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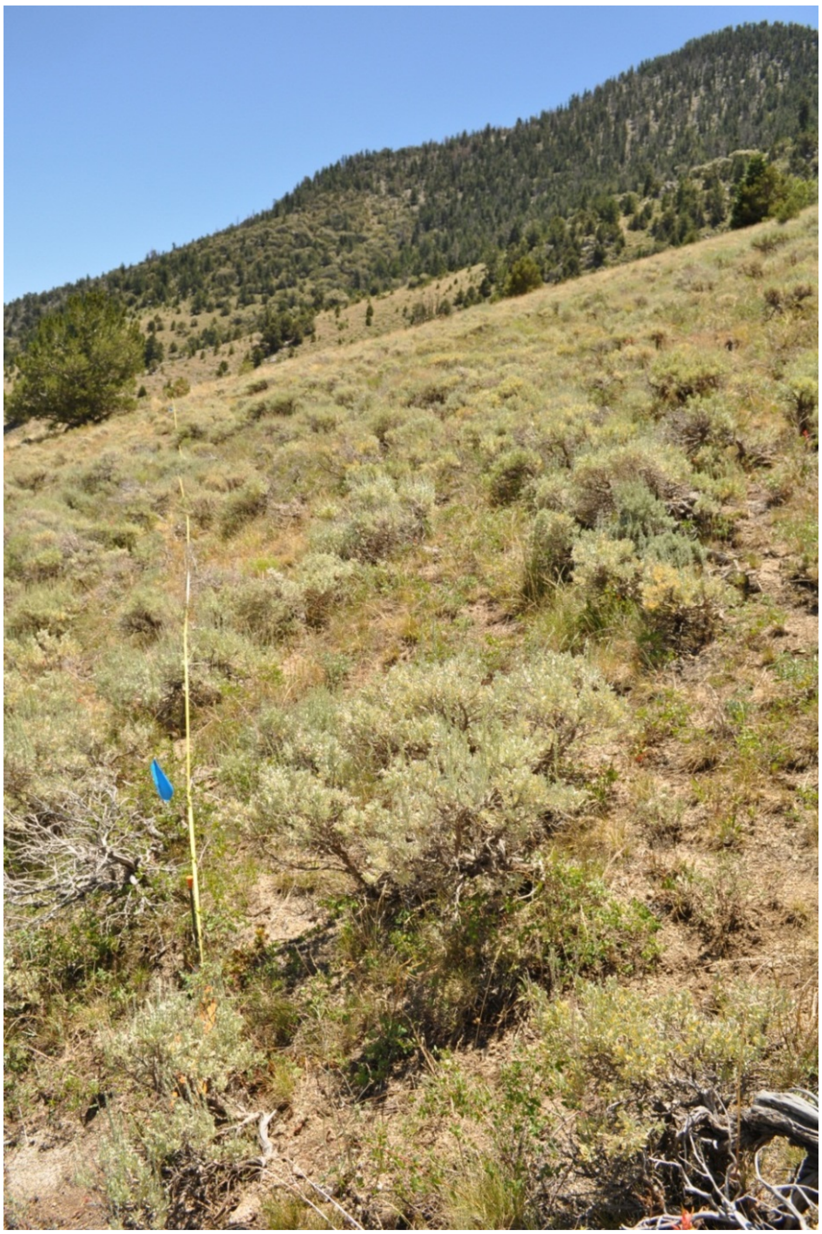
Natural Resource Stewardship and Science

Mojave Desert Network Integrated Upland Monitoring

2012 Pilot Study for Great Basin National Park

Natural Resource Technical Report NPS/MOJN/NRTR—2014/901



ON THE COVER
Sagebrush shrub steppe community monitoring plot, Great Basin National Park
Photograph by: Mojave Desert Network Inventory & Monitoring Program, Integrated Upland field crew, NPS.

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Executive Summary

The Integrated Upland (IU) Monitoring Protocol of the Mojave Desert Network Inventory and Monitoring Program (MOJN I&M) is one of the protocols developed for the National Park Service "Vital Signs Monitoring Program," a long-term ecological monitoring program that will provide rigorous, scientifically-based information on the status and trends of park ecosystems. Data from this program are intended to help park managers evaluate complex and challenging resource issues and make sound decisions that result in long-term protection of park resources. Information on park resource conditions will also be useful for park planning, research, education, and public awareness.

Twenty priority park vital signs - indicators of ecosystem health - that represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales were identified for MOJN I&M (Chung-MacCoubrey et al. 2008). The IU protocol (Pan et al. Unpublished Report [a]) addresses seven of these prioritized vital signs, including vegetation change, invasive plants, and soil-related vital signs. The focus of the IU protocol is upland shrub communities. Shrub communities were chosen because this physiognomic class collectively represents a large proportion of each park and captures several focal communities of interest (e.g., Joshua tree, creosote bush, and sagebrush), thus providing a common theme among parks (we use the term "park" for all units of MOJN). Each of the seven parks in the network, in collaboration with the MOJN I&M, selected a target upland community for monitoring. The sagebrush shrub steppe community was selected for monitoring at Great Basin National Park (GRBA).

A pilot study for the IU protocol (Pan et al. Unpublished Report [a]) was conducted in the spring and summer of 2012 and included the establishment and measurement of 19 plots across six of the MOJN parks (MANZ was not included as part of the pilot study). The objectives of the pilot study were to: 1) implement and fine-tune field methods and procedures (such as establishing macroplots, conducting field measurements, etc.) and 2) use information and time estimates from implementing field methods within target communities at parks to estimate protocol costs. In this report, findings based on the overall pilot study as well as park-specific field results for GRBA are presented. At GRBA, one macroplot was successfully established and had field procedures implemented, while two macroplots that were selected for methods testing had more limited data collection. We found seven shrub species and one tree species across the macroplots, detected one of the five target status and trends invasive species on the macroplots, and compared qualitative and quantitative soil parameters across macroplots. Cost estimates were generated, after field work was completed, for conducting field procedures, travel to field sites, and different crew staffing scenarios. Using information based on macroplots from all parks, the time to implement various field procedures ranged from around 30 min (Site Assessment for Invasive Plants) to up to 360 min (Soil Measurements) for a two-person field crew. At GRBA, the average estimated cost for each macroplot revisit (hiking time to field site plus field data collection, *not including driving time*) was $630, for a total of approximately $22,050 for 35 spatially randomly selected field sites. We discuss issues and make recommendations regarding sampling return intervals, crew sizes and schedules, and sampling procedures. Our primary recommendations include:

- ✓ Increase the monitoring interval for soil procedures, including basal/canopy gaps.
    - ▪ Analyze one soil sample per sampling point.
- ✓ Increase the monitoring interval for repeat photographs to every 3-4 monitoring periods (9-12 year intervals).

Acknowledgments

We thank the Great Basin National Park staff for their support before, during, and after our field work. We appreciate their arranging and meeting with us to discuss park and safety procedures. In particular, we thank Ben Roberts, our point of contact, who reviewed and provided advice on potential field sites, Bryan Hamilton for providing data and field advice, Gretchen Baker for facilitating our permit, Tod Williams, and the GRBA law enforcement rangers.

The field work could not have been done without our dedicated field crew: Student Conservation Association (SCA) interns Ashley Popham, Craig Rowell, Petra Murdoch, Heather Benedict, and Karin Edwards (contract botanist). Janel Brackin (MOJN I&M Science Communicator) and Bob Truitt (MOJN I&M Data Manager) provided much time on data entry, clean-up, and QA/QC. Natasha Antonova, GIS specialist at the North Coast and Cascades Network Inventory and Monitoring Program, ran the travel time cost surface model. David Gundlach, GIS specialist at the Mojave Desert Network Inventory and Monitoring Program, helped with some of the figures. We are grateful for the guidance that Kirk Sherill, developer of the travel time cost surface model, provided. Leigh Ann Starcevich conducted part of the repeat measurements analysis that is presented in Appendix C. We thank Lise Grace, technical editor at the North Coast and Cascades Network Inventory and Monitoring Program, for formatting the report and guiding us through the publication process.

Acronyms

BSC	Biological soil crust
DEM	Digital Elevation Model
DEVA	Death Valley National Park
EC	Electrical conductivity
GAP	California Gap Analysis Program
GIS	Geographic Information Systems
GPS	Global positioning system
GRBA	Great Basin National Park
GRTS	Generalized Random Tessellation Stratified
I&M	NPS Inventory and Monitoring Program
IU	MOJN I&M Integrated Upland Monitoring Protocol
JOTR	Joshua Tree National Park
LAKE	Lake Mead National Recreation Area
MANZ	Manzanar National Historic Site
MOJA	Mojave National Preserve
MOJN	Mojave Desert Network
NHD	National Hydrography Dataset
NPS	National Park Service
PARA	Grand Canyon-Parashant National Monument
PMTS	Percent of Maximum Travel Speed
SOP	Standard operating procedure
TTCSM	Travel Time Cost Surface Model
USGS	United States Geological Survey

1 Introduction

The parks of the Mojave Desert Network Inventory and Monitoring Program (MOJN I&M) are faced with increasing pressures from air pollution, habitat loss, fragmentation, and altered disturbance regimes (e.g., fire, land development; Chung-MacCoubrey et al. 2008). Climate models also predict significant climatic changes, with increasing temperatures and decreasing precipitation, for the southwestern United States (Seager et al. 2007, Archer and Predick 2008). The presence and composition of vegetation depends on a multitude of abiotic and biotic factors including climate, resource availability, and soil microbial community. This makes vegetation and the soils associated with it good general indicators of environmental change across parks (Vasek and Lund 1980, Janssens et al. 1998, Klironomos 2002, Hereford et al. 2006).

The Integrated Upland (IU) monitoring protocol was designed to provide the status and trends of natural resources (vegetation, soil, and invasive plants; see *Section 1.1 Vital Signs*) in upland shrub communities at all seven MOJN parks: Death Valley National Park (DEVA), Great Basin National Park (GRBA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAKE), Manzanar National Historic Site (MANZ), Mojave National Preserve (MOJA), and Grand Canyon-Parashant National Monument (PARA). Monitoring focuses on a target upland shrub community within each park. Data collected from IU monitoring plots will serve two very important purposes: 1) providing a quantifiable framework from which to build adaptive management policies, and 2) providing a baseline from which to establish additional scientific studies (e.g., those addressing cause and effect relationships). With a basic understanding of the park resources and processes affecting them, land managers can make more informed decisions about how to conserve these resources into the future.

We conducted a pilot study of the IU Monitoring Protocol at six of the MOJN parks (DEVA, GRBA, JOTR, LAKE, MOJA, PARA) and full implementation (where the planned number of macroplots were established and measured) of the protocol at the smallest park (MANZ). Nineteen macroplots were established and measured across the six pilot parks. We utilized findings from the six parks to estimate time and cost estimates for implementation of the IU Monitoring Protocol at each of the parks. This report describes the activities and findings of the 2012 pilot study at Great Basin National Park (GRBA), where we focused on the **sagebrush** (*Artemisia* spp.) **shrub steppe community** (Figure 1). The objectives of the pilot study were to: 1) implement and fine-tune field methods and procedures (such as establishing macroplots, conducting field measurements, etc.) and 2) use information and time estimates from implementing field methods at randomly selected field sites within target communities to estimate protocol costs. *We used the information collected during our pilot study to: 1) evaluate different travel cost scenarios to conduct IU monitoring (see Section 3 Results; Appendix B - Travel Cost Scenarios Tables), and 2) examine the field data collected using the SOPs, including limited data from the remeasurement of macroplots (see Appendix C).*

1.1 Vital Signs

After a series of vital signs scoping workshops, 20 priority vital signs - indicators of ecosystem health - that represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales were identified and ranked for MOJN I&M (Chung-MacCoubrey et al. 2008). The IU protocol directly addresses seven highly ranked vital signs, which we broadly categorize as vegetation change, invasive plants, and soils (number in parentheses is ranking as described in Chung-MacCoubrey et al. 2008):

- Vegetation change (2)
- Invasive/exotic plants (3)
- Soil-related:
  - Soil chemistry (9)
  - Soil hydrologic function (10)
  - Soil erosion and deposition (11)
  - Soil surface disturbance (12)
  - Biological soil crusts (13)

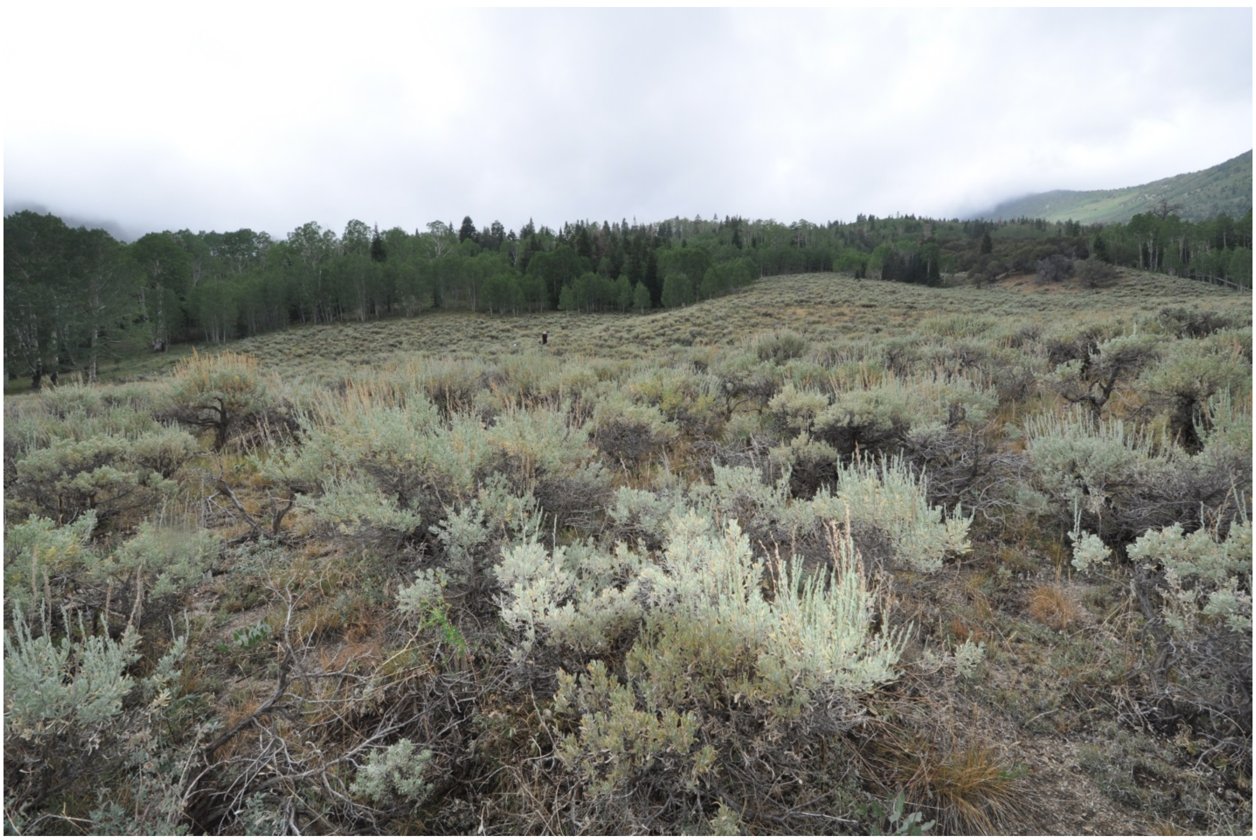

Figure 1. Sagebrush (*Artemisia* spp.) shrub steppe community at Great Basin National Park. Photo by Mojave Desert Network Inventory & Monitoring Program, Integrated Upland field crew, NPS.

