intentional damage to the environment within a 3m radius of the survey site. Removable and nonremovable graffiti are distinguished, as are the impacts of removing the vandalism from the affected surface (Arbogast 2009, Deacon 2006).

9. *Soil disturbance*. A visual assessment of the condition of the desert pavement and disturbed rocks within a 3m radius of the survey site. Heavily disturbed or absent desert pavement yield higher values since damaged desert pavement protects the soil beneath less effectively (Allen 2009, Okin et al. 2001).

After the first nine indicators were chosen, they were assessed for their efficacy and ease of use by taking several sample points at a site located at South Mountain Municipal Park in Phoenix, Arizona. Initial testing revealed that weathering and erosion factors caused confusion and those conducting the first test placed similar observations in both categories. Thus, these factors merge into a single category:

- *Erosion*. A brief visual inspection for visual signs of recent erosion within an approximate 3m radius of the survey site. Indicators can include rock debris from nearby surfaces, evidence of mass wasting, rills, gullies, crevasses, washes, and damage to established trails.

Discussions with field testers, followed by a supplemental review of the literature, revealed two additional factors that would allow volunteers greater flexibility in reporting information that may be important (Dorn et al. 2008, Hockings 2003). These added factors are:

- *Ambient noise*. An assessment of audible noises which are not native to a desert environment. This field allows the assessor to indicate signs of possible misuse of park resources that can be heard but not seen. This can include audible evidence of recreational vehicle use, large gatherings of people, unauthorized air traffic, etc. (Arbogast 2009, Timko 2008).
- *Other visible impact*. An assessment of any visible impact factor(s) visible from the study site that are not otherwise indicated. The other visible impact factor empowers volunteers to articulate concerns that are important to them (Moore and Polley 2007), enabling notable occurrences that fall outside of the other factors.

After recompiling the index, a field assessment strategy needed to be simple, and yet flexible enough to be carried out by a person with little or no specialized training. Furthermore, it had to yield results that would be meaningful when they were compiled into a final report, and which used a survey method that can be replicated by other groups over time (Loubser 2001).

In order to determine the best approach, two different sampling strategies were tested. Both data collection techniques can be considered stratified random sampling, although one ultimately relied on single, straight transects with few stops while the other relied upon a more structured "net" of sampled stops (Buckland, Burnham and Augustin 1998). After the field tests, that are detailed below, it became apparent that the net sampling structure took more time but yielded better results than line transects since they generated far more sample points (Hedley and Buckland 2004).

2.2.2: First Testing: South Mountain Municipal Park, Sonoran Desert, Phoenix, central AZ

In May of 2009, South Mountain Municipal Park, Phoenix served as the initial pilot site used to calibrate indicators (S1) and then deploy the index at four study sites (S2-S5) in the Sonoran Desert of central Arizona (Gober and Burns 2002). All of the study sites are located within the boundaries of South Mountain Municipal Park, the nation's largest municipal park (see Figure 1).

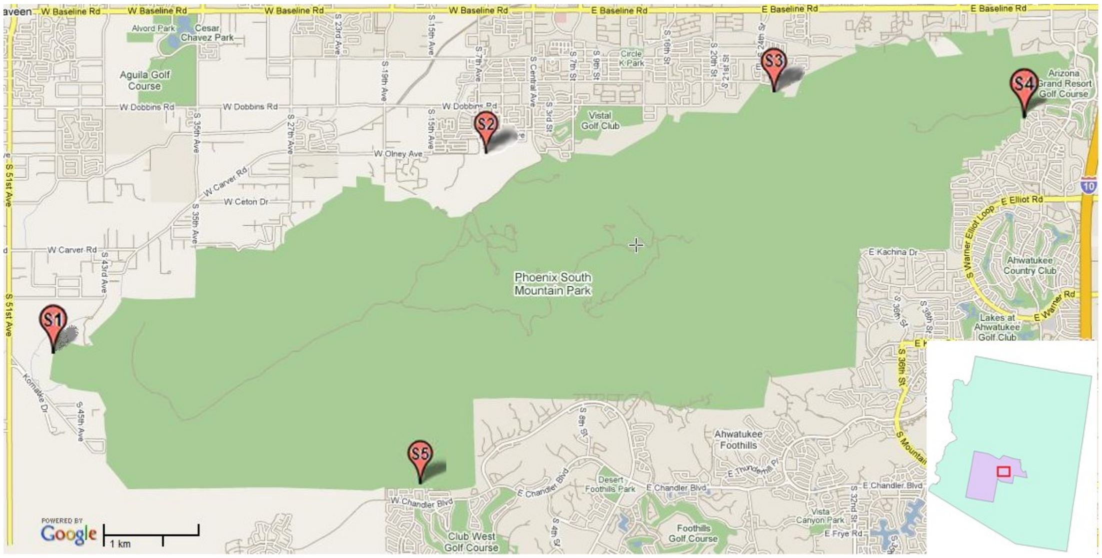
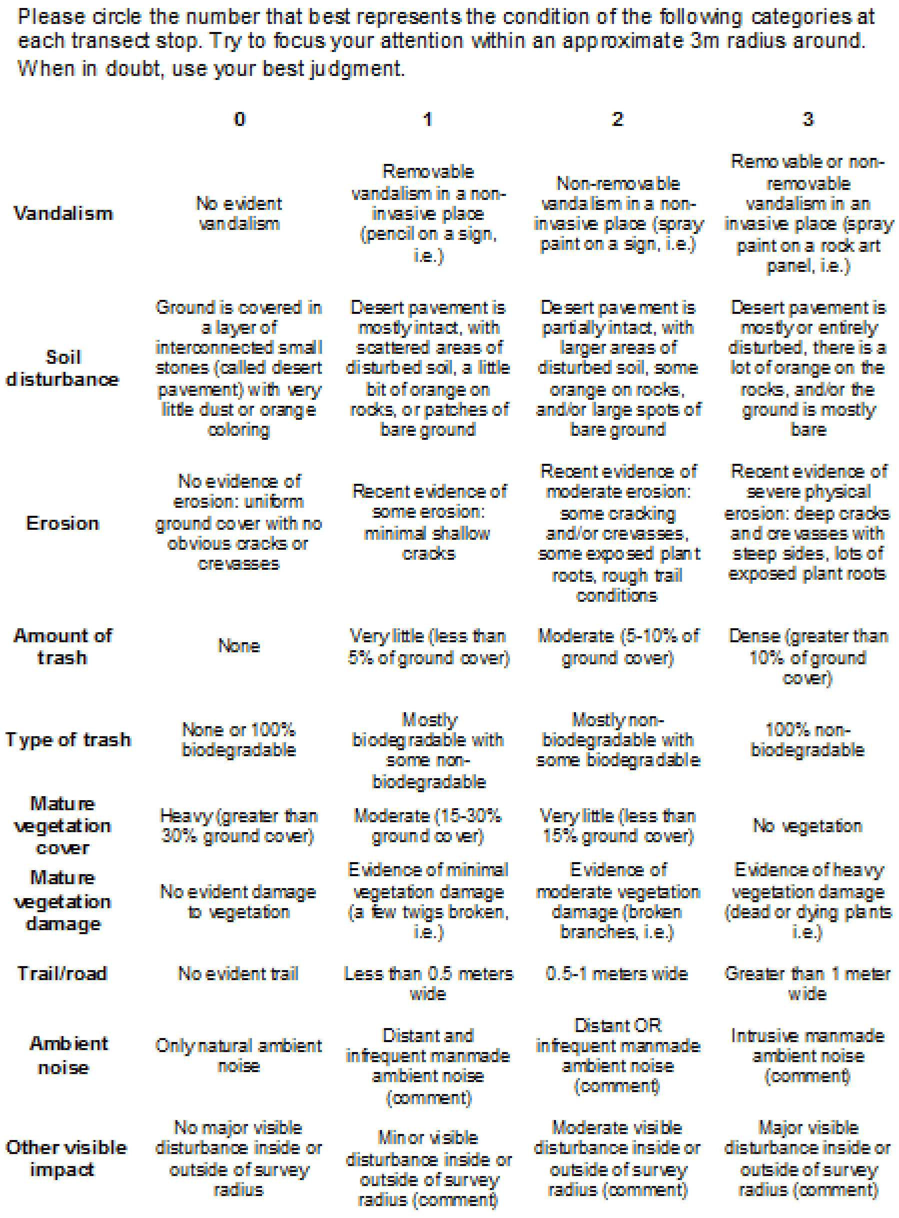


Figure 1: Location of the pilot site (S1) and the four study sites (S2, S3, S4, S5) at the urban-preserve boundary of South Mountain park.

Using a GPS unit and a transect tape to track their location, and a clipboard with a sheet of written instructions (see Figure 2), five teams of two successfully collected data in the field using 200-meter transects where they stopped every 50 meters to collect data points that focused on a 3m radius of a given position. Transects proved to be a consistently useful means of taking sample measurements to extrapolate insight to a larger area (c.f. Allen 2009, Hockings 1998, Southwell 1994, Hedley and Buckland 2004), and they are simple enough for volunteers to employ the transect concept after a short training session.

Volunteers spread out over four study sites collected a total of 93 data points across four study sites. There were frequent instances where transects could not be completed due to two reasons: (1) the volunteers were not physically able to move forward within the environment due to extreme circumstances such as sheer drops; or (2) volunteers had miscounted the number of points taken within that 200-meter transect and turned back too early.



Please circle the number that best represents the condition of the following categories at each transect stop. Try to focus your attention within an approximate 3m radius around. When in doubt, use your best judgment.

	0	1	2	3
Vandalism	No evident vandalism	Removable vandalism in a non-invasive place (pencil on a sign, i.e.)	Non-removable vandalism in a non-invasive place (spray paint on a sign, i.e.)	Removable or non-removable vandalism in an invasive place (spray paint on a rock art panel, i.e.)
Soil disturbance	Ground is covered in a layer of interconnected small stones (called desert pavement) with very little dust or orange coloring	Desert pavement is mostly intact, with scattered areas of disturbed soil, a little bit of orange on rocks, or patches of bare ground	Desert pavement is partially intact, with larger areas of disturbed soil, some orange on rocks, and/or large spots of bare ground	Desert pavement is mostly or entirely disturbed, there is a lot of orange on the rocks, and/or the ground is mostly bare
Erosion	No evidence of erosion: uniform ground cover with no obvious cracks or crevasses	Recent evidence of some erosion: minimal shallow cracks	Recent evidence of moderate erosion: some cracking and/or crevasses, some exposed plant roots, rough trail conditions	Recent evidence of severe physical erosion: deep cracks and crevasses with steep sides, lots of exposed plant roots
Amount of trash	None	Very little (less than 5% of ground cover)	Moderate (5-10% of ground cover)	Dense (greater than 10% of ground cover)
Type of trash	None or 100% biodegradable	Mostly biodegradable with some non-biodegradable	Mostly non-biodegradable with some biodegradable	100% non-biodegradable
Mature vegetation cover	Heavy (greater than 30% ground cover)	Moderate (15-30% ground cover)	Very little (less than 15% ground cover)	No vegetation
Mature vegetation damage	No evident damage to vegetation	Evidence of minimal vegetation damage (a few twigs broken, i.e.)	Evidence of moderate vegetation damage (broken branches, i.e.)	Evidence of heavy vegetation damage (dead or dying plants i.e.)
Trail/road	No evident trail	Less than 0.5 meters wide	0.5-1 meters wide	Greater than 1 meter wide
Ambient noise	Only natural ambient noise	Distant and infrequent manmade ambient noise (comment)	Distant OR infrequent manmade ambient noise (comment)	Intrusive manmade ambient noise (comment)
Other visible impact	No major visible disturbance inside or outside of survey radius	Minor visible disturbance inside or outside of survey radius (comment)	Moderate visible disturbance inside or outside of survey radius (comment)	Major visible disturbance inside or outside of survey radius (comment)

Figure 2: Written guidelines of index criteria provided to assessment volunteers at South Mountain Municipal Park

2.2.3: Retooling and Expanding Index Parameters Based On the First Case Study

After returning from the field, analysis on the data collected at South Mountain Municipal Park revealed that while many of the indicators that were described above proved effective individual measurements, the factors could be consolidated and improved. The evaluation strategy involved correlating each of the variables against one another in a matrix to check for highly-correlated values (Amezketa 2006) at each of the four study sites, as well as using the total values across all sites (see Appendix A).

The correlations between the amount of trash and the type of trash indicators yielded high r values at each of the study sites conducted in the pilot study, as well as in the overall analysis (minimum .835). Thus, including both indicators essentially counts occurrences of trash twice. As a result two indicators were combined into one factor:

- *Amount and type of trash*. Evaluates the amount of ground covered by trash, and accounts for biodegradability.

The mature vegetation cover indicator did not change significantly across the four study sites. Furthermore, mature vegetation cover is poorly-suited to the 0-3 ordinal scale, especially in an arid environment with a sparse cover of trees (Shupe and Marsh 2004). This variable was, therefore, removed from future iterations of the index.

Finally, examining the point data in the context of slope revealed that the soil disturbance and erosion indicators correlated more closely the steeper the slope became, presenting a skewed representation of these factors. In order to compensate for these areas of higher slope grade artificially inflating the index score, a new indicator needed to be developed for future iterations of the index:

- *Slope*. The volunteer estimates the grade of the slope that they are standing on, based on the perceived difficulty experienced in arriving at the point.

The slope indicator counts as a negative value against the total index score (Istanbulluoglu et al. 2008, Nepal and Nepal 2004). In this way, both the erosion and soil disturbance values can be used in future iterations of the index without risking the falsepositives that occurred on steep slopes in the first case study. In other words, if future researchers wish to remove either the soil disturbance or the erosion indicator, then the slope indicator should be excluded as well.

2.2.4: Second Testing: Petrified Forest National Park, semi-arid Colorado Plateau, northern AZ

A second case study took place at Petrified Forest National Park in Arizona using the revised index. Petrified Forest National Park, located approximately 30 miles east of Holbrook, Arizona, straddles the border between Apache and Navajo counties. The park's semi-arid environment preserves the Chinle Formation in the southern part of the park, part of the Painted Desert in the northern part of the park, and numerous prehistoric and historic archaeological sites that are scattered throughout (National Park Service 2007). Petrified wood located within the park's boundaries is a protected resource whose theft can be prosecuted under federal law.

Declared a National Monument in 1906 and a national park in 1962, Petrified Forest National Park currently addresses its tourism mandate in the form of several trails that were constructed by the Civilian Conservation Corps (CCC) between 1936 and 1942, through a series of scenic viewpoints that are accessible from the road, and through two tourism areas that serve as learning centers. The northern part of the park also includes a wilderness area open for backpacking and overnight camping with permit (National Park Service 2007, National Park Service 2004).

In 2004, USA President George W. Bush granted Petrified Forest National Park authorization to expand from 93,353 acres to 218,533 acres, more than doubling the park's size (National Park Service 2007). The gradual land acquisition will occur as funds become available to purchase surrounding lands (see Figure 3).

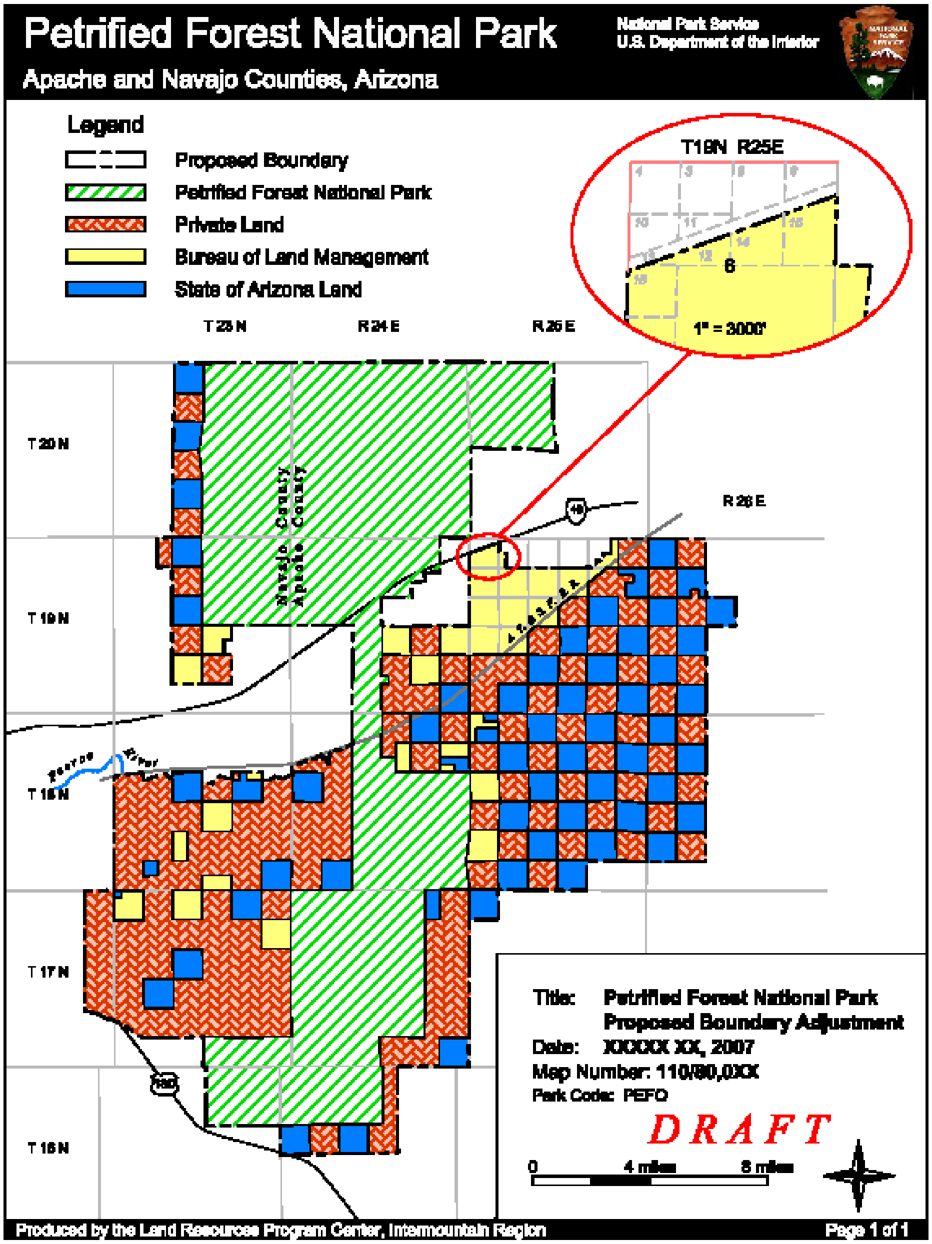
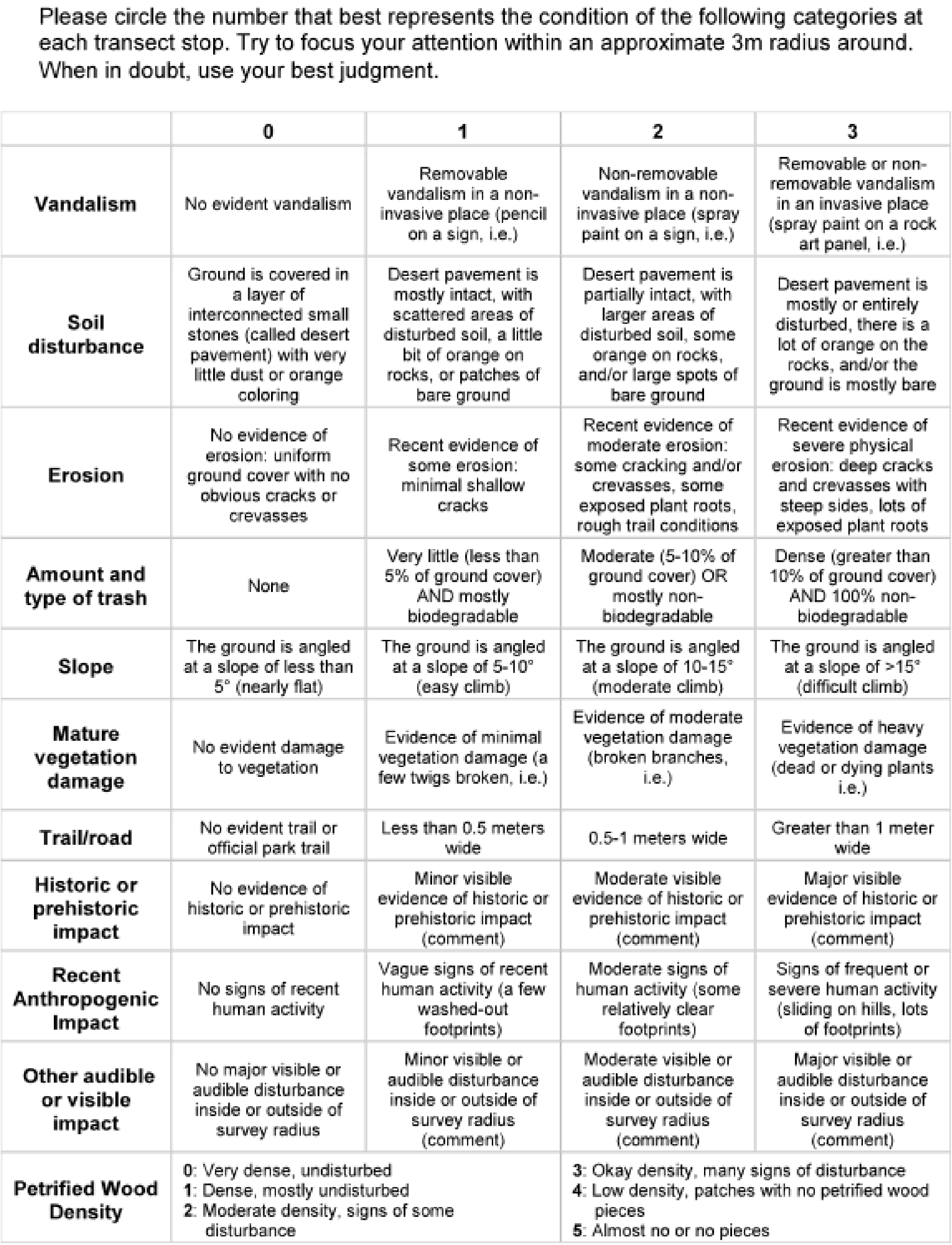


Figure 3: Existing boundaries of the Petrified Forest National Park and proposed expansion land.

The impending expansion of the Petrified Forest National Park gave park management the opportunity to balance tourism, heritage management, and conservation in a way that established national parks do not often get to accomplish in the USA. The existing structure of trails within the park, constructed nearly 80 years ago with an eye towards highlighting the park's natural beauty, do not necessarily facilitate protection of environmentally sensitive areas. As the park grows, the manager will be able to implement an updated general management plan to shape a future balance between recreation and preservation.



Please circle the number that best represents the condition of the following categories at each transect stop. Try to focus your attention within an approximate 3m radius around. When in doubt, use your best judgment.

	0	1	2	3
Vandalism	No evident vandalism	Removable vandalism in a non-invasive place (pencil on a sign, i.e.)	Non-removable vandalism in a non-invasive place (spray paint on a sign, i.e.)	Removable or non-removable vandalism in an invasive place (spray paint on a rock art panel, i.e.)
Soil disturbance	Ground is covered in a layer of interconnected small stones (called desert pavement) with very little dust or orange coloring	Desert pavement is mostly intact, with scattered areas of disturbed soil, a little bit of orange on rocks, or patches of bare ground	Desert pavement is partially intact, with larger areas of disturbed soil, some orange on rocks, and/or large spots of bare ground	Desert pavement is mostly or entirely disturbed, there is a lot of orange on the rocks, and/or the ground is mostly bare
Erosion	No evidence of erosion: uniform ground cover with no obvious cracks or crevasses	Recent evidence of some erosion: minimal shallow cracks	Recent evidence of moderate erosion: some cracking and/or crevasses, some exposed plant roots, rough trail conditions	Recent evidence of severe physical erosion: deep cracks and crevasses with steep sides, lots of exposed plant roots
Amount and type of trash	None	Very little (less than 5% of ground cover) AND mostly biodegradable	Moderate (5-10% of ground cover) OR mostly non-biodegradable	Dense (greater than 10% of ground cover) AND 100% non-biodegradable
Slope	The ground is angled at a slope of less than 5° (nearly flat)	The ground is angled at a slope of 5-10° (easy climb)	The ground is angled at a slope of 10-15° (moderate climb)	The ground is angled at a slope of >15° (difficult climb)
Mature vegetation damage	No evident damage to vegetation	Evidence of minimal vegetation damage (a few twigs broken, i.e.)	Evidence of moderate vegetation damage (broken branches, i.e.)	Evidence of heavy vegetation damage (dead or dying plants i.e.)
Trail/road	No evident trail or official park trail	Less than 0.5 meters wide	0.5-1 meters wide	Greater than 1 meter wide
Historic or prehistoric impact	No evidence of historic or prehistoric impact	Minor visible evidence of historic or prehistoric impact (comment)	Moderate visible evidence of historic or prehistoric impact (comment)	Major visible evidence of historic or prehistoric impact (comment)
Recent Anthropogenic Impact	No signs of recent human activity	Vague signs of recent human activity (a few washed-out footprints)	Moderate signs of human activity (some relatively clear footprints)	Signs of frequent or severe human activity (sliding on hills, lots of footprints)
Other audible or visible impact	No major visible or audible disturbance inside or outside of survey radius	Minor visible or audible disturbance inside or outside of survey radius (comment)	Moderate visible or audible disturbance inside or outside of survey radius (comment)	Major visible or audible disturbance inside or outside of survey radius (comment)
Petrified Wood Density	0: Very dense, undisturbed 1: Dense, mostly undisturbed 2: Moderate density, signs of some disturbance		3: Okay density, many signs of disturbance 4: Low density, patches with no petrified wood pieces 5: Almost no or no pieces	

Figure 4: Written guidelines provided to volunteers at Petrified Forest National Park, semi-arid Colorado Plateau environment, northern Arizona

One purpose of employing a rapid assessment index is the ability to modify the index to circumstances that change from preserve to preserve. Preparing for park expansion presented an ideal opportunity to conduct a case study using an iteration of the index adapted for the semi-arid Painted Desert. Prior to setting up the study, discussions with Jason Theuer, the park archaeologist, yielded information that lead to the addition of two new indicators to the index for use in the Petrified Forest National Park:

- *Historic or prehistoric impact*. Assess evidence of historic (more than 100 years) or prehistoric activity at the site, and comment with observations;
- *Petrified wood density*. Estimate the density of small petrified wood pieces on the ground in appropriate areas, as well as whether or not there exists evidence of disturbed wood or wood theft.

With the addition of these new indicators, the written guide was revised updated wording to adapt the index to the semi-arid Painted Desert, a different environment than the Sonoran Desert (see Figure 4).

Data collection occurred over seven weekends between July and November of 2009. During that time, six volunteers logged 1365 data points assessed at three study site trails: the Crystal Forest trail, the Long Logs trail, and the Giant Logs trail. Selected by the park archaeologist as ideal study areas, the three trails each embody different characteristics that make them ideal candidates for testing the versatility and utility of rapid assessment data collection in this environment. All three trails were established in the 1930s and early 1940s by the Civilian Conservation Corps, supported by the United States government (National Park Service 2013). These trails were not designed with preservation in mind; rather, they were created with an eye towards highlighting the natural beauty of the region.

The Crystal Forest trail (see Figure 5) is the northernmost of the three study areas. Situated just off the park's main thoroughfare, it is accessible via a parking lot at the trail head. The trail is located in the middle of a prehistoric quarry site where tools were once made from the beautiful and versatile petrified wood that is still found in abundance in this area. In addition to prehistoric activity the area is also close to the site of an historic carriage route, and is today one of the park's most popular trails. The trail is .77 miles long, and is located south of the Painted Desert in a semi-arid scrubland. Although visitors are asked to stay on the trail, it is very close to a wilderness area that is available for off-trail hiking and overnight camping with a permit. Due to the long history of past and present disruptions to this area, it was determined that this trail was an ideal candidate for a detailed impact analysis.

