National Park Service
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Natural Resource Stewardship and Science

Mojave Desert Network Integrated Upland Monitoring

2012 Pilot Study for Joshua Tree National Park

Natural Resource Technical Report NPS/MOJN/NRTR—2014/850

ON THE COVER
Joshua tree wooded alliance monitoring plot, Joshua Tree National Park
Photograph by: Photograph by: Jean J. Pan, 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 long-term monitoring 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 Unpublished Report [a]) addresses seven of these prioritized vital signs, including vegetation change, invasive plants, and soil-related vital signs.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. Each of the seven parks in the network, in collaboration with the MOJN I&M, selected a target upland community for monitoring. The Joshua tree wooded alliance community was selected for monitoring at Joshua Tree National Park (JOTR).

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 Unpublished Report [a]) was conducted in the spring and summer of 2012 and included the establishment and measurement of 19 plots across six of the MOJN parks (MANZ was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 JOTR are presented. Cost estimates were generated for conducting field procedures, travel to field sites, and different crew staffing scenarios. At JOTR, five macroplots were successfully established and field procedures implemented. 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 JOTR, the average estimated cost for each macroplot revisit (hiking time to field site plus field data collection, *not including driving time*) was $570, for a total of approximately $19,950 for 35 spatially randomly selected field sites. We found that shrub species composition varied greatly across five macroplots at JOTR, detected four of the five target status and trends invasive species on the macroplots, and compared qualitative and quantitative soil parameters across macroplots. 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 Joshua Tree 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 Josh Hoines, our point of contact, who helped us with everything, Michael Vamstad for facilitating our permit, and the Black Rock Interagency Fire Center staff for their hospitality during our stay at the Black Rock campground.

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. We are grateful for the guidance that Kirk Sherill, developer of the travel time cost surface model, provided. 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
DOQ	Digital Orthophoto Quad
DRG	Digital Raster Graphic
GAP	National 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 for Joshua Tree National Park (JOTR), where we focused on the **Joshua tree** (*Yucca brevifolia* var. *brevifolia*) **wooded alliance 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 (see Appendix C).*

1.1 Vital Signs

After a series of vital signs scoping workshops, 20 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 and ranked for MOJN I&M (Chung-MacCoubrey et al. 2008). The IU protocol directly addresses seven highly ranked vital signs out of the 20, which we broadly categorize as vegetation change, invasive plants, and soils (ranking out of 20):

- 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. Joshua tree (*Yucca brevifolia* var. *brevifolia*) wooded alliance community at Joshua Tree National Park. Photo provided by JOTR.

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, 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

We utilized the GRTS survey design (Stevens and Olsen 2004) to select potential field sites for the IU protocol pilot study. This design 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.

In order to select potential field sites, we first determined the spatial distribution of the target upland community at JOTR, the Joshua tree wooded alliance community. This iconic community was selected for monitoring because it is of special management concern and its sensitivity to environmental change. Joshua tree woodlands are a significant community on the western side of the park (Figure 2), which is the part of the park most heavily affected by air quality issues (Tonnesen et al. 2003).

The spatial distribution of the Joshua tree wooded alliance community was evaluated using the Joshua Tree National Park Vegetation Map (2010), the best available vegetation map for JOTR. The Joshua tree wooded alliance community at JOTR covers 16,292 ha (40,258 ac), ranging in elevation from 1000–1,400 m (3,200–4,500 ft). 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 well 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 unequal probability GRTS draw at JOTR in order to have representation across the different Joshua tree associations that made up the alliance. Five Joshua tree associations were identified in the JOTR Vegetation Map: *Yucca brevifolia* (Joshua tree)/*Coleogyne ramosissima* (blackbrush), *Yucca brevifolia-Juniperus californica* (California Juniper)/*Ephedra nevadensis* (Nevada Mormon tea), *Yucca brevifolia/Prunus fasciculata* (desert almond), *Yucca brevifolia/Larrea tridentata* (creosote bush) - *Yucca schidigera* (Mojave Yucca)/*Pleuraphis rigida* (big galleta), and *Yucca brevifolia/Pleuraphis rigida*. The *Yucca brevifolia/Prunus fasciculata* association was extremely small and limited in distribution, so it was included with the association that was closest spatially, the *Yucca brevifolia-Juniperus californica*/*Ephedra nevadensis* association. Thus, four associations were considered in the GRTS draw. We had an initial draw of 35 sites for each park (Figure 2) based on power analyses (see Pan et al. Unpublished Report [a] for details), with an oversample of 250 sites, which allows for elimination of sites due to sampling frame errors arising from map inaccuracies (e.g., non-target vegetation type, site on private land; see Pan et al. Unpublished Report [a]), as well as the addition of sites in the future.

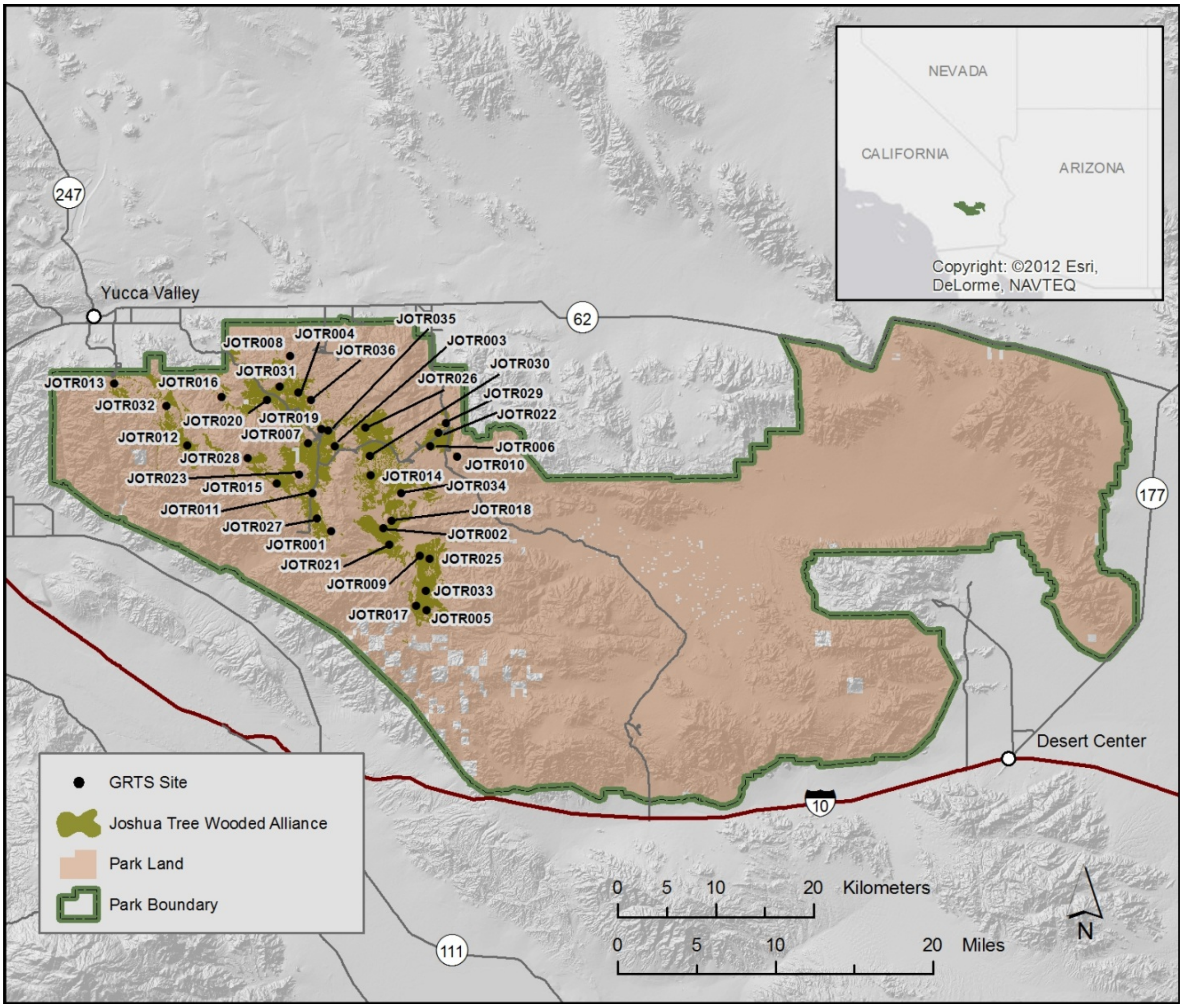

Figure 2. The first 35 sites selected from the Generalized Random Tessellation Stratified (GRTS) survey design draw for Joshua Tree National Park.

For the pilot season, we generated a list of potential field sites by selecting a subset of field sites that were within 2 miles of a road from the initial draw of 35 sites at JOTR. 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 JOTR, eliminating any sites that were unsuitable (e.g., unsafe, inaccessible). The remaining sites were then provided to JOTR park 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. A finalized list of potential field sites was provided to JOTR as part of the park research permit and before field work was started.

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 (see 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.

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 JOTR 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). Five primary datasets were used in the model (source in parentheses): trails (JOTR), roads (JOTR), boundary and NPS lands datasets (NPS Lands Resources Division), vegetation (USGS), digital elevation model (USGS), and stream (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 speed limit for paved roads (60 mph for paved roads), 35 mph for unpaved maintained roads, and 10 mph for unmaintained 4x4 roads. 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 points on the northwest side of the park were designated as travel start points to all 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 JOTR. 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 JOTR 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 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. However, *the field crew did not measure gaps created by perennial forbs and grasses and, instead, only measured gaps* *created by shrubs*. Thus, the number of gaps is likely to be underestimated, while gap sizes overestimated at JOTR.