2 Methods

Here, we describe how potential field sites were randomly selected using a Generalized Random Tessellation Stratified (GRTS; see *Section 2.1 Sampling Frames*) design or selected by field crews, how time and cost estimates were generated for travel cost scenarios (see *Section 2.2 Travel Cost Scenarios*), the field methods used for data collection (see *Section 2.3 Field Methods*), data quality assurance and control (QA/QC), data processing, and data analyses (see *Section 2.4 Data Summary*). These procedures are described in full in the MOJN IU protocol SOPs (Pan et al. Unpublished Report [b]).

2.1 Sampling Frames

At GRBA, field sites for macroplot establishment were selected either from the GRTS survey design or by the field crew from appropriate community types close to roads; the latter were used for methods testing and to examine crew measurement error (Appendix C), and would not be included in future IU monitoring. The GRTS survey design (Stevens and Olsen 2004) produces a randomly selected set of sites that are spatially balanced across the monitored community and then takes into account the spatial distribution of field sites during data analysis. New GRTS survey designs may be used when IU monitoring is implemented at all parks, depending on whether there are park requested changes in community criteria.

In order to select potential field sites, we first determined the spatial distribution of the target upland community at GRBA, the **sagebrush** (*Artemisia* spp.) **shrub steppe community**. This plant community was selected for monitoring because it is a community of special management concern at GRBA. Similar to sagebrush communities in other areas of the Great Basin ecoregion, sagebrush communities at GRBA are experiencing encroachment by pinyon-juniper trees and invasion by annual grasses. Over 80% of the sagebrush shrub steppe community has been lost at GRBA in the last 100 years, down from 16,400 ac to only 3,050 ac (Provencher et al. 2010). Managing for the maintenance of the sagebrush shrub steppe community at GRBA is crucial for wildlife management, as sagebrush shrub steppe provides valuable habitat for a number of sensitive small mammal species (Hamilton and Horner 2010).

The spatial distribution of the sagebrush shrub steppe community was evaluated using the provisional park vegetation map (2011) from the I&M vegetation mapping program, the best available vegetation map for GRBA. Using Geographic Information Systems (GIS), we created a 100 m buffer just inside the park boundary, which was removed from the spatial distribution of the target community to ensure that any sites selected would be entirely within the park boundary. Where possible, we also eliminated target vegetation areas that were too small to support the 1 ha macroplot. The remaining area served as the sampling frame for the GRTS site selection (see Figure 2) and is considered the population of inference.

We used an equal probability GRTS survey design at GRBA, so that all areas of the population of inference had an equal probability of being selected. We had an initial draw of 35 sites for the park (Figure 2) based on power analyses across the different park units (see Pan et al. Unpublished Report [a] for details; report is available upon request), with an oversample of 300 sites, which allows for elimination of sites due to sampling frame errors arising from map inaccuracies (e.g., non-target vegetation type; Pan et al. Unpublished Report [a]), as well as the addition of sites in the future if it is determined from power analyses that more macroplots are needed.

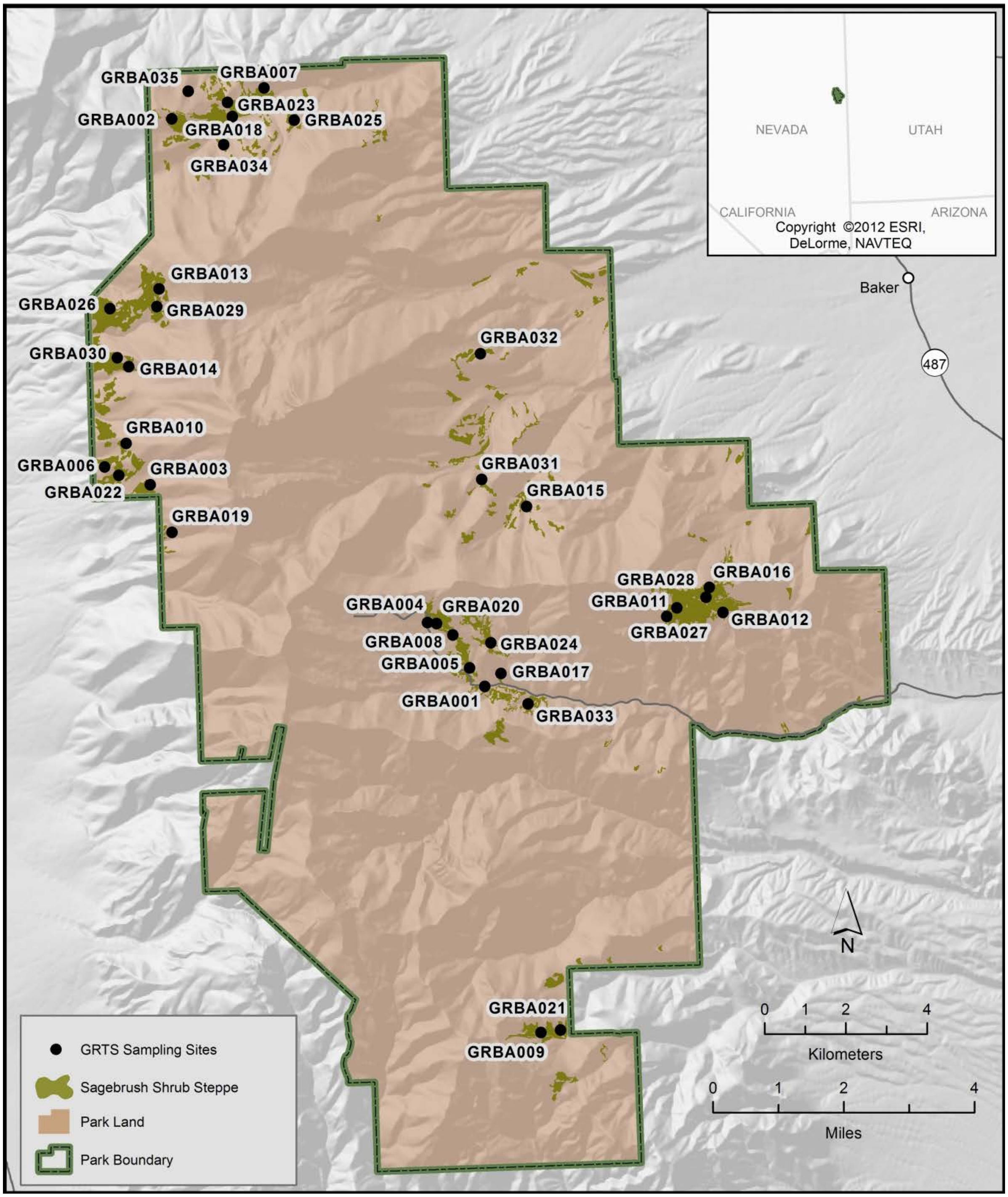

Figure 2. The first 35 sites selected from the Generalized Random Tessellation Stratified (GRTS) survey design draw for Great Basin National Park.

For the pilot season, we generated a list of 10 potential field sites by selecting a subset of field sites that were within 1 mile of a road from the initial draw of 35 sites at GRBA. We then used a Digital Elevation Model (DEM) and satellite imagery (available in Google Earth) to conduct office reconnaissance on the potential field sites at GRBA, eliminating any sites that were unsuitable (e.g., unsafe, inaccessible). The remaining sites were then provided to GRBA staff for further input. If park staff deemed a site inappropriate for long-term monitoring (e.g., culturally-sensitive, unsafe), then the field site was rejected. If needed, a replacement site was added from either the remaining sites in the initial draw or from the oversample.

Potential field site visitation order was determined by MOJN I&M office staff. Field sites could also be rejected after field crews physically visited sites (Pan et al. Unpublished Report [b], *SOP 6 – Site Characterization*). If a field site was rejected by the crew, then they proceeded to the next site on the list of potential sites. If a site was acceptable, then a macroplot was established and data were collected.

After visiting the first site, we realized the significant time commitment required to visit sites on the GRTS list. We put a greater priority on testing our field methods and obtaining data remeasurements and, therefore, decided to have the field crew select sites in the sagebrush shrub steppe community that were close to roads and to where the crew was staying. Thus, the full suite of data were collected on only one macroplot, and methods testing, limited data collection, and remeasurement occurred at two sites close to a road (see Figure C1). However, only the site from the GRTS draw was used in the travel time cost surface model (see section *2.2 Travel Cost Scenarios*).

2.2 Travel Cost Scenarios

We evaluated travel to field sites (time and/or distance) using a travel time cost surface model (TTCSM; Appendix A), the number of field crew members, field crew schedule (e.g., 8 vs. 10 hour work days), and local vs. traveling crew in the travel cost scenarios. TTCSM and crew-related scenarios were conducted after the pilot study (and based loosely on field experience from the pilot study, such as estimates of travel time to different park units) to provide an overall cost estimate for IU establishment and monitoring of 35 macroplots at each park. In contrast, scenarios proposed for initial establishment of macroplots, field procedures, and subsequent revisits that consist primarily of field data collection, were based on pilot study time estimates for the six parks.

Estimates for initial establishment of macroplots included all costs associated with the establishment of macroplots, including office and field reconnaissance of potential field sites, and macroplot set-up. We assumed that 50 potential field sites would be evaluated through office reconnaissance and 40 sites through field reconnaissance.

We ran a TTCSM on the first 35 field sites from the GRBA GRTS draw in ArcGIS (see *Section 2.1 Sampling Frames*). A TTCSM determines the shortest reasonable route to a field site and estimates the travel time to the site, given certain parameters (Sherrill et al. 2010). Six primary datasets were used in the model (source in parentheses): trails (GRBA), roads (GRBA), lakes (GRBA), vegetation (USGS), digital elevation model (USGS), and streams (USGS). An impediment value (i.e., how much the impediment obstructs a person from walking the maximum speed) is given for parameters within each layer (see *Appendix A – Travel Time Cost Surface Model* for detailed specifications). Driving speeds were set to the type of road: paved, primary roads were 55 mph, paved, secondary roads were 45 mph, paved/unpaved, light duty, all weather roads were 20 mph, unpaved, fair/dry weather roads were 15 mph, and unmaintained 4x4 roads were 10 mph. Since hiking/walking speeds are likely to vary with field crew members, we ran the model using three maximum hiking speeds, 2, 2.5, and 3 mph. Four locations (three on the east side and one on the west side) around the park were designated as travel start points to field sites (see Appendix B).

The costs for field crew travel time and field data collection/data management were estimated separately to show the cost of each component. Field data collection estimates were further separated by SOP and vital sign to allow for independent assessment under different monitoring scenarios (e.g., revisit periods). Field data collection times were estimated from field work conducted at all parks in the pilot study.

The scenarios that we examined for crew schedule were 8-hour days for 5 days a week, 10-hour days for 4 days a week, and 10-hour days for 8 days over a 2-week field tour. Crew travel time was estimated from the MOJN I&M office at LAKE, Boulder City, NV, to the park unit. Given the varying distances to the MOJN park units, travel was estimated to take 1-2 days of each week or 2-week field tour. Travel to GRBA will likely be closer to 2 days per field tour. Estimates of per diem for NPS employees were not included in the hourly rates, but are presented separately as part of this scenario. Backcountry per diem was estimated at $20 per person per night.

Crews may be based at the park that they are working in for the field season, instead of returning to the MOJN I&M office at the end of each field tour. In this scenario, crews can either be temporarily based at the park unit that is being monitored and return to the MOJN I&M office after all field work is completed or be park-based; in both cases, minimal travel is anticipated.

The cost of field crew time was estimated for a GS-5 field technician and 1-3 volunteer natural resource interns (e.g., Student Conservation Association interns). We used an hourly wage estimate of $22 per hour for the GS-5 position and $14 per hour for interns. A GIS specialist would be needed to assist with office reconnaissance of potential field sites and to generate recommended travel routes to field sites. The hourly wage estimate for a GS-11 GIS specialist is $39. Wage estimates included benefits, when applicable.

2.3 Field Methods

A brief description of each field data collection procedure is presented in this section and SOPs referenced in this section are from Pan et al. (Unpublished Report [b]). The vegetation change vital sign is measured using the point-intercept procedure (SOP 8) and repeat photographs procedure (SOP 13). The invasive species vital sign is measured using the point-intercept procedure (SOP 8), invasive species frequency quadrats procedure (SOP 10), and the site assessment for invasives procedure (SOP 12). The soils vital signs are primarily measured using methods in the soil measurements procedure (SOP 11), with the exception of the soil erosion and deposition vital sign, which is measured with the basal/canopy gaps procedure (SOP 9). For specific details on the macroplot design and SOPs, see Pan et al. (Unpublished Report [b]).

Each macroplot was 100 m by 100 m (Figure 3). Within each macroplot, we established three parallel, 50-m transects spaced 25 m apart. The origin and end of each transect and the corner of the macroplot closest to the origin of transect 1 were permanently marked with rebar, labeled with a tag, and the spatial location recorded using a GPS.

Three procedures were implemented on transects (referred to hereafter as transect-related procedures): the point-intercept, basal/canopy gaps, and invasive species frequency quadrats; the transect-related procedures provide data on the vegetation, soils, and invasive plant vital signs, respectively. The point-intercept procedure was used to measure vegetation, including target invasive plants, soil surface features, soil disturbance features, and biological soil crust (BSC) at points every 1 m along the transect. Identifiable vegetation was recorded to the species-level for shrubs and target invasive species; other identifiable vegetation was recorded by life form (i.e., grasses, forbs, or trees) or within a designated category (e.g., litter). Hereafter, species refers to both plant species and designations within life forms (e.g., annual grass, perennial grass) for plant cover. We used the basal/canopy gaps procedure to measure the potential for soil erosion by recording all gaps created by perennial plant bases and canopies along the transect that were ≥0.2 m.