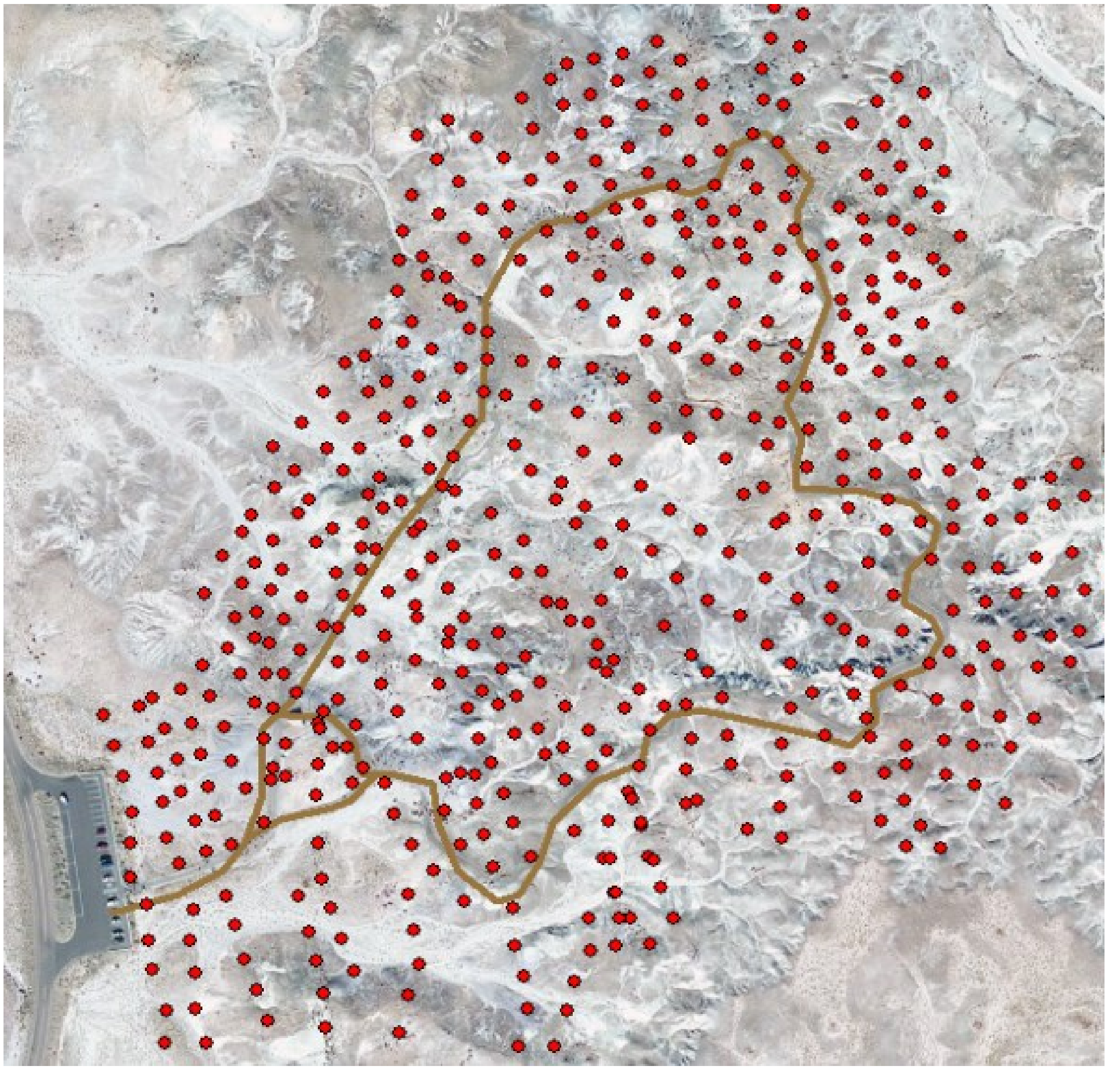


Figure 5: Example of the net sampling strategy employed at Petrified Forest National Park. Located in a semi-arid scrubland, the Crystal Forest trail is a frequently-visited area that is known to have a rich history of prehistoric, historic, and modern uses that have each left their mark on the area.

The park archaeologist requested that point data be collected every 15 meters in order to account for the high incidence of historic and prehistoric artifacts present in the study areas. Three study sites with trails were selected, each of which required point collection up to 60 meters away from the outer edge if a trail loop as well as sample points within the entire interior loop (see Figure 5). GPS devices set up prior to data collection to digitally tracked the transect progress and displayed it on the screen. This technology replaced the transect tape, and allowed for a much better representation of the user's position.

2.3: Results and Discussion

2.3.1: Overall Evaluation of the Desert Impact Assessment

After field testing at South Mountain Municipal Preserve and Petrified Forest National Park, the data from both field studies were entered into a database and then explored in ArcGIS. In each case, the point data could be used to paint a general picture of the study area's overall disturbance to help guide future maintenance efforts and resource allocation. The data successfully highlighted areas that may be of concern to park personnel or which may merit additional monitoring and evaluation, which fulfills the main purpose of a rapid assessment data collection (Fennessy et al. 2007, Ervin 2003b). Moreover, data collection was successfully executed by volunteers of varying ages and socioeconomic and education backgrounds which supports the directive that the methodology should be accessible to non-experts (Ervin 2003a, Fennessy et al. 2007). As with any nascent data collection methodology there were some shortcomings that can be addressed in future implementation scenarios to further refine the data collection process. For example, the long distances between transect stops at South Mountain created large gaps between the points that may prevent a thorough statistical analysis (Hockings 1998). This particular shortcoming was corrected in the following case study at Petrified Forest National Park, where the distance between transect stops was considerably shortened.

2.3.2: Assessing Indicator Performance in the Sonoran Desert and Petrified Forest National Park

Correlation matrices were produced for each of the three study sites and for the entire data set of points. These correlations assisted in dissecting the indicators for areas that could still be improved in future iterations of the index (Torrico and Janssens 2010). Table 1 reveals that the highly correlated values from the index points collected at South Mountain Municipal Park, and Table 2 shows the most notable correlated values from the points collected at Petrified Forest National Park. The full tables can be viewed in Appendix A (South Mountain) and Appendix B (Petrified Forest). Once the highly-correlated indicators were identified, it became possible to explore the reasons why they might be changing concurrently in the field and to make changes to the index to address these shortcomings where it was deemed necessary.

In some cases, finding higher correlations between indicators was expected behavior after visiting the study area, and did not necessitate substantial changes to the index. This is particularly evident in the relationship between unauthorized trails, soil disturbance, and amount of trash at South Mountain (see Figure 1). Although each of these indicators is measuring something different, there were many areas uncovered during field testing at the first two study sites where people intentionally left the trail and loitered in areas that were not meant to be public. The foot trails leading up to these areas, the soil disturbance from frequent foot traffic, and the garbage left behind by those visitors were the most obvious evidence that these areas were being used in a manner not intended by park personnel.

The most egregious correlation from the South Mountain field test (see Table 1) was the relationship between the two trash indicators. In this case, the presence of one indicator (amount of trash) predicated the presence of the second indicator (type of trash). This led to all instances of litter being counted twice in the index, artificially inflating the final result. To address this high correlation, the solution was to combine the two indicators into a single measurement moving forward.

Site	**First Indicator**	**Second Indicator**	**r**
Overall	Soil Disturbance	Erosion	.425**
Overall	Soil Disturbance	Trail	.472**
Overall	Amount of Trash	Type of Trash	.896**
Overall	Amount of Trash	Mature Vegetation Damage	.441**
S2	Soil Disturbance	Erosion	.532**
S2	Soil Disturbance	Mature Vegetation Damage	.614**
S2	Soil Disturbance	Trail	.595**
S2	Erosion	Mature Vegetation Damage	.476**
S2	Erosion	Trail	.575**
S2	Amount of Trash	Type of Trash	.835**
S2	Mature Vegetation Damage	Trail	.708**
S3	Erosion	Trail	.522*
S3	Amount of Trash	Type of Trash	.945**
S3	Amount of Trash	Mature Vegetation Damage	.632**
S3	Type of Trash	Mature Vegetation Damage	.636**
S4	Soil Disturbance	Trail	.633**
S4	Amount of Trash	Type of Trash	.853**
S4	Amount of Trash	Mature Vegetation Damage	.623**
S5	Soil Disturbance	Erosion	.458*
S5	Soil Disturbance	Mature Vegetation Damage	.701**
S5	Amount of Trash	Type of Trash	.982**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 1: Notable significant correlations between impact indicators at South Mountain Municipal Park

Whereas the data collected at South Mountain Municipal Park yielded several high r values that merited closer inspection, the data collected at Petrified Forest National Park generally yielded much lower correlations between the indicators at individual study sites and globally, indicating that the adjustments made to the index after the South

Mountain field test helped to reduce the overlapping measurements in the field. Correlation matrices between all of the variables showed that the r values dropped overall in the data collected at Petrified Forest National Park, generally falling into a range of 0 to .2 (p>=.1). A few notable exceptions are highlighted in Table 2.

Since consistently highly-correlated indicators may be measuring the same environmental impact twice, the lack of exceptionally high correlations within the data collected at Petrified Forest provides evidence that there is much less overlap between the indicators in the newer iteration of the index. Future implementations of the DIA index should continue to be adapted to minimize correlation between indicators (Hockings 2003, Nepal and Nepal 2004). In order to ensure the validity of the index measurements in different arid and semi-arid environments, each of the indicators will need to be examined and adjusted to align the observations with values that are appropriate to that region (Hockings 1998). This can be done a park manager, if necessary in conjunction with an expert in that particular region who can help determine acceptable ranges for each of the indicators (Fennessy et al. 2007).

Although r values as close to zero as possible are ideal, it is not a reasonable expectation in this context. Due to the nature of the rapid assessment data collection and the various environmental indicators measured in the field, a certain amount of overlap between the indicators should be expected (Bhardwaj et al. 2012). This can be accounted for in different ways; for example, the new slope variable is meant to offset the known overlap between the soil disturbance and erosion variables. I, therefore, anticipated that these three indicators show relatively high correlations between each other at the individual sites at Petrified Forest, as well as within the dataset as a whole.

All of the areas currently occupied by the surveyed trails have long histories of human impacts dating back to prehistoric times and continuing today (National Park Service 2007). In particular, the Crystal Forest trail now occupies a former quarry site where nearly every step yields new evidence of prehistoric and historic activity (Lubick 1996). Similarly, those areas remain interesting to the visiting public, which compounds the level of disturbance expressed through the index. In other words, although there are higher correlations between these indicators it is a logical result based on the known history of the surveyed areas.

One limitation that should be addressed in future iterations of the index is the limited usefulness of the historic and prehistoric indicator. Historic and prehistoric activity were initially combined into a single indicator in order to prevent volunteers in the field from having to determine whether their field observations were old enough to qualify as prehistoric. Combining prehistoric and historic indicators resulted in the unexpected side effect of forcing volunteers to rely heavily on the comment field to clarify their observations. This was especially true in instances where both prehistoric and historic evidence was observed. As long as the participants who will be collecting data in the field are able to differentiate between historic and prehistoric impacts, that indicator should be split into two for future implementations.

Another challenge during field work was the disturbed state of the area around the trails. This disturbance made it difficult to assess some of the indicators appropriately. The level of disturbance made it difficult for volunteers to make judgment calls regarding the likelihood that a particular event occurred in the recent past. For example, in instances where holes in the ground made it clear that petrified wood was removed from the area volunteers needed to decide whether there was evidence that the removal was recent. Other indicators that were difficult to judge very close to the trail for similar reasons to those stated above were erosion, soil disturbance, and modern anthropogenic impact.

Site	**First Indicator**	**Second Indicator**	**r**
Overall	Soil Disturbance	Modern Anthropogenic Impact	.353**
Overall	Soil Disturbance	Erosion	.313**
Overall	Slope	Erosion	.394**
Overall	Trail Spur	Modern Anthropogenic Impact	.351**
Overall	Prehistoric or Historic Impact	Petrified Wood Density	-.448**
Crystal	Vandalism	Prehistoric or Historic Impact	.354**
Crystal	Vandalism	Modern Anthropogenic Impact	.459**
Crystal	Soil Disturbance	Erosion	.341**
Crystal	Erosion	Slope	.399**
Giant Logs	Erosion	Slope	.415**
Giant Logs	Soil Disturbance	Modern Anthropogenic Impact	.495**
Giant Logs	Vandalism	Modern Anthropogenic Impact	.465**
Giant Logs	Mature Vegetation Damage	Soil Disturbance	.482**
Long Logs	Vandalism	Prehistoric or Historic Impact	.410**
Long Logs	Soil Disturbance	Erosion	.367**
Long Logs	Erosion	Slope	.366**
Long Logs	Trail Spur	Modern Anthropogenic Impact	.459**
Long Logs	Trail Spur	Other Notable Impact	.569**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 2: Notable significant correlations between impact indicators at Petrified Forest National Park

2.3.3: Indicator Development with Park Personnel

Beginning with the first iteration of the index, information taken from literature sources served as the foundation for many of the initial indicators. In order to ensure that the indicators are appropriate for the physical environment for which they will be used, however, field tests and conversations with park personnel (Stohlgren et al. 1997) helps ground the theoretical framework in the reality of the environment. Involving park personnel also ensures that the index returns results that are not only useful for conservation monitoring, but results of most relevance to park personnel (Hockings 2003).

Furthermore, involving park personnel in the index creation process at the earliest possible point is a vital step towards bridging the gap between an academic solution and a realistic problem-solving tool that will be implemented and used over time (Salafsky and Margoluis 1999). The more closely involved that park personnel are in the development of the indicators, the more those indicators will be grounded in the reality of the issues that will make an immediate impact on the way they perform their jobs (Hockings 2003).

Whenever possible throughout the iterative process of developing the index, park personnel and volunteer park stewards had the opportunity to provide input to help contextualize the indicators (c.f. Arbogast 2009, Hudson 2009). Their feedback helped to ensure that the indicators collected information that would be useful to them. More importantly, their input allowed the index to be calibrated closely to the specific environment for which it would be used in a way that a literature review alone could not accomplish (Amezketa 2006).

2.3.4: Determining Appropriate Spacing Between Transects

In both of the studies, data collection was conducted using line transects. Transects are a data collection technique where observations are collected at measured distances along one or more straight lines (Southwell 1994). This is a productive sampling technique that can produce results that are representative of an entire area (Hedley and Buckland 2004, Southwell 1994). Data collection at South Mountain Municipal Park was supported by transect tapes; at Petrified Forest National Park GPS units replaced the transect tapes.

While line transects collect data effectively, the 50m gaps between the transect stops at South Mountain are too large to draw accurate conclusions about the areas in between the points. In this case, it is better to spend a little bit more time in the field assessing a greater number of points than to settle for a faster data collection period that yields insufficient results (Buckland et al. 1998, Hedley and Buckland 2004).

The archaeologist at Petrified Forest National Park suggested using 15m spacing between transects out of deference to the abundance of prehistoric and historic impacts in the study area (National Park Service 2007). The closer transect points did yield much better coverage of the area at the cost of leading to a much more time-intensive data collection process. While the time in the field could be lessened through the addition of more manpower or better technology to reduce the amount of time at each stop, it is probable that 15m transects over a study area yields information that is more specific than necessary for most purposes (Buckland et al. 1998). Determining appropriate transect spacing for general applications of this index remains an area that is open to future refinement, and which will likely remain dependent on the specific needs of the park personnel overseeing the implementation of the index in each new context.

2.3.5: Comparing Desert Impact Analysis to Other Impact Analysis Techniques

The Desert Impact Analysis tool is not meant to be used by itself, but rather as one of many tools in a park manager's arsenal for creating and measuring progress towards achieving conservation goals (Hockings et al. 2000). Using a field analysis that measures impacts on the scale of meters to support smaller-scale field analysis and larger-scale digital analysis offers an opportunity to create a fuller picture of an area's overall health (Loubser 2001, Stohlgren et al. 1997). Many techniques at other scales have been created and discussed in literature, any of which could be used as part of a complementary solution to managing protected areas (c.f. Ludwig et al. 2006, Allen 2009).

	Micro-scale analysis (centimeters)	**Desert Impact Analysis (meters)**	**Remote Sensing analysis (kilometers)**
Cost	- Higher cost associated with analysis of soils and vegetation	+ Low cost	+/- Higher-resolution data increases cost
Time	+ Small time commitment	+/- Smaller time commitment that grows with increased data points	- Time commitment necessary to find data and prepare for analysis
Specialized skills	- Requires a deep understanding of environmental characteristics and study tools	+ None required	- Understanding of remotely sensed data analysis
Specialized software	+ None	+/- Spatial analysis calls for some specialized software, open source solutions available	- Remote sensing software required
Specialized hardware	- Requierd for in-depth analysis	- Location recording unit such as GPS	+ None
Ease of use	- Less accessible to non-experts without training	+ Survey is easy to conduct	- Expertise in remote sensing necessary
Directness of measurements	+ Direct ratio measurements	- Indirect ordinal measurements	- Measurements determined by raster resolution
Consistency	+ Yes	- Potential for different volunteers to measure impact differently	+ Yes

Table 3: Review of the benefits and drawbacks of the Desert Impact Analysis compared to analysis techniques at two other scales of measurement.

Table 3 explores the different benefits and drawbacks to micro-scale analysis and remote sensing analysis compared to the field-scale Desert Impact Analysis. While the Desert Impact Analysis technique is appealing and easily implemented because of its simplistic data collection process, the ordinal data that are collected cannot be used to support an analysis that is as reliable or as in-depth as other methodologies that collect ratio measurements. This adheres to the categorization of the Desert Impact Analysis technique as a Level 1 assessment as outlined in the framework developed by Hockings et al. (2000), whose primary purpose is to help explore the context of the area and to begin the planning process for conservation goals that will be worked towards over time.

2.3.6: Review of the Process of the Desert Impact Analysis Refinement

The process of refining the Desert Impact Analysis to adapt it to a new region with a similar environment should be relatively straightforward. A park manager or other person with knowledge of the region's physical characteristics should be able to make the necessary adjustments to ensure that the index is appropriately calibrated to their specific area of interest. The majority of the indicators used to create the Desert Impact Analysis are applicable to most arid and semi-arid environments. These can be repurposed to create an index that monitors anthropogenic and natural impacts in conservation areas, trail structures, and urban-fringe areas with only minimal revisions (e.g. Allen 2009, Deluca et al. 1998, Nepal and Nepal 2004, Andam et al. 2008, Rai and Sundriyal 1997).

The indicators can be divided into two primary categories: Anthropogenic and non-anthropogenic. The two groups of indicators can serve individually as the core of a new index, with new indicators that are relevant to the administrator's interests being added as necessary. They can also be combined to form the foundation of a more complete index that can be deployed with only minimal changes.

The anthropogenic group would include vandalism, trash, and historic or modern impacts. These are all a direct result of human interaction with an environment. They do not occur in nature, which makes them appropriate for areas that are exposed to tourism and recreational use. These indicators may not be necessary in an index that is meant to assess a conservation area that is closed to the public for restoration. They may be drawn upon more heavily than the non-anthropogenic in highly-trafficked areas such as a trail system.

The other group of indicators provides information about the environment. This group includes soil disturbance, erosion, mature vegetation damage, trail spurs, and slope. Each of these indicators might be influenced by anthropogenic activity, but they can occur naturally without human intervention. Since these indicators measure natural impacts that may be of concern to a park manager, they should be the core of any index that focuses on areas that are protected or that are undergoing restoration efforts. These indicators can also support an analysis of publicly accessible park land.

Once the core indicators are decided upon and the categorizations are adjusted to be appropriate for the environment, additional concerns should be assessed for inclusion in the index. The inclusion of the petrified wood density indicator for Petrified Forest National Park is an example of a situational indicator that was relevant in the context of that particular fieldwork, but which would not translate well to other similar regions worldwide. Depending on the area, these situational indicators could include animal sightings, sightings of a particular plant, viewshed considerations, auditory concerns, and more. When a list of indicators has been determined, a small field test can confirm the relevance of the indicators, and can be used to ascertain the best sampling strategy to use for wider deployment.

2.4: Conclusions

There remains a need for a time- and cost-efficient way to collect data about that produces reliable results useful for conservation monitoring and environmental and heritage management, and which can work in tandem with other data collection techniques as part of a whole-system monitoring strategy (Allen 2009, Shupe and Marsh 2004, Hockings et al. 2000). This challenge is slowly being addressed by park managers and within the academic community, with many new ideas developed and tested in the field each year. While some of those methods meet with only limited success, one repeatedly standout methodology is rapid assessment indices (Hockings et al. 2000). Proved effective in other ecoregions around the world, rapid assessment is not yet widely adapted to desert environments (Ervin 2003b, Fennessy et al. 2007, Stohlgren et al. 1997, Torrico and Janssens 2010).

One of the challenges of developing an effective rapid assessment strategies is creating indicators that are easy to measure in the field, and which yield robust, reproducible results (Timko 2008). Using the Level 1 framework outlined by Hockings et al. (2000), as well as input from park personnel, a rapid assessment index is developed and then field tested for efficacy in South Mountain Municipal Park in Phoenix, Arizona. The results of that field test are tabulated and the index is adjusted to address high correlations between certain indicators, as well as other weaknesses in the sampling strategy. After recalibration, the Desert Impact Analysis index is tested a second time in the Petrified Forest National Park, Arizona. Lastly, I explain a step-by-step process by which the DIA index can be imported into other arid and semi-arid settings.

2.5: Future Research Directions

Although the data collected at South Mountain Municipal Park helped to refine the index for future iterations, but the transect spacing and the high correlations between many of the different indicators ultimately yielded results insufficient for more in-depth analysis, the data collected from Petrified Forest National Park proved to be much more robust.

As a next step, the data collected at Petrified Forest National Park will be analyzed in a GIS environment to help ascertain the current status of the area around three of the park's trails. In addition, the data will be used to determine whether various attempts implemented by the park to keep visitors on the trail are working as intended. The results of these analyses will be used to help develop future improvements to the park's current trail structure, as well as to guide the planning process for new trails in the land that will be acquired by the park in the coming years.

In addition to conducting a more thorough analysis of previously collected data, there are many other avenues for future research and improvements and modifications to this index and its indicators. Created with an eye towards generalizations that will allow it to be recalibrated for arid and semi-arid environments that are different from the one for which it was initially designed, the index can be field tested and validated in other worldwide ecoregions as part of land management and conservation monitoring strategies (DeMott, Balaraman and Sorensen 2005). With plenty of room for additional indicators to be developed in areas such as endangered species monitoring and other area-specific considerations, the information gained from implementing a rapid assessment index can be valuable to park management.

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Chapter 3

CASE STUDY OF ENVIRONMENTAL DEGRADATION AT PETRIFIED FOREST NATIONAL PARK, COLORADO PLATEAU, ARIZONA USING THE DESERT IMPACT ASSESSMENT METHOD

3.1: Introduction

As the estimated amount of protected area worldwide continues to grow (Andam et al. 2008, Tear et al. 2005), those in charge of monitoring and maintaining preserves are faced with new management challenges. Various stakeholders with an interest in the protected area may have different and sometimes conflicting wishes for the management directions (Chase, MSchusler and Decker 2000, Hockings 2003). One consequence of this increased stakeholder interest is that the efficacy of protected areas is being called into question with growing frequency (Parrish, Braun and Unnasch 2003a). As a result, park managers are being called upon to document their conservation goals and to demonstrate progress (Tear et al. 2005, Salafsky and Margoluis 1999).

Great care is typically put into the construction of tourism amenities in parks. For example, the educational opportunities provided in visitor centers and through the literature available on signage throughout the park are well used (Hall and McArthur 1993b, Manning 2001, McArthur and Hall 1993, Moore and Polley 2007). Other considerations, such as the views afforded by outlooks and trails are also important (Bacon 1995, Bishop 2003). Creating an experience that appeals to the sense of naturalism that tourists who flock to these parks seek is vital; failure to do so may result in encouraging unwanted visitor behavior such as intentional vandalism or leaving designated trails in order to view interesting park features that are not accessible from paved areas (Ajzen, Czach and Flood 2009, Christiensen and Dustin 1989).

Balancing tourism demands with heritage and conservation concerns can be difficult to accomplish (c.f. Brooks and Champ 2006). Allowing tourism within protected areas can be counterproductive towards conservation efforts, as visitors in a fragile area leave an impact on the environment no matter how careful they may be (Manning 2001, McArthur and Hall 1993). It is possible to limit the impact of visitation through restrictive visitation programs such as the capacity-constrained tourism approach utilized by some United States National Parks, but even a small number of visitors passing through a park can hamper conservation goals (Manning 2001, Schwartza, Stewarta and Backlundb 2012, Brooks and Champ 2006). Balancing a tourism mandate with the goal of setting and working towards conservation goals can also put a strain on the physical and financial resources available to those who are in charge of these protected areas (National Park Service 2005, Soutullo, De Castro and Urios 2008).

The onus of developing monitoring systems to help achieve management goals often falls on park managers who may have inadequate training to determine acceptable ranges for conservation indicators; this can result in systems that do not accurately monitor intended goals, or which do not fully account for factors that may ultimately negatively impact an area (Parrish et al. 2003a, Brown 2003). Park managers are also faced with the challenge of maintaining an adaptable and successful tourism strategy that maximizes the amount of visitors the park can accommodate, augments the visitor’s experience, and minimizes anthropogenic impact (Hall and McArthur 1993a).

This paper evaluates and analyzes data collected at Petrified Forest National Park, Arizona, using a newly developed rapid assessment data collection technique called the Desert Impact Assessment. An analysis of the data set is used to determine the types of impacts the surveyed trails are facing, and to examine whether it is possible to differentiate between the anthropogenic impacts and the natural impacts. The dataset also allows a baseline impact assessment to be created for three of the park's trails, and the implication of providing insight to increase the efficacy of management efforts is explored.

3.2: Methods

3.2.1: Study Area

Declared a National Monument in 1906 and a National Park in 1962, Petrified Forest National Park exemplifies a conservation area that must balance preservation goals with mandated nature and heritage tourism. Presently, the park addresses its tourism mandate in the form of a number of hiking trails constructed by the Civilian Conservation Corps (CCC) between 1936 and 1942 and a number of educational and scenic stops along the road that require little or no walking. The park also operates two tourism areas that serve as learning centers, and two museums. The southern part of the park preserves a piece of the Chinle Formation, while the northern part of the park preserves part of the Painted Desert and serves a wilderness area for backpacking and overnight camping with permit.

3.2.2: Details on Study Sites

The Petrified Forest currently has seven official walking trails varying in length from approximately 0.25 miles to just under 1.5 miles. Constructed by the CCC during the 1930s, many of these trails remain open to public visitation. In addition to the trails, there are many scenic views and stops along the road that do not require any substantial walking. Each of the trails highlights an element of the park's rich history and natural beauty.

During study site selection, the park archaeologist requested an assessment for three of the seven trails. The study sites were each selected based on the qualities that made those trails unique and interesting to the park archaeologist, and which he felt would yield the best information regarding the efficacy of current maintenance practices as well as information that could be used to help guide the planning and implementation of future park trails as expansion land authorized by George W. Bush in 2004 is acquired.

The first study site, Crystal Forest Trail, was selected for its location in the heart of a preshistoric petrified wood quarry and for its popularity as one of the most-visited trails in the park (Lubick 1996). The park archaeologist was interested in the condition of the second study site, Long Logs Trail and the trailhead for the Agate House Trail, because drive-up access to the formerly-well trafficked trailhead was removed in 2004. The third study site, Giant Logs Trail, is located immediately behind the Rainbow Forest Museum, and is the site of many park outreach activities aimed at visitor education. All of the study sites are located in the semi-arid southern part of the park (see Figure 6).

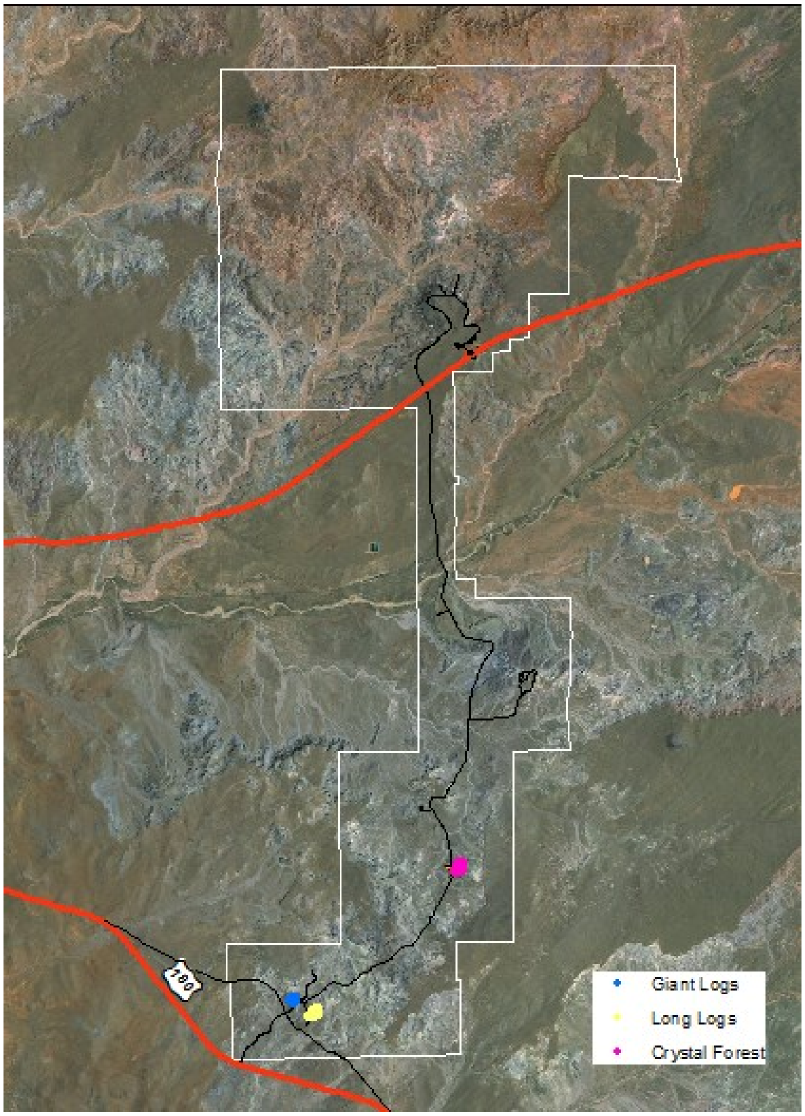


Figure 6: Location of study sites at Petrified Forest National Park

The Crystal Forest trail (see Figure 7; n=554) is the northernmost of the three study areas, and is accessible via a parking lot at the trail head. The trail is 0.75 miles long, and is located south of the Painted Desert in a semi-arid scrubland. An area rich in historic and prehistoric anthropogenic activity, the Crystal Forest remains a popular visitor attraction today, which made it an excellent candidate for an impact analysis study.