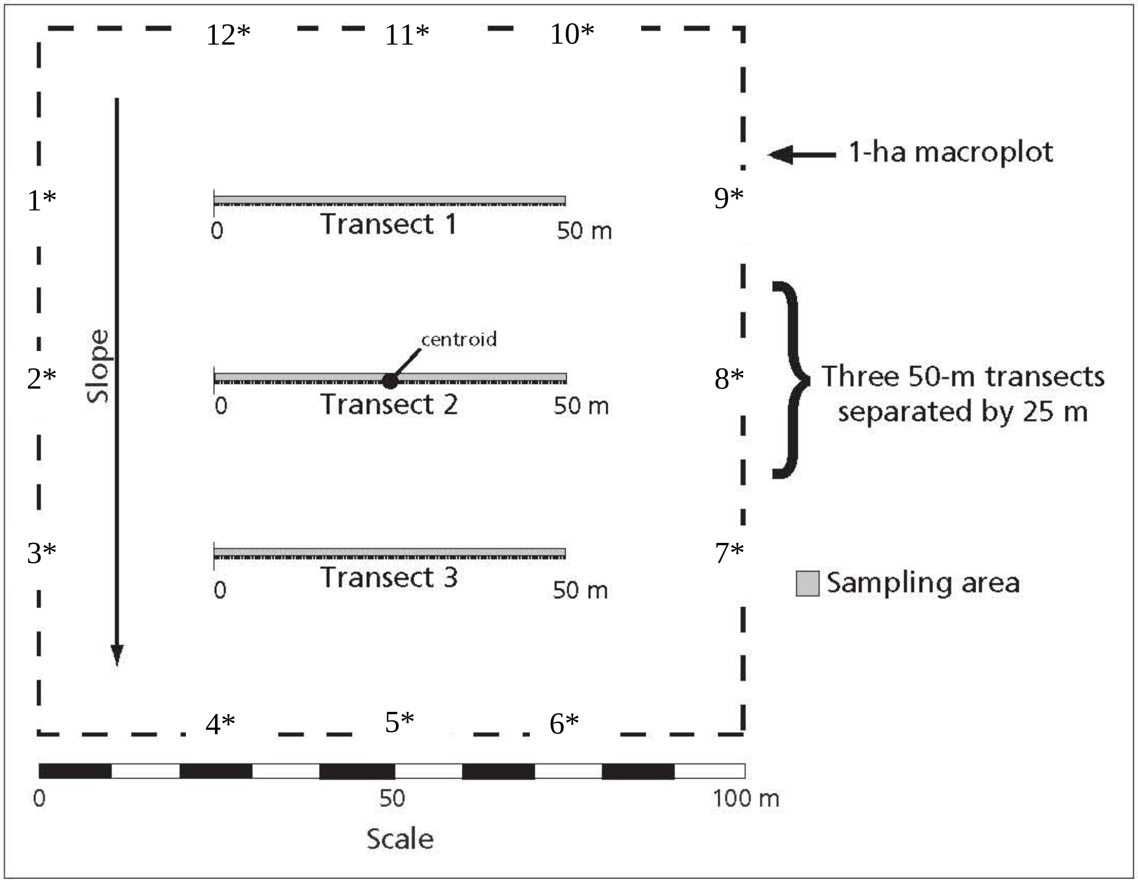

Figure 3. Standard macroplot and transect layout for integrated upland monitoring. Locations on the edge of the macroplot indicated by an "*" are sampling locations for soil parameters. The number next to the "*" is the sampling location number.

Five established upland invasive species, which we will refer to as status and trends (S&T) invasive species, were prioritized for monitoring at JOTR: *Brassica tournefortii* (Sahara mustard), *Bromus rubens* (red brome), *Bromus tectorum* (cheatgrass), *Erodium cicutarium* (redstem filaree), and *Schismus* spp. (Mediterranean grass). 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 species was further assessed using a patterned walk in the macroplot (SOP 12).

Soil parameters (SOP 11) 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, 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 data averaged across monitored macroplots at JOTR. 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 considering 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), 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 JOTR 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 – JOTR 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 JOTR ranged from $560 to $876 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 $668[1] during the initial establishment and the total cost was $23,380. Estimated cost for macroplot revisits (hiking time to field sites plus field data collection) averaged $570 per macroplot, and totaled $19,950 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 $2,850. 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 for set starting locations (see Appendix B). Driving times for the 35 GRTS sites included in the TTCSM ranged from <1 min to 86 min from the nearest park entrance (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 148 min (hike distances are provided in Appendix B). When we categorized the 35 GRTS field sites by hiking times, we found that most (89%) 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 JOTR ranged from $36 (<30 min hike one-way) to $178 (148 min hike one-way) for a 2-person

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[1] Macroplot cost was calculated by taking the average hiking cost ($53, 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 $247-316 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 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. Costs are in dollars.

SOP	Time Estimate	Time Estimate (min) 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. Estimated costs of 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. Costs are in dollars.

Vital Sign (rank)	Estimate of Time for SOPs (min)	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 JOTR (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. Four-day work weeks, with 10-hour work days, were the least economical, with an

[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.

estimated 36-40 travel days costing $12,816-14,240. Eight-hour days, 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, 1 day to and 1 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 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 estimates for the integrated upland protocol. Costs are in dollars.

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 five macroplots that were within 2 miles of roads during our 2012 pilot season at JOTR. 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 monitoring-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. In general, denser vegetation will require more time, particularly for the basal/canopy gaps procedure; the Joshua tree wooded alliance community at JOTR is on the medium to high density end of the vegetation spectrum. 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 point-based soil sampling 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, and 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 monitoring 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 JOTR are shown in Table 4; Table 4 cost estimates are based on the **recommended monitoring scenarios**[3]. The combination of procedures may vary from year to year, depending on the time between sampling events for each procedure, which may affect the estimated costs of monitoring for each sampling event.

The drawback to increasing the monitoring intervals for the soil and repeat photographs procedures is that it will take 30-50 years before enough data are collected to examine trends for quantitative data and an even longer period of time may be needed to detect whether trends exist.

[3] See *Section 4.2 Field Procedures* recommendation section below for description of recommendations. The average hiking cost per macroplot at JOTR was the same as used in results ($53). 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 estimates, including hike times, to conduct different subsets of field procedures during a sampling event for the integrated upland (IU) monitoring protocol at Joshua Tree 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 (in dollars) are provided per macroplot and for 35 macroplots. The IU protocol standard operating procedure number is shown in parentheses.

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
X		X		X		160-205	5,600-7,175
X	X	X		X		250-313	8,750-10,955
X		X		X	X	196-241	6,860-8,435
X		X	X	X		209-300	7,315-10,500
X	X	X	X	X	X	335-444	11,725-15,540

4.1.2 Travel Time to Field Sites

Although the pilot study focused on field sites that were "close to roads," or 1-2 miles from a road, hiking times to field sites still ranged from 60-90 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 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

<u>Recommendations:</u>

- ✓ 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 (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, BSC, or Joshua trees (see Appendix C).

<u>Recommendations:</u>

- ✓ 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.
- ✓ Joshua trees were not detected using this procedure, even though they were present on the macroplots at what should have been a detectable density. Although measuring Joshua trees is not a specific objective of the IU protocol, Joshua trees are a good indicator species for climate change. *We recommend that a quick count of Joshua trees by general size classes, as described in Barrow and Murphy-Mariscal (2012), be taken within each macroplot*. During the pilot study, one crew member counted the number of Joshua trees per macroplot and it generally took <30 min ($7-11).

Basal/canopy gaps (SOP 9) – We were not able to get good field time estimates for this procedure at JOTR because the field crew did not measure gaps created by perennial forbs and grasses. Thus, most of the recommendations for this procedure were based on findings from MOJA. 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 the quantitative data parameters (i.e., penetration resistance, pH), except for electrical conductivity, was low both within samples at a point and between soil sampling points at each macroplot at JOTR. While qualitative parameters varied within and between sampling points, macroplot-level assessments were fairly similar.

Recommendations:

- ✓ 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, land ownership, vegetation, streams, and Digital Elevation Model (DEM). We estimated Percent of Maximum Travel Speed (PMTS) values for the vegetation and land ownership 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 JOTR data used for the travel time cost model were acquired from JOTR before 2009, at which point the data were best available.

Trails Dataset

The trails line shapefile depicts the trails officially recognized by the park for planning and administrative purposes and was originally created for the Backcountry Management Plan approved in January, 2000.

Roads Dataset

The roads line shapefile (rds_pub2 shapefile) was created by Jeff Ohlfs and Gary Lindberg and represents roads in and around JOTR. The original data were drawn on 7.5 minute USGS maps by Jeff Ohlfs over several years during his time as Park Ranger. Roads were digitized on-screen in ArcView using DRGs (Digital Raster Graphics - scanned 7.5 USGS maps). DOQs (Digital Orthophoto Quads) were used if the roads were visible on the image. In 2000 - 2001, a major road project was undertaken in the area from Quail Springs picnic area to Cap Rock along Route 12 and from the Hidden Valley day use area to Barker Dam on routes 405 and 100.

Boundary and NPS Lands Datasets

This polygon shapefile represents the most current boundary for JOTR in 2009. The boundary is as described in the Desert Protection Act (PL 103-43, 10-31-94). Additional parcels have been added along the northern boundary, which were acquired by the park since the original legislation.

Vegetation Dataset

The vegetation layer used was the National GAP Land Cover 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.