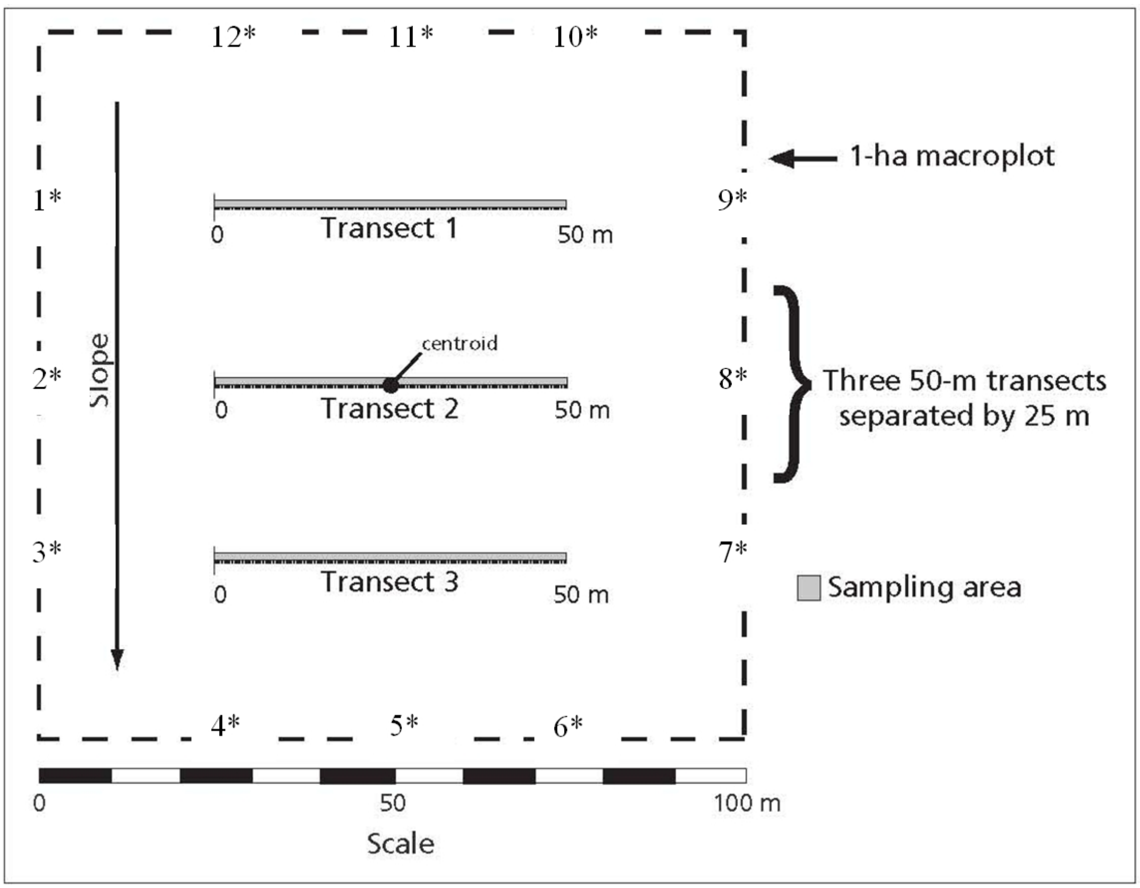

Figure 3. Standard macroplot and transect layout for integrated upland monitoring. Locations on the edge of the macroplot indicated by an “*” are sampling locations for soil parameters. The number next to the “*” is the sampling location number.

Five established upland invasive species, which we will refer to as status and trends (S&T) invasive species, were prioritized for monitoring at GRBA: *Bromus tectorum* (cheatgrass), *Erodium cicutarium* (redstem filaree), *Melilotus* spp. (sweetclover), *Salsola* spp. (Russian thistle), and *Sisymbrium altissimum* (tumble mustard). Frequency of target S&T invasive species and soil disturbance were assessed by placing 0.25 by 0.25 m quadrats every 1 m along transects. Presence of target S&T invasive species was further assessed using a patterned walk in the macroplot (SOP 12).

Soil parameters were sampled at 12 regularly spaced sampling points along the perimeter of each macroplot (Figure 3). At each soil sampling point, soil measures (except soil compaction readings) were taken for a vegetated (soil underneath vegetation) and barren (soil was not underneath vegetation) soil sample. Soil erosion will be assessed as direct and potential soil erosion (from the basal/canopy gaps procedure). We were not able to directly measure soil erosion during the pilot study because our assessment depends on the relative difference in soil height between monitoring periods at each of the rebar stakes ("soil erosion pin" method; Pan et al. Unpublished Report [b]). Canopy gap measurements can be used to assess the potential for wind erosion and basal gap measurements, the potential for water erosion.

One photograph was taken of each transect and one overview photograph was taken of the macroplot, all focusing on the vegetation (and used to address the vegetation vital sign), as described in the repeat photos procedure (SOP 13). Similarly, soil erosion specific photographs and an overview photograph of the macroplot focusing on the soil were taken and will, in future years, be used to assess soil erosion.

2.4 Data Summary

In this section, we describe the procedures used after data were collected in the field, starting with data entry, and continuing through QA/QC, data processing, and analysis. All measured variables were processed to provide macroplot-level estimates, making the macroplot the unit of replication and analysis.

QA/QC of data involved three main steps: verification, validation, and certification. During the pilot study, data were collected on hardcopy field forms. Data verification involved ensuring that data were accurately entered from the hardcopy field forms into the electronic database. To do this, each data field form was manually double-entered into the Infopath data entry system. Two different MOJN I&M staff entered each hardcopy field form into a SharePoint site using a Microsoft (MS) InfoPath front-end form. Digital files of the field forms were downloaded in a MS XML file format and converted to Excel and csv file formats in MS Excel 2010. Matching flat files for each field form were compared using the "Compare" procedure in SAS (SAS Institute, Inc.), which highlighted any differences in data entry between the two files. Differences between the files were manually checked against the paper field form and corrected in one flat file, which became the "official" digitized copy for the field form. Data validation involved checking the verified data files to ensure that the data values for each field were reasonable (e.g., pH values not >14, plant codes matched a species or group, recorded categories were valid for the field). We completed a 100% verification and manual validation check for data collected during the pilot study. Data certification procedures require that the MOJN I&M Program Manager certify the data, at which point, the data are ready for analysis and made available for distribution as appropriate.

Results are presented for individual macroplots or averaged across monitored macroplots. For transect-related procedures (i.e., point-intercept, basal/canopy gaps, invasive species frequency quadrats), the data were first averaged across a transect and then averaged across all three transects to derive a macroplot-level measure. To determine absolute % cover of variables for a transect using the point-intercept procedure, we counted the number of times a species/category was recorded across the 50 points (every 1 m along the transect), divided the number by the total number of points (50), and then multiplied by 100. For invasive species frequency quadrats, we counted the number of quadrats per transect in which each target invasive species was found and divided that number by the total number of quadrats (50) to obtain a frequency per transect. Invasive species live/dead status, spatial distribution, and phenophase frequencies were calculated for only those quadrats that each invasive species was present on for a transect (e.g., frequency for presence under canopy was calculated by taking the number of quadrats where the species was found under canopy and dividing by the total number of quadrats on the transect in which the species was found).

Soil parameters collected along the 12 soil sample points were categorized as vegetated or barren and averaged across the 12 points to obtain a macroplot-level estimate. In certain instances (e.g., sample location on bedrock, no soil could be obtained, soil sample numbers were reduced due to time constraints), there were fewer than 12 soil sampling points, so data were averaged over all available points. For qualitative soil data, we determined the dominant category and present the range of categories observed across the sampling points.

3 Results

A summary of the travel cost scenarios for GRBA, based on the information from the pilot study, is presented in this section. For more detailed information, including data collected during the pilot study, refer to *Appendix B – Travel Cost Scenario Tables* and *Appendix C – GRBA Macroplot Data from the Pilot Study*. For ease of presentation, travel cost scenarios were estimated for a 2-person crew, the minimum number of people needed for most procedures. However, with a larger field crew, field procedures can be conducted simultaneously, resulting in less time spent at a particular field site.

3.1 Travel Cost Scenarios

Travel cost scenarios were broken into three non-overlapping components: travel (driving and hiking) to field sites, initial macroplot establishment, and field data collection costs. *Not including any driving travel* (see below for explanation), estimated total costs for the initial year of monitoring at GRBA ranged from $560 to $903 per macroplot based on a 2-person crew for each procedure. For the randomly selected 35 sites from the GRTS draw, the average cost per macroplot was $728[1] during the initial establishment and the total cost was $25,480. Estimated cost for macroplot revisits (hiking time to field sites plus field data collection) averaged $630 per macroplot, and totaled $22,050 for the 35 macroplots. It is anticipated that five macroplots will be re-measured each field season to estimate crew measurement error. The estimated cost for the re-measurement of the five macroplots is $3,150. More detailed cost estimates, including a breakdown by vital signs, and scenarios for travel, field crew number, crew schedule, and local vs. traveling crew, are described below and in *Appendix B -Travel Cost Scenarios Tables*.

Travel costs are assumed recurring costs for monitoring and will not decrease with time or experience. We focused on hiking time in our travel scenario rather than total travel time (driving plus hiking) because the travel time cost surface model calculated travel time only from set starting locations (see Appendix B). Driving times for the 35 GRTS sites included in the TTCSM ranged from ~5 min to 42 min from the nearest park starting point (Appendix B). However, driving times will be highly dependent on the proximity of field sites (e.g., one drive may lead to multiple field sites), how sites are scheduled to be visited, and where the field crews are based. In some cases, the most substantial driving times may be from the MOJN I&M office to the park.

Hiking time and costs estimates are likely to be more consistent as they are measured from the nearest point off the road to the field site. Actual one-way hiking time estimates ranged from 1 to 216 min (hike distances are provided in Appendix B). When we categorized the 35 GRTS field sites by hiking times, we found that most (43%) of the field sites were accessible within a 60 min hike under the 2.5 mph model (Appendix B). Estimated costs for round-trip hiking to potential field sites at GRBA ranged from $36 (<30 min hike one-way) to $205 (171 min hike one-way) for a 2-person

[1] Macroplot cost was calculated by taking the average hiking cost ($113, as determined from Table B2) and the midpoint of the cost range for establishment ($111) and field work ($500).

crew. With a crew of three or four people, which may be needed during macroplot establishment, estimated round-trip hiking costs ranged from $49-63 to $365-445 per site, respectively.

Estimates for all field data collection that was conducted during the pilot study, including field data management, ranged from $428-572 per macroplot for a 2-person crew. Individual estimates of time by field procedure showed that the basal/canopy gaps and soil measurements procedures were the most time consuming (Table 1).

Table 1. Time (minutes) and cost (dollars) estimates for each field data collection procedure, field data management, and revisit set-up with a 2-person crew (one GS-5 field technician and one natural resource intern). Estimates are based on average to high density vegetation communities. Total time for all field procedures ranged from 660-900 min. Less dense communities, like creosote shrublands, will take less time, particularly for the point-intercept and basal/canopy gaps procedures, where times may be less than half the current estimate.

SOP	Time Estimate	Time Estimate for 3 Transects/12 Points	Cost Estimate - Field Technician	Cost Estimate - Intern	Total Crew Cost per SOP
Point-intercept (8)	20-30 min/transect	60-90	22-33	14-20	36-53
Basal/Canopy Gaps (9)	60-75 min/transect	180-225	66-83	41-51	107-134
Invasive Species Frequency Quadrats (10)	30-45 min/transect	90-135	33-50	20-31	53-81
Soils Measurements (11)	20-30 min/point	240-360	88-132	54-82	142-214
Site Assessment for Invasive Species (12)	30 min	30	11	7	18
Repeat Photos (13)	60 min	60	22	14	36
Field Data Management (field QA/QC, data download)	60 min/day		22	14	36
Revisit set-up*		15-30	5-11	3-7	8-18

*Upper estimate includes soil revisit set-up.

When field data collection costs were calculated by vital sign, **we found that costs were greatest for the soil-related vital signs and lowest for the vegetation change vital sign** (Table 2). On average, the cost for each of the seven vital signs ranged from $56-76 per macroplot. The cost per soil vital sign varied greatly, with soil surface disturbance and biological soil crust being negligible (embedded into point-intercept and invasive species frequency quadrats) to soil erosion deposition ranging from $113-140 per macroplot. We also compared the cost of conducting soil procedures in the field *vs*. collecting soil and conducting procedures in the office. Estimated costs for soil procedures in the field ranged from $142-214, while soil collection in the field plus office measurements ranged from

$260-486 per macroplot (Appendix B). Despite issues with the electrical conductivity meter[2] in the field, data did not vary greatly between samples measured in the field *vs*. in the office (data not shown).

Table 2. Time (minutes) and cost (dollars) estimates for field data collection by vital sign with a 2-person crew (one GS-5 field technician and one natural resource intern). Travel and data management costs are not included. Soil surface disturbance and biological soil crust data collection are completely embedded in the point-intercept and invasive species frequency quadrats and are individually negligible.

Vital Sign (rank)	Estimate of Time for SOPs	Cost Estimate - Field Technician	Cost Estimate - Intern	Total Crew Costs per Macroplot
Vegetation change (2)	110-140	40-51	25-32	65-83
Invasive Plants (3)	120-165	44-61	27-37	71-98
Soil chemistry (9) Soil hydrologic function (10)	240-360	88-132	54-82	142-214
Soil erosion & deposition (11)	190-235	70-86	43-54	113-140
Soil surface disturbance (12)	Negligible	---	---	---
Biological soil crusts (13)	Negligible	---	---	---

Costs associated with initial establishment of a macroplot are non-recurring and only expected once. Estimates for initial macroplot establishment, which included pre-clearance of potential field sites and macroplot set-up but *not* travel (see above for travel estimates), ranged from $96-126 per macroplot for a 2-person crew (Appendix B). Macroplot revisit set-up costs are shown in Table 1.

We considered various crew scenarios for conducting the IU protocol field monitoring, specifically variation in crew number, crew schedule, and traveling *vs*. local (park-based) crew. Variation in crew number was examined in previous scenarios. Primarily, we considered a base crew of two people for most procedures. An additional one to two volunteer interns can be added to the base crew number, if needed, and procedures, such as the point-intercept and soil measurements, can be conducted simultaneously.

The primary impact of different crew schedule scenarios are the number of days spent traveling from the MOJN I&M office to parks, given the minimum number of field work days needed to collect data. It is expected that under long-term implementation of the IU protocol, all field data collection will take 1 day; thus, a minimum of 35 working field days are needed (or 40 working field days if 15% of monitored macroplots are revisited within the same season to estimate measurement errors). One-way travel time was estimated to be ~1 day for GRBA (Appendix B).

We found that a crew schedule of 10-hour days, working 8 days out of 2 weeks, was the most economical, with 12-14 travel days, and the cost of travel time for a crew of two ranging from $4,272-4,984 to the more distant parks. Four-day work weeks, with 10-hour work days, were the least economical, with an estimated 36-40 travel days costing $12,816-14,240. Eight-hour days,

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[2] It was difficult to get a stable reading on the electrical conductivity meter under windy or hot conditions. The meter seemed to overheat when temperatures were above 100º F.

working 5 days a week, fell in between the other scenarios, with an estimated 24-26 travel days costing $6,835-7,405. Per diem costs for two crew members ranged from $1,840-1,920 for the 10-hour days, working 8 days out of 2 weeks, to $2,240-2,400 for the 10-hour work days, working 4 days per week (Appendix B).

Field crews could also be either temporarily or permanently based at the monitored parks. In both cases, the amount of time that crews spent in travel to parks was drastically reduced. Crews that were temporarily based at parks for the field season would require at most 2 travel days, one day to and one day from the park, which would cost $576 ($288 times 2 days). If park-based crews are available, they would not require any travel days to the park and would likely have limited travel-related costs (e.g., per diem).

3.2 Office and Support Staff Costs

In addition to costs directly related to field data collection, costs are incurred by MOJN I&M network staff as they are needed to organize and plan the field season, provide logistical and data management support, and produce protocol reports. Network staff consist of the Logistics Technician, Data Management Team (Data Manager, GIS Specialist, and Data Technician), and Ecologist. The Logistics Technician is expected to spend 1/3 of his/her time (~8 pay periods) on the IU protocol on a recurring basis. During the protocol initial establishment years, both the Data Management Team and the Ecologist are expected to spend more time on IU-related activities (e.g., 1/3 of the Ecologist's time). Once the protocol is established and monitoring consists primarily of revisits, it is anticipated that the Data Management Team and Ecologist effort will be reduced on IU-related activities (Table 3).

Table 3. Network staff cost (dollars) estimates for the integrated upland protocol.