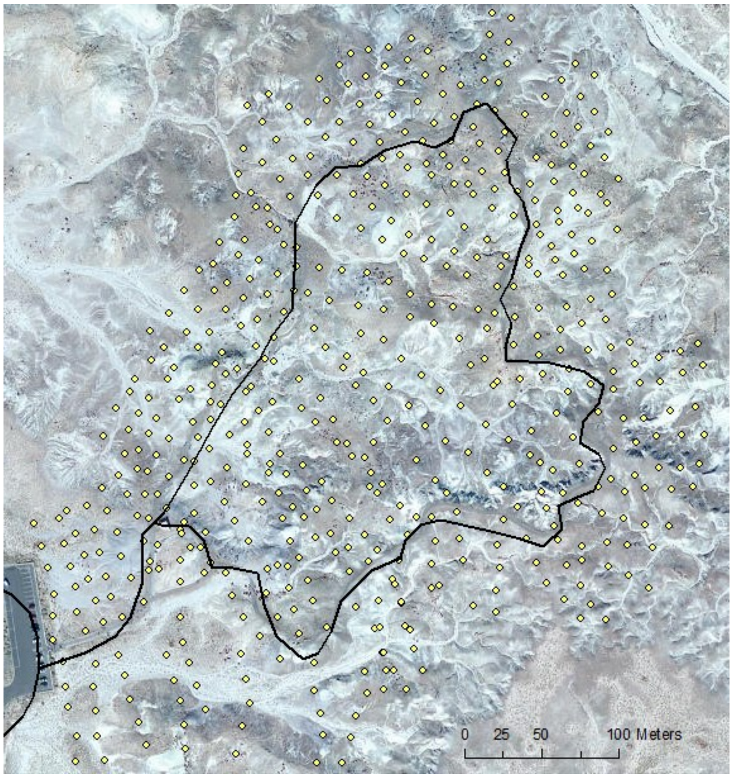


Figure 7: Surveyed point distribution at Crystal Forest Trail (n=554)

The Giant Logs Trail (see Figure 8; n=269) is located on the southwestern corner of the park near the park exit. It is approximately .4 miles long with several interior loops, and can be accessed through the Rainbow Forest Museum. It is the smallest of the three trails, and the most-traveled. Park personnel frequent this trail, giving tours and offering other educational programs that meet in the Rainbow Forest Museum.

The Long Logs Trail (see Figure 9; n=534) located just east of the Giant Logs Trail, also in the southwestern corner of the park. It is approximately 1.55 miles long. Although the trail head was once accessible from the road, it has been closed off to vehicular traffic; to reach the trail head, you must now park at the Rainbow Forest Museum and walk approximately .5 miles along the road. Because direct access has been removed, Long Logs Trail is the least trafficked of the three surveyed sites.

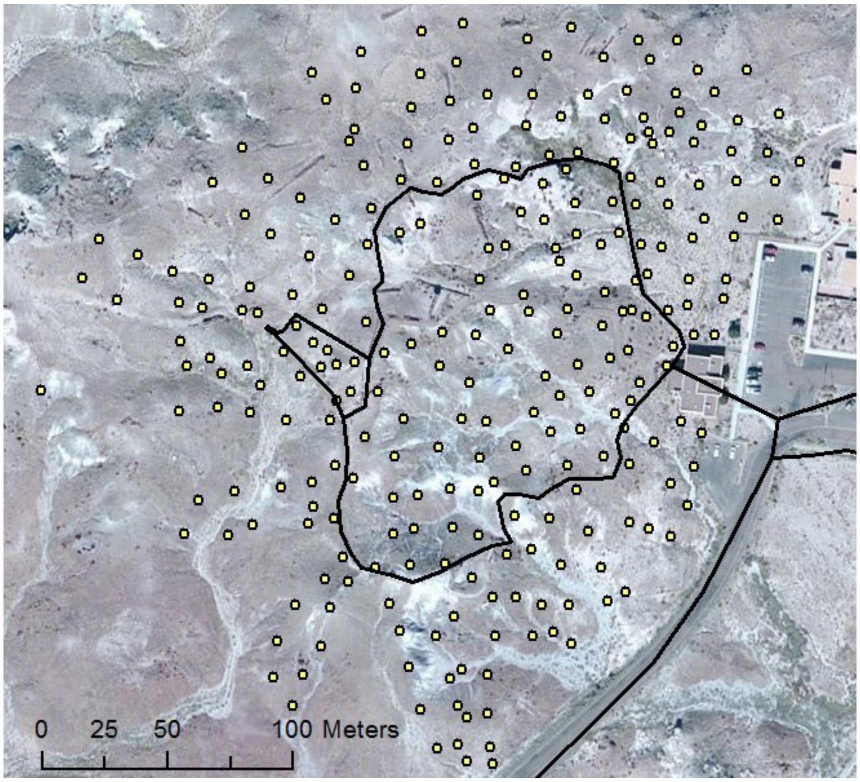


Figure 8: Surveyed point distribution at Giant Logs Trail (n=269)

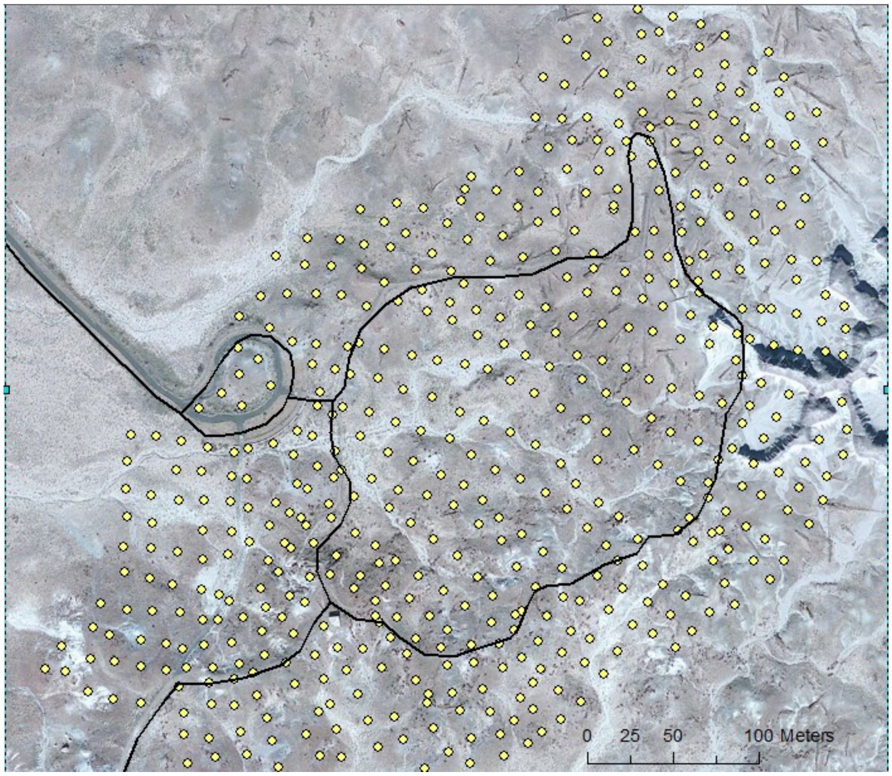


Figure 9: Surveyed point distribution at Long Logs Trail (n=534)

3.2.3: Desert Impact Assessment Technique

One means of collecting information about protected areas in the field to assess environmental impact and disturbance is rapid assessment (Hockings, Stolton and Dudley 2000). Rapid assessment techniques are considered Level One assessments by Hockings in his three-level framework of environmental assessment; in other words, they are meant to be quick and simple to use, requiring no expensive equipment or extensive expert knowledge of the area to be assessed (Hockings et al. 2000). Rapid assessment is further defined by later works that define guidelines regarding survey techniques and how data should be collected in the field, and which consider the best means of determining and implementing indicators to assess (c.f. Ervin 2003b, Fennessy, Jacobs and Kentula 2007, Torrico and Janssens 2010).

Rapid assessment methodologies are a popular means of collecting information in a number of environments where conservation and preservation are priorities. Each new ecosystem such as rainforests and wetlands demands a unique set of indicators that are unique to that environment (e.g. Bhardwaj et al. 2012, Fennessy et al. 2007, Stohlgren et al. 1997, Torrico and Janssens 2010, Twohig and Stolt 2011). The data that are analyzed in this paper are collected using a rapid assessment technique called the Desert Impact Analysis, whose indicators were selected for a desert environment. This index was field tested in an iterative process at South Mountain Municipal Park in Phoenix, Arizona and at Petrified Forest National Park, Arizona in the first paper of this dissertation.

After field testing the indicators and evaluating their efficacy, the following items were assessed at each stop:

- *Vandalism*: Evaluates the extent of intentional damage or violation of an area as the result of human activity.

- *Soil disturbance*: Evaluates the condition of the desert pavement (if applicable) and accounts for patches of bare soil.

- *Erosion*: Evaluates ground cracks and exposure of plant roots or poor trail conditions as a result of natural processes.

- *Amount and type of trash*: Evaluates the density and type of trash present.

- *Slope*: Evaluates the degree of slope to prevent soil disturbance and erosion from creating falsely inflated scores. This variable is measure negatively.

- *Mature vegetation damage*: Examines evidence that mature vegetation is abnormally damaged or dying.

- *Unauthorized trail or road*: Evaluates the width of footpaths if they exist.

- *Recent anthropogenic impact*: Evaluates whether there is evidence that people are using the area for off-trail activities.

- *Historic or prehistoric impact*: Evaluates whether there is evidence of historic or prehistoric activity such as old roads, pottery, arrowheads, and other artifacts.

- *Other audible or visible impact*: Combined with a free-response comment field, allows users to write down any other considerations or concerns.

- *Petrified wood density*: Evaluates the density of small petrified wood pieces on the ground.

Note that the last assessment item (petrified wood density) is unique to Petrified Forest National Park, illustrating the flexibility of this general strategy for arid and semi-arid environments.

During the case study at Petrified Forest National Park all of the indicators are assessed using an ordinal scale of 0-3, with 3 indicating the most impact for each of the variables. When the ten indicators that comprise the body of the DIA index are added together, a total score of overall impact can be produced. The indicators measured at Petrified Forest National Park can create a high of 27 points at each transect stop since the tenth indicator (slope) is measured negatively to account for instances where high slope created artificially high soil disturbance and erosion values (see Paper 1). The petrified wood density indicator is assessed separately on an ordinal scale of 0-5 in order to capture a more detailed overview of that element. This indicator is not used as part of the overall total.

3.2.4: Selection of Survey Data Points in Each Study Area

At the request of the park archaeologist, a stratified random point sampling strategy was used for each of the trails with stops every 15 meters. The study area included the entire interior of each trail loop, and a buffer of approximately 60 meters away from the outer edge of each trail. This was accomplished using transects that stopped every 15 meters over the extent of each study site (Hedley and Buckland 2004, Southwell 1994). In instances where the terrain became too dangerous to safely traverse, transects were ended early.

At each stop, the location was recorded using a GPS unit and the immediate area was evaluated for all indicators in the final version of the DIA index. The GPS device, which was also used to track transect progress, represents the only piece of specialized equipment used during field testing (Courrau 1999, Nepal and Nepal 2004). All of the indicators can be evaluated visually. Using transects created a point sample set with relatively even spatial distribution, and collecting data every 15 meters ensured a reasonable point density for each of the three study sites to support a spatial analysis (Hedley and Buckland 2004, Hockings 1998, Southwell 1994).

3.2.5: Interpolating Point Data

At each stop, the eleven indicators each contribute to an overall evaluation of the area. Each indicator yields information about one conservation or management concern that can be valuable on its own or when taken into context with the remaining indicators . Eleven indicators were evaluated at each stop. These indicators can be can be interpolated individually or in groups across the entire study area depending on the information that is desired at the time.

ArcGIS 10.0 Geospatial Analyst generated a semivariogram and covariance cloud for the point data from each site to explore the distribution of data values and to determine the best method of interpolating the results. One of kriging's inherent benefits is that it interpolates values in space based not only on distance between points (and their attribute of interest), but also based on the overall spatial arrangement of the points, taking spatial autocorrelation into account. The semivariogram and covariance clouds reveal no such structure at any of the trails. Therefore, inverse distance weighting (IDW) is a more appropriate method to employ at each of the sites since IDW operates only by examining distance between points.

The Spatial Analyst IDW tool in ArcGiS 10.0 generated three interploations for each of the three trail areas. The first surface is an interpolation of the total score with all of the Desert Impact Analysis indicators added together. This number does not include petrified wood distribution, which was measured separately at the request of the park archaeologist and never incorporated into the index measurements. The second interpolation at each study area shows the density of petrified wood distribution. The third interpolation for each site examines only the indicators that are anthropogenic in nature (vandalism, trash, trail spur, prehistoric or historic impact, and modern anthropogenic impact).

3.2.6: Viewshed Analyses to Gauge Behavioral Modification Success

Petrified Forest National Park employs shade structures at some of its trails in an attempt to modify visitor behavior and keep tourists on designated trails. These "shade shacks" provide shelter from the elements for park rangers and interpreters who often spend part of the day at those structures providing a friendly park presence and monitoring the visitors. In addition to serving as a venue that can be visited for additional information about the trail area, the presence of the permanent structure theoretically acts as a deterrent to people who are considering leaving the trail.

These shade shacks made Long Logs and Crystal Forest trails ideal candidates for data collection since an analysis of the rapid assessment data presents an opportunity to explore the efficacy of the shade shacks in keeping visitors on the trail. To accomplish this, a point file for each of the shade shacks is used to run a viewshed analysis in ArcGIS on a DEM with 5m resolution. After converting the resulting raster to vector, a spatial join assigns each point a categorization of visible or not visible from the trail's shade shack.

Once categorizations are assigned to each point, SPSS 19 can be used to perform a Mann-Whitney U test on each dataset to determine whether the impact scores for the two categories differ substantially. A significant difference between the visible points and the non-visible points can help to draw conclusions about the efficacy of the shade shacks as visible reminders for visitors to stay on the official park trails.

3.2.7: Buffer Analysis to Determine Distance Decay Moving Away From Trails

One way of determining whether a trail system is successful at reducing the impact of the visitors who use it is to look for a smaller amount of notable impact moving farther away from the trail. With the point data collected at Petrified Forest National Park, it is possible to explore the impacts closer to the trails compared to those farther away by using a buffer analysis to divide the points into categories.

A ring buffer is created at intervals of 10, 20, and 30 meters away from each of the three trails using ArcGIS. The points are then categorized depending on whether they fall into each of the three buffers. The results are explored using a Mann-Whitney U test on each dataset in SPSS 19. A significant difference between the points at all three trails that consistently grows smaller as distance increases can be used to support the existence of distance decay of impacts moving farther away from the trail.

3.3: Results

Three interpolations are created for each study site: petrified wood density, total desert impact assessment score, and a sum that counts only the indicators that measure anthropogenic activity. The results of the three IDW interpolations (Giant Logs, Long Logs, and Crystal Forest) are shown below (see Figures 10 – 18).

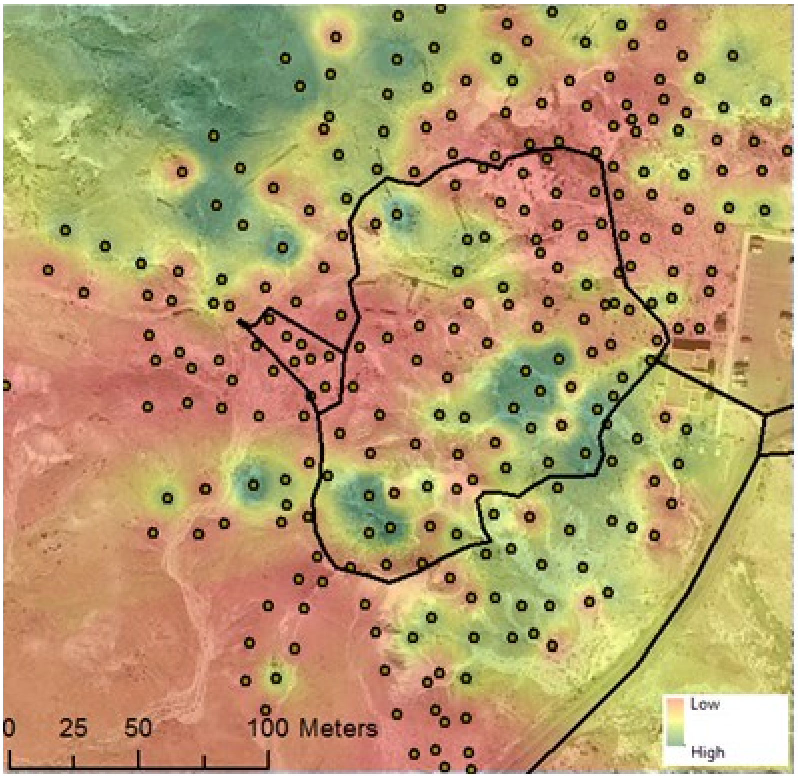


Figure 10: Petrified wood density interpolation at Giant Logs Trail. This trail area contained the least overall amount of petrified wood out of all three study sites. Crisscrossed by washes that remove loose pieces of wood from the area during rain events and a number of trails within the larger loop, the Giant Logs Trail does not present conditions that are conducive to dense deposits of petrified wood.

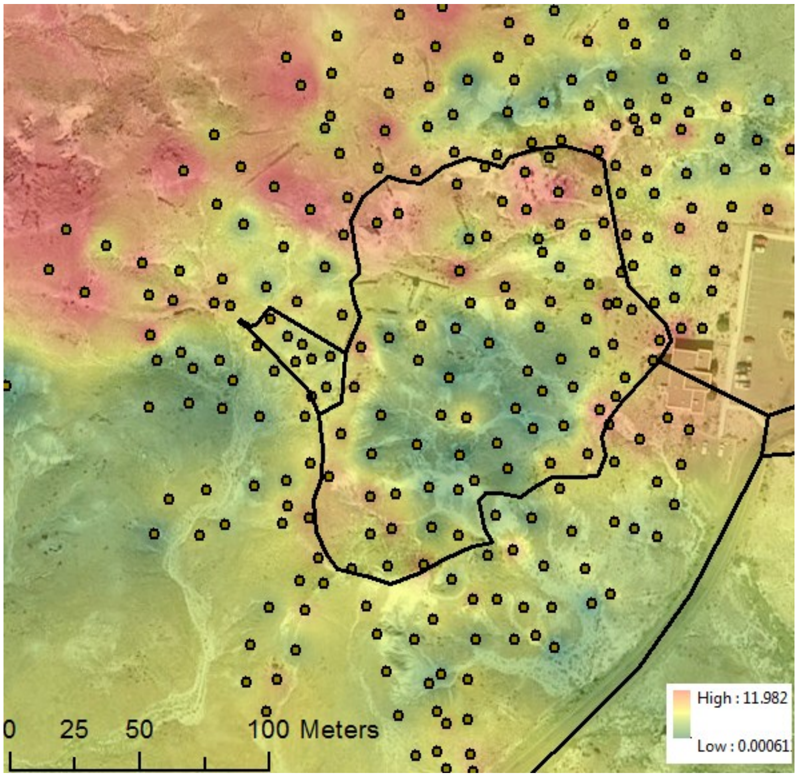


Figure 11: Anthropogenic indicators interpolated at Giant Logs Trail. The southwestern part of the trail experiences a moderate to low amount of clear anthropogenic activity. This could be attributed to the plethora or washes that crisscross the area and destroy evidence of previous anthropogenic activity after every rain event. In addition, the southern part of the trail is visible from the Rainbow Forest Museum, which is frequented by park personnel. The northwestern part of the trail is highlighted as an area of high impact due to a broad, highly visible footpath that was formally a part of the park's trail system. That trail is now decommissioned, but still experiences high foot traffic.

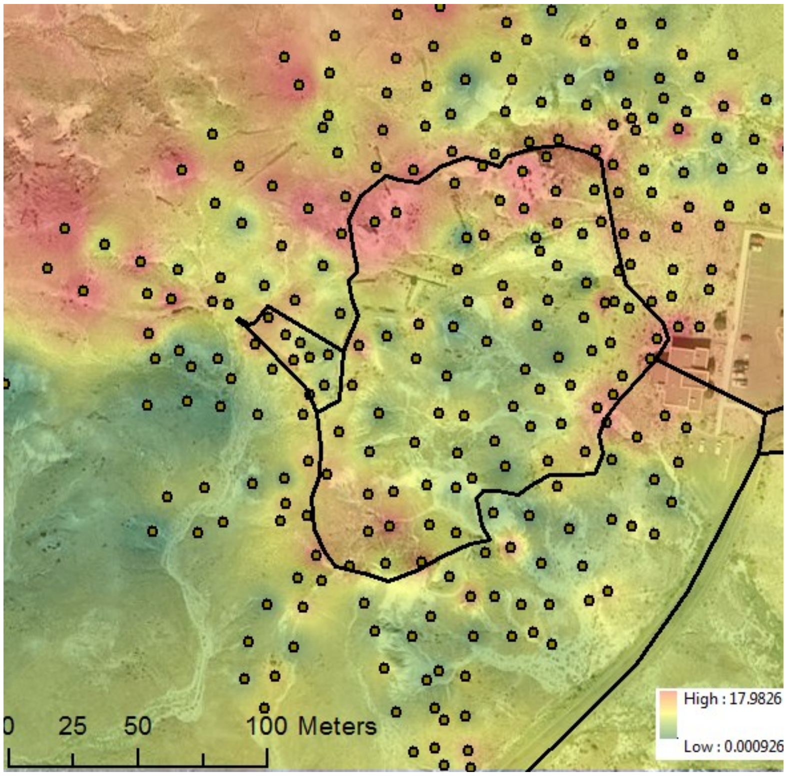


Figure 12: Total impact score interpolation at Giant Logs Trail. This image shows a better overall picture of the washes, which threaten the southernmost part of the trail and which crisscross the entire interior loop of the trail area. In the northern part of the trail a large, clear footpath leads away from the trail; many visitors were seen on this footpath during the study period. The northern part of the trail also experiences a higher amount of soil disturbance and erosion due in part to a large rocky outcropping that visitors climb on, and which obscures that part of the trail from the Rainbow Forest Museum.

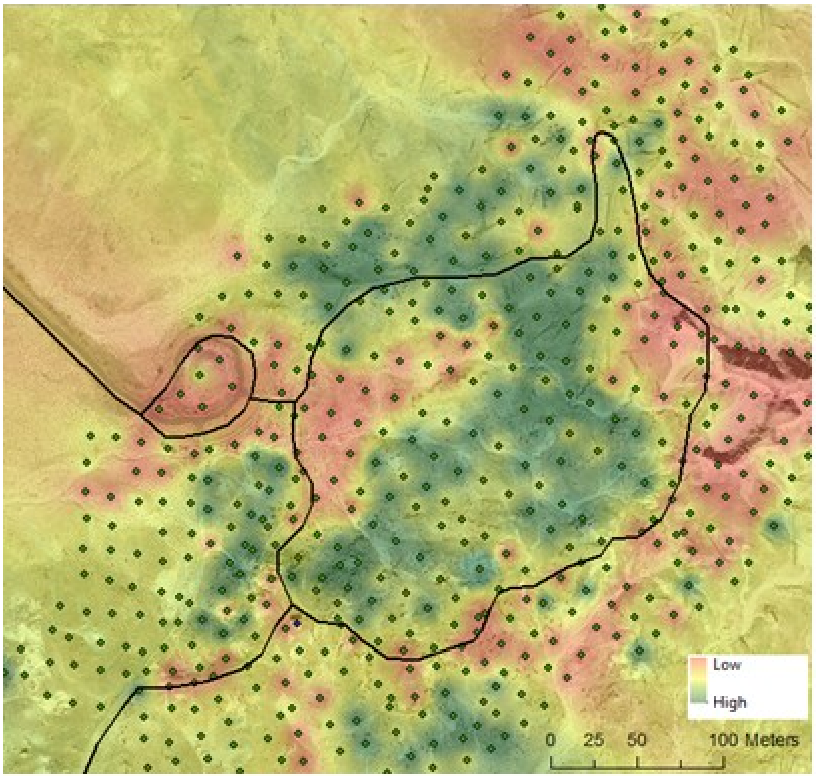


Figure 13: Petrified wood density interpolation at Long Logs Trail. The trail was designed to encircle a large deposit of petrified wood, cutting directly through the heart of the deposit in the southwestern corner and again on the northern corner. The ground is covered in pieces of petrified wood in those areas. Many of the areas with the lowest density of petrified wood are located in washes near the ravine towards the southeastern part of the trail. The eastern part of the trail also abuts against teepee rock formations with pieces of petrified wood eroding out of them, but no pieces on the surface.

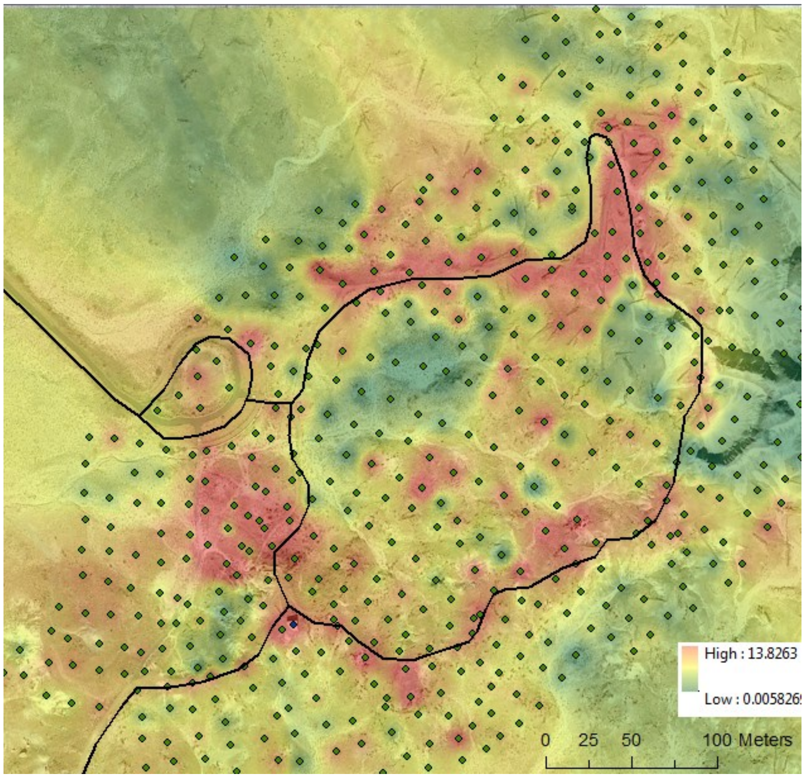


Figure 14: Anthropogenic indicators interpolated at Long Logs Trail show that the area immediately adjacent to the trail is highly disturbed almost universally. There is a particularly high level of anthropogenic disturbance in areas where the trail narrows to a very thin jut, with many indicators that people cut through that small area rather than walking around it. A second area of concern is the western part of the trail, where there is a large amount of obvious anthropogenic activity taking place in an area with a large density of petrified wood pieces. Finally, there is evidence that people are leaving the trail on the western and southeastern sides to enter the areas with a higher density of petrified wood.

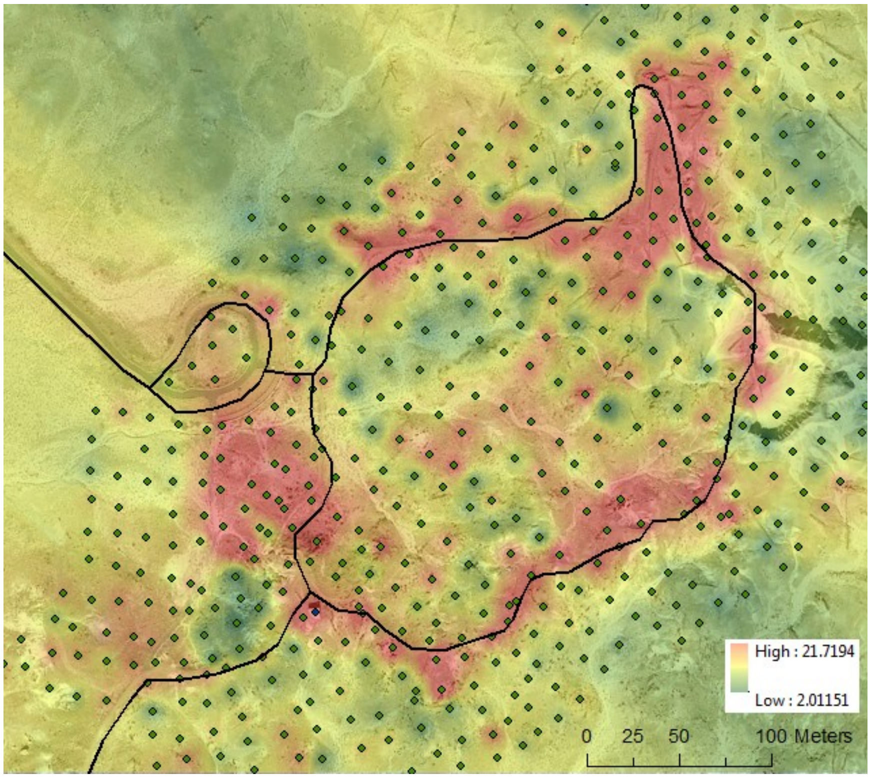


Figure 15: Total impact score interpolation at Giant Logs Trail. These findings coincide closely with the anthropogenic score, indicating that in this case much of the disturbance in the area of the trail is linked with human activity. A deep wash on the southeastern edge of the trail is encroaching on the paved walk, with pieces of asphalt eroding downhill. There are a number of washes on the interior of the trail loop that are clearly used as footpaths.