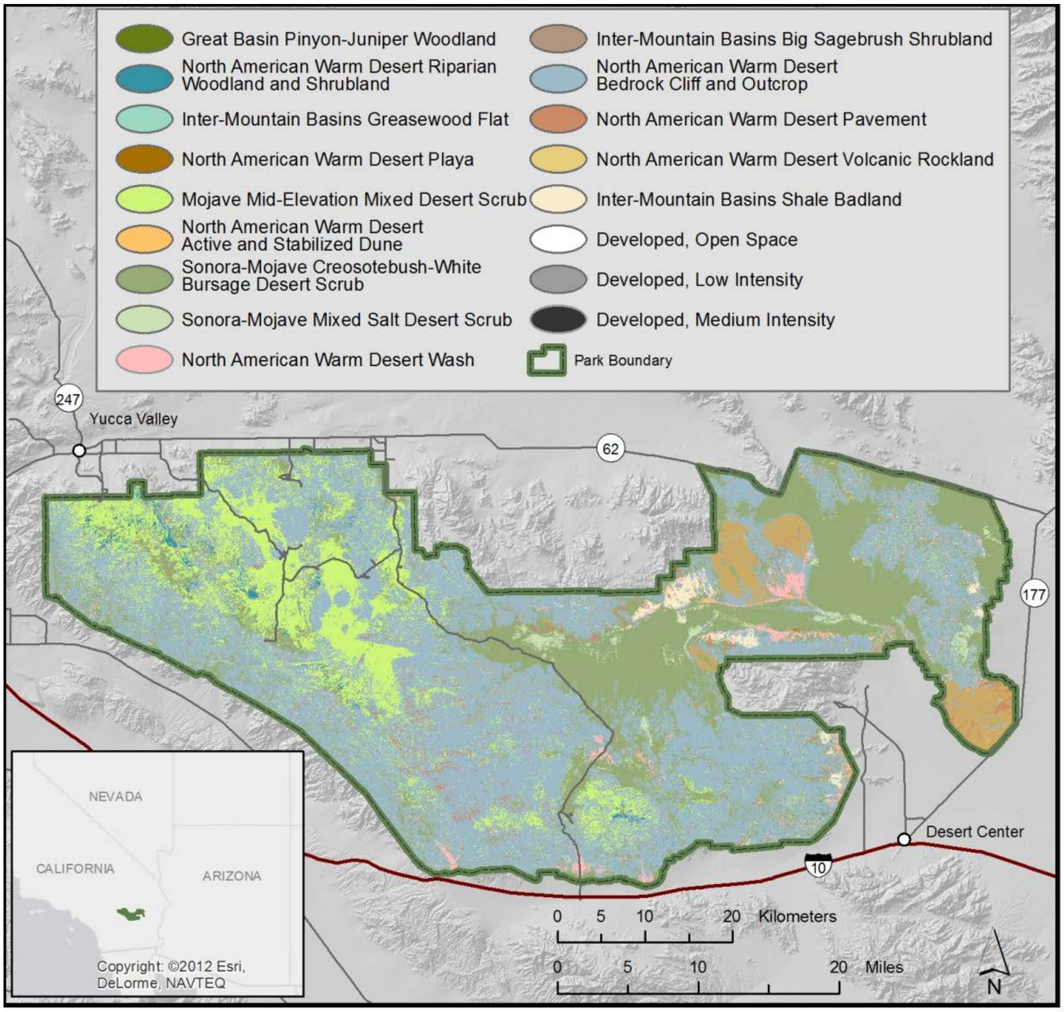

Figure A1. Spatial distribution of vegetation types at Joshua Tree National Park based on the National GAP Land Cover dataset version 2.1 (http://gapanalysis.usgs.gov/gaplandcover/).

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 = 75%
- 2nd order = 60%
- 3rd order = 50%
- 4th order = 30%
- 5th order = 20%

Land Ownership
- NPS = 100%
- Non_NPS = 0%

Vegetation
- Open water = 0%
- Developed, Open Space = 90%
- Developed, Low Intensity = 90%
- Developed, Medium Intensity = 90%
- Great Basin Pinyon-Juniper Woodland = 80%
- North American Warm Desert Riparian Woodland and Shrubland = 25%
- Inter-Mountain Basins Greasewood Flat = 80%
- North American Warm Desert Playa = 95%
- Mojave Mid-Elevation Mixed Desert Scrub = 80%
- North American Warm Desert Active and Stabilized Dune = 60%
- Sonora-Mojave Creosotebush-White Bursage Desert Scrub = 85%
- Sonora-Mojave Mixed Salt Desert Scrub = 85%
- North American Warm Desert Wash = 85%
- Inter-Mountain Basins Big Sagebrush Shrubland = 80%
- North American Warm Desert Bedrock Cliff and Outcrop = 100%
- North American Warm Desert Pavement = 100%
- North American Warm Desert Volcanic Rockland = 60%
- Inter-Mountain Basins Shale Badland = 50%

Travel Speeds

Driving
- Paved = 60 mph
- Unpaved maintained = 35 mph
- Unmaintained 4x4 = 10 mph

Walking
- 2 mph
- 2.5 mph
- 3 mph

Layer Priorities

1. roads
2. trails
3. streams
4. non-NPS lands
5. 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 JOTR (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 the volunteer natural resource interns. 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 (one GS-5 field technician and one volunteer natural resource intern); 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).

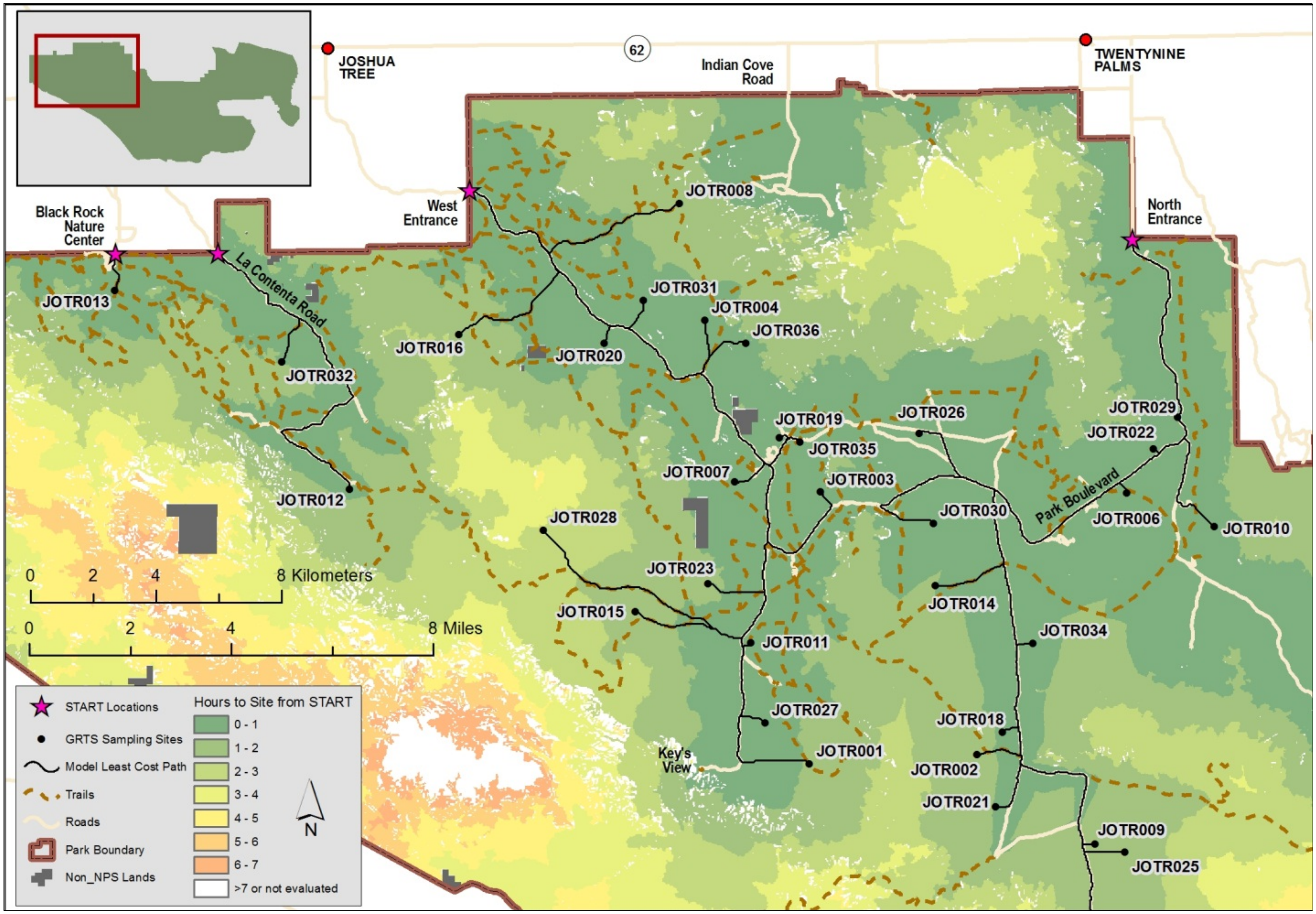

Figure B1. Least cost travel paths to 35 Generalized Random Tessellation Stratified (GRTS) sites generated by the travel time cost surface model from the nearest park entrances on the north side of Joshua Tree National Park. Routes shown include driving and hiking paths.

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 entrance on the north side of the park (see Figure B1). The five sites in bold were 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. Under the estimated hiking time, the times in parentheses are for hiking speeds of 2 to 3 mph.

Macroplot ID	Association Type*	Distance From Nearest Road (mi)	Estimated Hiking Time (min)	Drive Time (min)	Estimated Total One-way Travel Time (min)
JOTR001	YUBR-JUCA/EPNE - YUBR/PRFA	1.41	47.70 (39.75-59.62)	16.26	63.96
JOTR002	**YUBR/PLRI**	**0.97**	**26.92 (22.44-33.63)**	**42.63**	**69.55**
JOTR003	YUBR/CORA	0.35	11.02 (9.19-13.77)	13.12	24.14
JOTR004	**YUBR/PLRI**	**1.08**	**32.28 (26.90-40.35)**	**7.06**	**39.35**
JOTR005	YUBR-JUCA/EPNE - YUBR/PRFA	0.36	12.55 (10.47-15.66)	83.99	96.53
JOTR006	YUBR/LATR – YUSC/PLRI	0.27	11.01 (9.17-13.75)	6.75	17.76
JOTR007	YUBR/PLRI	0.40	11.95 (9.96-14.93)	9.78	21.73
JOTR008	YUBR/LATR – YUSC/PLRI	3.09	90.36 (75.30-112.95)	2.51	92.88
JOTR009	YUBR/LATR – YUSC/PLRI	0.24*	8.74 (7.29-10.89)	60.98	69.72
JOTR010	**YUBR/CORA**	**0.69**	**22.55 (18.79-28.18)**	**6.77**	**22.55**
JOTR011	YUBR/PLRI	0.19**	6.00 (5.00-7.50)	13.63	19.63
JOTR012	YUBR-JUCA/EPNE - YUBR/PRFA	0.13**	3.68 (3.07-4.58)	48.93	52.61
JOTR013	YUBR/CORA	0.55	16.00 (13.34-19.99)	0.33	16.33
JOTR014	YUBR/LATR – YUSC/PLRI	1.53	40.21 (33.51-50.24)	19.79	60.00
JOTR015	YUBR/LATR – YUSC/PLRI	2.36	70.52 (58.77-88.15)	13.46	83.98
JOTR016	YUBR/CORA	2.69	84.87 (70.72-106.08)	2.96	87.82
JOTR017	YUBR-JUCA/EPNE - YUBR/PRFA	0.35	13.53 (11.31-16.86)	85.65	99.18
JOTR018	YUBR/LATR – YUSC/PLRI	0.34	13.39 (11.17-16.72)	39.42	52.81
JOTR019	YUBR/PLRI	0.10**	2.62 (2.19-3.27)	10.37	12.99
JOTR020	YUBR/PLRI	0.40	12.96 (10.80-16.19)	4.54	17.49
JOTR021	YUBR/LATR – YUSC/PLRI	0.27	8.38 (6.99-10.46)	49.29	57.67

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 entrance on the north side of the park (see Figure B1). The five sites in bold were 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. Under estimated hiking time, the times in parentheses are for hiking speeds of 2 to 3 mph (continued).