Network Staff	Annual Cost - Initial Establishment	Annual Cost - Recurring
Logistics Technician (GS-7)	12,000	12,000
Data Management Team (GS-11, GS-11, GS-9)	27,000	15,000
Ecologist (GS-11)	31,000	24,000

4 Issues and Implementation Recommendations

We successfully established one macroplot from the GRTS draw that was within 1 mile of roads and tested methods at two macroplots not from the GRTS draw during our 2012 pilot season at GRBA. Through the pilot study, we examined the effectiveness of our field procedures in the target community and some of the challenges of monitoring vegetation within parks. Below we highlight some of the issues that were elucidated (through the pilot study or outside discussions or meetings) and our recommendations to address them. Coordinates for potential field sites may be re-drawn using the GRTS survey design, depending on the recommendations that are adopted.

4.1 Travel and Field Time

During MOJN I&M's start-up review, it was recommended that monitoring of individual macroplots be limited to 1 day, including travel time to sites. The initial set-up of field sites is estimated to take approximately half a day, depending on vegetation type and field crew size (see *Section 2.2 Travel Cost Scenarios*). However, initial macroplot set-up is anticipated to be a one-time occurrence and not expected to affect field time in the long-term. Therefore, we focus on revisit-related field efforts and recurring travel below.

4.1.1 Field Time

The amount of time needed for monitoring and data collection varies depending on the community type and density of vegetation; the sagebrush shrub steppe community at GRBA is on the medium to high density end of the vegetation spectrum. In general, denser vegetation will require more time, particularly for the basal/canopy gaps procedure. In years when there is a greater density of annuals, time needed for the point-intercept and invasive species frequency quadrats procedure will likely increase (SOP 9 considers only perennials). For all macroplots established during the pilot study (i.e., across all parks), it took ~360 to 480 min for a crew of three, working simultaneously on different procedures, to complete all vegetation, invasive plants, soil, and repeat photograph procedures; transect procedures were the time-limiting procedures.

<u>Recommendations:</u>

- ✓ Increase the time interval between sampling events for soil parameters, including basal/canopy gaps. For instance, transect-based basal/canopy gap measurements can be measured every other monitoring period (every 6 years), and soil sampling point-based procedures can be repeated every 5-6 monitoring periods (every 15-18 years). Under this proposed scenario, over a 20-year period, basal/canopy gaps would be monitored in years 1, 6, 12, 18, and soil sampling points in years 1 and 15. Direct monitoring of soil erosion with the soil erosion pin procedure can occur every monitoring period because the procedure is extremely quick (~15 min) and rates of soil erosion may be fairly rapid, depending on the local conditions.
- ✓ Increase the time interval between repeat photographs to every 3-4 monitoring periods (every 9-12 years); thus, repeat photographs would be taken in years 1, 9, and 18, or in years 1 and 12, over a 20-year period.

Cost estimates, including average hiking time, based on a 2-person crew for different combinations of field procedures at GRBA are shown in Table 4; Table 4 cost estimates are based on the **recommended monitoring scenarios**[3]. The combination of procedures may vary from sampling period to sampling period, depending on the time between sampling events for each procedure, which may affect the estimated costs of monitoring for each sampling event. For example, conducting all procedures (scenario 5 in Table 4) every 3 years, IU monitoring at GRBA would cost ~$82,950 to $105,840 over a 15-year period. On the other hand, following the recommendations above, such that the sequence of scenarios (Table 4) was 5, 1, 3, 2, 3, 4, over a 15 year period, monitoring costs would range from $61,600 to $76,160.

The drawback to increasing the monitoring intervals for the soil (including basal/canopy gap procedure) and repeat photographs procedures is that it will take much longer before enough data are collected for comparisons through time and an even longer period of time may be needed to detect whether trends exist. Previous power analysis results predicted that a 1% change can be detected with 80% power in 20 years, with monitoring occurring every 3 years, for vegetation cover (Pan et al., Unpublished Report [a]). Soils are likely to change more slowly than vegetation, so with monitoring occurring every 6 or 15 years, we may not be able to detect change in soils until ~50 to over 100 years, respectively.

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[3] See *Section 4.2 Field Procedures* recommendation section below for description of recommendations. The average hiking cost per macroplot at GRBA was the same as used in results ($113). The cost estimate for the soil measures ($49-95) and basal/canopy gaps procedure ($90-108) was based on the modifications recommended under *Section 4.2 Field Procedures*.

Table 4. Cost (dollars) estimates, including hike times, to conduct different scenarios of field procedures during a sampling event for the integrated upland (IU) monitoring protocol at Great Basin National Park. *Cost estimates for the basal/canopy gap procedure (SOP 9) and soils measurements procedure (SOP 11) are based on the field procedure modifications recommended in section 4.2*. Cost estimates are provided per macroplot and for 35 macroplots. The IU protocol standard operating procedure number is shown in parentheses.

Scenario*	Point-intercept (8)	Basal/ Canopy Gap (9)	Invasive Species Frequency Quadrats (10)	Soils Measurements (11)	Site Assessment for Invasive Species (12)	Repeat Photos (13)	Cost per Macroplot	Total Cost for 35 Macroplots
1	X		X		X		220-265	7,700-9,275
2	X		X		X	X	256-301	8,960-10,535
3	X	X	X		X		310-373	10,850-13,055
4	X		X	X	X		269-360	9,415-12,600
5	X	X	X	X	X	X	395-504	13,825-17,640

*Scenario descriptions (all scenarios include scenario 1, so only additions to scenario 1 will be noted for all other scenarios): 1 – vegetation and invasive species procedures, 2 – plus repeat photos, 3 – plus basal/canopy gap, 4 – plus soil measurements, 5 – all SOPs (i.e., plus basal/canopy gap, soils measurements, and repeat photos).

4.1.2 Travel Time to Field Sites

Although the pilot study focused on field sites that were "close to roads," or <1 mile from a road, hiking times to field sites still ranged from 30-60 min each way. Ideally, field crews will either camp within a short hike to the field site or establish a base camp that is within a short drive of a cluster of field sites. Even with careful planning and efficient travel planning, realistic hiking times at GRBA may average >60 min each way to sites.

Moreover, our current cost estimates will increase if field sites are to be a minimum distance from roads. Field sites that are close to roads are likely to experience greater disturbance (e.g., backcountry camping, high driving and walking traffic, road disturbances such as dust). Having field sites a minimum distance from roads could move many of the sites in the <30 min hike category into the 30-60 min category or greater, increasing the hike cost estimates by at least $36 per site for a crew of two.

4.1.3 Field Crews

Recommendations:

- ✓ Employ a minimum crew size of three during initial macroplot establishment for ease of carrying equipment and a minimum crew size of two during macroplot revisits. Use a crew size of 3-4 when soil parameters are measured, so that soil and transect procedures can be conducted simultaneously.
- ✓ Adopt a crew schedule of 10-hour days, working 8 days out of 2 weeks, to maximize the number of field data collection days.
- ✓ Use park field crews or temporarily park-based MOJN I&M field crews to reduce travel costs. However, park crews may not be available at all parks (e.g., MANZ, MOJA, or PARA).

4.2 Field Procedures

Through the pilot study, we were able to assess the effectiveness of the field procedures for gathering useful data to address the objectives for the IU protocol. Here, we focus on improving the vegetation and soil-related procedures, as we found the invasive species frequency quadrats procedure to be fairly efficient (Appendix C).

4.2.1 Transect-related Procedures

Point-intercept (SOP 8) – Implementing this procedure was fast and it was possible to read each transect in <60 min, depending on vegetation density. However, this procedure was not effective at detecting invasive plants or BSC.

Recommendations:

- ✓ Increase the number of points measured along transects. Currently, we read points at every 1 m (total = 50 points). *The number of points read could be increased to 100 per transect, or* *points read every 0.5 m*. Half-meter intervals should provide a good balance between detecting more plants and not measuring the same individual plant multiple times.

- ✓ BSC was not detected using this procedure, although non-descript cyanobacterial crust was likely present. *We recommend that detection of BSC either be measured during the invasive species frequency quadrats procedure or be dropped altogether (i.e., the vital sign be dropped from the protocol).* More mature crust can be detected when more surface area is examined.

Basal/canopy gaps (SOP 9) – Originally, we had hoped this procedure would enable us to assess the life forms that created gaps on macroplots to understand how changes in vegetation may affect soil processes. However, given time constraints, *we will focus on measuring the potential for soil erosion with the gap data and not identify the species or life forms creating the gap*. This may reduce procedure time by 10-15 min per transect.

- ✓ Cost estimate of modified basal/canopy gaps procedure for a 2-person crew is $90-108 per macroplot.

4.2.2 Soil Sampling Point Procedure

The primary issue with the soil sampling procedure is the amount of time needed to measure the parameters. In the current procedure, 24 soil samples are analyzed, one vegetated and one barren sample at each of the 12 sampling points of the macroplot. Variation in most of the quantitative data parameters (i.e., penetration resistance, pH) was low both within samples at a point and between soil sampling points at each macroplot at GRBA. While qualitative parameters varied within and between sampling points, macroplot-level assessments were fairly similar between vegetated and barren samples within a macroplot.

<u>Recommendations:</u>

- ✓ Analyze one soil sample per sampling point. Take a sample closest to the marked location, regardless of whether it is vegetated or barren.
- ✓ Reduce the number of soil sampling points to eight, two points on each side of the macroplot. Taken together, the total number of soil samples analyzed would be reduced from 24 to eight.
- ✓ Cost estimates for soil measurements would be reduced from $142-214 to $49-95.

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Appendix A: Travel Time Cost Surface Model

We used the travel time cost surface model (TTCSM) developed by Sherrill et al. (2010) to calculate point-to-point least-cost paths and travel times to potential field sites. Model input included six best-available spatial data sets for the park, including trails, roads, vegetation, streams, lakes, and Digital Elevation Model (DEM). We estimated Percent of Maximum Travel Speed (PMTS) values for the vegetation and streams layers and travel speeds for roads and trails. Our model was estimated under the inverse linear vertical graph type, where it is assumed that it is harder to walk uphill than downhill (speed reduction uphill is greater than speed increase for downhill). Details for model inputs are described below.

Spatial Datasets

The GRBA data used for the travel time cost model were acquired from GRBA before 2009, at which point the data were best available. While working on the model, it was noted that the lines within the trails layer were generalized and did not correspond well to the trail features visible on the National Agriculture Imagery Program (NAIP) aerial photography. Travel times on trails generated by the model should be treated as “approximate” and might increase in the field.

Trails Dataset

Minimal attribute information is available with this line shapefile and includes name and trail class, although the trail class information is unavailable for the Big Pine and Pole Canyon features. The shapefile was labeled by park staff as GRBA_trails_2006_nad27 but was determined using standard methods that it was actually in NAD83 Z11. The Big Pine and Pole Canyon trail shapefiles were merged into this shapefile. The data are presented as is and should be used with caution relative to accuracy and currency.

Roads Dataset

This dataset was acquired from GRBA and represents roads for the park and surrounding areas. The dataset may have originated from the roads_dlg.shp or south_snake_trans.shp also acquired from the park. This shapefile differs slightly from the other two shapefiles in that road segments have been removed from this shapefile that appear to be defined as trails in the Trails_GRBA_2006_NAD83Z11.shp dataset. The locational accuracy of this dataset is unknown, no ground truth data are available, and therefore, the dataset should be used with caution as some roads represented in the shapefile may not exist on the ground. Additionally, some roads on the ground may not be represented in this shapefile.

Vegetation Dataset

The vegetation layer used was the National GAP Landcover dataset, version 2.1, available from http://gapanalysis.usgs.gov/gaplandcover/.

Digital Elevation Model (DEM)

A 30-m DEM was used in the model. This is a standard USGS product available from: http://egsc.usgs.gov/isb/pubs/factsheets/fs04000.html.

Streams Dataset

Data were acquired from the National Hydrography Dataset (NHD; http://nhd.usgs.gov/) and converted to a stream order layer using the StreamOrder Tool for ArcGIS 9.3.

Lakes Dataset

This dataset was acquired from GRBA and consists of a polygon shapefile of lakes located within the park. Attributes associated with the shapefile include Lake Name.

PMTS Values

Percent of Maximum Travel Speed (PMTS) is set for each pixel of each layer based on cover type. PMTS ranges from 0 to 100% with 0% representing a cell that is not passable and 100% representing a cell with no impediment to travel. The layers are then overlaid in order of priority. The PMTS settings that we used are indicated below.

Roads and Trails

- Roads = 100%
- Trails = 100%

Slope

- 0 to 10 degree = 90%
- 10-20 degree = 60%
- 20-30 degree = 30%
- 30-35 degree = 10%
- >35 degree = 0%

Streams

- 1st order = 70%
- 2nd order = 60%
- 3rd order = 50%
- 4th order = 30%
- 5th order = 20%

Lakes

Lake = 0%

Vegetation

- Open water = 0%
- Developed, Open Space = 90%
- Barren Lands, Non-specific = 90%
- Agriculture = 90%
- Great Basin Pinyon-Juniper Woodland = 80%
- Great Basin Semi-Desert Chaparral = 70%
- Great Basin Xeric Mixed Sagebrush Shrubland = 80%

- Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland = 65%
- Inter-Mountain Basins Greasewood Flat = 80%
- Inter-Mountain Basins Big Sagebrush Shrubland = 80%
- Inter-Mountain Basins Big Sagebrush Steppe = 80%
- Inter-Mountain Basins Cliff and Canyon = 10%
- Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland = 75%
- Inter-Mountain Basins Mixed Salt Desert Scrub = 80%
- Inter-Mountain Basins Montane Sagebrush Steppe = 80%
- Inter-Mountain Basins Playa = 95%
- Inter-Mountain Basins Semi-Desert Grassland = 90%
- Inter-Mountain Basins Semi-Desert Shrub Steppe = 80%
- Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland = 55%
- Inter-Mountain Basins Wash = 85%
- Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex = 75%
- Invasive Perennial Grassland = 90%
- Invasive Annual and Biennial Forbland = 85%
- Invasive Annual Grassland = 90%
- North American Arid West Emergent Marsh = 0%
- Rocky Mountain Alpine Bedrock and Scree = 10%
- Rocky Mountain Aspen Forest and Woodland = 65%
- Rocky Mountain Bigtooth Maple Ravine Woodland = 60%
- Rocky Mountain Dry Tundra = 15%
- Rocky Mountain Gambel Oak-Mixed Montane Shrubland = 70%
- Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland = 60%
- Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland = 60%
- Rocky Mountain Ponderosa Pine Woodland = 70%
- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland = 55%
- Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland = 55%
- Rocky Mountain Subalpine-Montane Riparian Woodland = 10%
- Southern Rocky Mountain Montane-Subalpine Grassland = 90%

Travel Speeds

Driving

- Paved, primary road= 55 mph
- Paved, secondary road = 45 mph
- Paved/unpaved, light duty, all weather roads = 20 mph
- Unpaved, fair/dry weather road = 15 mph
- Unmaintained 4x4 = 10 mph

Walking
- 2 mph
- 2.5 mph
- 3 mph

Layer Priorities
- roads
- trails
- streams
- lakes
- landcover (vegetation)

Literature Cited

Sherrill, K. R., B. Frakes, and S. Schupbach. 2010. Travel time cost surface model: standard operating procedure. Natural Resource Report NPS/NRPC/IMD/NRR—2010/238. National Park Service, Fort Collins, Colorado.