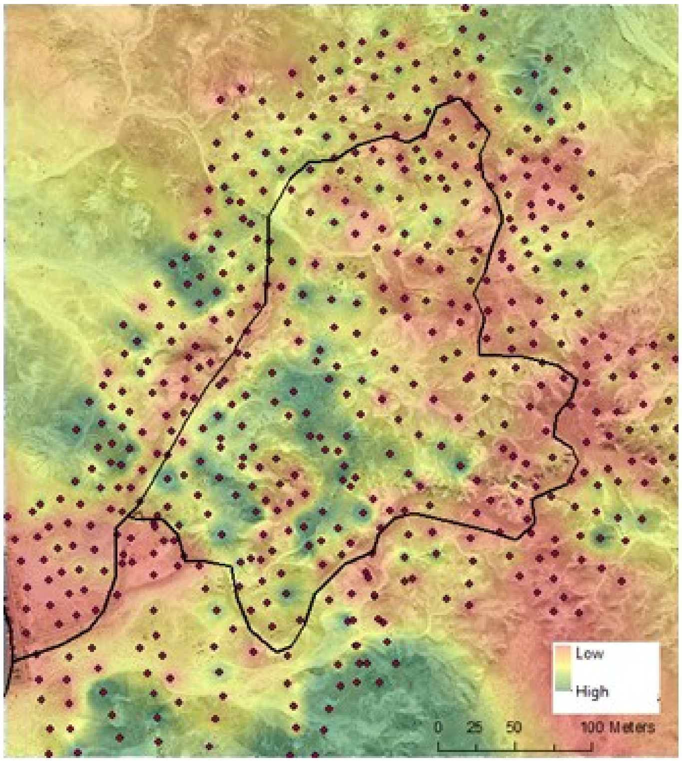


Figure 16: Petrified wood density interpolation at Crystal Forest Trail. Similar to the Long Logs Trail, the Crystal Forest Trail bisects a large deposit of petrified wood. There is another thick deposit of petrified wood to the south of the trail. The terrain on the eastern side of the hill becomes steep and hilly with a thick desert pavement and distinct washes. Very little petrified wood is naturally eroding out of the rock on that part of the trail.

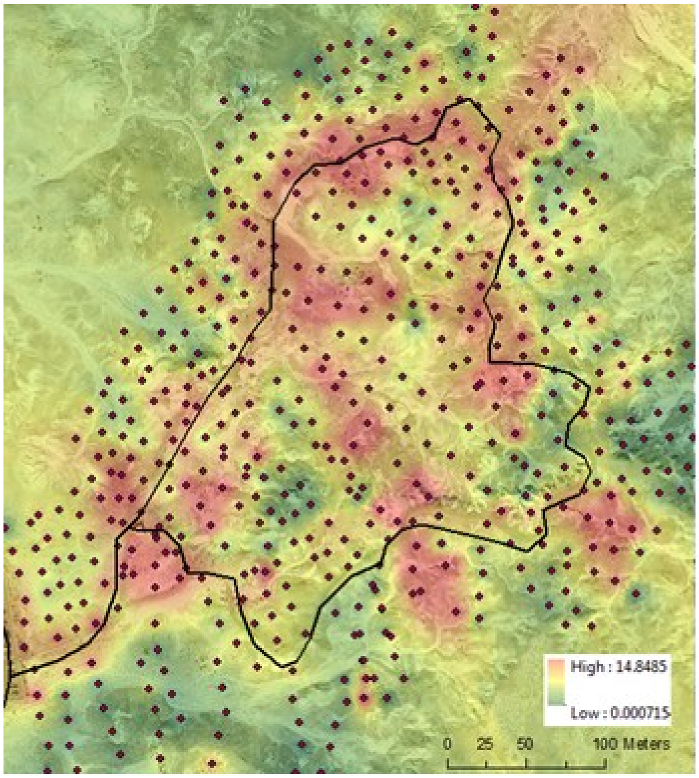


Figure 17: Anthropogenic indicators interpolated at Crystal Forest Trail. Similar to the Long Logs Trail, there is evidence of plenty of anthropogenic impact within a very close vicinity to the trail. At Crystal Forest Trail, the western part of the trail is crossed by several large, shallow washes. These showed signs of use as footpaths as people wandered closer to the thick deposits of petrified wood and some large, colorful wood pieces in the center of the trail loop. There is also evidence of people following washes away from the inner loop of the trail on the southern side.

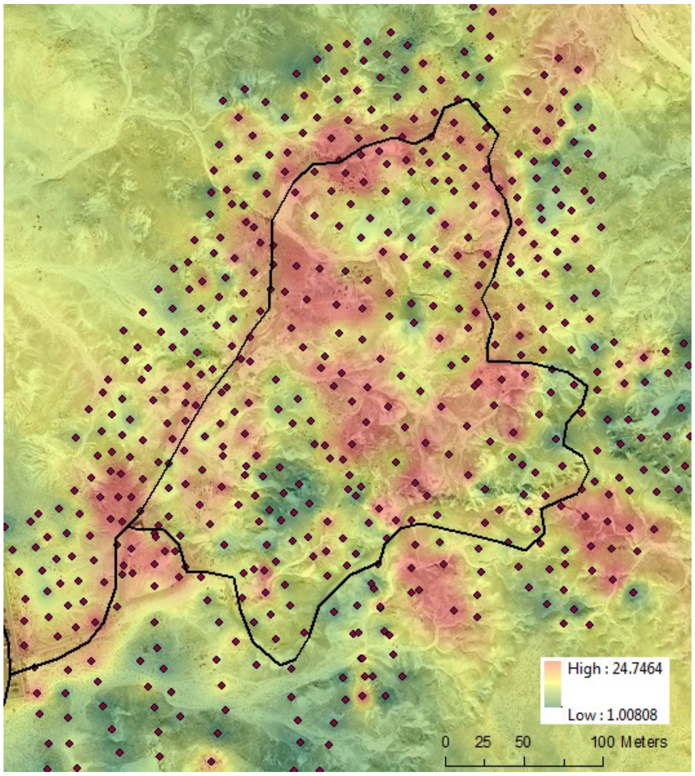


Figure 18: Total impact score interpolation at Crystal Forest Trail. The patterns of impact are similar to those generated by just the anthropogenic indicators, suggesting that the most disturbed parts of the Crystal Forest Trail area are a result of human activity. Much of the disturbance inside of the trail loop falls within areas that are easily accessible via the washes on the western part of the trail. The disturbed areas on the southeastern part of the trail are a second series of washes that are carved into hills, making them difficult to see from the trail after only a few steps.

In addition to interpolating the surfaces, a viewshed analysis run from the perspective of the shade shacks at the Long Logs Trail (see Figure 19) and the Crystal Forest Trail (see Figure 20) can be used to help gauge whether measures taken to keep visitors on the trail are working as intended. The viewshed is generated from a 5 m DEM. The results allow the points from the trail to be divided into two groups: visible from the shade shack at each trail, and not visible from the shade shack. A Mann-Whitney U test can determine whether the points inside the viewshed are substantially different from the points outside of the viewshed at each trail. Figure 21 shows results of a Mann-Whitney

U test on the points from Long Logs Trail, and Figure 22 presents results of a Mann-Whitney U test on the points from the Crystal Forest Trail.

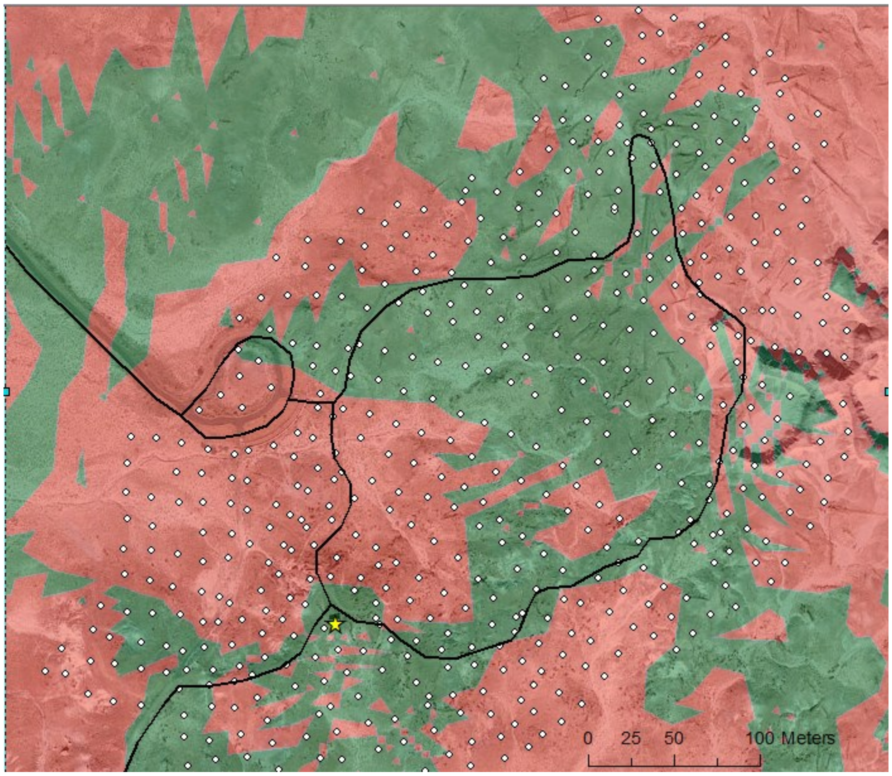


Figure 19: Results of a viewshed analysis from the shade shack at Long Longs Trail. The shade shack is at the southwestern corner of the trail, where the Long Logs Trail branches off into the trail head of the Agate House Trail. Although the shade shack is built on a hill, the hilly terrain immediately surrounding it leaves quite a bit of non-visible area to the west of the structure.

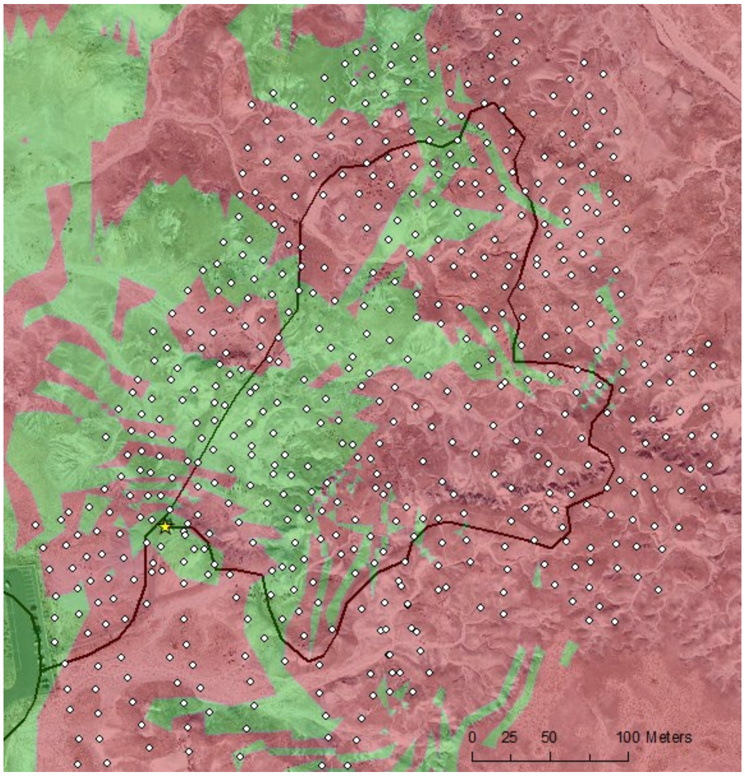
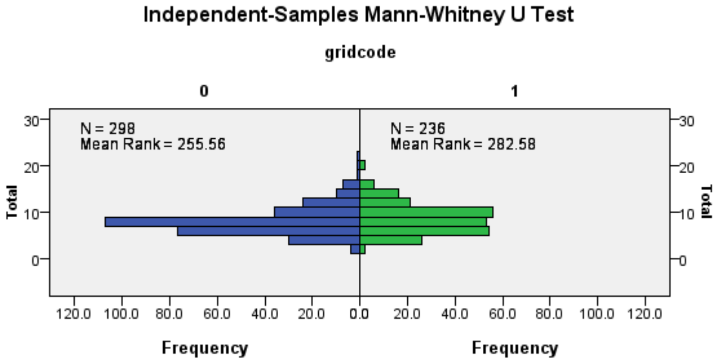
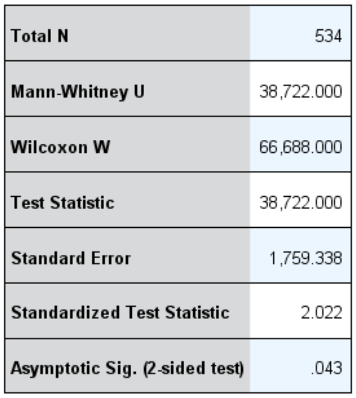


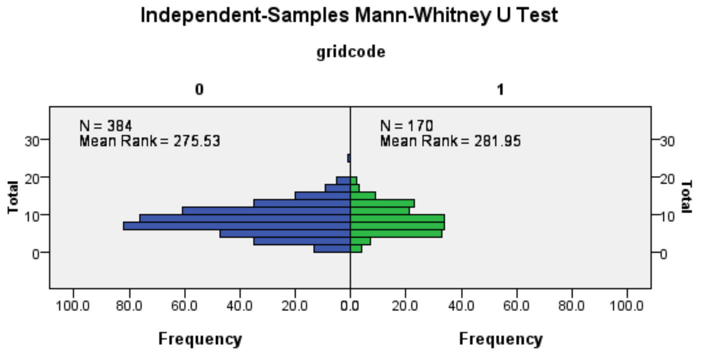
Figure 20: Results of a viewshed analysis from the shade shack at Crystal Forest Trail. The shade shack is again built on an incline at the southwest corner of the trail. This location promotes visibility from the northernmost part of the trail, but makes it difficult to see the eastern part of the trail from the shade shack due to the steep hills in that area.

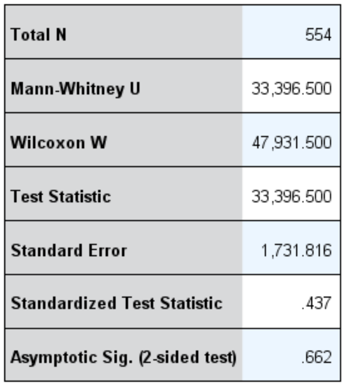




Total N	534
Mann-Whitney U	38,722.000
Wilcoxon W	66,688.000
Test Statistic	38,722.000
Standard Error	1,759.338
Standardized Test Statistic	2.022
Asymptotic Sig. (2-sided test)	.043

Figure 21: Results of a Mann-Whitney U Test between visible and non-visible points at Long Logs Trail. The median value in the non-visible group is 7 and the median value in the visible group is 8. The distribution of the two groups differed significantly (Mann-Whitney U = 38,722, $n_1 = 298$, $n_2 = 236$, $P < 0.05$ two tailed).

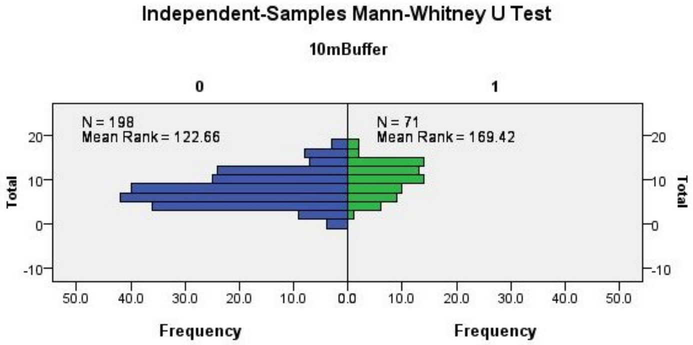


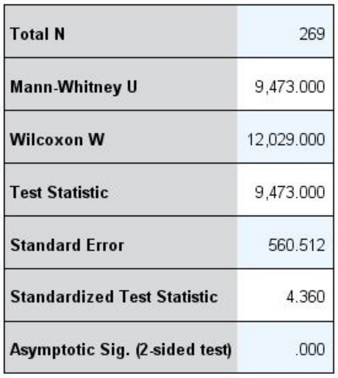


Total N	554
Mann-Whitney U	33,396.500
Wilcoxon W	47,931.500
Test Statistic	33,396.500
Standard Error	1,731.816
Standardized Test Statistic	.437
Asymptotic Sig. (2-sided test)	.662

Figure 22: Results of a Mann-Whitney U Test between visible and non-visible points at Crystal Forest Trail. The median value in the non-visible group is 8 and the median value in the visible group is 8. The distribution of the two groups did not differ significantly (Mann-Whitney U = 33,396.5, n_1 = 384, n_2 =170, $P > 0.05$ two tailed).

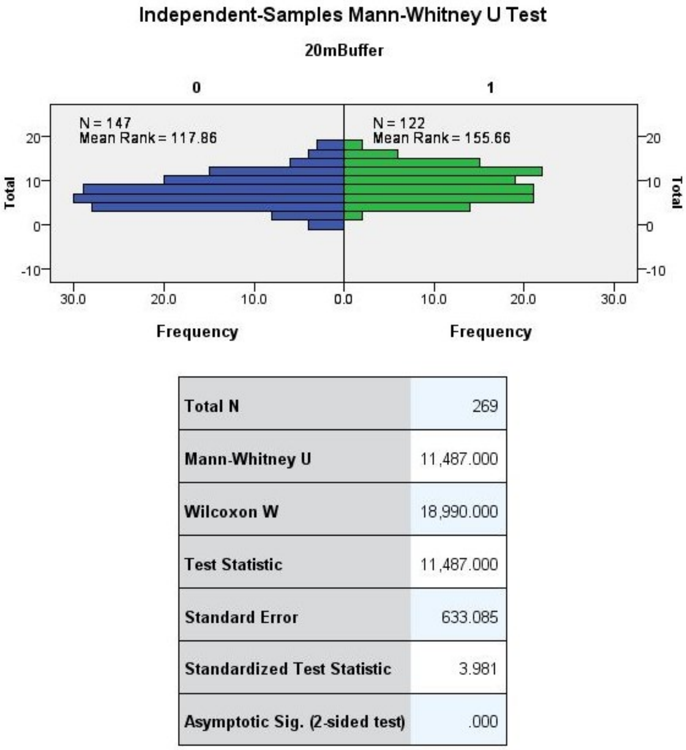
Finally, the points are categorized as being within 10 meters, 20 meters, 30 meters, or greater than 30 meters away from a trail. The results of a Mann-Whitney U test conducted on each of the nine resulting pairings can be found in Figures 23-31 below.





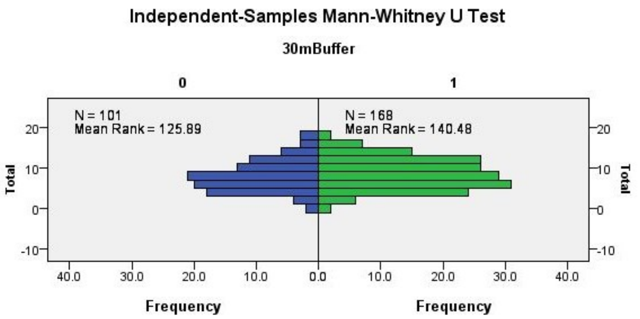
Total N	269
Mann-Whitney U	9,473.000
Wilcoxon W	12,029.000
Test Statistic	9,473.000
Standard Error	560.512
Standardized Test Statistic	4.360
Asymptotic Sig. (2-sided test)	.000

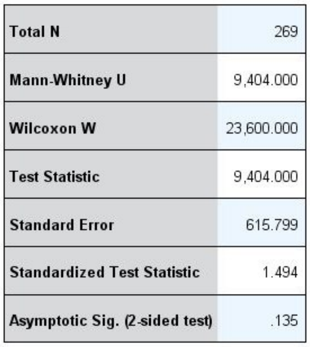
Figure 23: Results of a Mann-Whitney U Test between points inside and outside of the 10 meter buffer at Giant Logs Trail. The median value in the group inside the buffer is 10 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 9,473, n_1 = 198, n_2 =71, $P > 0.05$ two tailed).



Total N	269
Mann-Whitney U	11,487.000
Wilcoxon W	18,990.000
Test Statistic	11,487.000
Standard Error	633.085
Standardized Test Statistic	3.981
Asymptotic Sig. (2-sided test)	.000

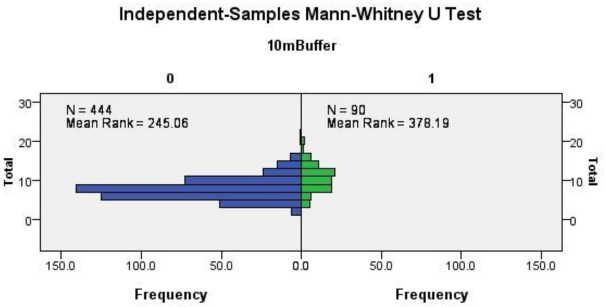
Figure 24: Results of a Mann-Whitney U Test between points inside and outside of the 20 meter buffer at Giant Logs Trail. The median value in the group inside the buffer is 9 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 11,487, n_1 = 147, n_2 =122, $P > 0.05$ two tailed).





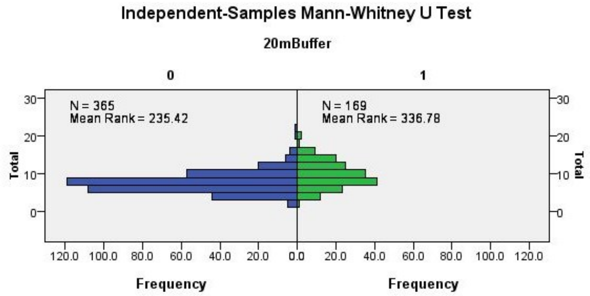
Total N	269
Mann-Whitney U	9,404.000
Wilcoxon W	23,600.000
Test Statistic	9,404.000
Standard Error	615.799
Standardized Test Statistic	1.494
Asymptotic Sig. (2-sided test)	.135

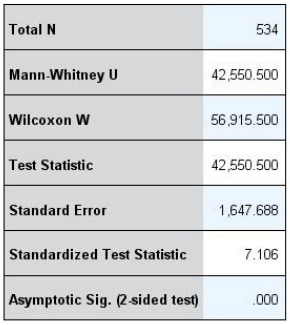
Figure 25: Results of a Mann-Whitney U Test between points inside and outside of the 30 meter buffer at Giant Logs Trail. The median value in the group inside the buffer is 8 and the median value in the outside group is 7. The distribution of the two groups does not differ significantly (Mann-Whitney U = 9,404, $n_1 = 101$, $n_2 = 168$, $P < 0.05$ two tailed).



Total N	534
Mann-Whitney U	29,942.000
Wilcoxon W	34,037.000
Test Statistic	29,942.000
Standard Error	1,326.166
Standardized Test Statistic	7.512
Asymptotic Sig. (2-sided test)	.000

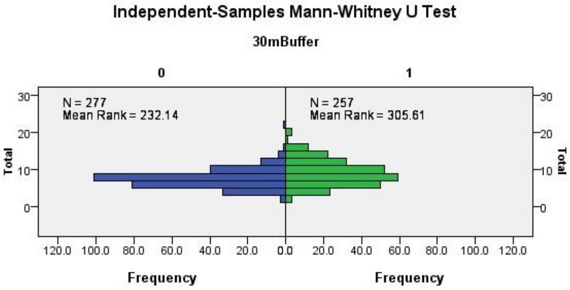
Figure 26: Results of a Mann-Whitney U Test between points inside and outside of the 10 meter buffer at Long Logs Trail. The median value in the group inside the buffer is 10 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 29,942, n_1 = 444, n_2 =90, $P > 0.05$ two tailed).

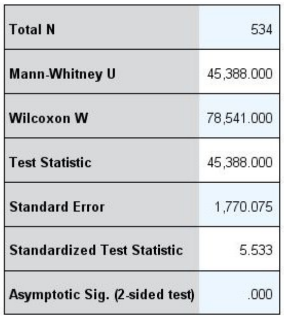




Total N	534
Mann-Whitney U	42,550.500
Wilcoxon W	56,915.500
Test Statistic	42,550.500
Standard Error	1,647.688
Standardized Test Statistic	7.106
Asymptotic Sig. (2-sided test)	.000

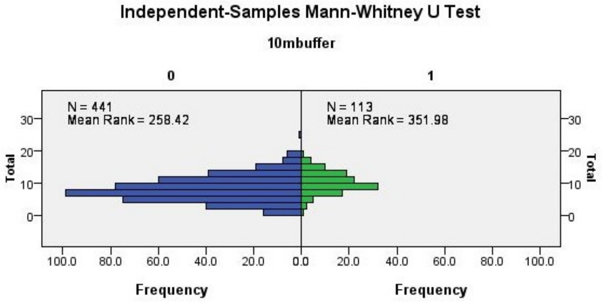
Figure 27: Results of a Mann-Whitney U Test between points inside and outside of the 20 meter buffer at Long Logs Trail. The median value in the group inside the buffer is 9 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 42,550.5, n_1 = 365, n_2 =169, $P > 0.05$ two tailed).

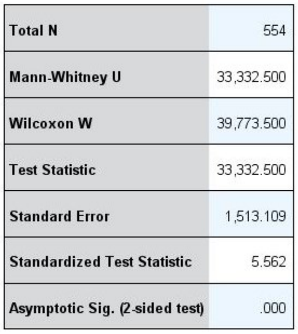




Total N	534
Mann-Whitney U	45,388.000
Wilcoxon W	78,541.000
Test Statistic	45,388.000
Standard Error	1,770.075
Standardized Test Statistic	5.533
Asymptotic Sig. (2-sided test)	.000

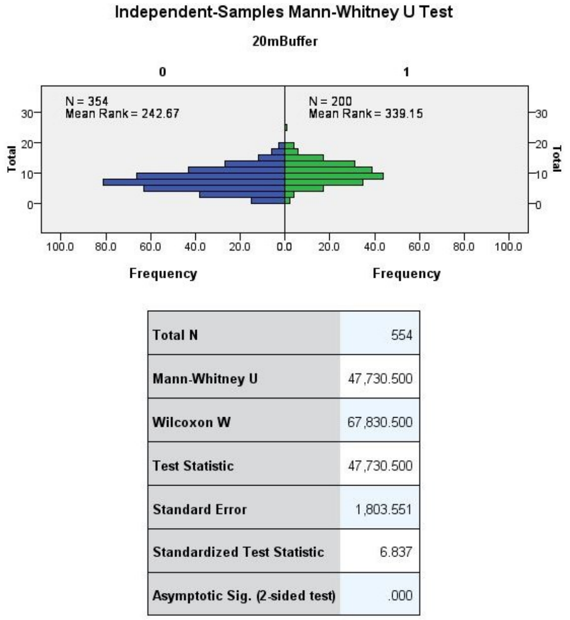
Figure 28: Results of a Mann-Whitney U Test between points inside and outside of the 30 meter buffer at Long Logs Trail. The median value in the group inside the buffer is 8 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 45,388, $n_1 = 277$, $n_2 = 257$, $P > 0.05$ two tailed).





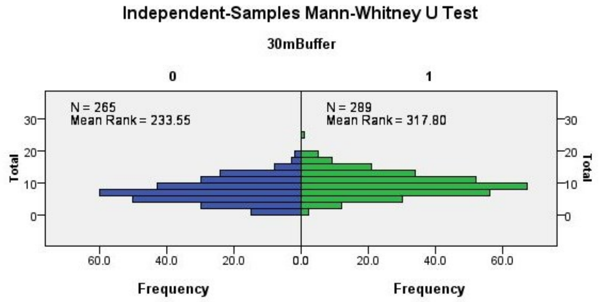
Total N	554
Mann-Whitney U	33,332.500
Wilcoxon W	39,773.500
Test Statistic	33,332.500
Standard Error	1,513.109
Standardized Test Statistic	5.562
Asymptotic Sig. (2-sided test)	.000

Figure 29: Results of a Mann-Whitney U Test between points inside and outside of the 10 meter buffer at Crystal Forest Trail. The median value in the group inside the buffer is 9 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 33,332.5, n_1 = 441, n_2 =113, $P > 0.05$ two tailed).