Macroplot ID	Association Type*	Distance From Nearest Road (mi)	Estimated Hiking Time (min)	Drive Time (min)	Estimated Total One-way Travel Time (min)
JOTR022	YUBR/CORA	0.13**	4.34 (3.62-5.42)	5.66	10.00
JOTR023	YUBR-JUCA/EPNE - YUBR/PRFA	1.20	51.25 (42.71-64.06)	12.29	63.54
JOTR025	YUBR/LATR – YUSC/PLRI	0.83	27.83 (23.20-34.72)	62.01	89.84
JOTR026	YUBR/PLRI	0.06**	1.48 (1.23-1.84)	13.72	15.20
JOTR027	YUBR-JUCA/EPNE - YUBR/PRFA	0.55	20.07 (16.73-25.08)	15.14	35.21
JOTR028	YUBR-JUCA/EPNE - YUBR/PRFA	4.97	147.60 (123.00-184.50)	13.46	161.06
JOTR029	YUBR/LATR – YUSC/PLRI	0.04**	0.95 (0.79-1.18)	4.50	5.45
JOTR030	**YUBR/PLRI**	**0.82**	**26.12 (21.77-32.65)**	**13.61**	**39.73**
JOTR031	**YUBR/PLRI**	**0.66**	**22.40 (18.67-28.00)**	**4.95**	**27.35**
JOTR032	YUBR/CORA	1.02	39.47 (32.90-48.78)	14.20	53.67
JOTR033	YUBR/LATR – YUSC/PLRI	0.11**	3.92 (3.28-4.89)	76.57	80.49
JOTR034	YUBR/LATR – YUSC/PLRI	0.35	11.59 (9.65-14.47)	29.83	64.46
JOTR035	YUBR/PLRI	0.06**	1.46 (1.22-1.82)	10.48	11.93
JOTR036	YUBR/PLRI	1.26	40.25 (33.54-50.31)	7.06	47.31

*Association types: YUBR/CORA = *Yucca brevifolia/Coleogyne ramosissima*, YUBR-JUCA/EPNE - YUBR/PRFA = *Yucca brevifolia-Juniperus californica/Ephedra nevadensis* - *Yucca brevifolia/Prunus fasciculata*, YUBR/LATR - YUSC/PLRI = *Yucca brevifolia/Larrea tridentata* - *Yucca schidigera/Pleuraphis rigida*, YUBR/PLRI = *Yucca brevifolia/Pleuraphis rigida*.

**Sites that are within 0.25 mi of road. An additional 11 sites are within 0.5 mi of a road.

Table B2. Estimated round-trip hiking costs for 35 sites from the Joshua Tree National Park Generalized Random Tessellation Stratified (GRTS) draw for a 2-person crew, consisting of one GS-5 field technician and one natural resource intern. # 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). Costs are in dollars.

One-Way Hiking Time (min)	Cost Estimate - Field Technician	Cost Estimate - Intern	Crew Cost per Site	# of Sites
<30	22	14	36	25
30-60	44	27	71	6
60-90	66	41	107	2
90-120	88	54	142	1
120+	109*	69*	178*	1

*Estimate was made based on the approximate hiking time for the site in this category, which was ~148 min.

Table B3. Estimated round-trip hiking costs for 35 sites from the Joshua Tree 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). Costs are in dollars.

One-Way Hiking Time (min)	Cost Estimate - Field Technician	Cost Estimate - Interns (2-3 interns)	Crew Cost per Site	# of Sites
<30	22	27-41	49-63	25
30-60	44	54-82	98-126	6
60-90	66	82-122	148-188	2
90-120	88	109-163	197-251	1
120+	109*	138-207*	247-316*	1

* Estimate was made based on the approximate hiking time for the site in this category, which was ~148 min.

Table B4. Time and cost 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. Costs are in dollars.

Procedure	Time Estimate (min)	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 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. Costs are in dollars.

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
Cultural clearance	?				
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 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]). Costs are in dollars. 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.

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

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Appendix C: JOTR Macroplot Data from the Pilot Study

We visited seven field sites at JOTR and established macroplots at five of the field sites (Figure C1). We present summaries of the vegetation, invasive plant, and soils data collected on the five macroplots. The data presented in this section pertain only to the monitored macroplots and cannot be extrapolated to the Joshua tree (*Yucca brevifolia* var. *brevifolia*) wooded alliance community as a whole.

From the vegetation measurements, we found that community composition of the five monitored macroplots was different, as no shrub species, including Joshua trees (the characteristic species of the community; see Table C5) was found on all macroplots, and most shrub species were found on only one macroplot (Table C1). From the invasive plant procedures, we detected four of the five target invasive species in the macroplots, but only two of the macroplots, 30 and 31, had all four species. *Bromus rubens* (red brome) and *Erodium circutarium* (redstem filaree) were the only species detected on all five macroplots. For most soil parameters, the range of values detected overlapped across macroplots (Table C4). We examined the potential for soil erosion with the basal/canopy gaps procedure.

We initially planned to establish five macroplots at JOTR and were able to establish five macroplots after visiting seven field sites in approximately 14 days (this included travel time to the park from Boulder City, NV; Figure C1). We established four macroplots (macroplots 2, 4, 30, 31) in the Joshua tree-big galleta grass (*Yucca brevifolia/Pleuraphis rigida*) association and one macroplot (macroplot 10) in the Joshua tree-blackbrush (*Yucca brevifolia/Coleogyne ramosissima*) association. Two of the sites, macroplots 30 and 31, exhibited signs of past fire, with macroplot 31 appearing to have been more recently burned, as there was little vegetation recovery (see Appendix D; JOTR fire records indicate that macroplot 31 was in an area that burned in 1999).

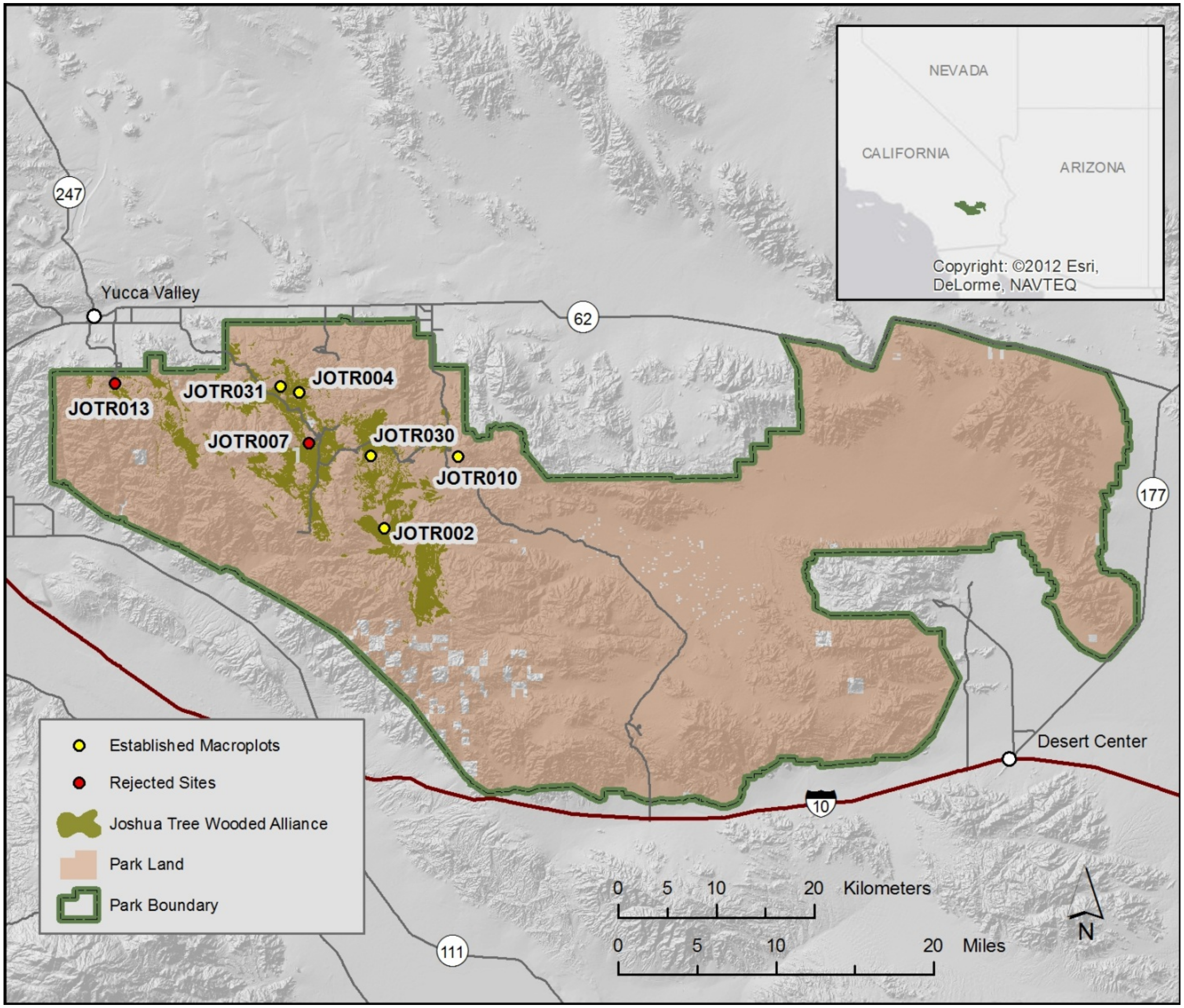
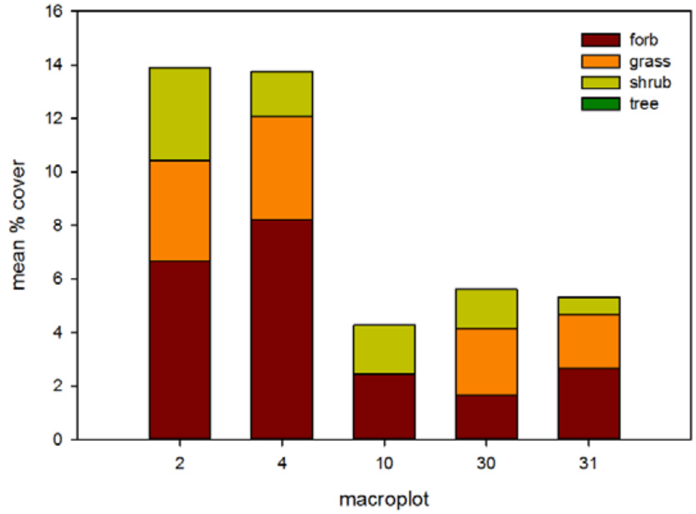


Figure C1. Locations of visited field sites within the Joshua tree (*Yucca brevifolia* var. *brevifolia*) wooded alliance community at Joshua Tree National Park. Five macroplots were established out of seven visited sites.