Appendix B: Travel Cost Scenarios Tables

The travel time cost surface model generated the least-cost travel paths to the first 35 sites generated from the GRTS draw for GRBA (see *Section 2.1 Sampling Frames* in this report). Least-cost travel paths generally provided the fastest travel path (both driving and hiking) to the target location from a given start point (Figure B1). We ran three models, varying maximum hiking speeds from 2, 2.5, to 3 mph. Distances and travel times to the 35 sites are shown in Table B1.

Travel time and distance estimates from the TTCSM were made for one-way travel. Cost estimates based on hiking time for one-way travel were doubled to estimate round-trip cost estimates (Tables B2-B3). We used an hourly wage estimate of $22 per hour for the GS-5 position and $14 per hour for natural resource intern crew members. The hourly wage estimate for a GS-11 GIS specialist is $39. Wage estimates included benefits, when applicable. Estimates of per diem for NPS employees were not included in the hourly rates or field costs. Cost estimates were generated by multiplying the time to conduct the task by the hourly wage of the crew member. Most cost estimates were generated for a field crew of two; to get an estimate for additional field crew members, we add the appropriate rate for the additional field crew member to the estimate for the crew of two. For example, in Table B4, to estimate the cost for a 3-person crew to conduct field soil measurements, we would add the rate of the additional field crew member ($54-82) to the estimate for a 2-person field crew ($142-214) for a total of $196-296.

Cost estimates were also made for: soil procedures in the field *vs.* office (Table B4), site reconnaissance and initial macroplot set-up (Table B5), and different crew schedule scenarios (Table B6).

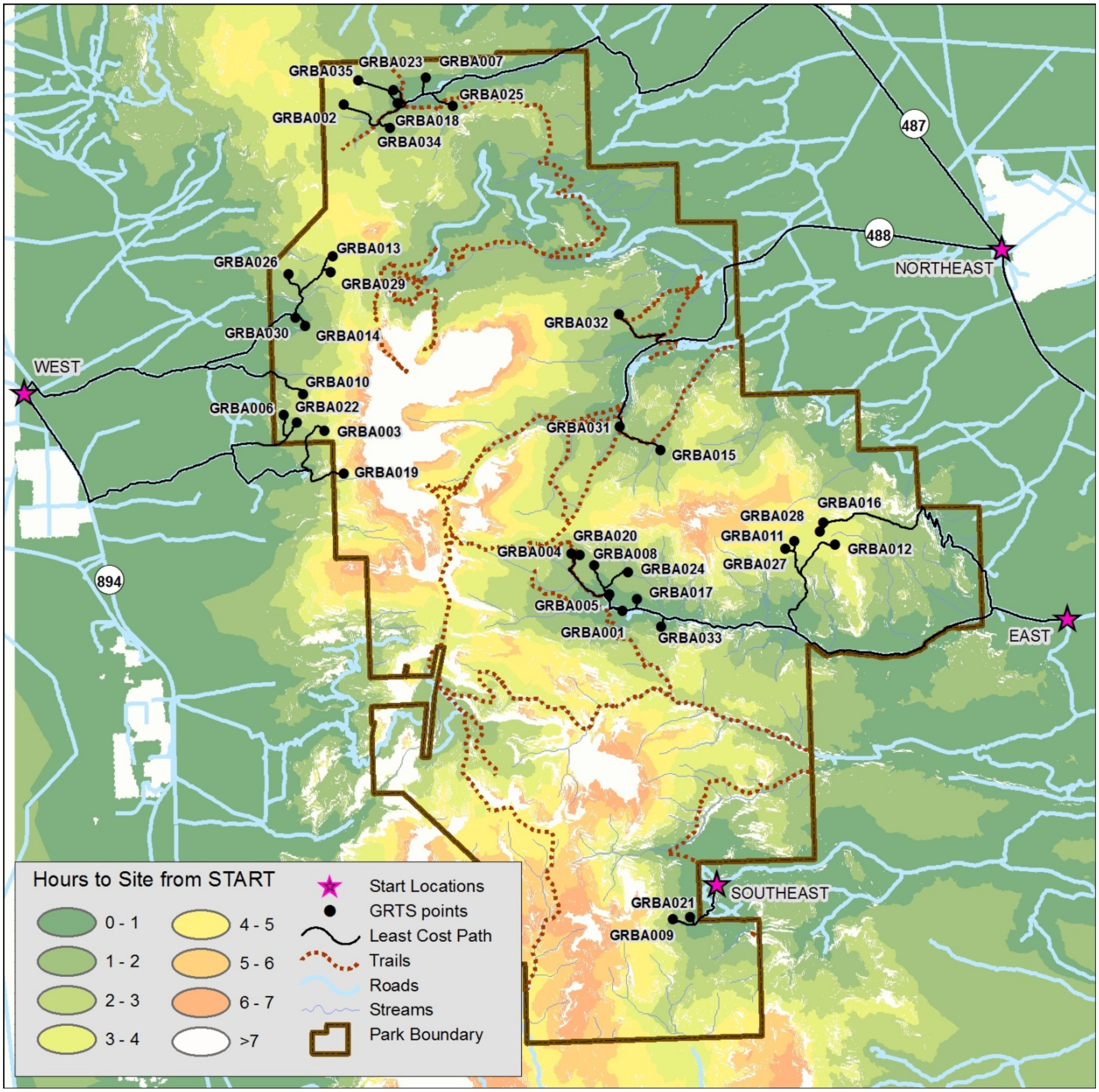


Figure B1. Least cost travel paths to 35 Generalized Random Tessellation Stratified (GRTS) sites generated by the travel time cost surface model from the designated start points for Great Basin National Park. Routes shown include driving and hiking paths.

Table B1. Travel time cost surface model estimates for one-way hiking, driving, and total travel time to 35 potential field sites selected in the Generalized Random Tessellation Stratified (GRTS) draw. Drive times were estimated from the closest designated start point for the park (see Figure B1). The site in bold was visited and established with a macroplot during the 2012 pilot field season. The estimated times shown are for a hiking speed of 2.5 mph. The times in parentheses for the estimated hiking time column are for hiking speeds of 2 to 3 mph.

Macroplot ID	Distance From Nearest Road (mi)	Estimated Hiking Time (min)	Drive Time (min)	Estimated Total One-way Travel Time (min)
GRBA001	0*	0	29.12	29.12
GRBA002	1.46	119.53 (99.74-149.60)	42.01	161.54
GRBA003	1.21	143.41 (119.52-179.32)	34.97	178.38
GRBA004	1.20	58.17 (48.48-72.71)	30.48	88.65
GRBA005	0.16*	11.48 (9.57-14.35)	29.53	41.01
GRBA006	1.06	93.30 (77.76-116.62)	26.30	119.60
GRBA007	0.33	18.49 (16.85-25.30)	40.13	58.62
GRBA008	0.64	47.92 (39.94-59.89)	30.48	92.88
GRBA009	0.75	86.70 (72.26-108.37)	4.59	91.30
GRBA010	0.99	120.78 (100.64-150.97)	27.44	148.23
GRBA011	1.61	198.70 (165.58-248.37)	18.88	217.57
GRBA012	1.90	216.43 (180.36-270.54)	18.88	235.31
GRBA013	1.40	159.28 (132.74-199.10)	34.51	193.80
GRBA014	0.22*	19.78 (16.49-24.72)	35.19	54.97
GRBA015	1.40	79.06 (65.89-98.82)	19.79	98.86
GRBA016	2.16	184.68 (153.98-230.84)	26.65	211.32
GRBA017	0.16*	11.31 (9.45-14.13)	27.19	38.50
GRBA018	0.12*	6.46 (5.42-7.61)	41.86	48.32
GRBA019	0.96	166.57 (138.81-208.26)	34.97	201.54
GRBA020	1.22	60.35 (50.30-75.44)	30.48	90.83
GRBA021	0.50	51.97 (43.31-64.95)	4.59	56.56

Table B1. Travel time cost surface model estimates for one-way hiking, driving, and total travel time to 35 potential field sites selected in the Generalized Random Tessellation Stratified (GRTS) draw. Drive times were estimated from the closest designated start point for the park (see Figure B1). The site in bold was visited and established with a macroplot during the 2012 pilot field season. The estimated times shown are for a hiking speed of 2.5 mph. The times in parentheses for the estimated hiking time column are for hiking speeds of 2 to 3 mph (continued).

Macroplot ID	Distance From Nearest Road (mi)	Estimated Hiking Time (min)	Drive Time (min)	Estimated Total One-way Travel Time (min)
GRBA022	0.96	81.44 (67.87-101.79)	26.30	107.74
GRBA023	0.36	20.79 (17.30-25.41)	41.76	62.54
GRBA024	0.73	58.73 (48.95-73.40)	30.48	89.21
GRBA025	0.44	38.03 (31.70-47.53)	39.55	77.58
GRBA026	0.93	92.37 (76.98-115.46)	34.51	126.89
GRBA027	1.58	189.18 (157.65-236.47)	18.88	208.06
GRBA028	2.28	190.34 (158.70-237.92)	26.65	216.99
GRBA029	1.22	136.64 (113.87-170.80)	34.51	171.16
GRBA030	0.04*	1.95 (1.69-2.43)	34.90	36.85
GRBA031	0.48	27.00 (22.50-33.72)	19.79	46.79
GRBA032	1.24	65.89 (55.11-82.06)	15.26	81.14
GRBA033	**0.20***	**24.88 (20.74-31.10)**	**25.36**	**50.24**
GRBA034	0.83	67.73 (56.57-84.85)	42.16	109.89
GRBA035	0.97	89.18 (71.83-111.47)	41.86	131.04

* Sites that are within 0.25 mi of road. An additional five sites are within 0.5 mi of a road.

Table B2. Cost (dollars) estimates for round-trip hiking to 35 sites from the Great Basin National Park Generalized Random Tessellation Stratified (GRTS) draw for a 2-person crew. # of sites represents the number of field sites within each hiking time category from the 2.5 mph hiking speed travel time cost surface model (TTCSM).

One-Way Hiking Time (min)	Cost Estimate - Field Technician	Cost Estimate - Intern	Crew Cost per Site	# of Sites
<30	22	14	36	10
30-60	44	27	71	5
60-90	66	41	107	7
90-120	88	54	142	3
120+	125*	80*	205*	10

*Estimates were made based on the second highest approximate hiking times for the 10 sites in this category, which was ~171 min.

Table B3. Cost (dollars) estimates for round-trip hiking to 35 sites from the Great Basin National Park Generalized Random Tessellation Stratified (GRTS) draw for a 3-4 person crew, consisting of one GS-5 field technician and 2-3 natural resource interns. The first estimate in each range represents the estimate for a crew of three and the second for a crew of four. # of sites represents the number of field sites within each hiking time category from the 2.5 mph hiking speed travel time cost surface model (TTCSM).

One-Way Hiking Time (min)	Cost Estimate - Field Technician	Cost Estimate - Intern (2-3 interns)	Crew Cost per Site	# of Sites
<30	22	27-41	49-63	10
30-60	44	54-82	98-126	5
60-90	66	82-122	148-188	7
90-120	88	109-163	197-251	3
120+	125*	240-320*	365-445*	10

*Estimates were made based on the second highest approximate hiking times for the 10 sites in this category, which was ~171 min.

Table B4. Time (minutes) and cost (dollars) estimates for conducting the soil measurements procedure (SOP 11) in the field *vs*. in the office. Time estimates for office measurements was based on soil samples collected from Great Basin National Park and Manzanar National Historic Site. Total costs for office measurement of soils are $246-459.

Procedure	Time Estimate	Cost Estimate - Field Technician	Cost Estimate - Intern	Total Costs
Field	240-360	88-132	54-82	142-214
Office (collect soil)*	100	36	23	59
Office (measurements)	140-240	36-88	23-54	59-142
Office (travel to return soil or disposal procedure)	240-480	88-176	54-109	142-285

*Certain soil measurements still need to be made in the field (e.g., penetrometer).

Table B5. Cost (dollar) estimates for initial macroplot set-up, including pre-reconnaissance of potential field sites. Office reconnaissance conducted by GIS specialist (GS-11) and field reconnaissance by a field crew of two (GS-5 field technician and natural resources intern). SOP 6 is the site characterization procedure and SOP 7 is the macroplot establishment and revisit set-up procedure.

Procedure	Time Estimate (min) per Macroplot	Cost Estimate - Field Technician	Cost Estimate - Intern	Crew Cost per Macroplot	Total Cost for Macroplots
Office reconnaissance (assume 50 sites)	20-30	13-19	---	13-19	650-950
Field reconnaissance (*on-site only*; assume 40 sites plus completion of SOP 6)	20-30	7-11	5-7	12-18	480-720
Macroplot set-up (includes SOP 7 for 35 macroplots)	120-150	44-55	27-34	71-89	2485-3115 (3430-4305; 4375-5495)*

*Estimate for 3- and 4-member crews, respectively, are shown in parentheses. Initial macroplot set-up will likely require a minimum 3-person field crew, given equipment and field weight requirements.

Table B6. Scenarios for crew schedules for a crew of two. Cost (dollar) estimates are the total for the field season. We assumed that one-way travel to parks would take either 1 day (Death Valley National Park, Great Basin National Park, Joshua Tree National Park, Manzanar National Historic Site, Grand-Canyon Parashant National Monument) or ½ day (Lake Mead National Recreation Area [LAKE], Mojave National Preserve [MOJA]). Per diem costs were estimated by taking the total number of travel days plus 40 field work days and subtracting the number of work weeks or field tours for the season (or ½ the number for LAKE, MOJA).

Procedure	# of Travel Days from LAKE (1/2 travel)	# of Field Work Days*	Cost Estimate for Travel – Field Technician	Cost Estimate for Travel - Intern	Per Diem Costs
8 hour days, 5 days/wk**	24-26 (12-13)	40	4224-4576 (2112-2288)	2611-2829 (1306-1414)	2040-2120 (1840-1880)
10 hour days, 4 days/wk	36-40 (18-20)	40	7920-8800 (3960-4400)	4896-5440 (2448-2720)	2240-2400 (1960-2000)
10 hour days, 8 days/2 wks	12-14 (6-7)	40	2640-3080 (1320-1540)	1632-1904 (816-952)	1840-1920 (1720-1760)

*Travel days were estimated for up to 40 field work days, as up to 15% of the macroplots may be revisited to estimate crew measurement error. With an additional 5 field days, 2 travel days were added to each scenario. The number of pay periods for field work ranged from ~7 (10-hour days, 8 days/2 wks) to ~10 (10-hour days, 4 days/wk) for the 1-day travel parks.

**Time would be tight to finish procedures, QA/QC, and daily travel to the more distant sites.

Appendix C: GRBA Macroplot Data from the Pilot Study

We established three macroplots at GRBA, one site from the GRTS draw and two sites in sagebrush (*Artemisia* spp.) shrub steppe communities near roads. The latter sites were primarily chosen to assess field methods and for repeat measurements, so may not be representative of the plant community to be measured because they were selected for certain traits (e.g., dominated by sagebrush and with little to no pinyon-juniper tree encroachment). In addition, data collection on these macroplots were limited due to the repeat measurements. Nonetheless, we present summaries of the vegetation, invasive plant, and soils data collected on all three macroplots, plus relevant repeat measurements where applicable. The data presented in this section pertain only to the monitored macroplots and cannot be extrapolated to the sagebrush (*Artemisia* spp.) shrub steppe community at GRBA.