Total N	554
Mann-Whitney U	47,730.500
Wilcoxon W	67,830.500
Test Statistic	47,730.500
Standard Error	1,803.551
Standardized Test Statistic	6.837
Asymptotic Sig. (2-sided test)	.000

Figure 30: Results of a Mann-Whitney U Test between points inside and outside of the 20 meter buffer at Crystal Forest Trail. The median value in the group inside the buffer is 9 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 47,730.5, n_1 = 354, n_2 =200, $P > 0.05$ two tailed).



Total N	554
Mann-Whitney U	49,939.500
Wilcoxon W	91,844.500
Test Statistic	49,939.500
Standard Error	1,875.788
Standardized Test Statistic	6.209
Asymptotic Sig. (2-sided test)	.000

Figure 31: Results of a Mann-Whitney U Test between points inside and outside of the 30 meter buffer at Crystal Forest Trail. The median value in the group inside the buffer is 9 and the median value in the outside group is 7. The distribution of the two groups differs significantly (Mann-Whitney U = 49,939.5, n_1 = 265, n_2 =289, $P > 0.05$ two tailed).

3.4: Discussion

3.4.1: Establishing a Baseline of Impacts

Petrified Forest National Park hosts a long history of human impacts (e.g Lubick 1996). Anthropogenic activity continues today with the majority of the park being open to hiking and camping, including permit-based trips into the wilderness area. Any new baseline using an impact assessment tool must therefore be conducted with the understanding that this area is not, in fact, pristine (Brooks and Champ 2006, Bushell et al. 2003, Marris 2009).

The purpose of initial impact assessments such as the one conducted here, therefore, rests in establishing baseline measurements of areas of concern (Salafsky and Margoluis 1999). Creating a known baseline for a conservation area gives researchers and park managers a starting point towards building and measuring progress towards reasonable conservation goals (Tear et al. 2005). It also reduces the risk of a shifting baseline of disturbance in that area over time, that occurs when each successive park manager or researcher implicitly assumes that the condition of the area when they come on board as the starting point for any goal setting (Pauly 1995). This baseline makes it possible to make accurate conjectures assessing current methods employed by the park to modify undesirable visitor behavior.

Taking baseline measurements using a data collection methodology that can be repeated has the added benefit of helping to establish a sampling strategy that can be repeated over time. This yields both a quantified starting point to work with moving forward, and also sets guidelines for resampling an area over time to determine the efficacy of conservation and (if applicable) tourism management strategies (Hockings et al. 2000). The hope is that the rapid assessment method employed here, the data set gathered, and subsequent analyses can remain relevant over time (Tear et al. 2005).

3.4.2: Indicator Weighting

Prior to running interpolations for the surveyed trails, a weighting system was considered in order to create a "weighted total score." The weighting system would assign a multiplier of three to all of the anthropogenic indicators and a multiplier of two assigned to indicators such as erosion and soil disturbance that are sometimes the result of natural processes. This would result in a total score with an emphasis on anthropogenic impacts while still accounting for natural impacts as part of an overall assessment.

When creating and executing a rapid assessment methodology, there is some precedent that supports assigning weights to some of the indicators before adding them up to create a total score (e.g. Allen 2009, Roovers, Baeten and Hermy 2004, Bruner et al. 2001, Ervin 2003b, Ervin 2003a). Assigning weights to certain indicators allows park managers to identify those indicators that are of higher interest or importance to them, while still exploring those spatial trends in the context of the remaining indicators (Bruner et al. 2001). When a weighted total score is interpolated, it can highlight areas that should be a higher priority to park managers who are concerned with tourism and its impacts on protected areas more effectively than a simple total of all indicators.

In the case of the Petrified Forest National Park dataset, though, weighting certain indicators could not be justified. Adding weights to certain indicators in this case may be useful to park managers as they explore the data, but it is not scientifically relevant for the purposes of a raw data analysis. Assigning weights to certain indicators can lead to an artificial inflation of the overall index score without necessarily contributing to the overall analysis (Johnstone 2003). This is particularly true when data collection is conducted for the purpose of establishing a baseline that will be used as a starting point for resampling over time, which is one of the intended purposes for the data collected at Petrified Forest National Park (Tear et al. 2005).

Furthermore, the data collected by the Desert Impact Assessment is quantified using an ordinal scale, which is already somewhat subjective in spite of a fairly comprehensive written guideline sheet (Acar and Sakici 2008). Weighting some indicators more heavily than others would compound the subjective nature of the data without providing a real, measurable benefit. Since indicators were recorded individually in the field, the option also exists to run an analysis using only the indicators that are of interest—the ones that might have been candidates for weighting. This is demonstrated by identifying the indicators that can only occur as the result of anthropogenic activity (vandalism, trash, trail spur, historic and prehistoric impacts, and modern anthropogenic impacts) to create an anthropogenic index. An interpolation using the anthropogenic indicators is performed at each of the three study sites.

3.4.3: Exploring Interpolations at the Three Trails

By examining all three of the trails and the distribution of impacts, some conclusions about visitor behavior in the southern part of Petrified Forest National Park can be drawn. All of the trails share certain characteristics that are highlighted by the IDW analysis. Most notably, the highest impact scores in all three trails falls immediately adjacent to the trails themselves (see Figures 12, 15, and 18). The higher assessment scores drop quickly moving away from the trails in either direction, although the scores remain higher inside of the trail loop than outside of the loop at the three trails. Additionally, all of the surveyed trails showed evidence of trail spurs cutting into the internal loop of the trail, with much less prevalence of unofficial footpaths heading away from the trail towards the wilderness areas. A notable exception to this is the footpath at the Giant Logs Trail (see Figure 12); when this well-defined footpath was noted in the field, the park archaeologist confirmed that it is a formerly-maintained park trail that is still unofficially open to visitation. This is reflected in the interpolated scores at Giant Logs, and is discussed in further detail below.

Washes at all of the trail areas should be of concern to park personnel. All of the trails show signs of some natural impact from washes. The washes cutting through the trail loops create gaps in the petrified wood deposits by washing the pieces away as they erode downhill. At two of the three trail sites the washes directly threaten the integrity of the trail resulting in very poor trail conditions that are difficult to traverse. Most of the washes that present as flat, sandy areas also showed clear signs of use as makeshift footpaths, particularly where they offer an easy-to-follow route into the interior part of the trail.

These trends of greater impact close to trails are consistent with those from other surveyed trail structures where visitors who do stray from the trails are not likely to go far due to implied and overt social pressure to conform to park rules (Deluca et al. 1998, Nepal and Nepal 2004, Christiensen and Dustin 1989). Evidence suggests that although the park cannot maintain a constant human presence at the trails during operating hours, there is a certain amount of respect for requests to visitors to remain on the trails. Although visitors seem to perceive the inside loop as an area that is more acceptable to enter, they are generally constrained within that area. Such social pressure is very much in evidence at Petrified Forest National Park where park rules are enforced by visitors; during data collection participants were frequently confronted by tourists while out in the field with demands to return to the designated trail. This perceived responsibility for some visitors to uphold park rules and to hold others to that standard is consistent with research in other protected areas (Ajzen et al. 2009, Christiensen and Dustin 1989).

Finally, at all three trails the areas that contained the highest density of petrified wood (see Figures 10, 13, and 16) clearly experienced a large amount of modern foot traffic. These thick deposits of petrified wood earned the highest anthropogenic impact scores (see Figures 11, 14, and 17). Most of the trail spurs led directly to these deposits and terminated there. To some extent these impacts cannot be avoided regardless of efforts made by the park to enforce their rules because of the close proximity of petrified wood deposits to trails (McKercher, Weber and du Cros 2008).

Some visitors will always feel that they are within their rights to leave the trail, and the easily-seen petrified wood pieces are an attractive temptation to visit (Ajzen et al. 2009, Christiensen and Dustin 1989, Bishop 2003, McKercher et al. 2008). Many of these visitors rationalize their behavior, believing that the rules and the laws regarding petrified wood vandalism and theft do not apply to them, and research suggests that it is unlikely that any deterrent the park implements will reach all of them (e.g. Deacon 2006, McKercher et al. 2008, Ajzen et al. 2009, Christiensen and Dustin 1989, Randall and Rollins 2009).

The remainder of this section analyzes interpolations for the three trail areas, with an eye towards park management issues.

3.4.4: Exploring the Giant Logs Interpolations

Giant Logs Trail is unique to the three surveyed trails in a few ways. The trail head is accessible from the rear of the Rainbow Forest Museum, and a panoramic window makes the majority of the trail area visible to park personnel. It is also the site of many visitor outreach programs. This makes Giant Logs one of the highest-trafficked trails in the park, as well as the most consistently monitored trail in the southern part of the park.

With its network of crisscrossing trail segments inside the main trail loop, Giant Logs also features also unique layout among the three surveyed trails. These trail segments divide the inside of the loop into a series of small sections that offer visitors the opportunity to travel into the trail's interior area without negative consequences. The trail segments made this the most difficult of the three trails to survey evenly. The 15 m transects did not mesh well with the small sections of the inner trail, and in several cases surveyors shortened the distance between stops to ensure that multiple points were surveyed within each small section.

In addition to the highly visible Rainbow Forest Museum and the persistent presence of park personnel, low wooden fences border parts of the interior trail segments. The fences are placed inconstantly and are very short – generally extending for less than 3 meters. It may be possible in the future to explore the efficacy of the fences as a deterrent to leaving the trails with points surveyed closer together, but the 15 m distance between points in this dataset made such an analysis impossible.

The interpolation of total impact in the vicinity of the trail seems to reflect the high visibility of the majority of the southern part of the trail (see Figure 12). Much of the impact that was picked up by the index on the southern part of the trail is the result of erosion and soil disturbance from washes that crisscross the area, and not as the result of visitors leaving the trail and intentionally disturbing the area. Little evidence suggested that visitors strayed far from this part of the trail, which may be partially attributed to the southern part of the trail facing the park thoroughfare and lacking interesting physical characteristics.

The only part of the trail that is not easily visible from the Rainbow Forest Museum is the northern part of the trail; this segment of the trail is obscured by a large rocky outcrop (see Figure 32). The obscured area can be clearly seen as an area of higher impact when the total score is interpolated over the entire trail area (see Figure 12). The rocky outcrop itself is an attractive place for visitors to climb off-trail, and it provides an opportunity for visitors to leave the trail without feeling visible from the museum. This is reflected in the interpolation, where much of the highest impact in the entire trail area occurs on and immediately behind the outcrop.

Figure 32: Outcrop at Giant Logs Trail from the perspective of the Rainbow Forest Museum. This outcrop blocks the view of the northern part of the trail from the museum and is also attractive for visitors to climb on due to its immediate proximity to the trail.

Most of the evidence of tourists leaving the trail is on the northwestern part of the trail, which is also partly obscured by the rocky outcrop. In this part of the trail, a large, well-traveled foot path leads visitors off of the established trail and out of sight of the museum. The footpath was once a maintained park trail that remains clearly visible to visitors. No signage exists stating that this area is off-limits, which creates confusion among visitors who are unsure of whether they are permitted off the paved trail in this area. This area was the most impacted part of the entire Giant Logs Trail, in large part because the trail is no longer officially recognized as a park trail and must therefore be scored as a 3 on the DIA index.

The northeastern part of the trail is directly adjacent to and easily accessible from park employee housing. This area is partially hidden from the trail by a short drop-off approximately 50 yards away from the trail. The drop-off showed signs of recreational use by either park personnel or by visitors who stumbled across the relative anonymity of that small rise. Compared to the surrounding area it was very disturbed; this can be seen on the interpolation as two small, red circles off the northeastern tip of the trail on both the anthropogenic score and the total score (see Figures 11 and 12).

An interpolation of the petrified wood indicator at Giant Logs makes it clear that although the trail sits in the center of a deposit of petrified wood the density at this trail is lower than the density at Long Logs and Crystal Forest Trails. These lower values should not be entirely unexpected. The petrified wood deposit at Giant Logs is naturally not as dense or as extensive as the deposits at the other trails, which is evidenced by the lower density of petrified wood pieces outside of the immediate trail area where there is less evidence of anthropogenic activity (see Figures 10 and 11).

3.4.5: Exploring the Long Logs Interpolations

The Long Logs trailhead serves both the Long Logs Trail and the Agate House Trail. Only the Long Logs Trail was assessed in the field. Although the Long Logs Trail was once accessible to drive-up traffic with a parking lot at the trail head, vehicular access to the trail was removed in response to a mandate in the 2004 general management plan (National Park Service 2004). Jason Theueur, the park archaeologist, selected this trail for assessment so that it could be monitored over time to determine whether the restricted walk-up access allowed the area to recover noticeably from the impact of high tourist traffic.

Of the three surveyed trails, Long Logs is the most obviously in need of improved maintenance and upkeep. The interpolation of total impact across this area (see Figure 15) shows that there are high levels of impact along nearly the entire trail. A large part of the southeastern segment of the trail is in danger of being eroded away completely into a wash that encroaches on the trail. Walking along this stretch is often difficult due to the uneven surface; in many places the asphalt is cracked with large pieces missing entirely, and the edges of the wash are littered with black asphalt pebbles. As a direct result of the cracked trail, there is a large trampled area on the southeastern part of the trail where people clearly walk off the trail on the flatter dirt surface.

The farthest eastern part of the Long Logs Trail abuts against a large outcrop of colorful teepees that run alongside the trail. The points surveyed in that area show evidence of anthropogenic activity along the edge of the teepees, which were not climbed by volunteers participating in the point survey. The teepees themselves showed signs of erosion and other natural processes, but they rise steeply enough to be easily climbed or otherwise impacted by visitors. At one point, however, the trail cuts between the main body of teepees and a single smaller teepee that falls inside the trail loop (see Figure 33). The slope of this smaller teepee is much shallower than the others nearby (see Figure 34) and shows clear evidence that visitors climb it and slide down the sides. This activity hastens the erosion process and creates long cracks in the hard crust that maintains the teepee's shape. Dirt from the teepee pools along its sides and is tracked onto the trail by anthropogenic activity and by the area's ubiquitous washes.

Figure 33: Long Logs Trail cuts between two teepees, creating an area that is vulnerable to erosion.

Figure 34: Profile view of the teepee formation inside of the Long Logs Trail loop (Source: Panoramio.com user bcm79)

The northern part of the trail consists of a long jut that is very narrow in width—approximately 17 yards across. The jut gives visitors the opportunity to walk around large pieces of petrified wood and turns back after circling around a large rocky outcrop. Many large pieces of petrified wood lay between the two sides of the trail; they are within only a few steps of either side of the paved trail. There is clear evidence that visitors climb on the logs; during field work, tourists were seen mounting the logs and taking pictures. The trampled vegetation on the ground and disturbed soil with many footprints provide additional evidence that tourists pass through this part of the trail from one side to the other without concern for staying on the pavement.

At the former parking lot the trailhead is split into two parts, allowing visitors to choose which direction they would like to travel around the trail. The western part of the trailhead leads more directly to the Agate House Trail, and the eastern part of the trailhead leads directly into the Long Logs Trail loop. Along the western side of the study area the trail is split into two parts that creates another narrow corridor bounded by trail similar to the one described above. Another area of high anthropogenic impact falls inside that corridor between these trailheads on the western side of the trail (see Figures 14 and 15). Similar to the impacts from the narrow jut on the northern part of the trail, there is evidence of many trail spurs where people take shortcuts between the two trails. The entire area is disturbed with footprints and associated surface disturbance, and there is evidence that many people pick up and move the petrified wood pieces that are plentiful in that space.

All of areas that are the most disturbed areas along the trail correspond very closely with the interpolation of the anthropogenic indicators, indicating that human activity along Long Logs Trail is a primary contributor to the trail's disturbed condition (see Figures 14 and 15). Furthermore, the areas that show the highest overall disturbance coincide closely to the areas with a high density of petrified wood pieces (see Figure 13 This suggests that the proximity of the trail to petrified wood deposits acts as a powerful draw to visitors who would like to view the petrified wood deposits up close.

It is not possible to draw conclusions about whether closing Long Logs to public drive-up traffic is effectively helping reduce anthropogenic impacts within the trail area. No baseline of impact was established at this trail prior to restricting access to the trailhead, nor was any baseline of impact established at Crystal Forest or another, similar trail for future comparison purposes. Without baseline information to refer to, it is impossible to draw conclusions about whether the changes implemented by the park are successfully helping to rehabilitate the area.

3.4.6: Exploring the Crystal Forest Interpolations

The Crystal Forest Trail area is located several miles north of the other study sites and is accessible to drive-up traffic. The first part of the trail leads directly to a shade shack that overlooks the area. The shade shack contains historic and geologic information for visitors inside of the shelter. Leading up to the shelter are several educational signs, as well as a plethora of warnings to stay on the trail and to refrain from touching the petrified wood pieces. From there, visitors can choose which direction they would like to take to traverse the trail.

Out of the three study sites, the history of Crystal Forest is the richest and most physically destructive to the area. It is the site of a prehistoric quarry where tools were created using the durable and pretty petrified wood found in abundance (Lubick 1996). Later, before the area became part of a protected National Monument that criminalized the theft of petrified wood, a carriage route ran close to the present-day trail and stopped in this area to allow passengers the chance to leave the carriage to admire the scenic beauty (Lubick 1996, National Park Service 2013). When the trail at Crystal Forest was constructed by the CCC, very little care was taken to minimize the impact that the workers left on the area. This can be seen by the myriad historic artifacts littering the trail area, such as glass bottles and aluminum cans that can be dated back to that time by the Park Archaeologist. There are also shattered remnants of petrified wood logs that were blown up with dynamite during trail construction. According to the Park Archaeologist, the explosions were generally performed for recreational purposes and not to support trail construction.

Similar to the Long Logs Trail, interpolation of the total score (see Figure 18) shows that the area in the immediate vicinity of the trail itself is heavily disturbed. Interpolation of the anthropogenic indicators (see Figure 17) shows that areas with clear signs of human activity correspond very closely to the areas of high impact near the trail, indicating that human off-trail activity plays a large role in the notable impact observed at this trail. This is further confirmed by field observations recorded in comments, which include many notes where participants observed people leaving the trail to cut across sharp corners or to get close to the large petrified logs that the trail was built to show off.

There are relatively few areas at Crystal Forest where it is appealing to visitors to leave the trail traveling away from the inner loop. Most of the visually appealing large pieces of wood are located within the inside loop or close enough to the trail on the outside loop to satisfy visitor curiosity. The steep drop-offs that border the eastern and northern parts of the trail discourage visitors from straying away from the trail in those directions, and the park’s main thoroughfare acts as a deterrent to visitors who might leave the trail traveling east. A notable exception to the lesser prevalence of visitors moving away from the trails is a system of washes on the southeastern part of the trail, which does offer visitors an easy opportunity to leave the trail without being easily observed. This is reflected in the interpolations.

The inside loop of the Crystal Forest Trail is the most consistently disturbed of all of the surveyed sites, logging the highest scores on the DIA index and showing signs of high impact throughout. The most disturbed areas occur along washes that offer easily accessible flat, sandy paths. Inside the trail loop, a series of washes pass over the trail and terminate at large deposits of petrified wood and a few entire petrified logs. Evidence of anthropogenic activity along these washes can be easily seen in the form of many footprints; in some cases, the washes are so well traveled that they are considered trail spurs. Although these washes cannot necessarily be diverted, this is one area where additional signage or the construction of nominal barriers such as the knee-high fences at Giant Logs Trail could make a difference in the amount of off-trail foot traffic.

The trail cuts through a large deposit of petrified wood that is presently divided into three well-defined, dense deposits ranging along the western and southern parts of the trail area. Within approximately 15 meters of where the trail cuts through this deposit petrified wood, pieces are very scarce (see Figure 16). Along the western side of the trail and abutting against the parking lot, this can be partially attributed to a wash that carries any pieces of wood that might erode out of the ground into the center of the trail loop where there is a large deposit.

The thickest and least disturbed part of the petrified wood deposit falls outside of the trail loop to the south. This part of the deposit is not as crisscrossed by washes as the part to the north, limiting the natural movement of the petrified wood pieces in that area. Furthermore, this deposit of petrified wood is largely obscured from the trail by a hill, limiting the temptation for visitors to leave the trail and explore this area further. Since visitors must climb the hill and put themselves in a very visible position in order to reach this part of the deposit, the hill serves a secondary purpose in protecting this area from anthropogenic activity. This area shows the least evidence of anthropogenic activity of the entire surveyed area with the exception of evidence of a fire near a large log on the southern side of the hill. This can be clearly seen on both the anthropogenic interpolation and the total interpolation (see Figures 17 and 18).

There is very little petrified wood in the area closest to the parking lot, but this lack may be the result of natural processes as much as a result of anthropogenic impacts. This area is dominated by a soft sandy surface that is not covered by desert pavement or a soil crust. Although there are many footprints in this area, and visitors were frequently seen walking off-trail to take pictures of the scenic view to the north and west of the trail, there are no indications to suggest that there is a large amount of petrified wood for them to disturb or steal in this area.

The eastern part of the trail is also sparsely populated by petrified wood pieces, although again this may be the result of natural processes more than anthropogenic impacts. This region is dominated by steep hills that are covered in a thick soil crust with small rounded pebbles eroding out of the surface. The hills extend into narrow ridges that fall away steeply on both sides of the trail. The ridges are treacherous due to the small pebbles, and can be dangerous on windy days. There are no measures to prevent people from walking onto these ridges on either side of the trail, which could be a liability to the park.

3.4.7: Viewshed Analysis

Viewshed is an important consideration in establishing nature tourism amenities such as trails (Bishop 2003, Sang, Miller and Ode 2008). This concept can be used to ensure that trails are constructed within sight of the interesting and beautiful features that the conservation area is meant to protect (Bacon 1995, Nepal and Nepal 2004). Considering viewshed along a trail's intended location can also be useful during the trail planning process to help reduce the visibility of manmade structures and maximize the naturalness of the trail's overlooks (Bacon 1995, Wilson, Lindsey and Liu 2008).

Constructing signs and structures that are easily visible from large swaths of a trail in order to remind visitors to remain on trails is another way that parks can take advantage of viewshed (Bishop 2003, Pattengill-Semmens and Semmens 2003). The physical presence of park personnel at tourism sights can also act as a deterrent to unwanted behavior (Randall and Rollins 2009). At Crystal Forest Trail and Long Logs Trail, permanent shade shack structures that house park rangers and interpreters on a rotating basis are placed on overlooks that can see a large part of the trail. The intended purpose of these shade shack structures is twofold: first, to protect park personnel from the elements as they are stationed during rotating shifts at the trails; and second, to act as a visual deterrent to prevent people from leaving the trail.

Viewshed analysis is frequently used to determine the potential visual impact of new structures on an environment (e.g. Bishop 2003, Mouffis et al. 2008, Bishop 2002). The surveyed points at Crystal Forest Trail and Long Logs Trail, offer an opportunity to explore the relationship between the existing shade shacks and their respective trail environments. A viewshed analysis (see Figures 19 and 20) allows the points at each trail to be categorized as "visible" and "not visible" from the observer point of the shade shack. The point groups can then be analyzed to determine whether there is a substantial difference between the total impact observed at the visible points and the non-visible points.

A Mann-Whitney U test on the Long Logs points (see Figure 21) reveals a slight, but significant ($P > 0.05$) difference between the two bodies of points at that trail. Unexpectedly, the points within the viewshed are slightly more disturbed than the points outside of the viewshed: the median value of points inside the viewshed is 7 and the median for points outside of the viewshed is 8 (U = 38,722, $n_1 = 298$, $n_2 = 236$, $P < 0.05$ two tailed). A Mann-Whitney U test on the Crystal Forest points (see Figure 18) shows no significant difference between the visible and non-visible points at that location.

Prior to the construction of the shade shacks, no baseline of disturbance in these trail areas was ever established. This makes good conclusions regarding possible reasons why the areas within view of the shade shacks are equally or slightly more impacted than the areas outside of the viewshed difficult to draw. For example, the assumption that shade shacks might be a deterrent to undesirable visitor behavior precipitated their construction on higher ground overlooking the most disturbed parts of the trail system. Greater human impacts in those areas prior to construction of the shade shacks may be the cause of the slightly higher median score at Long Logs Trail despite some possible recovery of the area.

3.4.8: Buffer Analysis

Determining the distance within which the construction of a trail may create the largest environmental impact as a result of anthropogenic activity is another important consideration (Anthony 2007). Knowledge of the distances that visitors tend to travel away from the trail within a particular park can be influential to the placement of future trails. This is particularly vital information when sensitive areas that contain heritage artifacts that are not open to the public are considered. There are many such areas within Petrified Forest National Park, which makes this knowledge a powerful component of plans for the construction of new trail systems in the expansion lands that will be acquired by the park.

The point data collected at Petrified Forest National Park can be used to explore whether distance decay exists between the impact scores closer to the trail and the impact scores farther away from the trail at 10, 20, and 30 meter distances. The results of these tests for each of the three trails can be seen in Figures 22-31 in the Results section, and are summarized in Table 4 below.

	10m Inside	**10m Outside**	**20m Inside**	**20m Outside**	**30m Inside**	**30m Outside**
Crystal Forest	9	7	9	7	9	7
Long Logs	10	7	9	7	8	7
Giant Logs	10	7	9	7	8*	7*

*Value is not significant at $p > 0.05$.

Table 4: Median values of points inside and outside the specified buffered distances away from each trail at Petrified Forest National Park.

At every trail the median value of all points within 10 meters and 20 meters of the trail is significantly higher than the value of points outside of that radius. At 30 meters away from the trail, a difference between the median values of the points inside the buffer and those outside of the buffer still exists, but at Giant Logs Trail that difference drops below a significance threshold of $p > 0.05$.

Both Giant Logs Trail and Long Logs Trail have a smaller difference in the median values of the two groups as the buffers grow to encompass points farther away from the trail. Crystal Forest Trail exhibits the same difference between the points within the buffer and those outside the buffer at all three thresholds. This may be partially due to the close proximity of a wilderness area, which some visitors access by traveling off the back of the trail at Crystal Forest Trail. The larger presence of historic and prehistoric impacts in the Crystal Forest Trail area compared to the areas occupied by the other two trails may also contribute to the lack of distance decay evident at that trail.

The buffer analysis creates evidence to support the belief that the areas closer to trails at Petrified Forest National Park are more impacted than those areas further away. Furthermore, the falling median values at Long Logs Trail and Giant Logs Trail moving farther away from the trail supports the existence of distance decay of measurable impacts moving away from the paved park trails.

3.5: Conclusions

Petrified Forest National Park, Arizona served as a study site to better assess the utility of the Desert Impact Analysis rapid assessment methodology adapted for arid and semi-arid environments is employed at. Ten indicators of impact were measured using an ordinal scale based on visual observation in the field (Moore and Polley 2007, Salafsky and Margoluis 1999). An eleventh indicator of petrified wood density was also gauged in order to support a separate analysis at the request of the Park Archaeologist. Using this index, three trails were surveyed using 15 m stratified random sampling to cover the entire interior loop of the trail areas and a buffer of 60 ms away from the trail (Bakus et al. 2006, Hedley and Buckland 2004).

The close proximity of stops while transects are conducted creates a body of point data that support an inverse distance weighting (IDW) analysis of the three surveyed trails to interpolate the point data across the entire trail area (Buckland, Burnham and Augustin 1998, Hedley and Buckland 2004, Hockings 1998). Furthermore, since indicators are assessed and recorded individually, they can be analyzed separately or in groups (Perez, Telfer and Ross 2003, Timko 2008). This presents park managers with incredible flexibility regarding which indicators they would like to explore. In this paper the total of the ten base indicators, the total of only the anthropogenic indicators, and the petrified wood indicator by itself are interpolated and analyzed for each trail to demonstrate the flexibility provided by the DIA index.

The analyses generated in this research is potentially useful to park management in order better direct present and future decision-making about the distribution of park resources (Stohlgren et al. 1997). As Petrified Forest National Park continues to acquire land as authorized by President George W. Bush in 2004, a unique opportunity to learn from the established trails within the park and use those results to reduce the impact of future trails presents itself (National Park Service 2013). The data and analyses obtained from the field assessment can be used in a number of different ways, now and in the future:

- Interpolations of the sums of multiple indicators allows a park manager to customize his or her exploration of the data by restricting the analysis to only the elements that are of immediate interest. The anthropogenic indicators used as an example in this paper are compared to a total score of interpolation to determine whether highly impacted areas suffer from particularly high evidence of human disturbance, or whether the disturbance may be partially attributed to natural causes.

- The interpolations make clear a trend that the inside of each of the trail loops experienced a consistently high amount of anthropogenic impact. The ground in the immediate vicinity of the trails (approximately 10-15 meters) was also consistently disturbed, but moving away from the trails, the scores quickly dropped. This indication that visitors tend to stay within the area defined by the trail, thereby turning that place into something of a sacrificial site, could potentially influence the location of future trails.