Vegetation

Across the five macroplots, we found a total of 25 shrub species. Interestingly, none of the 25 species were found on all macroplots and most were found on only one macroplot. The mean number of shrub species on macroplots ranged from 2-15 (Figure C2b), but the mean % cover of those species was fairly low at generally <3% per species (Table C1). The species found on the most macroplots, four, was *Hymenoclea salsola* (Burrobrush). The species characteristic of the monitored community, *Yucca brevifolia* var. *brevifolia* (Joshua tree), was not detected on any of the macroplots, even though it was observed on all macroplots (Table C5).

a)



b)

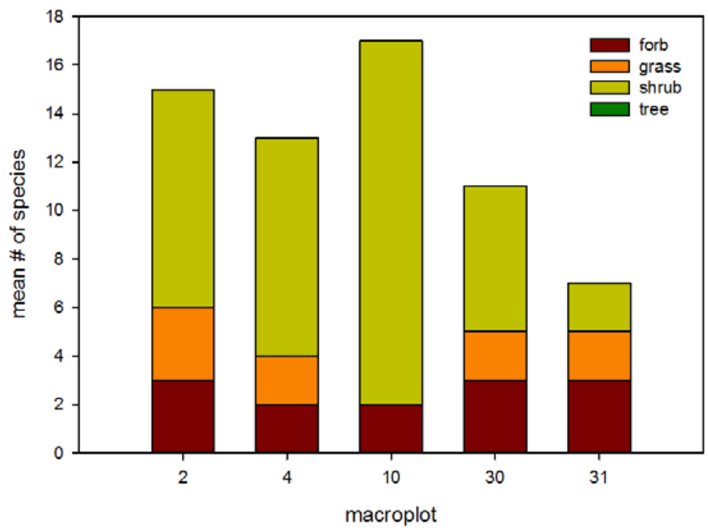


Figure C2. Mean a) % cover and b) species richness of species for each life form by macroplot. Species richness for all life forms except shrubs could include target invasive species and/or life form categories. For example, species richness for grasses would include target invasive grass species and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

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

Shrub Species	Common Name	Live (L) or Dead (D)	No. Plots Where Found	Mean % Cover (range)*
Ambrosia dumosa	White bursage	L	1	0.267 (0-1.333)
		D	1	0.133(0-0.667)
Coleogyne ramosissima	Blackbrush	L	1	0.933 (0-4.667)
		D	1	0.800 (0-4.000)
Cylindropuntia echinocarpa	Golden cholla	L	1	0.133(0-0.667)
		D	1	0.133(0-0.667)
Cylindropuntia ramosissima	Pencil cholla	L	3	0.400 (0-0.667)
Echinocereus mojavensi	Mojave kingcup cactus	L	1	0.133 (0-0.667)
Ephedra aspera	Rough jointfir	L	1	0.133 (0-0.667)
		D	1	0.267(0-1.333)
Ephedra californica	California jointfir	L	1	0.133(0-0.667)
Ephedra nevadensis	Nevada mormon tea	L	1	0.133 (0-0.667)
Ericameria cooperi	Goldenbush	L	1	0.133 (0-0.667)
Eriogonum fasciculatum var. polifolium	California buckwheat	L	1	0.533 (0-2.667
		D	1	0.267 (0-1.333)
Grayia spinosa	Spiny hopsage	L	1	0.400 (0-2.00)
		D	1	0.267 (0-1.333)
Gutierrezia sarothrae	Broom snakeweed	L	1	0.133 (0-0.667)

Table C1. Mean % cover per macroplot of shrub and tree species found across five macroplots in 2012 (continued).

Shrub Species	**Common Name**	**Live (L) or Dead (D)**	**No. Plots Where Found**	**Mean % Cover (range)***
Hymenoclea salsola	Burrobrush	L	4	1.067 (0-2.667)
		D	2	0.400 (0-1.333)
Krameria erecta	Range ratany	L	1	0.267 (0-1.333)
Krameria grayi	White ratany	L	1	0.133 (0-0.667)
Larrea tridentata	Creosote bush	L	2	0.933 (0-3.333)
Lycium andersonii	Anderson wolfberry	L	3	1.067 (0-3.333)
		D	1	0.400 (0-2.00)
Lycium cooperi	Cooper wolfberry	D	1	0.133 (0-0.667)
Prunus fasciculatus var. fasciculatus	Desert almond	L	1	0.267 (0-1.333)
Salazaria Mexicana	Mexican bladdersage	L	2	0.800 (0-2.667)
		D	2	0.267 (0-0.667)
Simmondsia chinensis	Jojoba	L	1	0.133 (0-0.667)
Tetradymia stenolepis	Mojave horsebrush	L	1	0.533 (0-2.667)
Viguiera parishii	Parish's Viguiera	L	1	0.800 (0-4.00)
Yucca schidigera	Mohave Yucca	L	3	1.067 (0-3.333)

*Mean % cover over the five plots.

Total % cover on macroplots at JOTR, determined by whether any vegetation was detected during the point-intercept procedure, ranged from 41-75% (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 the mean % cover for dead species/life form was much higher than for live species/life form when we included litter/woody debris as a "life form" (Figure C4). When we excluded litter/woody debris, the mean % cover for live and dead species/life form was fairly similar (Figure C4). There was great variation in % cover by life form (forbs, grasses, shrubs, and trees), with the exception of the tree life form, as no trees were detected on any macroplot (Figure C2a). Interestingly, mean % shrub cover was often less than the mean % cover of other life forms that were present.

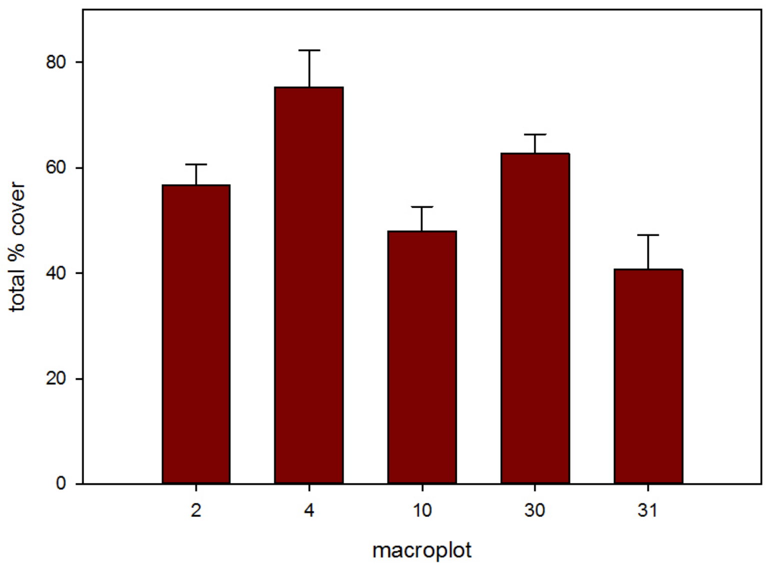


Figure C3. Mean (+SE) total % cover by macroplot.

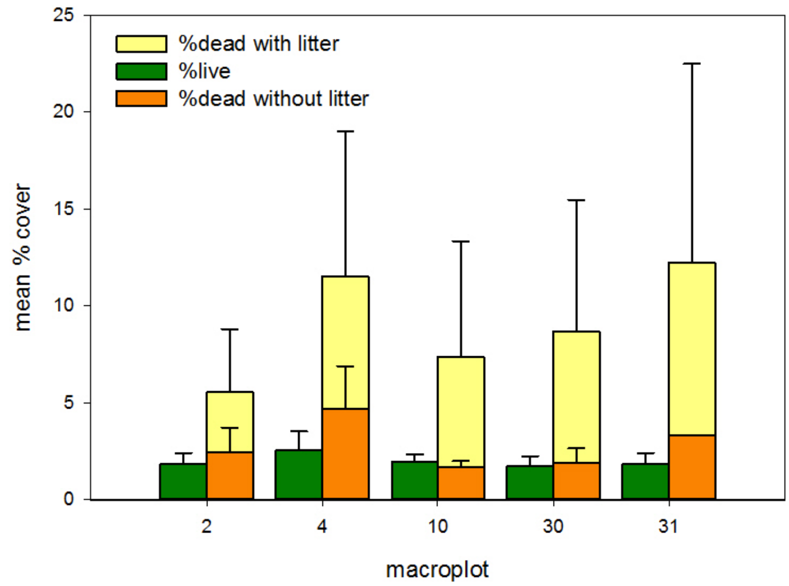


Figure C4. Mean (+SE) % cover of live and dead species/life form by macroplot. Dead species/life form cover included or excluded litter/woody debris as a dead species/life form category.

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 four of the five target invasive species at JOTR in the macroplots. Three target invasive species were detected using the point-intercept procedure (Table C2), *Bromus rubens*, *Erodium circutarium* (redstem filaree), and *Schismus* spp. (Mediterranean grass). One additional species was detected using the invasive species frequency quadrats, *Bromus tectorum* (cheatgrass). *Bromus rubens* and *Erodium circutarium* were the only species detected on all five macroplots and by both procedures (Figure C5). An additional species, *Bromus tectorum*, was detected on macroplots 30 and 31 using the site assessment for invasive species procedure. The only target S&T species that we did not detect on any of the macroplots was *Brassica tournefortii* (Sahara mustard).