From the vegetation measurements, we found seven shrub species and one tree species across the three measured macroplots. Four shrub species, including sagebrush (*Artemisia sp.*), was found on all macroplots (Table C1). From all of the invasive plant procedures, we detected only one of the five target invasive species in the macroplots, *Bromus tectorum* (cheatgrass). For most soil parameters, the range of values detected were the same or overlapped between macroplots (Table C2). We examined the potential for soil erosion with the basal/canopy gaps procedure.

We initially planned to establish five macroplots at GRBA and were able to establish three macroplots and collected limited data after visiting five field sites in approximately eight days (this included travel time to the park from Boulder City, NV; Figure C1). One macroplot was established on a site from the GRBA GRTS draw, while the other two sites were established on non-GRTS sites and selected by the field crew in sagebrush shrub steppe areas close to the road. All three macroplots were located in the center of the park off of Snake Creek Road (Figure C1).

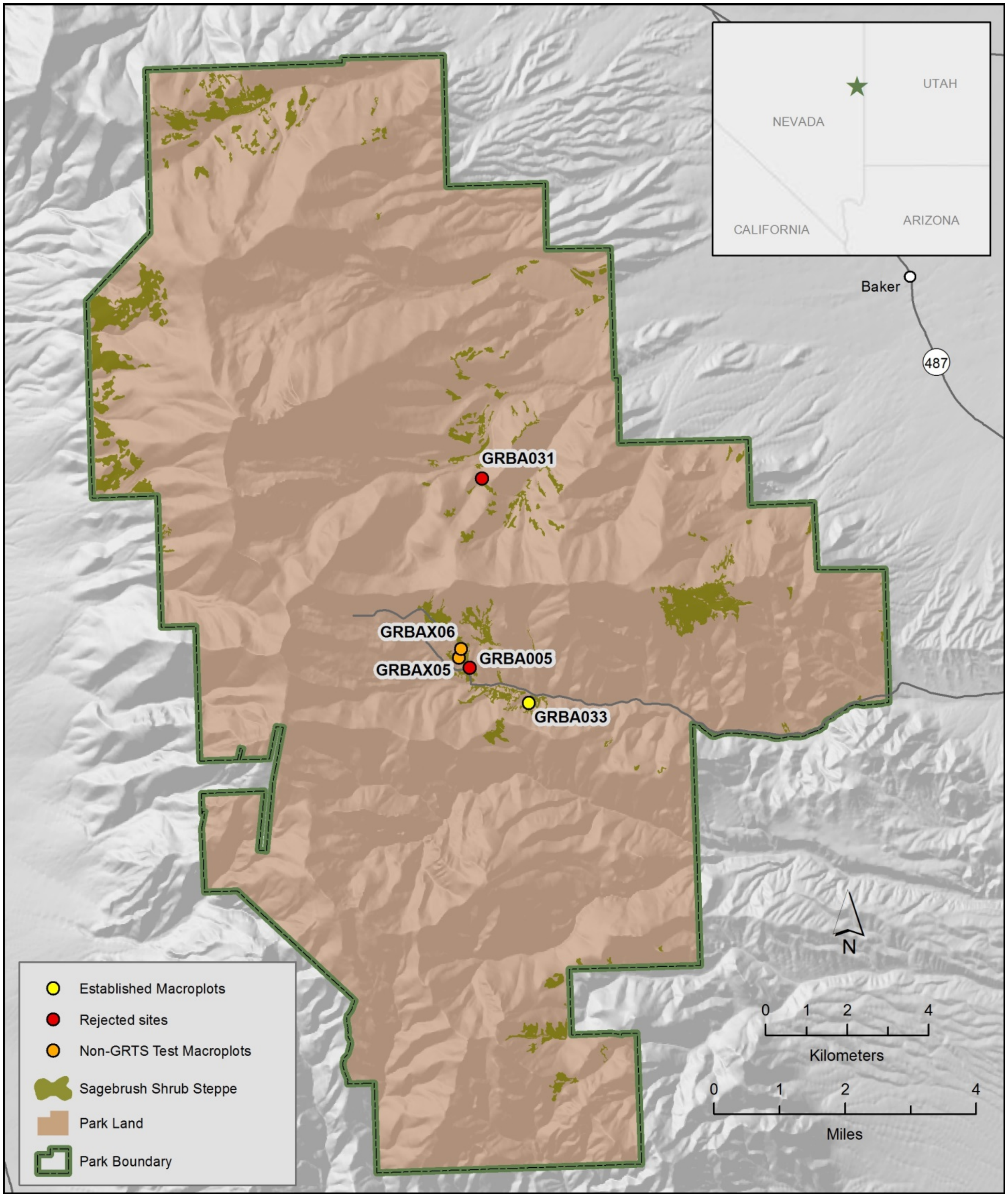
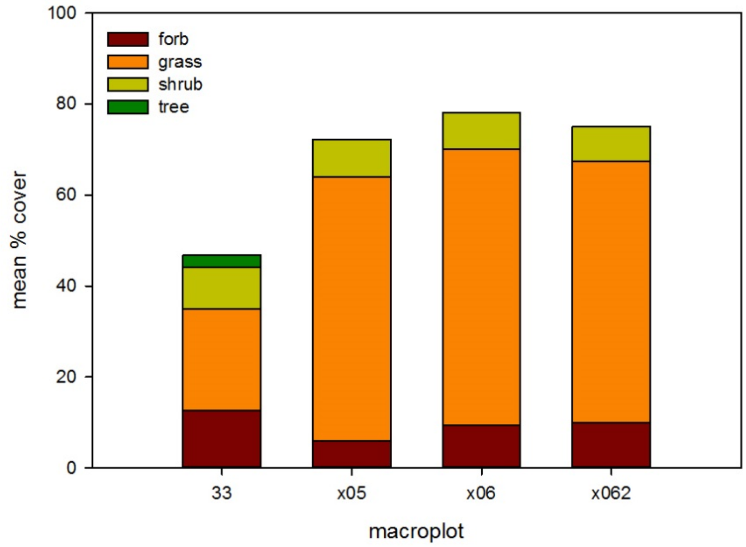


Figure C1. Locations of visited field sites and established macroplots within the sagebrush (*Artemisia* spp.) shrub steppe community at Great Basin National Park.

Vegetation

Across the three macroplots, we found a total of seven shrub and one tree species (Table C1). Four shrub species were found on all macroplots, including the species characteristic of the community, sagebrush (*Artemisia sp.*). Sagebrush was the dominant shrub species on the macroplots with a mean % cover ~30% (Table C1). On the other hand, three shrub species were found only on macroplot x06 and the tree species was found only on macroplot 33. The mean number of shrub species on macroplots ranged from 3-6, but the mean % cover of those species was fairly similar across macroplots, at ~8-10% per species (Figure C2; Table C1).

a)



b)

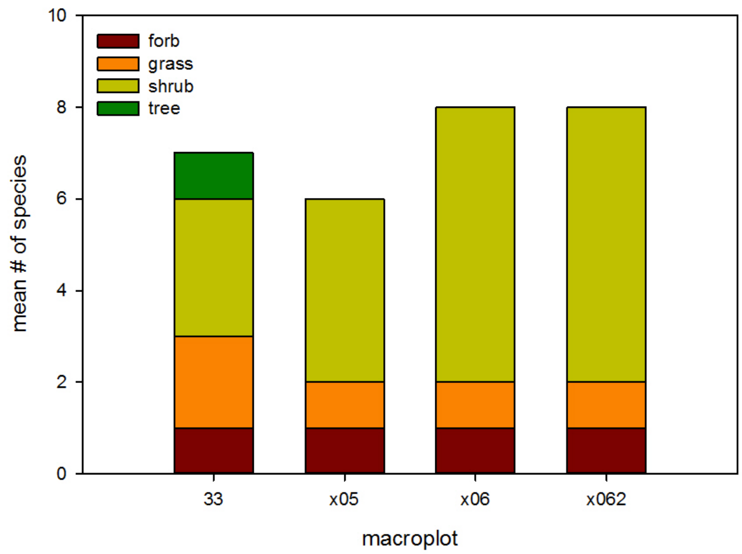


Figure C2. Mean a) % cover and b) species richness of species for each life form by macroplot. Species richness for all life forms except shrubs could include target invasive species and/or life form categories. For example, species richness for grasses would include target invasive grass species and vegetation recorded as annual grass, perennial grass, etc. Macroplot x062 is the data from the repeat measurement of macroplot x06.

Table C1. Mean % cover per macroplot of shrub and tree species found across three macroplots in 2012.

Shrub Species	Common Name	Live (L) or Dead (D)	No. Plots Where Found	Mean % Cover (range)*
Amelanchier utahensis	Western serviceberry	L	1	1.111 (0-3.333)
Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	L	3	30.222 (25.333-38.667)
		D	3	1.556 (0.667-2)
Chrysothamnus viscidiflorus ssp. viscidiflorus	Yellow rabbitbrush	L	1	0.889 (0-2.667)
Eriogonum microthecum var. laxiflorum	Slender buckwheat	L	2	1.778 (0-4.667)
Pinus monophylla	Singleleaf pinyon	L	1	0.889 (0-2.667)
Rosa woodsii ssp. ultramontana	Woods' rose	L	2	1.111 (0-2)
Symphoricarpos oreophilus	Mountain snowberry	L	3	10.667 (6-19.333)
Tetradymia canescens	Spineless horsebrush	L	1	0.444 (0-1.333)

*Mean % cover over the three plots.

Total % cover on macroplots at GRBA, determined by whether any vegetation was detected during the point-intercept procedure, was high ranging from ~85-92% (Figure C3). For each species or life form that was encountered, we recorded whether it was live or dead (senesced) in order to understand the composition of the vegetation in the community and as a possible early indicator of vegetation mortality. Unidentified or loose senesced vegetation was categorized as either litter or woody debris. Examining the components of cover, we found that plant cover was primarily live or litter/woody debris; the standing dead species/life form contributed very little to plant cover (Figure C4). There was great variation in % cover by life form (forbs, grasses, shrubs, and trees; Figure C2a). Mean % cover for shrubs was fairly similar across all macroplots, despite relatively large differences in species present. On the other hand, mean % cover of grass species varied across macroplots, even with very few species (Figure C2).

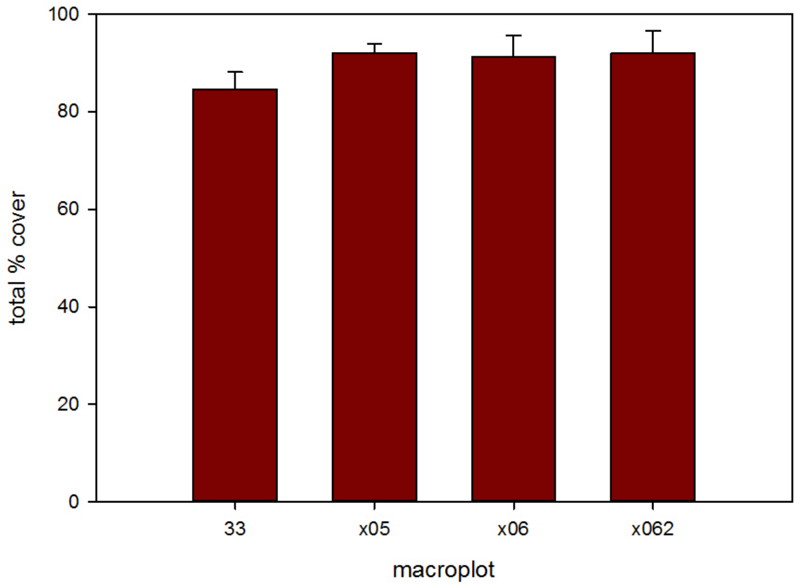


Figure C3. Mean (+SE) total % cover by macroplot. Total cover included any vegetation that was detected, including litter and dead vegetation.

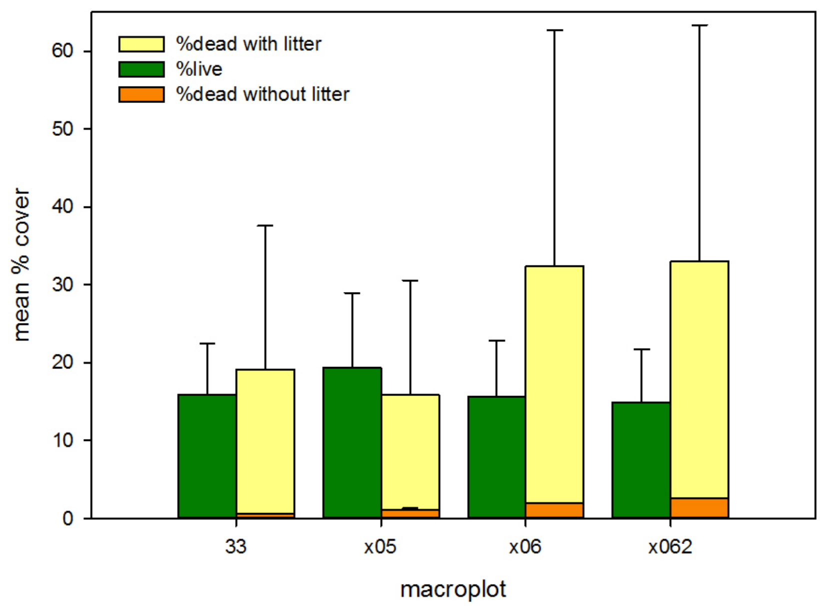


Figure C4. Mean (+SE) % cover of live and dead species/life form by macroplot. Dead species/life form cover included (% dead with litter) or excluded (% dead without litter) litter/woody debris as a dead species/life form category.

Status and Trends Invasive Plant Species

Using the point-intercept (SOP 8), invasive species frequency quadrats (SOP 10), and site assessment for invasive species (SOP 12) procedures, we detected one of the five target invasive species in the macroplots at GRBA. No target invasive species was detected using the point-intercept or invasive species frequency quadrats procedure. One species, *Bromus tectorum* (cheatgrass), was detected using the site assessment for invasive species procedure. *Bromus tectorum* was found on macroplot x06 as scattered plants, with 0-2% cover, and primarily dead.

Since no invasive species were detected with the point-intercept procedure, the estimate of mean % cover for invasive species with this procedure was 0% for all macroplots. On the other hand, the mean % cover of native species on macroplots ranged from ~12-14% (Figure C5).

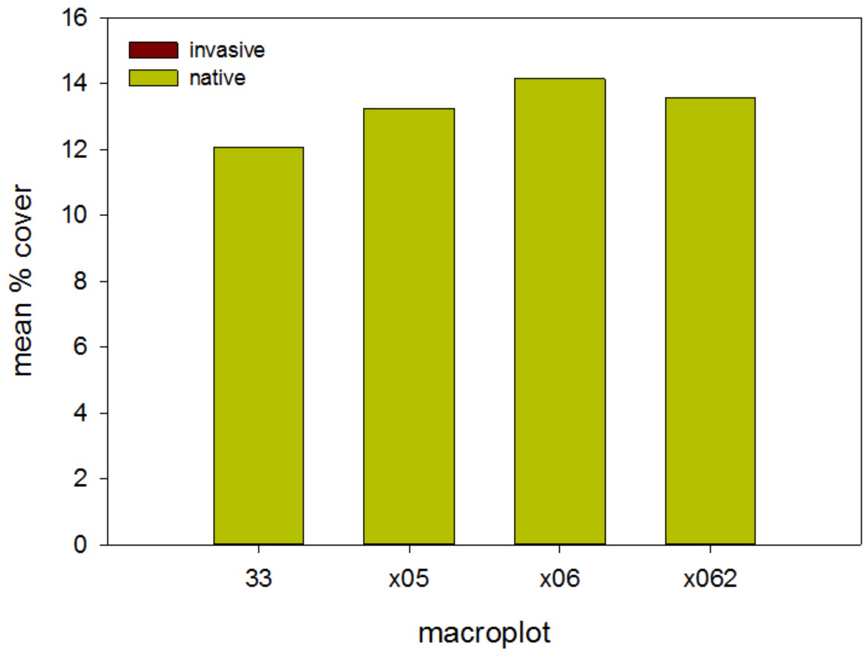


Figure C5. Mean % cover for invasive and native species by macroplot. Mean % cover for native species is the average of the % cover for each native species.