- The results from the field assessment can be used to establish a baseline condition at each of the three trails (Pauly 1995, Salafsky and Margoluis 1999, Tear et al. 2005). This helps prevent a shifting baseline, setting the foundation for any analysis that might take place if trails are surveyed again over time (Hockings et al. 2000, Parrish, Braun and Unnasch 2003b, Pauly 1995).

- An interpolation of the single petrified wood density indicator creates a surface at each site that shows the location and approximate outline of all of the large petrified wood deposits in the trail area. This establishes a separate baseline that can be used to monitor petrified wood deposits in the trail area to determine whether they are becoming less dense or smaller in size (Pauly 1995, Tear et al. 2005).

- Repeated survey can also be used to support a viewshed analysis from the observer point of a barrier or other method the park employs in an effort to keep visitors on the trail in order to determine whether these measures are effective (Christiensen and Dustin 1989, Schwartza et al. 2012, Bishop 2003). Measures that prove to be effective over time should be widely implemented at the new trails and perhaps considered for implementation at existing trails, while measures that are not statistically effective over time should be abandoned.

- Interpolations highlight areas where the trail is in need of maintenance. This becomes increasingly clear when comments for points in highly impacted areas are examined since poor trail conditions are frequently explained more clearly in a short-response field.

- Buffer analysis can be used to confirm distance decay of impacts moving away from trails. This analysis can also be used to determine an approximate sphere of influence of the trail area, where visitor use can be expected to create higher impacts on the environment and any physically or culturally sensitive resources.

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Chapter 4

CASE STUDY OF THE IMPLEMENTATION OF CROWDSOURCING AS A TRAIL MAINTENANCE TOOL AT TEMPE BUTTE PRESERVE, TEMPE, ARIZONA

4.1: Introduction

As the prevalence of nature tourism continues to increase (Schwartza, Stewarta and Backlundb 2012), monitoring protected environments and balancing conservation efforts with environmental tourism remain important issues for preserve designers and managers. Growing along with the interest in nature-based tourism are an array of individuals and organizations with an interest in the management of these protected areas, often for varied reasons which sometimes conflict with each other within the same space (Bushell et al. 2003, Hockings 1998). Stakeholders in any given park may range from the government, to non-profit groups, to private individuals and companies, and more; and each of these stakeholders typically demands some level of accountability from the park's management (Brown 2003, Bushell et al. 2003, Chase, MSchusler and Decker 2000).

Public interest in visiting protected spaces and enjoying the amenities that they offer continues an upward trajectory as well (c.f. Deacon 2006). The downside to this increased visitation rests in the greater impact that protected, often fragile areas face due to increased traffic and tourist usage (McArthur and Hall 1993, Moore and Polley 2007, Nepal and Nepal 2004). As a result, park staff are placed in a position where they must constantly seek new ways to balance the demands of visitation against the inevitable effect that such tourism will have on the environment that these areas are meant to protect (Bushell et al. 2003, Uddhammar 2006).

A number of data collection techniques designed to assist park personnel in conservation monitoring efforts over time are being developed in academia and field tested in protected areas worldwide (c.f. Andam et al. 2008, Ervin 2003a, Salafsky and Margoluis 1999, Scott, Abbit and Groves 2001a, Timko 2008). Many of these techniques are being created in response to a 2000 call for improvements to such methods (Hockings, Stolton and Dudley 2000).

4.1.1: Rapid Assessment Data Collection

Rapid assessment is a family of data collection techniques used to collect information about a relatively large area (c.f. Ervin 2003b). Developed to meet the criteria for a Level 1 assessment methodology (Hockings et al. 2000), rapid assessment provides a "quick and dirty" assessment of a protected area. Some techniques already exist for fragile environments with a large proportion of protected area such as rainforests (c.f. Courrau 1999), wetlands (c.f. Fennessy, Jacobs and Kentula 2007), and mountainous areas (c.f. Ervin 2003b). Their effectiveness varies, in large part because of the sweeping changes that must be made in order to alter the technique for each new environment to be assessed (c.f. Parrish, Braun and Unnasch 2003a, Timko 2008).

In order to gather accurate information about an environment's condition, it is important to tailor the methodology to the specific environment it seeks to maintain (Ervin 2003a); in other words, a rapid assessment technique designed for a rainforest will not give reliable information if used in other environments. This limits the usefulness of rapid assessment data collection technique in any given situation until it has been evaluated, field tested, and validated for each new environment (Ervin 2003b). Different ecoregions within the same general environmental type require additional refinements to ensure that the data collected is meaningful (Torrico and Janssens 2010).

One of the biggest challenges is that a one-size-fits-all management strategy may not be globally successful. Creating site-specific management plans with clear preservation goals, and monitoring protected areas to ensure that those goals are being met are vital steps towards a successful conservation effort (Deacon 2006, Ervin 2003a). Preserves with a unique or fragile resource demand unique assessment approaches, although there are currently no unified opinions regarding which areas or resources are in the greatest need of conservation efforts (Soutullo, De Castro and Urios 2008).

Compared to other ecological regions such as wetlands and rainforests that receive a great deal of conservation attention, arid and semi-arid environments remain relatively underserved by data collection techniques that are adapted to meet the particular needs of that environment (Whitfield and Reed 2012, Ludwig et al. 2006). At the same time, these areas tend to be overrepresented compared to other conserved spaces (Scott et al. 2001a, Scott et al. 2001b). Arid and semi-arid regions are particularly sensitive to disturbances that lead to land degradation such as off-trail anthropogenic activity (Okin, Murray and Schlesinger 2001), which other environments may be able to absorb more effectively.

Given the challenges in enforcing the implementation of a global framework, it is no surprise that development of monitoring systems that are unique to specific areas is a slow process. Neither is it surprising that existing systems are often designed for a single purpose without region-wide portability in mind. Current methods of assessing disturbance to desert environments are limited by scale and available technology. Some methodologies, such as the tool developed by Allen (2009) to monitor long-term anthropogenic impact of the Upper Sonoran Lifestyle, focus on measurements over a small scale (<2 meters) and may require the use of specialized equipment or training. Others methodologies for measuring impact in a desert environment rely on remotely-sensed imagery to allow for a broad assessment over a large area (Shupe and Marsh 2004).

No current rapid assessment method can be quickly and effectively applied in the field to determine impact within the intermediate scale of an arid or semi-arid environment preserve. In order to address this gap, an index must be designed to account for often-cited natural and anthropogenic indicators of disturbance in arid environments, while still being easy and cost-effective to use. Such an index must be an easy-to-grasp method that can be used to collect and aggregate basic information about the general status of protected areas quickly and easily. Although such an index has been designed and field tested (see Chapter 1), further adaptations may provide even more utility and flexibility in the way that it is implemented, particularly in areas frequented by the public.

4.1.2: Volunteered Geographic Information and Crowdsourcing

One characteristic that many field data collection techniques share is their time-consuming nature in the field (Hockings 1998, Hockings 2003, Hockings et al. 2000). Another is that they can often only be carried out in an official capacity by paid park officials or volunteer park stewards who are trained in the collection process (Phoenix 2012, Schwartza et al. 2012). Park personnel time is a valuable commodity, particularly in light of government budget cuts that continue to impact state and national parks (Schwartza et al. 2012). It is therefore prudent to explore the possibility of building on existing data collection techniques with the goal of modifying them to become less time consuming and potentially more accessible to members of the public who are willing to donate time and energy to improving the protected spaces they enjoy using — but who do not wish to make the commitment of becoming a volunteer park steward.

Increasingly, new trends in technology offer versatile possibilities. Of particular interest is the advent of crowdsourcing technology, which makes use of small bits of volunteered geographic information collected and contributed by a non-expect geographic community, also called *neogeographers* (Turner 2006, Haklay, Singleton and Parker 2008). Although the concept of turning to a decentralized group of people for information collection is not new (Butcher 1990), improvements in technology are allowing better and more creative use cases. Implementing crowdsourcing solutions to facilitate the development of large datasets is becoming an increasingly common tool in biodiversity and biology monitoring, as well as in conservation monitoring (e.g. Couvet et al. 2008, Danielsen et al. 2005, Connors, Lei and Kelly 2012).

A crowdsourcing system aimed at allowing casual, interested users of park resources to submit their feedback into a database can significantly reduce the amount of time that paid personnel must spend in the field watching for problems and concerns to address (Connors et al. 2012, Fraternali et al. 2012, Pedersen, Kearns and Kelly 2007). As information is submitted by users, it can then be aggregated into a report that can be used to highlight areas of interest or concern to park management (Connors et al. 2012, Fraternali et al. 2012).

This paper details the steps taken to transition a rapid assessment data collection methodology from an individualized task into a crowdsourced solution. As the methods section explains, the crowdsourcing interface uses a simplified version of a rapid assessment index, where users submit information about a point only if an indicator is observed in the field — as opposed to using transects to create a stratified random sampling scheme (Southwell 1994, Connors et al. 2012, Rinner, Kessler and Andrulis 2008, Sullivan et al. 2009). This paper details the creation of a beta version of a new crowdsourcing tool, as well as analysis of a field test conducted at Tempe Butte Preserve in Tempe, Sonoran Desert, Arizona.

4.2: Methods

4.2.1: Constructing a Crowdsourcing Trail Assessment Tool

A useful trail assessment crowdsourcing tool must be able to meet a number of criteria. This tool must be relatively easy to use with little or no training, but must still output meaningful information once a sufficient amount of data has been fed into it (Driedger et al. 2007, Newman et al. 2010). To support ease of use, there should not be any complicated measuring, and no specialized equipment must be required (Courrau 1999); instead, data collection must be limited to observations about specific places (c.f. Sullivan et al. 2009).

The publicly accessible part of the tool must be easy to find, both in the field and later, when the collected data are reported (Aanensen et al. 2009, Ghaemi et al. 2009). Visitors with good intentions cannot be counted on to have long attention spans (Moore and Polley 2007), meaning that the entire process must be fast and must require little time commitment. Finally, there must be a means of submitting collected information into the database that is complete with clear instructions (Aanensen et al. 2009, Fraternali et al. 2012). Any tool must accept information from the user and aggregate it in such a way that it can be accessed by a park manager who can interpret meaningful results from the output (Morehouse and O'Brien 2008). The remainder of this section details the development of a rapid assessment crowdsourcing technique in arid environments.

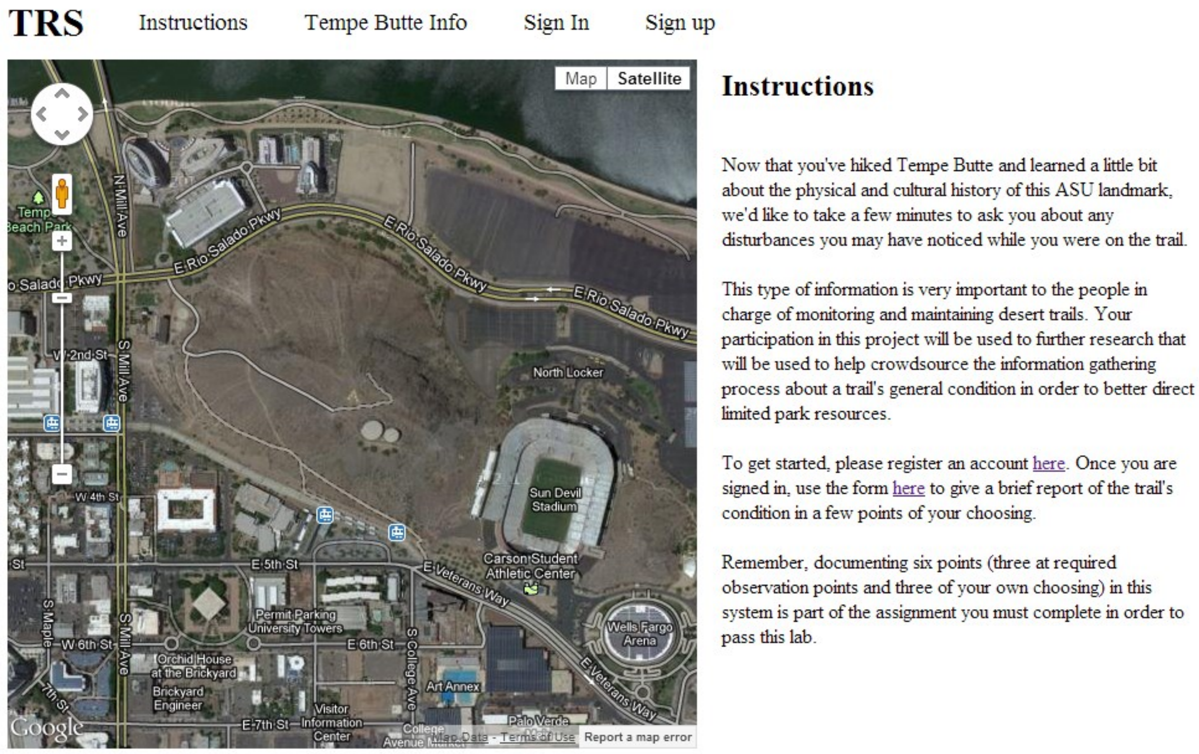
The study site selected for piloting is the City of Tempe preserve at Tempe Butte, located on the northern edge of the Arizona State University in Tempe, Arizona. This is area visited extensively by the general public interested in natural vegetation, prehistoric archaeological features such as petroglyphs, and the mountain terrain. Because several public trails are used each semester by introductory geography classes to complete lab assignments, Tempe Butte presented an excellent opportunity and an available audience to field test the crowdsourcing tool.

In order to allow the assessment technique to be used without a GPS unit and to help clarify the information this tool is designed to track, a single sheet of paper is prepared to be taken into the field with the user (see Appendix B). This sheet contains all of the instructions necessary to collect information, as well as an aerial photograph of the area of interest that could be used to plot the location of data points that were collected. For each point the student will indicate whether they noted any of the following characteristics they saw in the field:

- Erosion near trails
- Poor trail conditions
- Trash
- Dead or dying mature vegetation
- Unauthorized trails
- Graffiti or vandalism
- Animal sighting
- Other concerns

A comment field (other concerns) allows the student to add to their initial assessment or to elaborate about information that is outside the limitations of the basic form. Again, this form corresponds to the handout that the geography students received to fill out as part of their lab.

The second part of the process involved creating a website for users to visit upon completing their data collection in the field. This website needed to provide the core functionality for users to click the approximate location where they observed their point, and then to quickly and easily input the information that was collected. It was important that this process be standardized so that the information could be added to a database and retrieved later for assessment by park personnel.



Instructions

Now that you've hiked Tempe Butte and learned a little bit about the physical and cultural history of this ASU landmark, we'd like to take a few minutes to ask you about any disturbances you may have noticed while you were on the trail.

This type of information is very important to the people in charge of monitoring and maintaining desert trails. Your participation in this project will be used to further research that will be used to help crowdsource the information gathering process about a trail's general condition in order to better direct limited park resources.

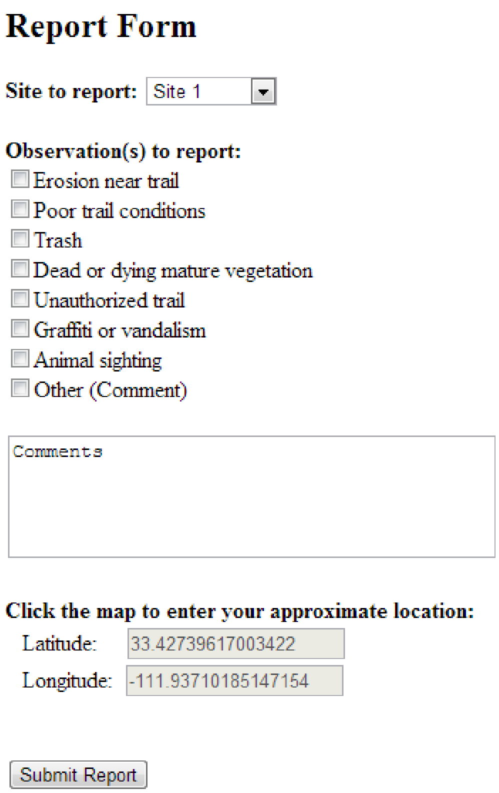
To get started, please register an account here. Once you are signed in, use the form here to give a brief report of the trail's condition in a few points of your choosing.

Remember, documenting six points (three at required observation points and three of your own choosing) in this system is part of the assignment you must complete in order to pass this lab.

Figure 26: The landing page for the crowdsourcing reporting website.

The website (see Figure 35) is modeled largely after the successful OakMapper website (http://oakmapper.org/) used to collect and map crowdsourced information about Sudden Oak Death syndrome (Kelly et al. 2007, Kelly, Tuxen and Kearns 2004, Kelly and Tuxen 2003). Of particular note is that the OakMapper website shifts away from an older trend for crowdsourcing websites to boast interfaces too technical for the average user; instead they used Google Maps for a simpler and more familiar interface (Connors et al. 2012, Elwood 2006).

Students can view instructions for their assignments and general information about Tempe Butte prior to completing the login process. The website's options expand once a user logs in, allowing the selection of multiple attributes of concern at each point submitted (see Figure 36). The foundation of the reporting system is a Google Maps interface running the v3 API. Students can only create reports when they are logged in so that points can be attributed to the submitting user. A database then provides the foundation for a backend design that can be queried later to display data.



Report Form

Site to report: Site 1

Observation(s) to report:
☐ Erosion near trail
☐ Poor trail conditions
☐ Trash
☐ Dead or dying mature vegetation
☐ Unauthorized trail
☐ Graffiti or vandalism
☐ Animal sighting
☐ Other (Comment)

Comments

Click the map to enter your approximate location:
Latitude: 33.42739617003422
Longitude: -111.93710185147154

Figure 36: Reporting form for the trail reporting website.

4.2.2: Collecting Student Data

After website construction, students enrolled in introductory physical geography classes worked on an aerial photography lab that required a visit to Tempe Butte. While walking between stops visited for the aerial photo interpretation, students were tasked to collect six observations. Three stops were chosen to serve as control points, and three were left to the student's discretion. To submit their field reports, students were directed to use a computer and submit their reports online at the conclusion of their lab.

Although students are able to see the map with the three control points when they visit the website, they are not able to interact with the site until they create an account and log in. Since the reporting system is implemented as part of a graded assignment, the login serves two purposes:

1. It allows the supervising instructor to generate a list of students who have completed the assignment in their specified lab section; and

2. Points that have been submitted can be attributed to specific users, allowing either the user or an administrator to later retrieve all points that have been submitted by that particular user if necessary.

Once the student creates an account and logs in, the point submission form appears. A dropdown menu lets users select whether they were at one of the three control points (which fills in the appropriate latitude and longitude), or click a location to input one of their own points. The three control points are listed first, and the three student-selected points are listed second. When the student has selected one of the sites of his choosing from the drop-down menu, a differently-colored marker appears on the map where the student clicks. This marker can be dragged to a new location if the student misclicks; it can also be placed again if the student clicks a new location on the map. Its location is not finalized until the student submits the form.

4.3: Results

Students from six Introduction to Physical Geography lab sections participated in the data collection process. The first group of students submitted points over October 30, October 31, and November 1, 2012. The second group of students went into the field on November 29 and November 30, 2012. At the end of data collection, 106 students submitted a total of 348 data points. Of those, 185 of the point submissions are for the designated control points (n=70 at site 1; n=58 at site 2; n=57 at site 3). A total of 163 points were submitted for the user's choice. The distribution of points can be seen in Figure 37.

The number of times each indicator was selected at each of the three control points, as well as at all other points is displayed in Table 1. A visual representation the point distribution for each indicator can be viewed in Figures 38-44.

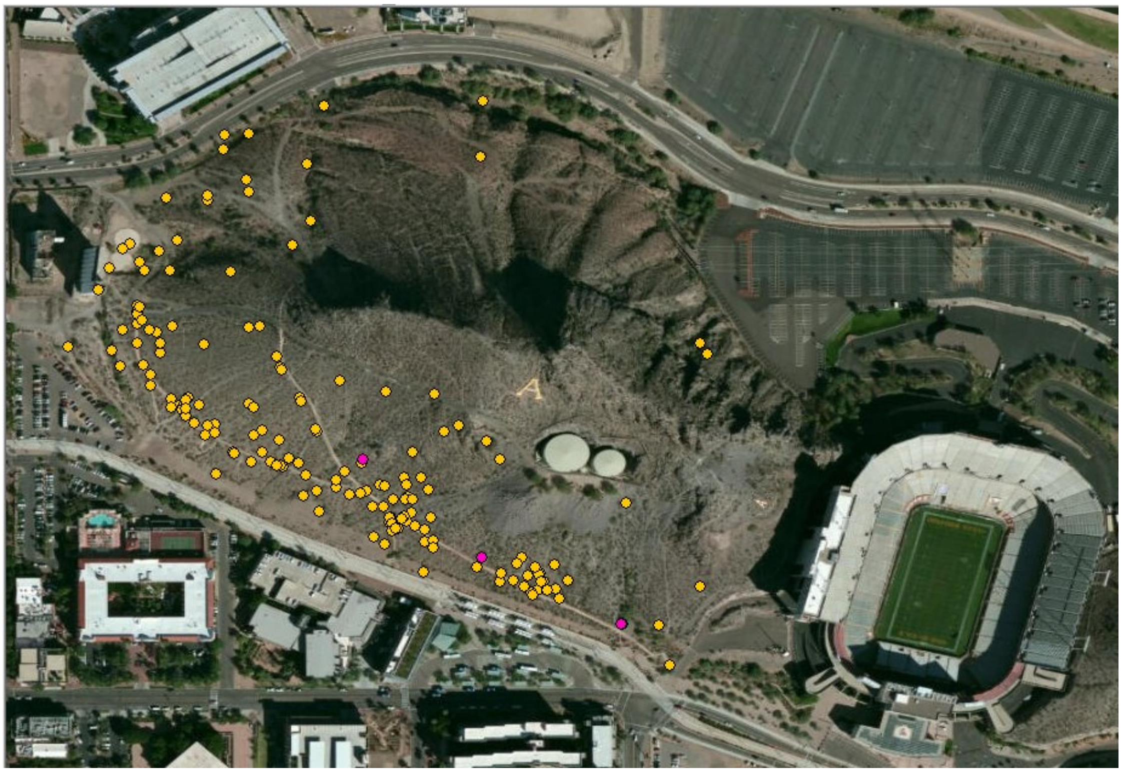


Figure 37: Distribution of data points collected at Tempe Butte. Yellow points are the user's choice; pink points represent the three pre-defined stops.

	Control Site 1	**Control Site 2**	**Control Site 3**	**Other sites**
Total Points	70	58	57	163
Erosion	22	20	21	50
Poor Trail	9	9	6	43
Trash	41	31	33	84
Mature Vegetation Damage	0	0	0	0
Trail Spur	8	5	7	36
Vandalism	16	7	9	36
Animal Evidence	2	8	5	14
Other	7	5	5	19

Table 5: Breakdown of the frequency with which each indicator was reported

Figure 38: Reports of unauthorized trails at Tempe Butte

Figure 39: Reports of erosion at Tempe Butte

Figure 40: Reports of poor trail conditions at Tempe Butte

Figure 41: Reports of trash at Tempe Butte

Figure 42: Reports of vandalism at Tempe Butte

Figure 43: Reports of animal sightings at Tempe Butte

Figure 44: Reports of other notable impacts at Tempe Butte

4.4: Discussion

4.4.1: Analysis of Impacts

The quantity of information in the pilot study reveals patterns within each of the indicators when they are examined individually (see Figures 38-44). The exception is the mature vegetation damage indicator that was not reported, and that may not have been present or visible in any notable way at Tempe Butte during the time that data collection occurred. Although it was not reported, vegetation damage remains an important indicator, as damage to mature vegetation can indicate vandalism and other destructive anthropogenic off-trail activities (Nepal and Nepal 2004, Rai and Sundriyal 1997).

Reports of unauthorized trails can assist park managers in locating areas where visitors are leaving the established trail system (Arbogast 2009). While a single report of an unauthorized trail spur may not be enough to generate managerial concern, numerous reports within a small physical area may merit further attention. On Tempe Butte, the 50 reports of unauthorized trails, three areas emerged as potential points of concern that may be worthy of a field check by park management (Figure 38).

Erosion within a trail system is a problem that has been linked to both natural and anthropogenic causes, often without a clear way of determining which of those two factors is at work in a given situation (Nepal and Nepal 2004). Regardless of the cause, incidences of erosion must be monitored and, if necessary, addressed before they encroach on the existing trail structure (Deluca et al. 1998). With the user reports of erosion along a network of trails furnished by a crowdsourced solution such as the one pilot tested at Tempe Butte, a map of erosion incidents can be created and consistently updated (see Figure 39). Such a visualization can be a useful tool for park management, particularly in conjunction with reports of poor trail conditions (Figure 40), to support good resource allocation with regards to trail maintenance (Bushell et al. 2003, Moore and Polley 2007, Nepal and Nepal 2004).

Litter along trails is a consistent visitor concern that should be addressed by park management and volunteers (Deluca et al. 1998, Moore and Polley 2007, Nepal and Nepal 2004). Indeed, the presence of trash was the most-reported indicator at the Tempe Butte preserve, suggesting that refuse is easily spotted by park visitors. Crowdsourced information about trash (see Figure 41) has the potential to be useful to park management – for example, it can help guide a volunteer trash collection session by highlighting the locations of the most prominent instances of refuse, and can help guide park management towards locations that could benefit from a simple trash can.

Vandalism is another occurrence within publicly accessible trail systems that visitors find noticeable and off-putting (Chiesura 2003, Christiensen and Dustin 1989). Depending on the environment, vandalism can take a number of different forms ranging from graffiti to intentional destruction of part of the trail or an area within sight of the trail. Using a crowdsourced tool to locate areas in need of attention and cleanup efforts can help optimize the efforts to remedy these situations.

Reports of animal sightings (see Figure 43) were low during the pilot study, and restricted mostly to dogs and birds, but the importance of including this indicator should not be underestimated. For managers of larger preserves than Tempe Butte, particularly those that are home to vulnerable or endangered species, visitor sightings of animals can support efforts to keep track of those populations (Scott et al. 2001b, Southwell 1994).

The pilot study revealed that the other field (see Figure 44), reserved for observations that do not fall within the other available categories, was used reliably in conjunction with the comment box. This combination supports an expanded response format that gives participants an opportunity to type their observations in greater detail than the checkbox form alone provides (Anthony 2007). The most frequent comments were elaboration about poor trail conditions, as well as comments about areas where cactus vegetation infringes on the trails. Some users took this opportunity to point out areas on the trail that they found interesting, which could be of some use in supporting future development of self-guided stops within the trail structure (c.f. McArthur 1993).

Protected areas and conservations efforts are growing at a rapid pace worldwide, as is nature-based tourism that takes advantage of the public amenities those spaces offer (Bushell et al. 2003, Uddhammar 2006). Despite their important role in the conservation and management of these areas, park personnel face serious financial cutbacks and time restrictions (Parrish, Braun and Unnasch 2003b). This can place an incredible strain on park managers who must juggle conservation and tourism management as just part of their jobs (Schwartza et al. 2012).

With the advent of new technology and a growing interest in volunteered geographic information, or neogeography, a unique opportunity exists for park managers to distribute the effort of monitoring tourism areas for problems (Haklay et al. 2008, Turner 2006, Girres and Touya 2010, Haklay 2010). This can be accomplished in part by adapting existing field-scale assessment techniques, whereby the data collection process is simplified and information is aggregated within a system that is accessible to the public (Newman et al. 2010, Ratti et al. 2006, Connors et al. 2012).

The results obtained in this case study reveal the power to gather and display information about human modifications to a preserve environment. The data collection process itself flowed relatively smoothly, and demonstrated that this is a tool that could be used to support future park management decision making, particularly if additional adjustments and improvements are made in response to management input. Each of the indicators collected during the pilot study offers information that can be valuable to park managers, including the ability to direct attention towards areas that have been identified by trail users as being in need of attention.

4.4.2: Coding Issues

During the first half of the pilot study, a coding error prevented the system from accepting submissions for one of the user-defined sample points. As a result, only five submissions (three control points and two user-defined points) could be turned in by any participant until the error was rectified.

The coding error was invisible to the students, who were able to submit that point normally through the user interface. The problem occurred when the option “Your site X” was selected from the dropdown menu. That option was assigned a name of “0” in the backend of the code, which then caused the point to fail a Boolean check that was necessary for the information to be written to the database.

A total of 40 students may have been affected by this error before it was corrected, although only 12 of those students (25%) completed the other five points they were assigned to collect. It is impossible to know how many of those students attempted to submit the point that was not recorded.

The loss of points likely did not impact the overall patterns that were reported in the first part of the discussion section, although the additional points would have helped to create a more robust image of the study area.

4.4.3: Limitations from the Perspective of the Crowdsourcer

While many of the participants at Tempe Butte were able to complete the task with few questions or challenges, there were a handful of students who did run into difficulty either in the field or in the process of reporting their observations through the web system. Of the 105 students who participated in the field and reported data online, approximately two dozen students experienced problems that they reported to their lab instructors.