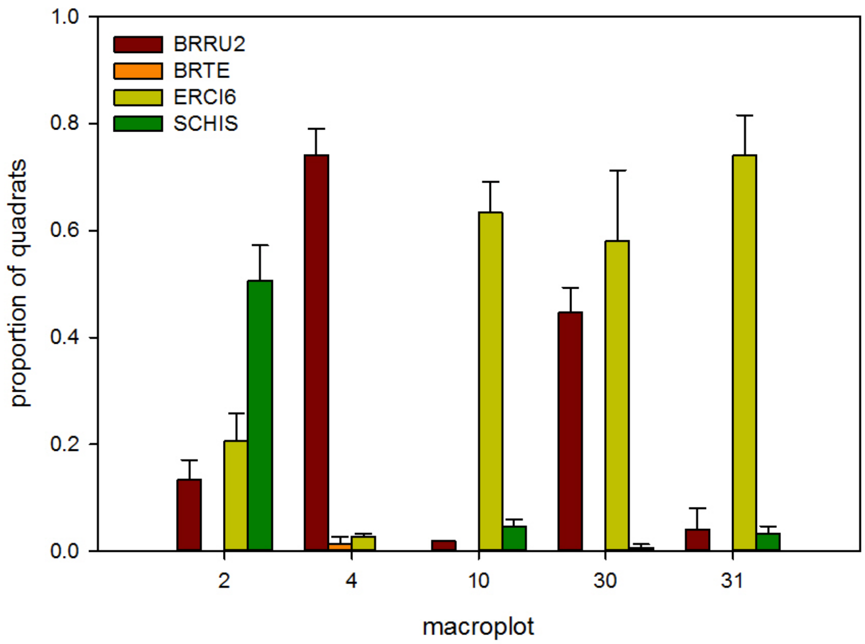


Figure C5. Mean (+SE) proportion of quadrats infested by target invasive species by macroplot. BRRU2 = *Bromus rubens* (red brome), BRTE = *Bromus tectorum* (cheatgrass), ERCI6 = *Erodium cicutarium* (redstem filaree), and SCHIS = *Schismus* spp. (Mediterranean grass).

The mean % cover of dead *B. rubens* was almost four times that of live *B. rubens* (Table C2). In contrast, all *E. circutarium* detected was alive. The mean % cover of invasive species observed on each macroplot was higher than the mean % cover of native species (Figure C6).

Table C2. Mean % cover per macroplot of invasive species found across five macroplots in 2012. Data from point-intercept procedure (SOP 8).

Shrub Species	Common Name	Live (L) or Dead (D)	No. Plots Where Found	Mean % Cover (range)
Bromus rubens	Red brome	L	3	1.067 (0-3.333)
		D	3	3.600 (0-12)
Erodium circutarium	Redstem filaree	L	4	2.800 (0-4.667)
*Schismus spp.**	Mediterranean grass	L	2	1.200 (0-5.333)
		D	1	0.400 (0-2)

**Schismus arabicus* at JOTR.

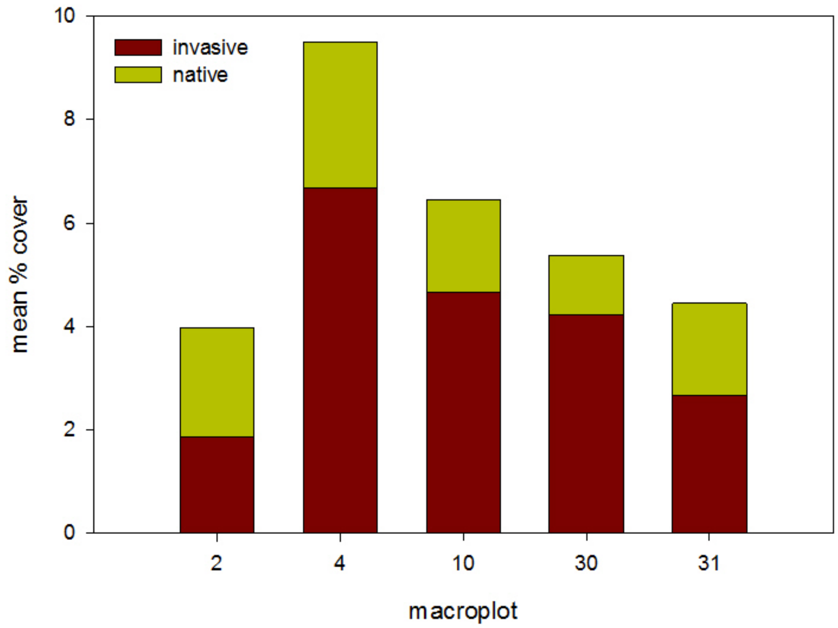


Figure C6. Mean % cover for invasive and native species by macroplot.

The proportion of quadrats in which each of the invasive species was found varied greatly across macroplots. However, where invasive species were found, they were often alive (Table C3). Although *B. rubens* and *E. cicutarium* were both found on all five macroplots, the proportion of quadrats in which they were found varied from 2-74% and ~3-74%, respectively. Interestingly, different species seem to be dominant on different macroplots (Figure C5). Other than *B. rubens*, which was equally found in the canopy and interspaces, the invasive species were predominantly found in the interspaces of the macroplots. At the time of data collection, the invasive species exhibited a range of phenophases from early vegetative to senescent (Table C3).

We detected an additional invasive species, *Bromus tectorum*, on macroplots 30 and 31, using the site assessment for invasive species procedure. From all of the procedures, *B. tectorum* was found on three macroplots but had low presence (0-2% cover category) on those macroplots. With the detection of *B. tectorum* on macroplots 30 and 31, these two macroplots, both of which exhibited signs of burns, had the most invasive species (four species) out of the five macroplots we monitored.

Out of all of the procedures, the invasive species frequency quadrat was the most effective for detecting invasive species (using it, we detected four invasive species compared to three using the point-intercept procedure) and provided the greatest amount of data on target invasive species. The site assessment for invasive species would be most useful to understand the invasion process, as we would be more likely to detect species in the earlier phases of macroplot invasion (e.g., *Bromus tectorum*). Taken together, the three procedures would provide a more comprehensive understanding of the invasion process and invasive species population growth.

Table C3. Frequency of quadrats for dead *vs*. live, spatial location, and phenophase of invasive species found across five macroplots in 2012. Ranges of data are in parentheses. Invasive plants in quadrats were categorized into one of nine phenophase stages and only phenophases found in the macroplots are shown here.

Shrub Species	**Common Name**	**Dead vs. Live**		**Location***		
		Dead	Live	C	CI	I
Bromus rubens	Red brome	0.452 (0.313-0.690)	0.548 (0.310-0.687)	0.453 (0.135-1)	0.078 (0- 0.184)	0.467 (0- 0.681)
*Bromus tectorum***	Cheatgrass	0	1	0	0	1
Erodium cicutarium	Redstem filaree	0.324 (0.022-1)	0.676 (0-0.978)	0.139 (0- 0.363)	0.111 (0.036-0.278)	0.749 (0.523- 0.907)
Schismus spp.	Mediterranean grass	0.052 (0-0.207)	0.948 (0.793-1)	0.227 (0-0.444)	0.082 (0-0.222)	0.691 (0.333-1)

Shrub Species	**Common Name**	**Phenophase***							
		2	3	4	5	6	7	8	9
Bromus rubens	Red brome	0.025 (0.013-0.037)	0	0.019	0.426 (0.327-0.617)	0.333	0.038	0.190	0.448 (0.313-0.673)
*Bromus tectorum***	Cheatgrass	0	0	0	1	0	0	0	0
Erodium cicutarium	Redstem filaree	0.221 (0.057-0.397)	0	0.030 (0.012-0.056)	0.036 (0.033-0.053)	0.008	0.557 (0.301-0.877)	0.045 (0.016-0.067)	0.388 (0.022-1)
Schismus spp.	Mediterranean grass	0	0	0	0.804 (0.437-1)	0.059	0.071 (0.030-0.111)	0.184 (0.111-0.256)	0.219

*Location: C=canopy, CI=canopy and interspaces, I=interspace; phenophase: 2=vegetative/ basal rosette or multiple tillers, 3=flower bud forming or boot stage, 4=early flowering (<25% flowers open per plant or inflorescence), 5=flowering, 6=late flowering (>75% flowers open per plant or inflorescence), 7=fruit/seed formation or ripening, 8=mature fruit/seed scatter, 9=dead/senescent.

**Found on only one macroplot.

Soil Measurement Parameters

For most of the soil parameters, the range of values detected overlapped across macroplots, and variation in quantitative soil parameters was low (Table C4). Soil compaction (penetration resistance) was predominantly “extremely low” on all macroplots. pH ranged from ~7.2-8.2 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. However, gaps created by perennial forbs and grasses were inadvertently not measured, so *the number of gaps is likely to be underestimated, while the size of gaps overestimated*.

We recorded five soil surface features on macroplots using the point-intercept procedure, with mean % cover per macroplot ranging from <1% to >81% (Figure C7) and bare soil having the greatest % cover.