At GRBA, the site assessment for invasive species procedure was the only procedure that detected any of the target invasive species. The site assessment for invasive species would be most useful to understand the early invasion process, as we would be more likely to detect species in the earlier phases of macroplot invasion. This assertion is supported by what we found at GRBA, since invasive species were absent or in very low abundance on the measured macroplots. On the other hand, the point-intercept and invasive species frequency quadrats procedures would be more effective at detecting species that are of higher abundance and more widespread, given the limited area of the macroplot that is sampled. Taken together, the three procedures provide a more comprehensive understanding of the invasion process and invasive species population growth.

Soil Measurement Parameters

Soil measurement data (SOP 11) was incomplete at GRBA because of the focus on methods testing and repeat measurements for the vegetation data. Complete soil measurement data were collected for two macroplots, while some soil measurements were not taken for samples from macroplot x06. Data are presented for all macroplots and the missing data indicated where appropriate.

For most of the soil parameters, the range of values detected overlapped across macroplots (Table C2) and variation in quantitative soil parameters was low. Soil compaction (penetration resistance) was generally “very low” for all macroplots, but ranged from extremely low to low within a macroplot. pH ranged from ~5.7-6.3 and did not differ greatly between vegetated and barren soil samples. Soil salinity was fairly low on all macroplots, such that soils on all macroplots were considered non-saline. The potential for soil erosion was estimated using the basal/canopy gaps procedure.

We recorded eight soil surface features on macroplots using the point-intercept procedure, with mean % cover per macroplot ranging <1% to >98% (Figure C6). Bare soil was the dominant soil surface feature, as the other seven features all had a mean % cover of <1%.

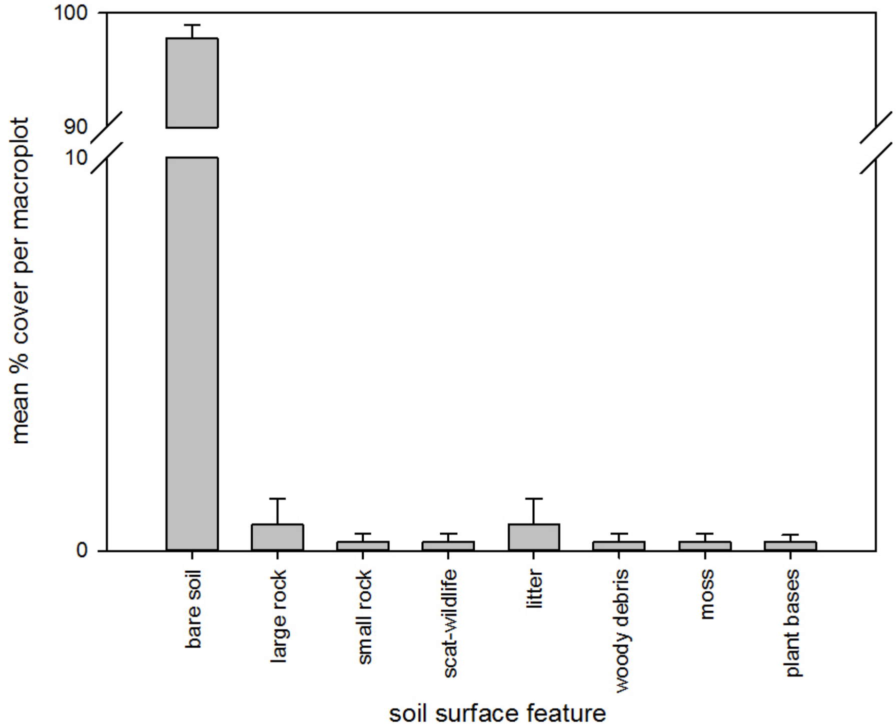
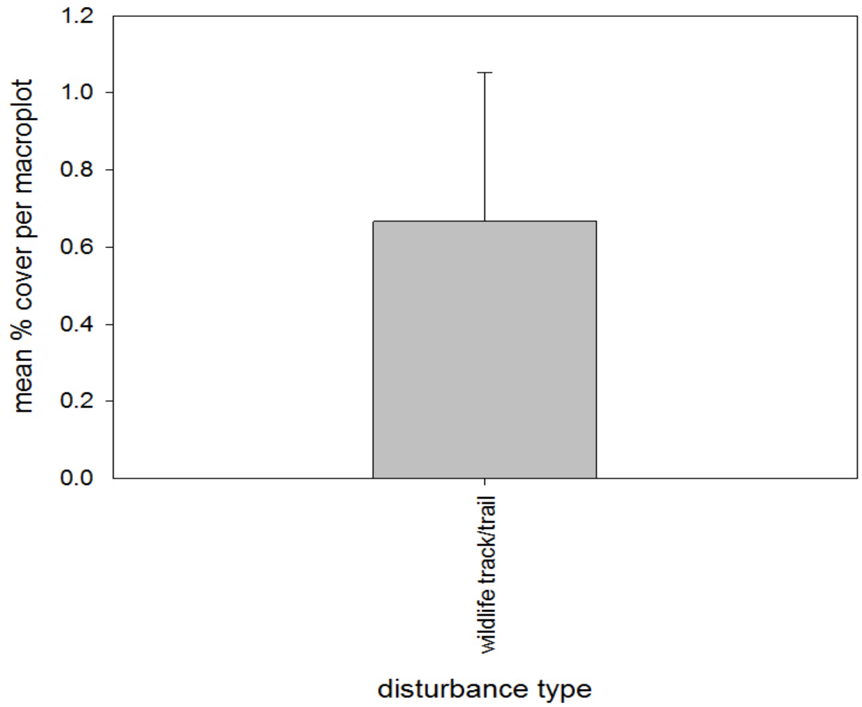


Figure C6. Mean (+SE) % cover of soil surface features per macroplot.

Soil disturbance features were detected using both the point-intercept and invasive species quadrats procedures. One disturbance category, wildlife track/trail, was detected with the point-intercept procedure and a mean % cover of <1% (Figure C7a). An additional four disturbance categories were detected with the invasive species quadrats procedure (Figure C7b). Wildlife track/trail was still the most commonly detected disturbance, found in >18% of quadrats. On the other hand, the other four disturbances were found in <1% of all quadrats.

a)



b)

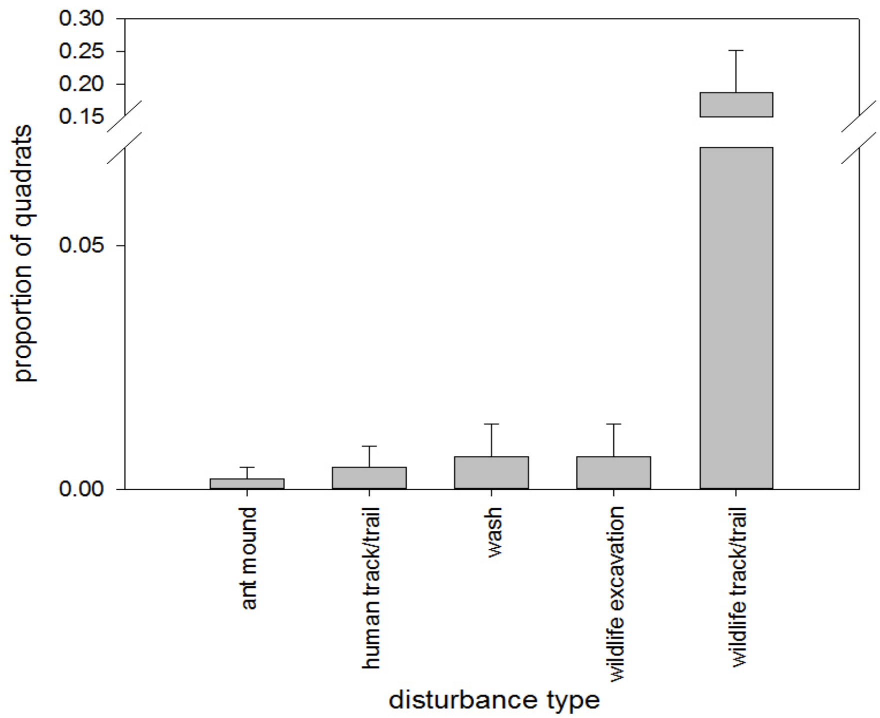


Figure C7. Mean (+SE) a) % cover and b) proportion of quadrats of soil disturbance features per macroplot from the point-intercept (SOP 8) and invasive species frequency quadrats (SOP 10) procedures, respectively.

The basal/canopy gaps procedure is designed to measure the potential for soil erosion by recording all gaps ≥0.2 m created by perennial plant bases and canopies along the transect. Canopy gaps can be used to assess the potential for wind erosion. The total number of canopy gaps ≥0.2 m ranged from 15-33[4] gaps per macroplot. The distribution of canopy gaps varied across macroplots, but gaps were predominantly in the smallest size category for all macroplots; none of the macroplots had gaps that were >2 m (Figure C8). Macroplots 33 and x05 had more similar canopy gap distributions, even though macroplots x05 and x06 were closer to each spatially and were both selected by the crew as methods testing plots. Despite differences in gap distribution, mean canopy gap size was ~0.4 m for all three macroplots (Figure 9a). The relatively small mean gap size was exhibited in the mean total gap length, which ranged from 6 to just over 13% per transect, (Figure C9a), reflecting the relatively dense vegetation of the sagebrush steppe community.

[4] Data for macroplot x05 was incomplete because data for the basal/canopy gap procedure (SOP 9) was taken for only 30 min per transect, resulting in only part of transects being sampled. Thus, the lower number in these ranges will be an underestimate of the data.

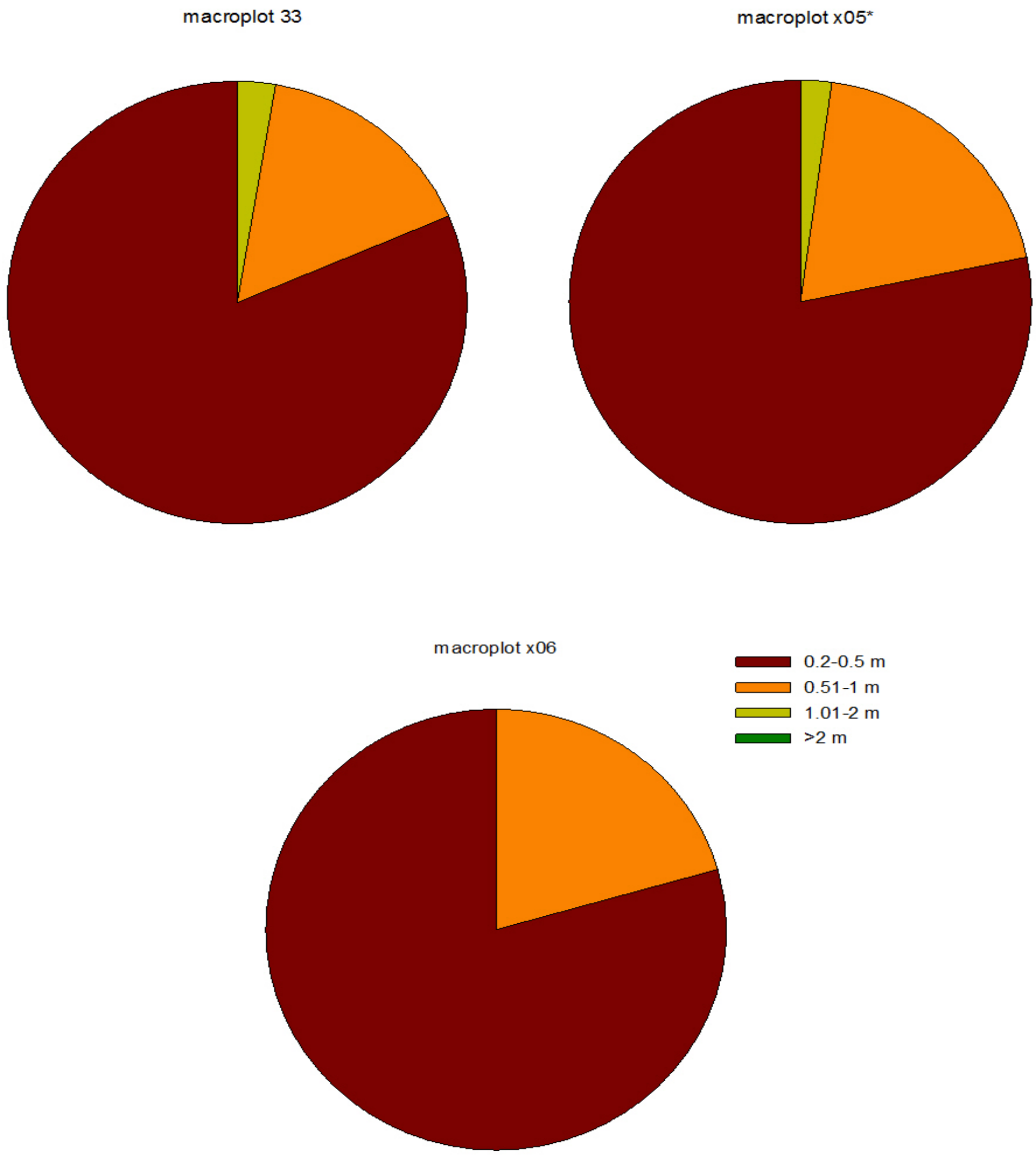


Figure C8. Mean number of canopy gaps for a given size category per macroplot. Macroplot 33 had a total of 33 gaps, macroplot x05*, 15 gaps, and macroplot x06, 23 gaps. *Data for macroplot x05 were incomplete because data were collected for only 30 min per transect, resulting in incomplete sampling of transects.