The most common problem was an element of confusion regarding the extent of their assigned task. Many of the students did not fully complete the assignment, which resulted in them collecting either too few points or none at all. A related limitation is that an unknown number of students elected not to write down their observations in the field, claiming that they would remember them to submit later. Both of these problems likely impacted the number of data points collected, and may have affected the integrity of some of the submitted points. Finally, some students submitted their responses online as a single point rather than differentiating between the three control points and the three user-selected points. This is possible because users are able to check multiple indicators at each stop in order to account for the presence of multiple disturbances in a small area.

There is no guarantee regarding the reliability and accuracy of volunteered geographic information, regardless of how simplified the data collection process may be (Haklay 2010, Cooper et al. 2007). Furthermore, the system as it is currently designed cannot treat the input of certain trusted users as more important than the input of other unknown users (Shneiderman 2000). It lacks either the established community of users or the body of data that would be required to create a reputation system, which might help weight points from more reliable users (Fraternali et al. 2012, Shneiderman 2000, Marsh and Dibben 2003).

The challenges and limitations faced by students at Tempe Butte may not be addressable from a coding perspective. In other words, within the body of data submitted by neogeographers, there are likely to be some incorrect or less accurate results (Haklay et al. 2008, Turner 2006). It is through the volume of results that crowdsourcing finds its true strength, as the volume of points compensates for inaccurate submissions (Haklay et al. 2010).

4.4.4: Implementation Considerations

In order to begin implementing a crowdsourcing system across a system of trails larger than the Tempe Butte Preserve, a broader audience will need to be reached within the trail area as part of a visitor experience (Nepal and Nepal 2004, Manning 2001). In particular, an appeal must be made to individuals who use the trail system to encourage them to make observations during their time outside and then to report them once they return home. Moreover, this must be done in a passive manner, whereby participants can discover that the crowdsourcing system exists and learn how to contribute to it without explicit instruction from park personnel (Pedersen et al. 2007, Cooper et al. 2007).

An informational pamphlet may be one way to accomplish this awareness. For preserves with volunteer stewards at trailheads, a laptop could illustrate the ease of use. Information about the area such as a guide to local plants and animals can be combined with a map of the trail system and basic instructions in order to create an educational experience that will appeal to casual users (Pattengill-Semmens and Semmens 2003). By publicizing the tool at trailheads or in a similarly high-traffic area such as a visitor's center, a park manager also has an excellent opportunity for public outreach (Cooper et al. 2007).

4.4.5: Contextualizing Crowdsourcing Compared to Other Data Collection Tools

Many data collection techniques designed to collect data about impact in a tourism environment exist (c.f. Allen 2009, Ludwig et al. 2006). An additional tool for this purpose, the Desert Impact Assessment rapid assessment methodology, is proposed in Chapter 2 of this dissertation. By revisiting the indicators proposed in Chapter 2 for this rapid assessment methodology and retooling them to be simpler and based on observation, a new tool is created that shares many of the benefits of rapid assessment data collection while eliminating some of the time costs associated with the more structured approach. The differences between these two techniques, along with a micro-scale analysis and a remote sensing analysis are outlined below in Table 6.

With the Desert Impact Assessment approach described in Chapter 2 and the crowdsourced data collection approach discussed here are born from similar roots, their execution and the quality of data that they collect are quite different. Whereas the DIA requires a structured stratified random sampling strategy to effectively collect ordinal data for all indicators at each point, the crowdsourced approach is designed to accept individual reports and to aggregate the volume of single observations. This makes a crowdsourced solution ideal for active trail systems that may require an ongoing collection of reports for trail maintenance and upkeep purposes, while the structured approach offered by the micro-scale, DIA, and remote sensing data strategies described in Table 5 is appropriate for routine monitoring at specific points over time.

	Micro-scale analysis	**Desert Impact Analysis**	**Crowdsourcing analysis**	**Remote Sensing analysis**
Cost	- Higher cost associated with analysis of soils and vegetation	+ Low cost	+ Low cost	+/- Higher-resolution data increases cost
Time	+ Small time commitment	+/- Smaller time commitment that grows with increased data points	+ Small time commitment	- Time commitment necessary to find data and prepare for analysis
Specialized skills	- Requires a deep understanding of environmental characteristics and study tools	+ None required	+ None required	- Understanding of remotely sensed data analysis
Specialized software	+ None	+/- Spatial analysis calls for some specialized software, open source solutions available	+/- Can be executed entirely with open source software	- Remote sensing software required
Specialized hardware	- Requierd for in-depth analysis	- Location recording unit such as GPS	+ None required	+ None
Ease of use	- Less accessible to non-experts without training	+ Survey is easy to conduct	+ Observation-based survey is conducted by visitors	- Expertise in remote sensing necessary
Directness of measurements	+ Direct ratio measurements	- Indirect ordinal measurements	- Phenomenon-based binary measurements	- Measurements determined by raster resolution
Consistency	+ Yes	- Potential for different volunteers to measure impact differently	- Relies on report volume	+ Yes

Table 6: Review of the benefits and drawbacks of the crowdsourcing as an input collection and analysis tool compared to other analysis techniques designed for arid and semi-arid environments impacted by tourism.

4.4.6: Analyzing One Scenario: Blitz Data Collection

Another way of potentially implementing a crowsdourcing tool such as the one described in this paper might be for a park manager to advertise to the public a one-day event where a large amount of data will be collected at once (c.f. Butcher 1990, Sullivan et al. 2009). This has the advantage of creating a thorough snapshot of the trail system in a short amount of time, offering a large quantity of data that can be analyzed together (Connors et al. 2012, Haklay et al. 2010).

Once those data are compiled into a computerized format, the point data may tempt park managers or a municipal or county-level GIS analyst to attempt running one or more spatial analysis tools. Many analysis tools that seem like good candidates for use with these point data are inappropriate due to the structure of the data collection process, as well as the process through which data are obtained. Since data are focused along the trail system, for example, interpolating the information collected over the entire preserve area to try to predict which areas are the most disturbed would not create meaningful results. Although it may seem appropriate to then turn to a hot spot analysis or a cluster analysis, both of which return point data with information about the spatial relationships between observations, this is again a poor direction to take.

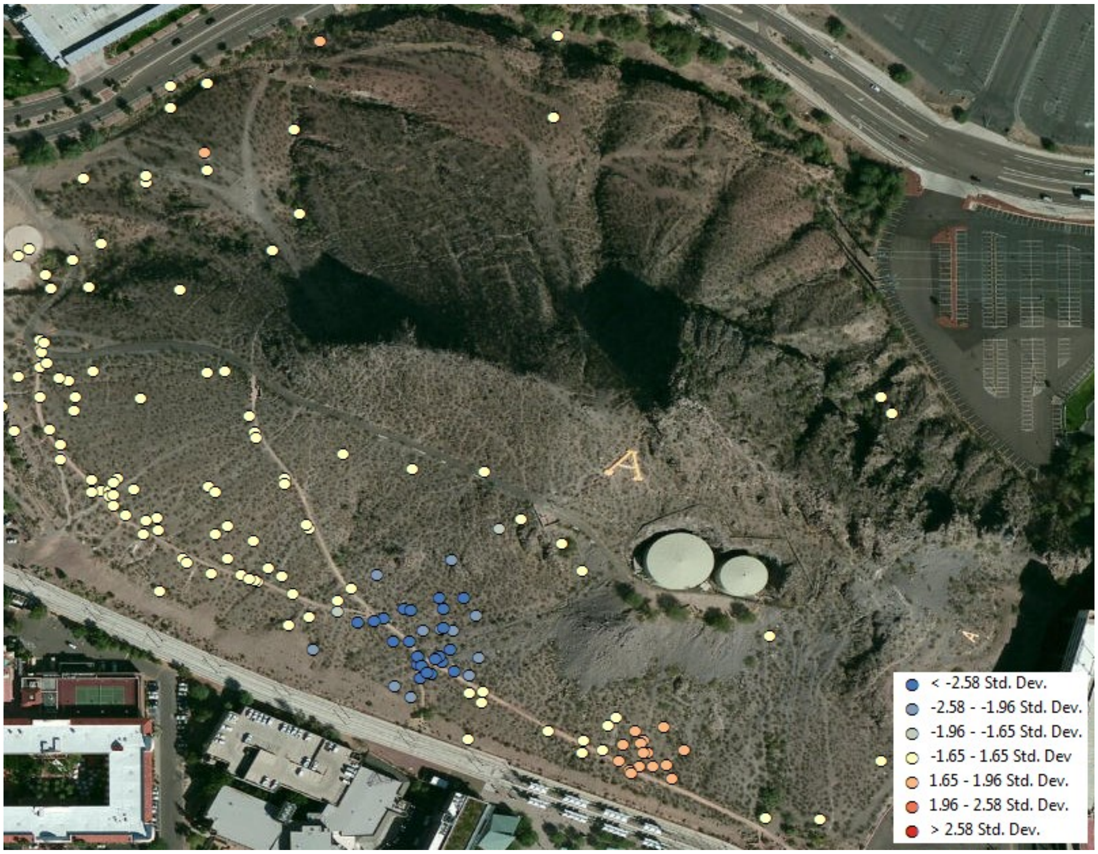


Figure 45: Results of a hot spot analysis on the trash indicator at Tempe Butte Preserve

A hot spot analysis conducted on the trash indicator at Tempe Butte Preserve (see Figure 45) reveals results that are inconsistent with the actual observances of trash at the preserve (see Figure 31). A "cool spot" appears in an area that had numerous sightings of litter, none of the litter sightings on the west side of the preserve are highlighted. Similarly, a cluster analysis (see Figure 46) highlights the same "cool spot" area while disregarding the remaining instances of litter within the preserve. Eliminating the points that did not cite trash as a concern from each of these analyses prevents the tools from running all. In other words, using the hot spot tool or the cluster analysis tool to locate areas of impact yields misleading results.

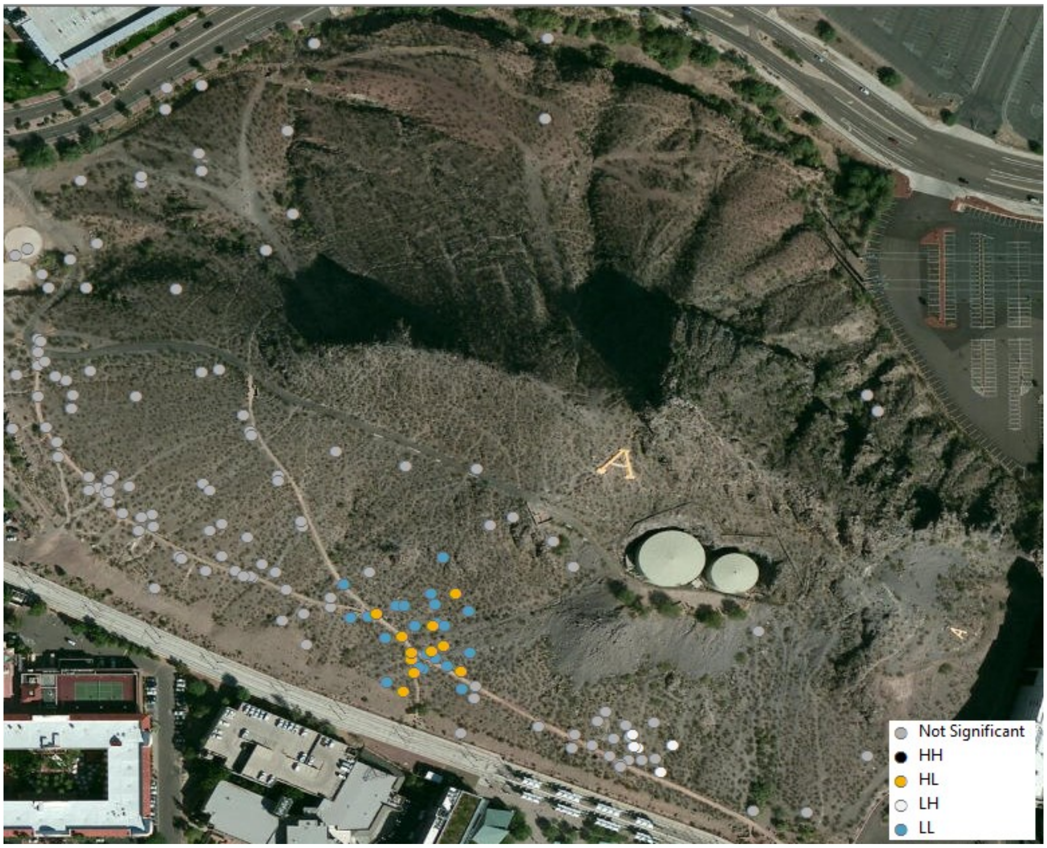


Figure 46: Results of a cluster analysis on the trash indicator collected at Tempe Butte

Similar trends can be seen in hot spot and cluster analyses of trail spur sightings (see Figures 47 and 48). In this case, the hot spot analysis highlights an area on the west side of the preserve as potentially interesting to park managers, but a second group of points that contains several mentions of unauthorized trails on the south side of the preserve is disregarded (see Figure 36). Again, the hot spot analysis in particular returns results that look valid, but that are ultimately misleading.

In summary, a strategy of gathering a large set of volunteers is a great idea to “blitz” a preserve for crowdsourcing data collection. The way that those data are analyzed, however, still requires a rigorous treatment in terms of the appropriate spatial analysis techniques. Without that, the results of spatial analyses may be misleading, reducing the usefulness of the collected data.

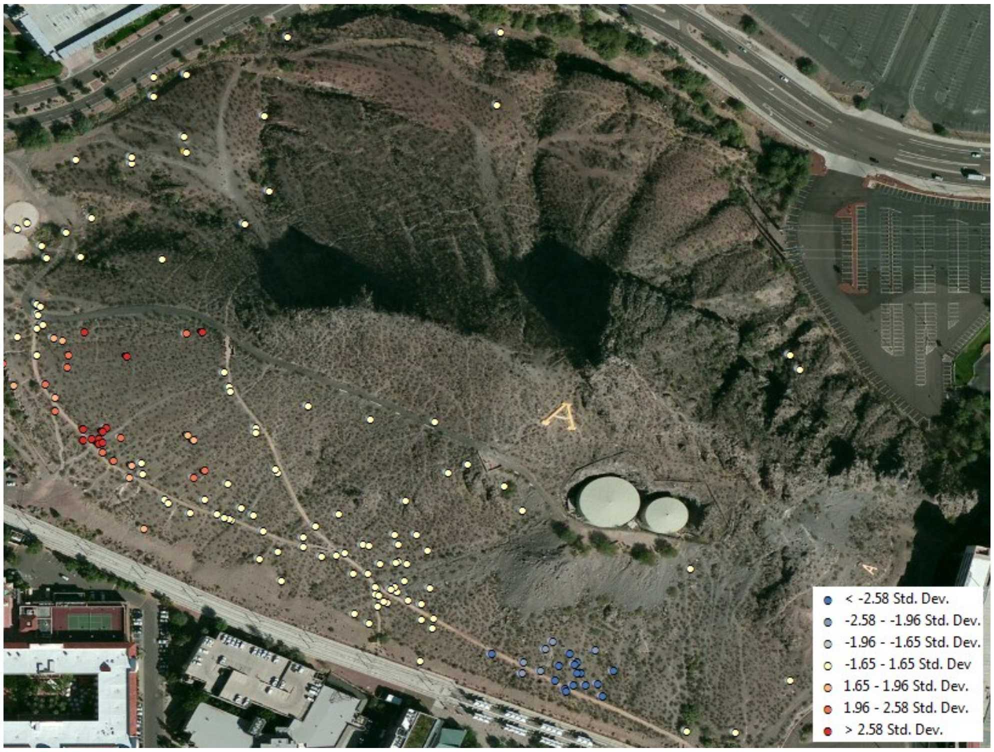


Figure 38: Results of a hot spot analysis on the trail spur indicator collected at Tempe Butte

Figure 39: Results of a cluster analysis on the trail spur indicator collected at Tempe Butte

4.5: Conclusions

A number of tools exist to assist managers of protected areas in monitoring conservation progress, with many more in development (c.f. Dudley 2009, Ervin 2003a, Salafsky et al. 2002). Methods such as rapid assessment data collection which require time spent in the field can create useful data sets, but can only paint a snapshot of an area during the timeframe that is spent in the field (Fennessy et al. 2007). For areas that are not subject to tourist visitation, these snapshots may be sufficient; for areas that are frequently used by visitors, however, a refined methodology that consistently delivers information about the environment may be able to supplement official data collection. This paper outlines the development of a tool that calls upon interested volunteers to submit observations into a system that aggregates the individual reports.

The crowdsourcing tool was field tested by students taking introductory geography classes at Tempe Butte Preserve in Tempe, Arizona in October and November of 2012. The point data submitted by the students upon returning from the field revealed many patterns that may be useful to park managers. This is particularly true for determining where to direct available resources for trash cleanup and trail improvement efforts. Out of the eight indicators, sightings of trash were the most commonly reported; this coincides with prior research indicating that litter in natural settings is a problem that is of high concern to visitors (Moore and Polley 2007).

The crowdsourcing tool has the potential to be useful to park management within the Phoenix Metropolitan area, particularly in areas with extensive trail systems that are frequented by hikers, mountain bikers, and others users. Distributing data collection and relying on nanogeographers to collaboratively paint a partial picture of the area over time creates additional resources for land managers (Jacobson et al. 2009, Sieber 2003, Turner 2006). Volunteered geographic information is currently an underutilized resource in conservation management, but its use is gradually becoming more pervasive (e.g. Connors et al. 2012, Couvet et al. 2008, Pattengill-Semmens and Semmens 2003, Butcher 1990). Adapting this data collection technique to help monitor trail systems in protected areas is a logical next step, in so long as the analyst follows current guidelines in rigorous and appropriate analytical tools.

4.6: Future Research Directions

Future research steps to improve this system will be to create a manager login that produces basic informational reports. A tool that allows park management to select a single indicator of interest and to see a map that shows all of the submissions regarding this indicator would be a logical first step towards making the tool more robust. Adding the ability to further filter the submissions by date and to mark a group of points as “fixed” or “addressed” would be other systematic improvements that will make this tool more useful.

Another future direction would be to find an actual trail system within which to implement this system. When the captive audience of the geography students is removed, there will have to be alternate ways to reach out to the public in order to encourage use of the system. One way of accomplishing this may be to create informational pamphlets about each trail system to be placed at trailheads, and to include within that literature a panel introducing the crowdsourced system to the public.

Finally, making the entire system mobile-friendly or producing a mobile app that can be downloaded from the Android and iOS marketplaces is a goal that should be worked toward in the future. By making this tool compatible with mobile phones, several of the hurdles that might reduce user participation can be overcome: The phone’s internal GPS unit can be used to collect more accurate locational data than users can provide by clicking on a map after exiting the field, and there will be no time lapse during which the user might forget to visit the website.

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Chapter 5

CONCLUSION

5.1: Summary of dissertation results

Chapter 2 describes the iterative process undertaken to create effective indicators of environmental impact in an arid environment (Hockings et al. 2000, Moore and Polley 2007). Indicator development relied on three crucial steps: (i.) a literature review to identify physical processes that are relevant to the study area; (ii.) communication with park management regarding their specific areas of interest and concern; and (iii.) multiple field tests to ensure the integrity of the indicators. The indicators are developed into a rapid assessment technique that can be executed in the field quickly and efficiently. An iterative process is used to ensure that each indicator measures something different, where a correlation matrix between indicators guides adjustments to indicators between trips into the field. Field tests are conducted at two study sites using stratified random sampling with intervals of 50 meters between transect stops at the first site and intervals of 15 meters between transect stops at the second site. It is determined that 50 meters is too large an interval to support accurate analysis, but the 15 meter intervals create a dataset of sufficient density to proceed with a detailed analysis in Chapter 3.

Chapter 3 examines the results of a case study performed at Petrified Forest National Park, Painted Desert, Arizona. Three of the park's seven trails are surveyed using ordinal data collection for all indicators. Inverse distance weighting (IDW) is used to perform interpolations on single indicators, as well as groups of indicators. The results are used to craft a detailed assessment of each of the three trails with commentary about various areas that may be of concern to present or future management. This assessment can serve as a baseline that the park can revisit with future data for monitoring purposes (Pauly 1995). The surveyed points can also be used to determine whether certain parts of the trail are more impacted than others; this is demonstrated through a viewshed analysis that compares the index score of points within sight of a shade structure to that are not visible. Although the results of this analysis are ambiguous, the potential implications for future research are discussed.

Chapter 4 reimagines the data collection process established in Chapter 2, distributing the survey effort among a group of novice geographers (Turner 2006). Observations are made in the field and points are inputted into the database using a simple Google Maps API. Each indicator can be mapped individually to visualize the user input. These maps can support management decision-making and resource distribution. Cluster analysis and hot spot analysis are discussed as potential analysis methods that might be attractive temptations, but which are ultimately flawed in this context because of the way data collection was conducted.

5.2: Contribution to academic knowledge

In conclusion, each chapter in this dissertation provides a new contribution to the existing body of knowledge regarding the design and implementation of rapid assessment data collection, as well as the field of conservation management. First, indicators are designed and field tested for rapid assessment in arid and semi-arid regions in the Sonoran Desert and Painted Desert, Arizona. The process of developing these indicators is explained with the intention that this methodology can be followed by managers of protected deserts in other regions of the world. Many of the existing indicators can be used as the foundation of an updated version of the index with only minor adjustments to adapt the measurements to the area of interest.

Second, the use of interpolations as a tourism and conservation management tool is explored as a step in the analysis process of a rapid assessment dataset. The interpolations can be used to support the creation of a baseline for the entire surveyed area, which is an important first step to creating and working towards reasonable conservation goals (Pauly 1995, Tear et al. 2005). This is particularly important to Petrified Forest National Park as it moves forward with authorized land acquisitions that will double the size of the existing park (National Park Service 2013). Information from these baselines can help guide the development of new trails for hiking and other recreational uses as new land is made open to the public.

Third, exploration of the surveyed datasets with regards to the visibility or non-visibility from an observer point serves as a contribution to the practical application of viewshed analysis. Viewshed can be an important consideration from the perspective of outlook and trail and building construction (Bacon 1995, Bishop 2003, Sang et al. 2008). In this context, however, viewshed is utilized as part of an analysis that explores the efficacy of park resources at enforcing good visitor behavior. This process can be applied in other environments with very little modification.

Finally, altering the index to create a crowdsourcing tool designed for trail monitoring contributes to crowdsourcing literature and tourism management literature. Although crowdsourcing is used in conservation monitoring, there is no literary precedent that describes its use as part of a trail management system (e.g. Connors et al. 2012, Kelly, Tuxen and Kearns 2001, Butcher 1990). While the means through which this particular dataset were collected does not support a deep statistical analysis, it sets a precedent that can be built upon by future research.

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APPENDIX A

FULL CORRELATION TABLES FOR SOUTH MOUNTAIN AND PETRIFIED FOREST

South Mountain Overall Correlations

		Vandalism	Soil disturbance	Erosion	Amount of Trash	Type of Trash	Mature Vegetation Cover	Mature Vegetation Damage	Trail	Ambient Noise	Other Visible Impact
Vandalism	Pearson Correlation	1.000	-.032	-.030	.066	.106	-.144	.130	.068	.179	.187
	Sig. (2-tailed)		.763	.772	.531	.313	.168	.215	.515	.085	.072
	N	93	93	93	93	93	93	93	93	93	93
Soil disturbance	Pearson Correlation	-.032	1.000	.425**	.270**	.249*	.057	.465**	.472**	.127	.170
	Sig. (2-tailed)	.763		.000	.009	.016	.584	.000	.000	.225	.103
	N	93	93	93	93	93	93	93	93	93	93
Erosion	Pearson Correlation	-.030	.425**	1.000	.313**	.305**	-.058	.417**	.274**	.162	.069
	Sig. (2-tailed)	.772	.000		.002	.003	.578	.000	.008	.120	.511
	N	93	93	93	93	93	93	93	93	93	93
Amount of Trash	Pearson Correlation	.066	.270**	.313**	1.000	.896**	-.171	.441**	.289**	.353**	.315**
	Sig. (2-tailed)	.531	.009	.002		.000	.102	.000	.005	.001	.002
	N	93	93	93	93	93	93	93	93	93	93
Type of Trash	Pearson Correlation	.106	.249*	.305**	.896**	1.000	-.228*	.396**	.359**	.396**	.237*
	Sig. (2-tailed)	.313	.016	.003	.000		.028	.000	.000	.000	.022
	N	93	93	93	93	93	93	93	93	93	93
Mature Vegetation Cover	Pearson Correlation	-.144	.057	-.058	-.171	-.228*	1.000	.084	-.077	-.110	-.003
	Sig. (2-tailed)	.168	.584	.578	.102	.028		.423	.463	.294	.980
	N	93	93	93	93	93	93	93	93	93	93

Mature Vegetation Damage	Pearson Correlation	.130	.465**	.417**	.441**	.396**	.084	1.000	.380**	.192	.140
	Sig. (2-tailed)	.215	.000	.000	.000	.000	.423		.000	.065	.180
	N	93	93	93	93	93	93	93	93	93	93
Trail	Pearson Correlation	.068	.472**	.274**	.289**	.359**	-.077	.380**	1.000	.209*	-.032
	Sig. (2-tailed)	.515	.000	.008	.005	.000	.463	.000		.045	.762
	N	93	93	93	93	93	93	93	93	93	93
Ambient Noise	Pearson Correlation	.179	.127	.162	.353**	.396**	-.110	.192	.209*	1.000	.114
	Sig. (2-tailed)	.085	.225	.120	.001	.000	.294	.065	.045		.276
	N	93	93	93	93	93	93	93	93	93	93
Other Visible Impact	Pearson Correlation	.187	.170	.069	.315**	.237*	-.003	.140	-.032	.114	1.000
	Sig. (2-tailed)	.072	.103	.511	.002	.022	.980	.180	.762	.276	
	N	93	93	93	93	93	93	93	93	93	93

**. Correlation significant at the 0.01 level (2-tailed).

*. Correlation significant at the 0.05 level (2-tailed).

South Mountain S2 Correlations

		Vandalism	Soil Disturbance	Erosion	Amount of Trash	Type of Trash	Mature Vegetation Cover	Mature Vegetation Damage	Trail	Ambient Noise	Other Visible Impact
Vandalism	Pearson Correlation	1.000	-.075	-.081	.011	.068	-.235	.120	.084	.163	.214
	Sig. (2-tailed)		.667	.645	.952	.698	.173	.492	.633	.349	.217
	N	35	35	35	35	35	35	35	35	35	35
Soil Disturbance	Pearson Correlation	-.075	1.000	.532**	.419*	.334*	.411*	.614**	.595**	.103	.222
	Sig. (2-tailed)	.667		.001	.012	.050	.014	.000	.000	.555	.199
	N	35	35	35	35	35	35	35	35	35	35
Erosion	Pearson Correlation	-.081	.532**	1.000	.377*	.358*	.180	.476**	.575**	.106	-.014
	Sig. (2-tailed)	.645	.001		.026	.034	.302	.004	.000	.546	.938
	N	35	35	35	35	35	35	35	35	35	35
Amount of Trash	Pearson Correlation	.011	.419*	.377*	1.000	.835**	-.218	.349*	.402*	.268	.373*
	Sig. (2-tailed)	.952	.012	.026		.000	.208	.040	.017	.120	.027
	N	35	35	35	35	35	35	35	35	35	35
Type of Trash	Pearson Correlation	.068	.334*	.358*	.835**	1.000	-.342*	.300	.491**	.267	.275
	Sig. (2-tailed)	.698	.050	.034	.000		.045	.080	.003	.120	.110
	N	35	35	35	35	35	35	35	35	35	35
Mature Vegetation Cover	Pearson Correlation	-.235	.411*	.180	-.218	-.342*	1.000	.204	-.091	-.241	-.109
	Sig. (2-tailed)	.173	.014	.302	.208	.045		.241	.602	.162	.534
	N	35	35	35	35	35	35	35	35	35	35

Mature Vegetation Damage	Pearson Correlation	.120	.614**	.476**	.349*	.300	.204	1.000	.708**	.079	.017
	Sig. (2-tailed)	.492	.000	.004	.040	.080	.241		.000	.652	.924
	N	35	35	35	35	35	35	35	35	35	35
Trail	Pearson Correlation	.084	.595**	.575**	.402*	.491**	-.091	.708**	1.000	.256	.015
	Sig. (2-tailed)	.633	.000	.000	.017	.003	.602	.000		.137	.930
	N	35	35	35	35	35	35	35	35	35	35
Ambient Noise	Pearson Correlation	.163	.103	.106	.268	.267	-.241	.079	.256	1.000	.006
	Sig. (2-tailed)	.349	.555	.546	.120	.120	.162	.652	.137		.971
	N	35	35	35	35	35	35	35	35	35	35
Other Visible Impact	Pearson Correlation	.214	.222	-.014	.373*	.275	-.109	.017	.015	.006	1.000
	Sig. (2-tailed)	.217	.199	.938	.027	.110	.534	.924	.930	.971	
	N	35	35	35	35	35	35	35	35	35	35

**. Correlation significant at the 0.01 level (2-tailed).

*. Correlation significant at the 0.05 level (2-tailed).