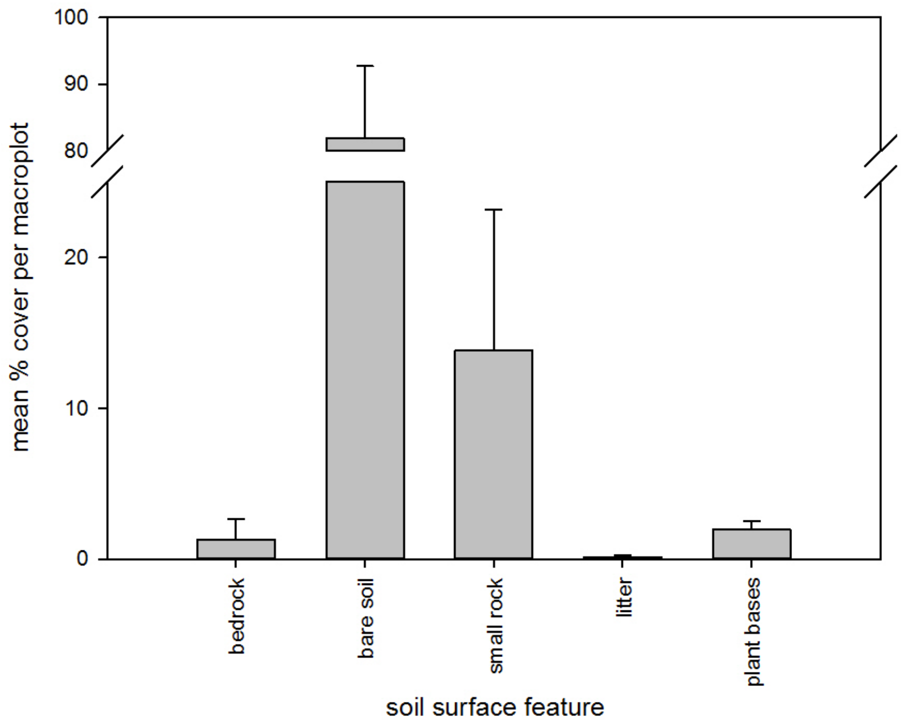
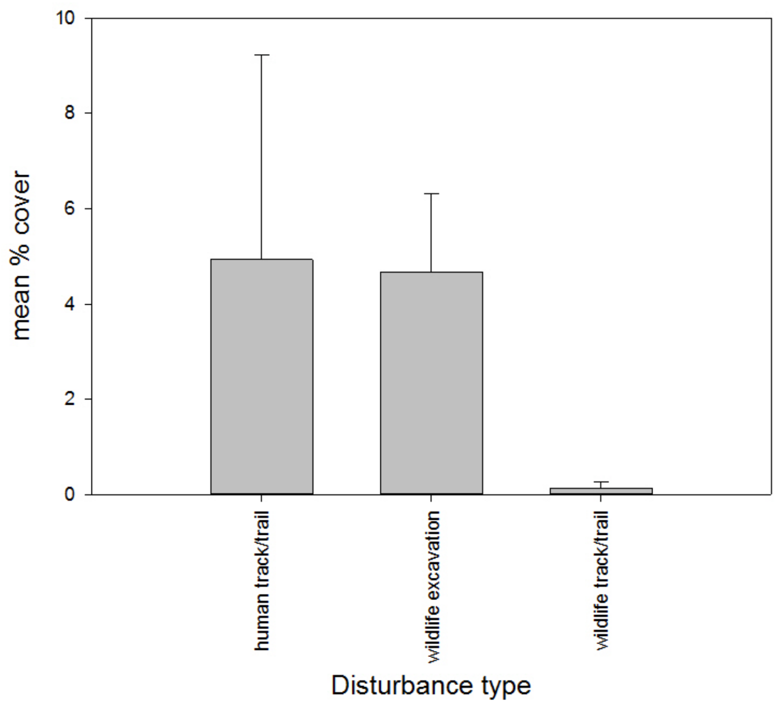


Figure C7. Mean (+SE) % cover of soil surface features per macroplot.

Soil disturbance features were detected using both the point-intercept and invasive species quadrats procedures. Three disturbance categories were detected with the point-intercept procedure, with human track/trails and wildlife excavations having the highest % cover (Figure C8a). An additional three disturbance categories were detected with the invasive species quadrats procedure, ant hill, undifferentiated, and wash, but were in low frequency (<2% of quadrats) (Figure C8b).

a)



b)

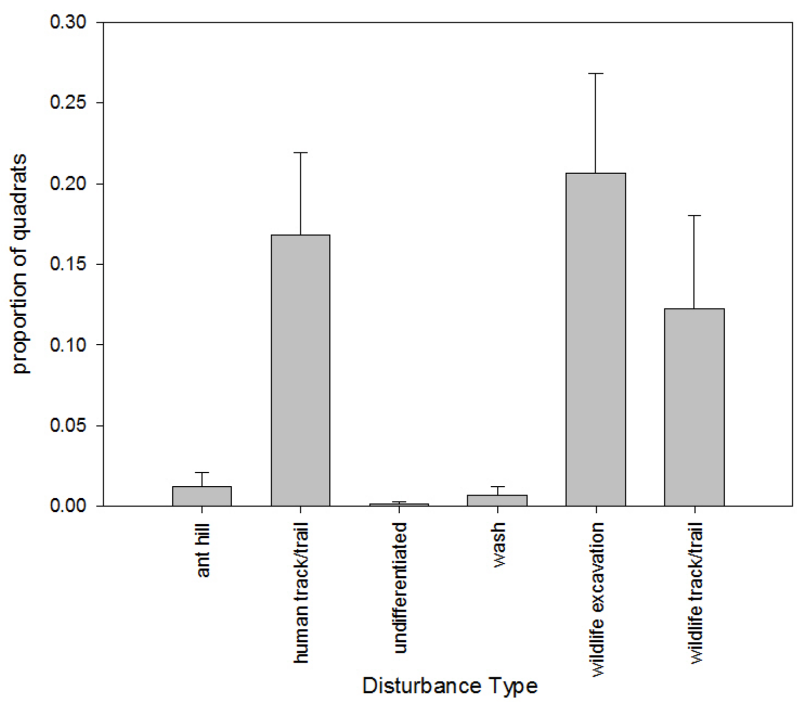


Figure C8. Mean (+SE) a) % cover and b) proportion of quadrats of soil disturbance features per macroplot from the point-intercept (SOP 8) and invasive species frequency quadrats (SOP 10) procedures, respectively.

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. However, the field crew did not measure gaps created by perennial forbs and grasses and instead, only measured gaps created by shrubs. Thus, *the number of gaps is likely to be underestimated, while size of gaps overestimated* at JOTR.

Canopy gaps can be used to assess the potential for wind erosion. The total number of canopy gaps ≥0.2 m ranged from 3-20 gaps per macroplot. The distribution of canopy gaps varied across macroplots, with macroplots 2, 4, and 30 having more similar distributions (Figure C9). Mean canopy gap size varied from <2 m to almost 20 m (Figure C10a). Macroplot 31 had the fewest number of gaps and the largest mean gap size, reflecting its sparse vegetation from a relatively recent burn (1999; Appendix D). Despite different distributions of gap sizes, the mean total length of all of the canopy gaps comprised more than 70% of transects for all macroplots, with nearly entire transects (e.g. macroplot 31) being “canopy gap” (Figure C10a).

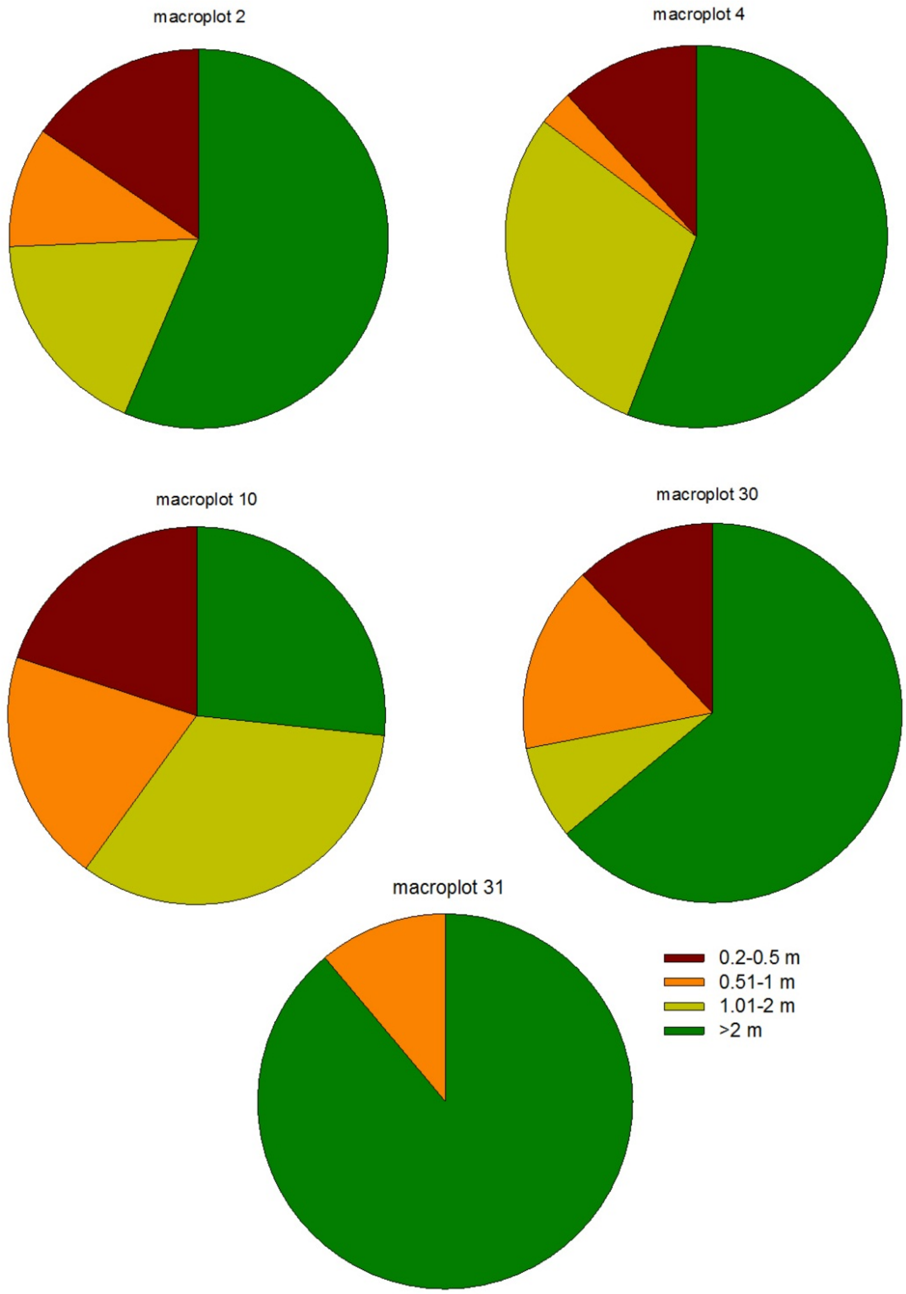
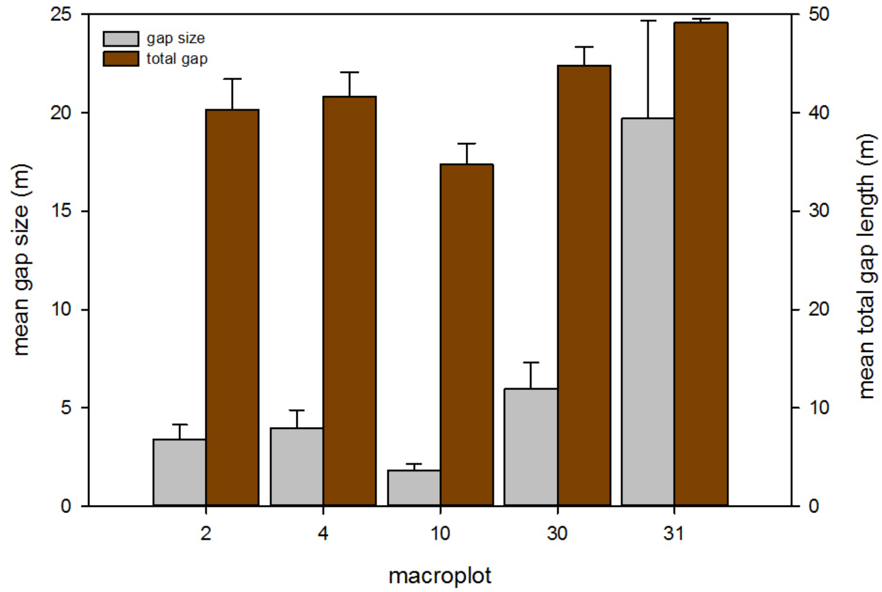