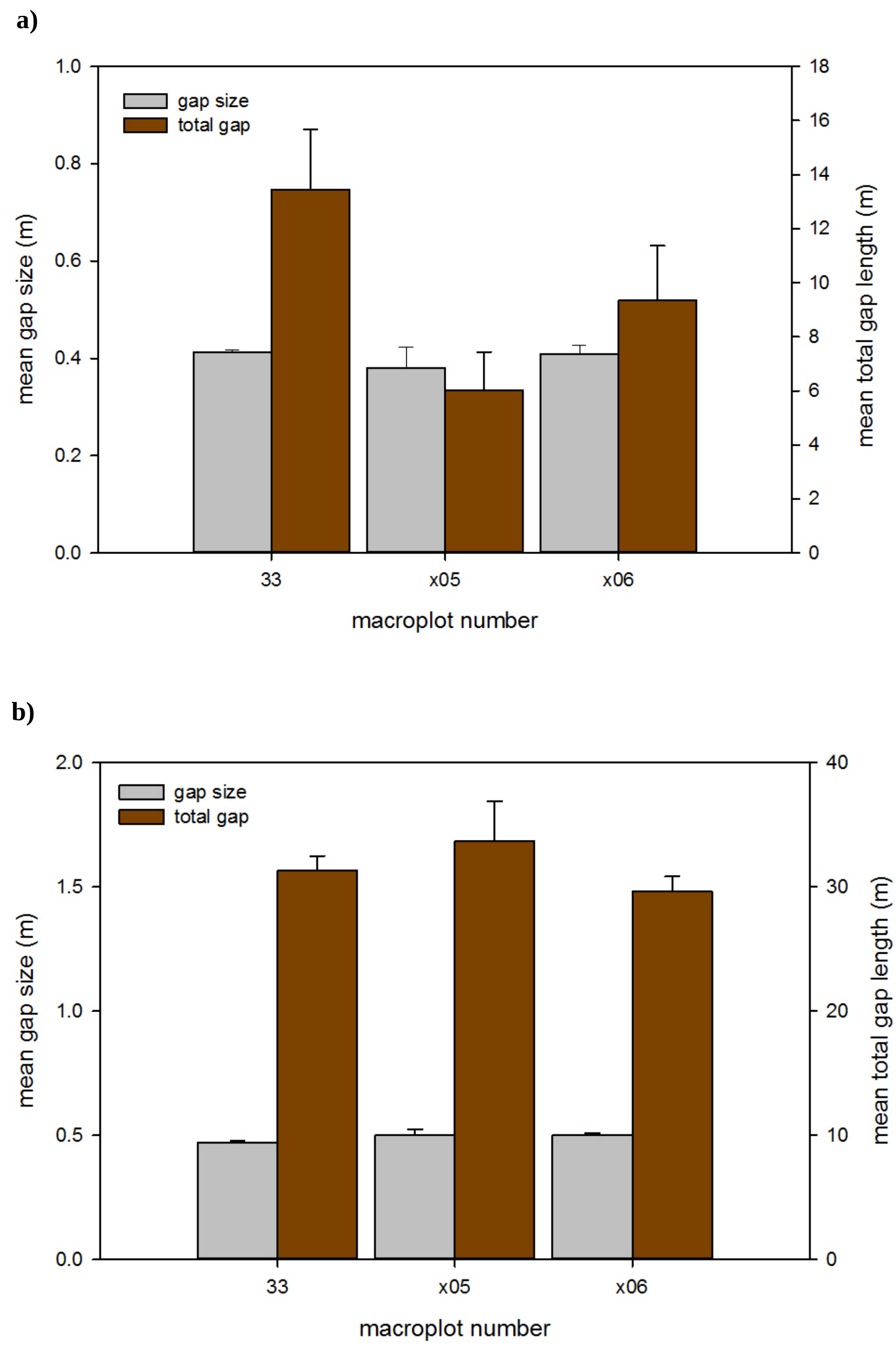


Figure C9. Mean (+SE) gap size and total gap length per transect by macroplot for a) canopy and b) basal gaps.

Basal gaps can be used to assess the potential for water erosion. The total number of basal gaps ≥0.2 m ranged from 30-66 gaps per macroplot. The basal gap distribution was similar for all macroplots, with a majority of the gaps in the smallest size category and very few to none of the gaps in the larger size categories (>1 m; Figure C10). Similarly, the mean basal gap size was very similar for the three macroplots at ~0.5 m (Figure C9b).Mean total basal gap length ranged from ~29 to 34 m, or ~58-68% of the entire transect for all macroplots (Figure C9b).

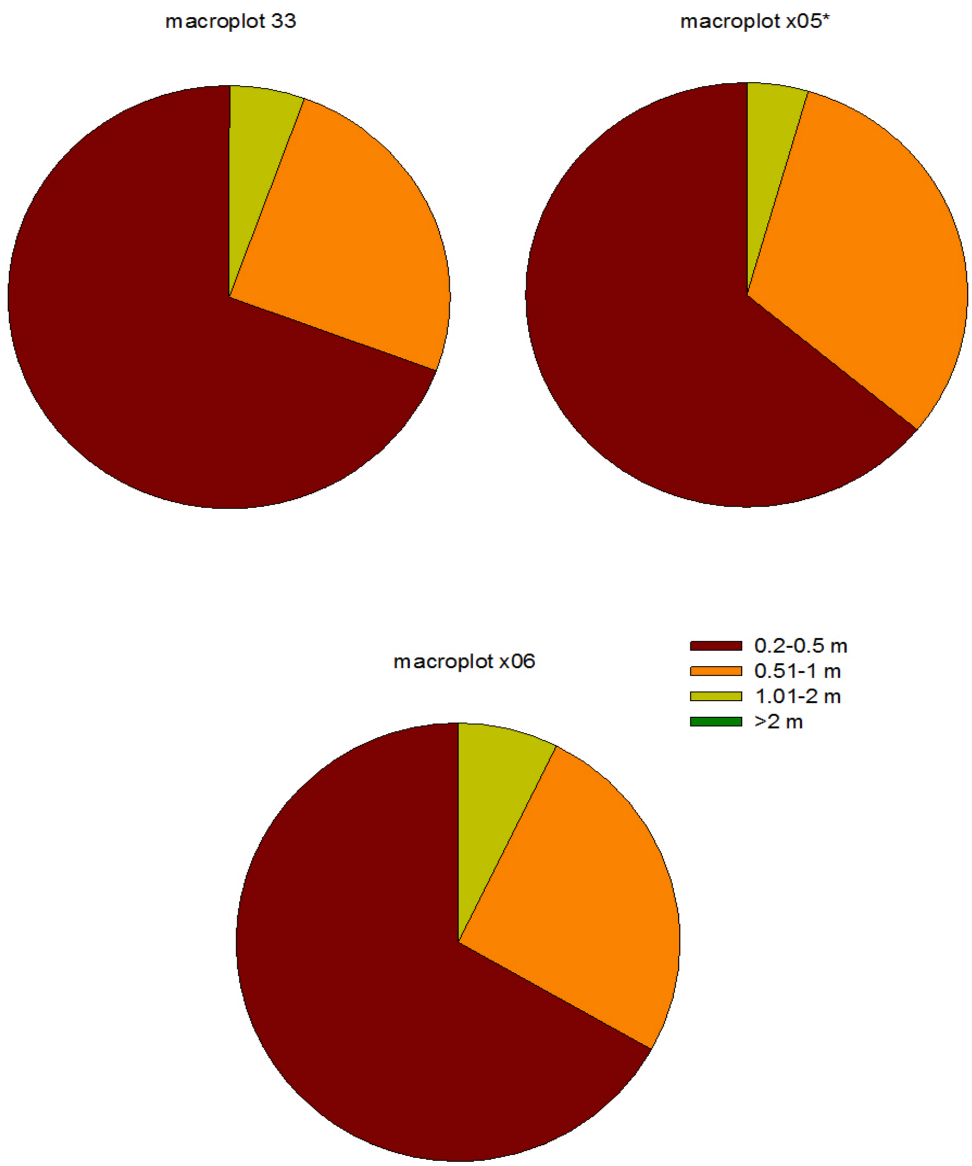


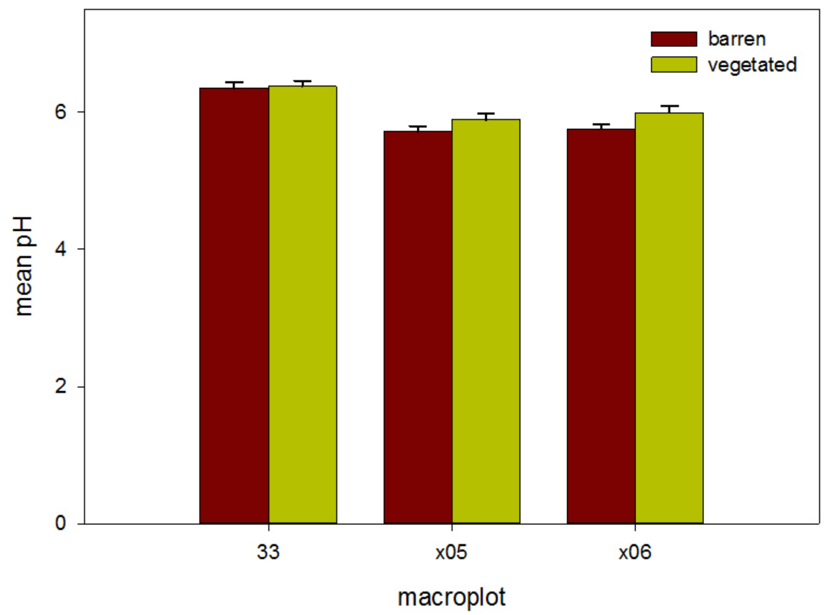
Figure C10. Mean number of basal gaps for a given size category per macroplot. Macroplot 33 had a total of 66 gaps, macroplot x05, 30 gaps, and macroplot x06, 59 gaps. *Data for macroplot x05 were incomplete because data were collected for only 30 min per transect, resulting in incomplete sampling of transects.

Soil compaction (penetration resistance) was generally predominantly "very low" for all macroplots, but ranged from extremely low to low for soil sample points within a macroplot.

pH values were <6 for the two macroplots that were spatially closer to each other, x05 and x06 (Figure C11a). pH values were ~6.3 for vegetated and barren samples on macroplot 33 (Figure C11a). For all macroplots, vegetated samples had slightly higher pH values than barren samples.

Soil salinity was low on all macroplots, with the highest mean value at <0.18 mS/cm, and all macroplots were considered non-saline (Figure C11b). Similar to pH readings, conductivity readings were more similar for the two macroplots that were spatially closer together, x05 and x06. Macroplot 33 had the lowest mean readings at < 0.12 mS/cm.

a)



b)

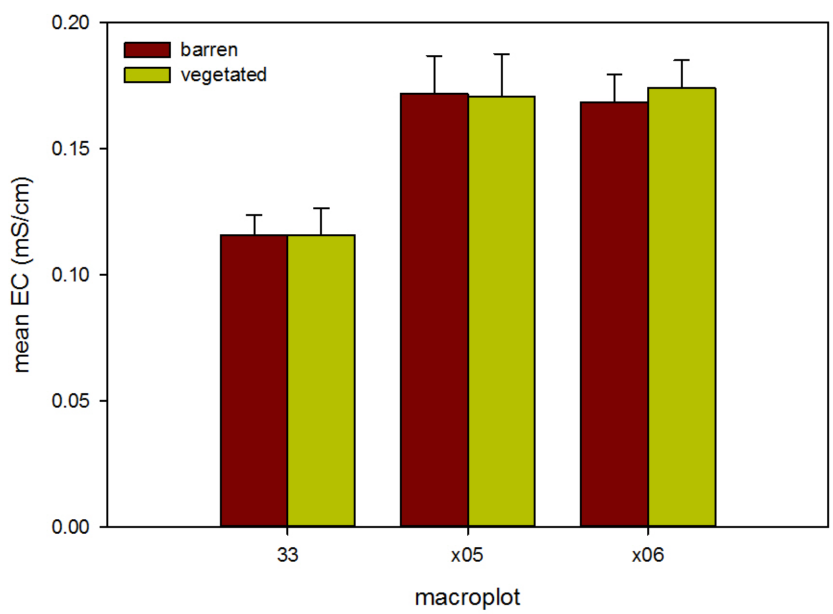


Figure C11. Mean (+SE) values for a) pH and b) electrical conductivity (EC) by macroplot.

Qualitative soil parameters are shown in Table C2 for barren and vegetated soil samples for each macroplot. For most of the soil parameters, the macroplots were very similar and the range of values detected overlapped across macroplots. For example, the most variable soil parameter for the three macroplots, soil color, was a variation of dark brown, ranging from very dark grayish brown to very dark brown to dark brown.

Table C2. Dominant qualitative soil characteristics for three monitored macroplots in 2012. Range of responses are in parentheses. "---" indicates that data were not collected.

Macroplot #	Soil from:	Carbonates*	Soil color	Rupture resistance**	Stickiness***	Plasticity****	Texture
33	Barren	NE	Dark brown	S	SO	PO	Gravelly loamy sand (gravelly-very gravelly loamy sand)
	Vegetated	NE	Dark brown	S	SO	PO	Gravelly loamy sand (gravelly-very gravelly loamy sand)
x05	Barren	NE	Very dark brown (dark grayish brown-very dark brown)*****	VFR	SO	PO	Gravelly loamy sand (gravelly-very gravelly loamy sand)
	Vegetated	NE	Very dark brown (very dark grayish brown-very dark brown)*****	VFR	SO	PO	Gravelly loamy sand (loamy sand-gravelly loamy sand)
x06	Barren	NE	Very dark grayish brown (dark gray-very dark grayish brown)	S (S-SH)	---	---	Gravelly loamy sand (gravelly-very gravelly loamy sand)
	Vegetated	NE	Very dark grayish brown (dark gray-very dark grayish brown)	S	---	---	Gravelly loamy sand (loamy sand-gravelly loamy sand)

*NE=noneffervescent (little/no carbonates), VS=very slightly effervescent, SL=slightly effervescent, ST=strongly effervescent, VE=violently effervescent (high amounts of carbonates).

**L/EW=loose/extremely weak, S/VW/VFR=soft/very weak/very friable (for moist soils), SH/W=slightly hard/weak, MH/M=moderately hard/moderate, HA/MS=hard/moderately strong.

***SO=non-sticky, SS=slightly sticky, MS=moderately sticky, VS=very sticky.

****PO=non-plastic, SP=slightly plastic, MP=moderately plastic, VP=very plastic.

*****Data based on 11 sampling points.

Repeat Measurements Analysis

A secondary objective of the pilot study at GRBA was to examine within and between observer measurement error to assess how different observers might affect variation in the data. Thus, 1) all three transects on macroplot x06 were measured by the same observer on two different days (within observer error), and 2) three different observers measured the same transect on two different macroplots, x05 and x06 (between observer error). In the interest of time and likelihood of shorter revisit periods for the vegetation procedures, we focused on collecting data for the point-intercept procedure (SOP 8) during remeasurement.

Data were calculated at the macroplot-level for the within observer error comparisons and at the transect-level for the between observer error comparisons. Qualitative comparisons for the within observer error were made because it was not possible to compare data between the two macroplots since there is no replication and, thus, no variation. A nonparametric Friedman test was used to test whether there were differences in the median % cover between observers (between observer error), using each transect (macroplot) as a replicate.

Macroplot-level data were very consistent when collected by the same observer (Figures C2-C5). Data from the first data collection was indicated as x06 and data from the second data collection was indicated as x062. In all measurements, the mean and variance were very similar and looked nearly identical in most cases, suggesting that individual observers (at least the one in our study) were fairly consistent and that within observer error is likely to be low. We also found no significant between observer effects for any of the transect-level data; $p>0.05$ for total % cover (with and without litter) and soil surface features.

From the repeat measurement data at GRBA, we were not able to detect any significant differences within or between observer measurements. However, this may have been due to a lack of power because of the scarcity of data.

Appendix D: Macroplot Overview Photographs from the 2012 Pilot Study

Photographs of the established macroplots taken through the repeat photos procedure (SOP 13) from the IU protocol.

Figure D1. Macroplot overview photo for macroplot 33.

Figure D2. Macroplot overview photo for macroplot X05.

Figure D3. Macroplot overview photo for macroplot X06.

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