South Mountain S3 Correlations

		Vandalism	Soil Disturbance	Erosion	Amount of Trash	Type of Trash	Mature Vegetation Cover	Mature Vegetation Damage	Trail	Ambient Noise	Other Visible Impact
Vandalism	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)		.	.	.	.	.	.	.	.	.
	N	17	17	17	17	17	17	17	17	17	17
Soil Disturbance	Pearson Correlation	.[a]	1	.471	.000	.060	-.351	.140	.337	.152	.184
	Sig. (2-tailed)	.		.056	1.000	.821	.168	.591	.186	.561	.480
	N	17	17	17	17	17	17	17	17	17	17
Erosion	Pearson Correlation	.[a]	.471	1	.281	.251	-.482	.085	.522*	.063	.020
	Sig. (2-tailed)	.	.056		.275	.332	.050	.744	.032	.810	.938
	N	17	17	17	17	17	17	17	17	17	17
Amount of Trash	Pearson Correlation	.[a]	.000	.281	1	.945**	-.376	.632**	.289	-.163	.171
	Sig. (2-tailed)	.	1.000	.275		.000	.137	.006	.261	.532	.512
	N	17	17	17	17	17	17	17	17	17	17
Type of Trash	Pearson Correlation	.[a]	.060	.251	.945**	1	-.336	.636**	.385	.006	.116
	Sig. (2-tailed)	.	.821	.332	.000		.187	.006	.127	.981	.658
	N	17	17	17	17	17	17	17	17	17	17
Mature Vegetation Cover	Pearson Correlation	.[a]	-.351	-.482	-.376	-.336	1	-.292	-.063	-.116	-.182
	Sig. (2-tailed)	.	.168	.050	.137	.187		.256	.812	.656	.485
	N	17	17	17	17	17	17	17	17	17	17

Mature Vegetation Damage	Pearson Correlation	.[a]	.140	.085	.632**	.636**	-.292	1	.275	-.075	.182
	Sig. (2-tailed)	.	.591	.744	.006	.006	.256		.285	.774	.485
	N	17	17	17	17	17	17	17	17	17	17
Trail	Pearson Correlation	.[a]	.337	.522*	.289	.385	-.063	.275	1	.280	-.120
	Sig. (2-tailed)	.	.186	.032	.261	.127	.812	.285		.277	.646
	N	17	17	17	17	17	17	17	17	17	17
Ambient Noise	Pearson Correlation	.[a]	.152	.063	-.163	.006	-.116	-.075	.280	1	-.079
	Sig. (2-tailed)	.	.561	.810	.532	.981	.656	.774	.277		.764
	N	17	17	17	17	17	17	17	17	17	17
Other Visible Impact	Pearson Correlation	.[a]	.184	.020	.171	.116	-.182	.182	-.120	-.079	1
	Sig. (2-tailed)	.	.480	.938	.512	.658	.485	.485	.646	.764	
	N	17	17	17	17	17	17	17	17	17	17

a. Cannot be computed because variable is constant.

*. Correlation significant at the 0.05 level (2-tailed).
**. Correlation significant at the 0.01 level (2-tailed).

South Mountain S4 Correlations

		Vandalism	Soil Disturbance	Erosion	Amount of Trash	Type of Trash	Mature Vegetation Cover	Mature Vegetation Damage	Trail	Ambient Noise	Other Visible Impact
Vandalism	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)		.	.	.	.	.	.	.	.	.
	N	21	21	21	21	21	21	21	21	21	21
Soil Disturbance	Pearson Correlation	.[a]	1	.179	.000	.159	-.168	.067	.633**	-.143	-.233
	Sig. (2-tailed)	.		.439	1.000	.491	.468	.773	.002	.535	.310
	N	21	21	21	21	21	21	21	21	21	21
Erosion	Pearson Correlation	.[a]	.179	1	.037	.118	-.341	.341	-.188	.132	-.347
	Sig. (2-tailed)	.	.439		.875	.609	.130	.130	.415	.569	.123
	N	21	21	21	21	21	21	21	21	21	21
Amount of Trash	Pearson Correlation	.[a]	.000	.037	1	.853**	.048	.623**	.049	.322	-.167
	Sig. (2-tailed)	.	1.000	.875		.000	.836	.003	.832	.154	.470
	N	21	21	21	21	21	21	21	21	21	21
Type of Trash	Pearson Correlation	.[a]	.159	.118	.853**	1	-.016	.360	.239	.415	-.142
	Sig. (2-tailed)	.	.491	.609	.000		.944	.109	.297	.061	.539
	N	21	21	21	21	21	21	21	21	21	21
Mature Vegetation Cover	Pearson Correlation	.[a]	-.168	-.341	.048	-.016	1	.014	-.047	-.093	.048
	Sig. (2-tailed)	.	.468	.130	.836	.944		.953	.838	.689	.836
	N	21	21	21	21	21	21	21	21	21	21
Mature Vegetation Damage	Pearson Correlation	.[a]	.067	.341	.623**	.360	.014	1	-.002	.093	-.216
	Sig. (2-tailed)	.	.773	.130	.003	.109	.953		.992	.689	.348
	N	21	21	21	21	21	21	21	21	21	21

Trail	Pearson Correlation	.[a]	.633**	-.188	.049	.239	-.047	-.002	1	-.136	-.297
	Sig. (2-tailed)	.	.002	.415	.832	.297	.838	.992		.556	.192
	N	21	21	21	21	21	21	21	21	21	21
Ambient Noise	Pearson Correlation	.[a]	-.143	.132	.322	.415	-.093	.093	-.136	1	.322
	Sig. (2-tailed)	.	.535	.569	.154	.061	.689	.689	.556		.154
	N	21	21	21	21	21	21	21	21	21	21
Other Visible Impact	Pearson Correlation	.[a]	-.233	-.347	-.167	-.142	.048	-.216	-.297	.322	1
	Sig. (2-tailed)	.	.310	.123	.470	.539	.836	.348	.192	.154	
	N	21	21	21	21	21	21	21	21	21	21

a. Cannot be computed because variable is constant.

**. Correlation significant at the 0.01 level (2-tailed).

South Muontain S5 Correlations

		Vandalism	Soil Disturbance	Erosion	Amount of Trash	Type of Trash	Mature Vegetation Cover	Mature Vegetation Damage	Trail	Ambient Noise	Other Visible Impact
Vandalism	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)		.	.	.	.	.	.	.	.	.
	N	20	20	20	20	20	20	20	20	20	20
Soil Disturbance	Pearson Correlation	.[a]	1	.458*	.390	.378	-.286	.701**	.096	-.124	.398
	Sig. (2-tailed)	.		.042	.089	.100	.221	.001	.687	.602	.083
	N	20	20	20	20	20	20	20	20	20	20
Erosion	Pearson Correlation	.[a]	.458*	1	.103	.075	.000	.394	.000	-.264	.360
	Sig. (2-tailed)	.	.042		.665	.752	1.000	.086	1.000	.262	.118
	N	20	20	20	20	20	20	20	20	20	20
Amount of Trash	Pearson Correlation	.[a]	.390	.103	1	.983**	-.297	.264	.170	-.196	.077
	Sig. (2-tailed)	.	.089	.665		.000	.203	.261	.475	.407	.748
	N	20	20	20	20	20	20	20	20	20	20
Type of Trash	Pearson Correlation	.[a]	.378	.075	.983**	1	-.339	.241	.219	-.179	.017
	Sig. (2-tailed)	.	.100	.752	.000		.144	.306	.353	.450	.942
	N	20	20	20	20	20	20	20	20	20	20
Mature Vegetation Cover	Pearson Correlation	.[a]	-.286	.000	-.297	-.339	1	-.175	-.184	-.063	.133
	Sig. (2-tailed)	.	.221	1.000	.203	.144		.462	.437	.791	.577
	N	20	20	20	20	20	20	20	20	20	20
Mature Vegetation Damage	Pearson Correlation	.[a]	.701**	.394	.264	.241	-.175	1	-.143	-.224	.435
	Sig. (2-tailed)	.	.001	.086	.261	.306	.462		.548	.342	.056
	N	20	20	20	20	20	20	20	20	20	20

Trail	Pearson Correlation	.[a]	.096	.000	.170	.219	-.184	-.143	1	.396	-.128
	Sig. (2-tailed)	.	.687	1.000	.475	.353	.437	.548		.084	.589
	N	20	20	20	20	20	20	20	20	20	20
Ambient Noise	Pearson Correlation	.[a]	-.124	-.264	-.196	-.179	-.063	-.224	.396	1	.098
	Sig. (2-tailed)	.	.602	.262	.407	.450	.791	.342	.084		.682
	N	20	20	20	20	20	20	20	20	20	20
Other Visible Impact	Pearson Correlation	.[a]	.398	.360	.077	.017	.133	.435	-.128	.098	1
	Sig. (2-tailed)	.	.083	.118	.748	.942	.577	.056	.589	.682	
	N	20	20	20	20	20	20	20	20	20	20

a. Cannot be computed because variable is constant.

*. Correlation significant at the 0.05 level (2-tailed).
**. Correlation significant at the 0.01 level (2-tailed).

All Petrified Forest Correlations

		Vandal	Soil Dist	Erosion	Trash	Slope	MatVeg Dam	Trail Spur	PreHisImp	ModImp	Other	PetWood Den
Vandal	Pearson Correlation	1	-.011	-.256**	.021	-.177**	-.068*	.110**	.260**	.303**	.208**	-.091**
	Sig. (2-tailed)		.688	.000	.434	.000	.012	.000	.000	.000	.000	.001
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
SoilDist	Pearson Correlation	-.011	1	.313**	.088**	.076**	.113**	.256**	-.105**	.353**	.029	.120**
	Sig. (2-tailed)	.688		.000	.001	.005	.000	.000	.000	.000	.291	.000
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
Erosion	Pearson Correlation	-.256**	.313**	1	.014	.394**	.013	.133**	-.117**	-.048	.009	.098**
	Sig. (2-tailed)	.000	.000		.604	.000	.623	.000	.000	.078	.735	.000
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
Trash	Pearson Correlation	.021	.088**	.014	1	-.008	.109**	.049	.035	.100**	.050	.020
	Sig. (2-tailed)	.434	.001	.604		.780	.000	.070	.193	.000	.064	.455
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
Slope	Pearson Correlation	-.177**	.076**	.394**	-.008	1	-.055*	-.065*	-.131**	-.054*	.022	.045
	Sig. (2-tailed)	.000	.005	.000	.780		.043	.016	.000	.045	.415	.097

	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
MatVegDam	Pearson Correlation	-.068*	.113**	.013	.109**	-.055*	1	.054*	.127**	.202**	.013	-.060*
	Sig. (2-tailed)	.012	.000	.623	.000	.043		.048	.000	.000	.637	.026
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
TrailSpur	Pearson Correlation	.110**	.256**	.133**	.049	-.065*	.054*	1	.085**	.351**	.240**	.074**
	Sig. (2-tailed)	.000	.000	.000	.070	.016	.048		.002	.000	.000	.006
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
PreHisImp	Pearson Correlation	.260**	-.105**	-.117**	.035	-.131**	.127**	.085**	1	.081**	.058*	-.448**
	Sig. (2-tailed)	.000	.000	.000	.193	.000	.000	.002		.003	.033	.000
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
ModImp	Pearson Correlation	.303**	.353**	-.048	.100**	-.054*	.202**	.351**	.081**	1	.242**	.083**
	Sig. (2-tailed)	.000	.000	.078	.000	.045	.000	.000	.003		.000	.002
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365
Other	Pearson Correlation	.208**	.029	.009	.050	.022	.013	.240**	.058*	.242**	1	.095**
	Sig. (2-tailed)	.000	.291	.735	.064	.415	.637	.000	.033	.000		.000
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365

PetWoodDen	Pearson Correlation	-.091**	.120**	.098**	.020	.045	-.060*	.074**	-.448**	.083**	.095**	1
	Sig. (2-tailed)	.001	.000	.000	.455	.097	.026	.006	.000	.002	.000	
	N	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365	1365

**. Correlation significant at the 0.01 level (2-tailed).

*. Correlation significant at the 0.05 level (2-tailed).

Crystal Forest Correlations

		Vandal	SoilDist	Erosion	Trash	Slope	MatVegDam	Trail	PreHisImp	ModImp	Other	PetWoodDen
Vandalism	Pearson Correlation	1	.171**	-.102*	-.011	-.167**	.026	.268**	.354**	.459**	.191**	-.076
	Sig. (2-tailed)		.000	.016	.793	.000	.534	.000	.000	.000	.000	.074
	N	554	554	554	554	554	554	554	554	554	554	554
Soil_Distu	Pearson Correlation	.171**	1	.341**	.036	.078	-.063	.319**	-.116**	.291**	.103*	.151**
	Sig. (2-tailed)	.000		.000	.403	.065	.139	.000	.006	.000	.016	.000
	N	554	554	554	554	554	554	554	554	554	554	554
Erosion	Pearson Correlation	-.102*	.341**	1	.063	.399**	.000	.192**	-.127**	.047	.083	.128**
	Sig. (2-tailed)	.016	.000		.138	.000	.993	.000	.003	.273	.051	.003
	N	554	554	554	554	554	554	554	554	554	554	554
Amount_and	Pearson Correlation	-.011	.036	.063	1	-.043	.063	.033	.054	.076	.079	.035
	Sig. (2-tailed)	.793	.403	.138		.316	.136	.442	.208	.073	.064	.410
	N	554	554	554	554	554	554	554	554	554	554	554
Slope	Pearson Correlation	-.167**	.078	.399**	-.043	1	-.131**	-.113**	-.230**	-.031	.108*	.091*
	Sig. (2-tailed)	.000	.065	.000	.316		.002	.008	.000	.462	.011	.033
	N	554	554	554	554	554	554	554	554	554	554	554
Mature_Veg	Pearson Correlation	.026	-.063	.000	.063	-.131**	1	-.001	.102*	.056	.067	.030

	Sig. (2-tailed)	.534	.139	.993	.136	.002		.990	.016	.185	.115	.483
	N	554	554	554	554	554	554	554	554	554	554	554
Trail_Spur	Pearson Correlation	.268**	.319**	.192**	.033	-.113**	-.001	1	.086*	.280**	.110**	.086*
	Sig. (2-tailed)	.000	.000	.000	.442	.008	.990		.044	.000	.010	.043
	N	554	554	554	554	554	554	554	554	554	554	554
Historic_o	Pearson Correlation	.354**	-.116**	-.127**	.054	-.230**	.102*	.086*	1	.072	.001	-.316**
	Sig. (2-tailed)	.000	.006	.003	.208	.000	.016	.044		.089	.973	.000
	N	554	554	554	554	554	554	554	554	554	554	554
Modern_Ant	Pearson Correlation	.459**	.291**	.047	.076	-.031	.056	.280**	.072	1	.223**	.180**
	Sig. (2-tailed)	.000	.000	.273	.073	.462	.185	.000	.089		.000	.000
	N	554	554	554	554	554	554	554	554	554	554	554
Other_Nota	Pearson Correlation	.191**	.103*	.083	.079	.108*	.067	.110**	.001	.223**	1	.082
	Sig. (2-tailed)	.000	.016	.051	.064	.011	.115	.010	.973	.000		.055
	N	554	554	554	554	554	554	554	554	554	554	554
Portable_P	Pearson Correlation	-.076	.151**	.128**	.035	.091*	.030	.086*	-.316**	.180**	.082	1
	Sig. (2-tailed)	.074	.000	.003	.410	.033	.483	.043	.000	.000	.055	
	N	554	554	554	554	554	554	554	554	554	554	554

**. Correlation significant at the 0.01 level (2-tailed).

*. Correlation significant at the 0.05 level (2-tailed).

Giant Logs Correlations

		Vandalism	Soil Dist	Erosion	Trash	Slope	MatVegDam	Trail	PreHist Imp	ModImp	Other	PetWoodDen
Vandalism	Pearson Correlation	1	.015	-.294**	.141*	-.203**	.146*	.175**	.239**	.465**	.238**	-.103
	Sig. (2-tailed)		.809	.000	.020	.001	.016	.004	.000	.000	.000	.089
	N	274	274	274	274	274	274	274	274	274	274	274
SoilDist	Pearson Correlation	.015	1	.134*	.174**	-.015	.482**	.151*	-.228**	.495**	-.088	.099
	Sig. (2-tailed)	.809		.027	.004	.805	.000	.012	.000	.000	.148	.100
	N	274	274	274	274	274	274	274	274	274	274	274
Erosion	Pearson Correlation	-.294**	.134*	1	.032	.415**	.043	-.066	-.129*	-.193**	-.035	.097
	Sig. (2-tailed)	.000	.027		.602	.000	.480	.279	.033	.001	.563	.109
	N	274	274	274	274	274	274	274	274	274	274	274
Trash	Pearson Correlation	.141*	.174**	.032	1	.003	.138*	-.047	-.005	.109	-.037	-.045
	Sig. (2-tailed)	.020	.004	.602		.964	.022	.440	.934	.073	.544	.454
	N	274	274	274	274	274	274	274	274	274	274	274
Slope	Pearson Correlation	-.203**	-.015	.415**	.003	1	.005	-.050	-.089	-.151*	-.071	.115
	Sig. (2-tailed)	.001	.805	.000	.964		.934	.411	.141	.012	.241	.058
	N	274	274	274	274	274	274	274	274	274	274	274
MatVegDam	Pearson Correlation	.146*	.482**	.043	.138*	.005	1	.075	-.056	.366**	-.073	-.087

	Sig. (2-tailed)	.016	.000	.480	.022	.934		.215	.353	.000	.228	.150
	N	274	274	274	274	274	274	274	274	274	274	274
Trail	Pearson Correlation	.175**	.151*	-.066	-.047	-.050	.075	1	.100	.348**	.199**	.081
	Sig. (2-tailed)	.004	.012	.279	.440	.411	.215		.097	.000	.001	.182
	N	274	274	274	274	274	274	274	274	274	274	274
PreHistImp	Pearson Correlation	.239**	-.228**	-.129*	-.005	-.089	-.056	.100	1	-.014	.217**	-.349**
	Sig. (2-tailed)	.000	.000	.033	.934	.141	.353	.097		.818	.000	.000
	N	274	274	274	274	274	274	274	274	274	274	274
ModImp	Pearson Correlation	.465**	.495**	-.193**	.109	-.151*	.366**	.348**	-.014	1	.089	.003
	Sig. (2-tailed)	.000	.000	.001	.073	.012	.000	.000	.818		.143	.956
	N	274	274	274	274	274	274	274	274	274	274	274
Other	Pearson Correlation	.238**	-.088	-.035	-.037	-.071	-.073	.199**	.217**	.089	1	.094
	Sig. (2-tailed)	.000	.148	.563	.544	.241	.228	.001	.000	.143		.122
	N	274	274	274	274	274	274	274	274	274	274	274
PetWoodDen	Pearson Correlation	-.103	.099	.097	-.045	.115	-.087	.081	-.349**	.003	.094	1
	Sig. (2-tailed)	.089	.100	.109	.454	.058	.150	.182	.000	.956	.122	
	N	274	274	274	274	274	274	274	274	274	274	274

**. Correlation significant at the 0.01 level (2-tailed).

*. Correlation significant at the 0.05 level (2-tailed).

Long Logs Correlations

		Vandal	SoilDist	Erosion	Trash	Slope	MatVegDam	Trail	PreHisImp	ModImp	Other	PetWoodDen
Vandal	Pearson Correlation	1	-.105*	-.191**	.057	-.121**	-.037	.113**	.410**	.264**	.180**	-.315**
	Sig. (2-tailed)		.015	.000	.189	.005	.393	.009	.000	.000	.000	.000
	N	537	537	537	537	537	537	537	537	537	537	537
SoilDist	Pearson Correlation	-.105*	1	.367**	.081	.128**	.008	.241**	-.119**	.326**	.141**	.206**
	Sig. (2-tailed)	.015		.000	.060	.003	.853	.000	.006	.000	.001	.000
	N	537	537	537	537	537	537	537	537	537	537	537
Erosion	Pearson Correlation	-.191**	.367**	1	-.081	.366**	-.151**	.097*	-.255**	-.111**	.073	.205**
	Sig. (2-tailed)	.000	.000		.059	.000	.000	.024	.000	.010	.090	.000
	N	537	537	537	537	537	537	537	537	537	537	537
Trash	Pearson Correlation	.057	.081	-.081	1	.020	.117**	.158**	.112**	.077	.092*	-.040
	Sig. (2-tailed)	.189	.060	.059		.650	.007	.000	.010	.075	.033	.359
	N	537	537	537	537	537	537	537	537	537	537	537
Slope	Pearson Correlation	-.121**	.128**	.366**	.020	1	-.027	-.038	.000	-.056	.020	-.066
	Sig. (2-tailed)	.005	.003	.000	.650		.527	.375	.993	.194	.651	.129
	N	537	537	537	537	537	537	537	537	537	537	537
MatVegDam	Pearson Correlation	-.037	.008	-.151**	.117**	-.027	1	.000	.285**	.241**	.061	-.243**
	Sig. (2-tailed)	.393	.853	.000	.007	.527		.992	.000	.000	.161	.000
	N	537	537	537	537	537	537	537	537	537	537	537
Trail	Pearson Correlation	.113**	.241**	.097*	.158**	-.038	.000	1	.077	.459**	.569**	.060

	Sig. (2-tailed)	.009	.000	.024	.000	.375	.992		.073	.000	.000	.165
	N	537	537	537	537	537	537	537	537	537	537	537
PreHisImp	Pearson Correlation	.410**	-.119**	-.255**	.112**	.000	.285**	.077	1	.205**	.136**	-.647**
	Sig. (2-tailed)	.000	.006	.000	.010	.993	.000	.073		.000	.002	.000
	N	537	537	537	537	537	537	537	537	537	537	537
ModImp	Pearson Correlation	.264**	.326**	-.111**	.077	-.056	.241**	.459**	.205**	1	.394**	-.068
	Sig. (2-tailed)	.000	.000	.010	.075	.194	.000	.000	.000		.000	.115
	N	537	537	537	537	537	537	537	537	537	537	537
Other	Pearson Correlation	.180**	.141**	.073	.092*	.020	.061	.569**	.136**	.394**	1	.037
	Sig. (2-tailed)	.000	.001	.090	.033	.651	.161	.000	.002	.000		.394
	N	537	537	537	537	537	537	537	537	537	537	537
PetWoodDen	Pearson Correlation	-.315**	.206**	.205**	-.040	-.066	-.243**	.060	-.647**	-.068	.037	1
	Sig. (2-tailed)	.000	.000	.000	.359	.129	.000	.165	.000	.115	.394	
	N	537	537	537	537	537	537	537	537	537	537	537

*. Correlation significant at the 0.05 level (2-tailed).

**. Correlation significant at the 0.01 level (2-tailed).

APPENDIX B

TRAIL ASSESSMENT WORKSHEET (TO BE UPLOADED ONLINE AFTER THE FIELD EXPERIENCE)

As you traverse Tempe Butte, you will follow a trail that has been carved into the desert environment. Maintaining trails such as the one you are using and planning the construction of new trails comes with many challenges. The desert is a fragile environment that shows the impact of human interaction very quickly and can take a long time to recover when it is disturbed.

It can be difficult to maintain the integrity of trails when there are many people using them daily and only a handful of personnel are available to monitor them and repair problems. Exploring new ways for the users of trails to lend a hand in maintaining them is imperative to keep these systems well-regulated for continued use in the future.

Today, you will be exploring the use of crowdsourcing technology to help distribute the effort of monitoring trails for signs of distress. The concept of crowdsourcing relies on asking many people to make a few observations while they are on the trail. When the observations are combined, parts of the trail that have been impacted by human or natural factors will be ideally be identifiable thanks to a larger number of reports in those areas.

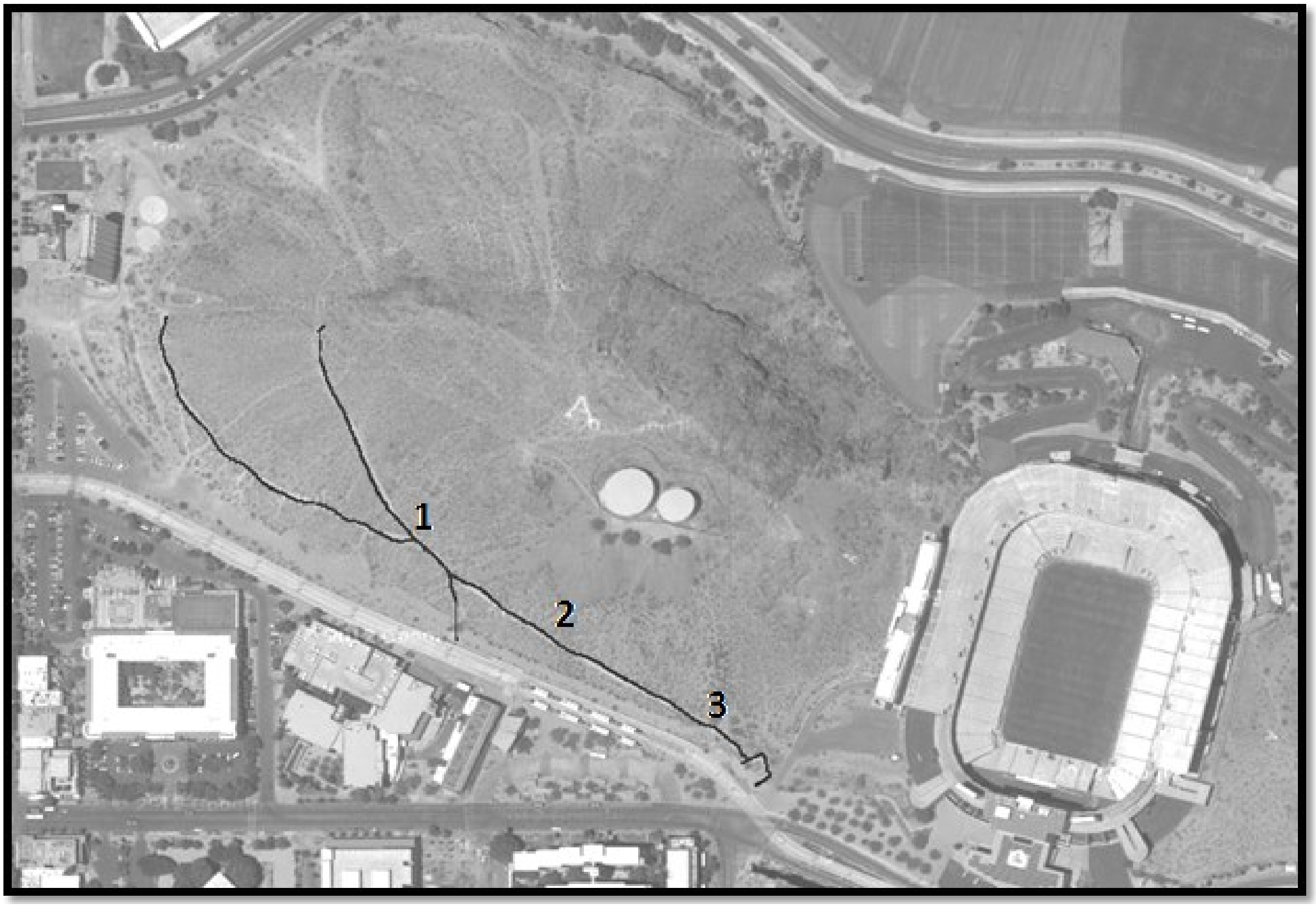
Instructions

To complete this assignment, you must stop and assess a minimum of six points—three that are marked on the map on the following page and three of your own choosing—for problems and notable observations that might be of concern to the people who maintain the trail. You will specifically be looking for evidence of:

- **A. Erosion near trails:** Gullies and deep rivulets that are encroaching on the trail and should be monitored.
- **B. Poor trail conditions:** The trail is washed out, rough, difficult to see, or otherwise obstructed.
- **C. Trash:** There is trash on the ground or caught in vegetation that must be cleaned up.
- **D. Dead or dying mature vegetation:** An individual mature plant or small group of mature plants shows signs of stress (unseasonable loss of leaves, large broken limbs) or has died.
- **E. Unauthorized trails:** Visible paths branching out from the park sanctioned and maintained trail.
- **F. Graffiti or vandalism:** Another person has intentionally destroyed part of the trail or part of the natural habitat in the vicinity of the trail.
- **G. Animal sighting:** Collecting reports about animal sightings can help park personnel understand the movement of wildlife.
- **H. Other concerns:** If you see something else of note that is not encompassed by this list, let us know in a comment!

Keep an eye out for these characteristics as you walk to your next assigned location. If you see something of interest, take a moment to stop and note the letter associated with that indicator (A-H) at your approximate location on the map printed on the following page.

When you get home, visit **http://hosted.seservices.us/elyssa/phx_tr/** to enter your points into the GPH 111 crowdsourcing system and to receive credit for your work



- **A. Erosion near trails**
- **B. Poor trail conditions**
- **C. Trash**
- **D. Dead or dying mature vegetation**
- **E. Unauthorized trails**
- **F. Graffiti or vandalism**
- **G. Animal sighting**
- **H. Other concerns (write note)**

Observation Point	Notes you take in the field
1	
2	
3	
Your spot X	
Your spot Y	
Your Spot Z	