Figure C9. Mean number of canopy gaps for a given size category per macroplot. Macroplot 2 had a total of 13 gaps, macroplot 4, 11 gaps, macroplot 10, 20 gaps, macroplot 30, eight gaps, and macroplot 31, three gaps.

a)



b)

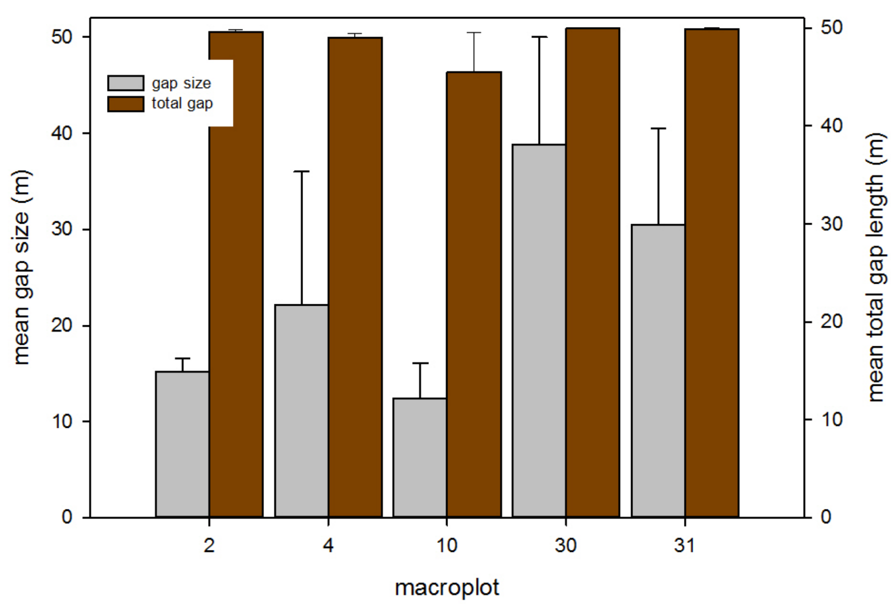


Figure C10. Mean (+SE) gap size and total gap length per transect by macroplot for a) canopy and b) basal gaps.

Basal gaps can be used to assess the potential for water erosion. The total number of basal gaps ≥0.2 m ranged from 2-5 gaps per macroplot (Figure C11). A majority of the basal gaps for each macroplot were in the largest gap category (>2 m). Mean gap size ranged from <13 m to >38 m, with macroplot 30 having the largest mean basal gap size (Figure C10b). Despite the differences in gap distribution and mean gap size, mean total basal gap length was >45 m, or nearly the entire transect for all macroplots (Figure C10b).

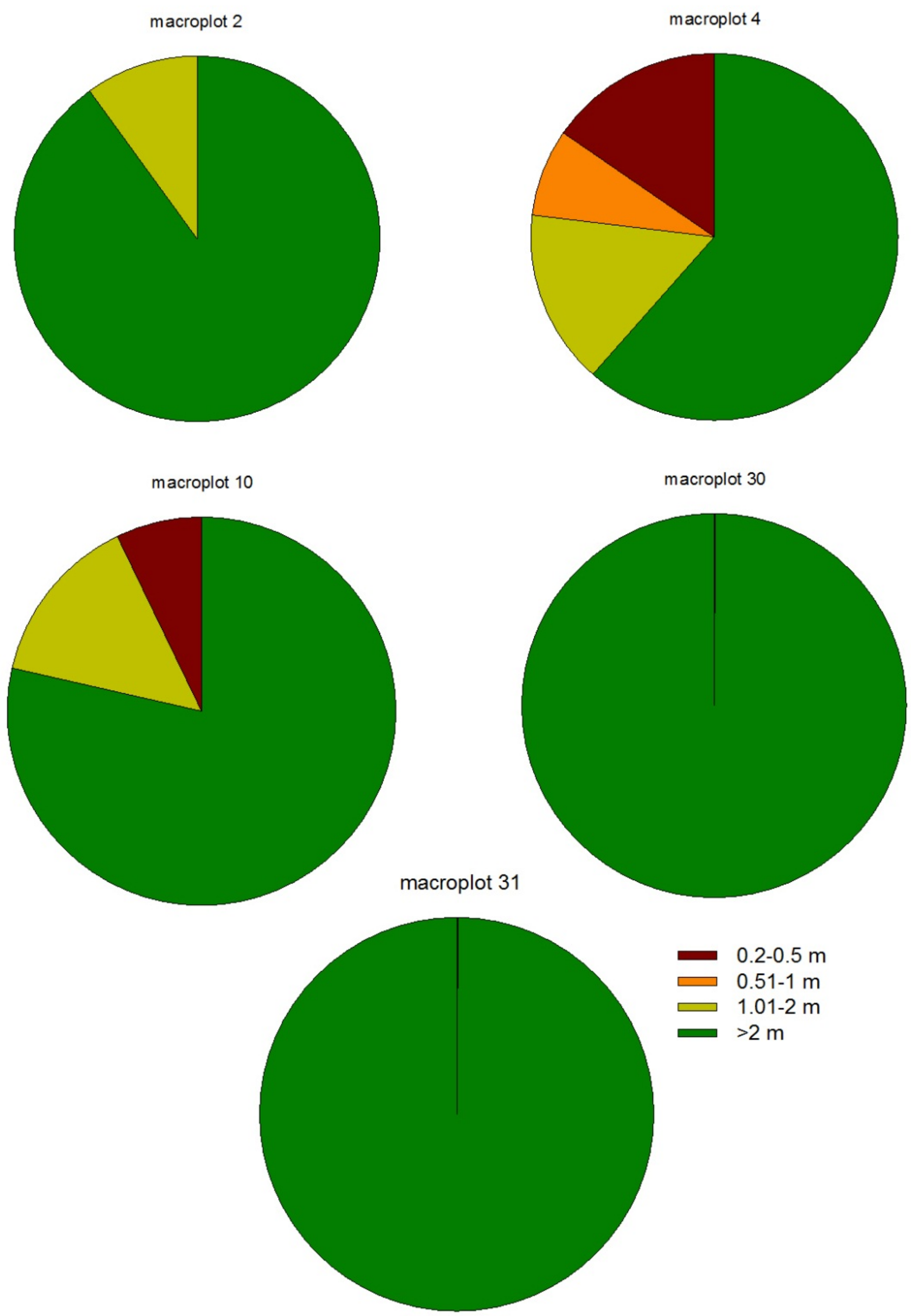


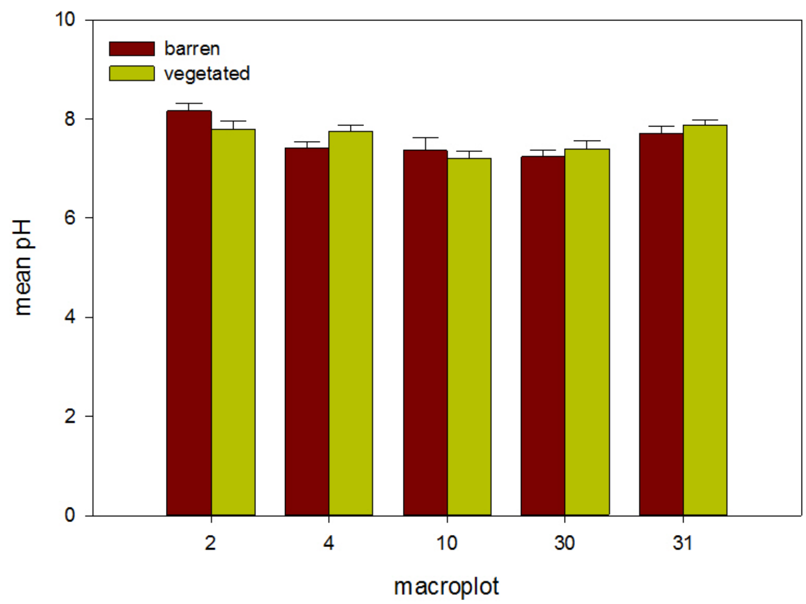
Figure C11. Mean number of basal gaps for a given size category per macroplot. Macroplot 2 had a total of three gaps, macroplot 4, four gaps, macroplot 10, five gaps, macroplot 30, two gaps, and macroplot 31, two gaps.

Soil compaction (penetration resistance) was predominantly extremely low on all macroplots. All sample points on macroplot 31 exhibited extremely low soil compaction. Soil compaction varied from extremely low to very low on the other four macroplots.

pH ranged from ~7.2-8.2 and did not vary greatly between vegetated and barren soil samples (Figure C12a).

Soil salinity was fairly low on all macroplots, with mean values <0.40 mS/cm; all macroplots were considered non-saline. There seemed to be a trend for vegetated samples to have higher conductivity readings than barren samples (Figure C12b), indicating greater salinity in soils under vegetation and suggesting that vegetation has an influence on soil hydrology.

a)



b)

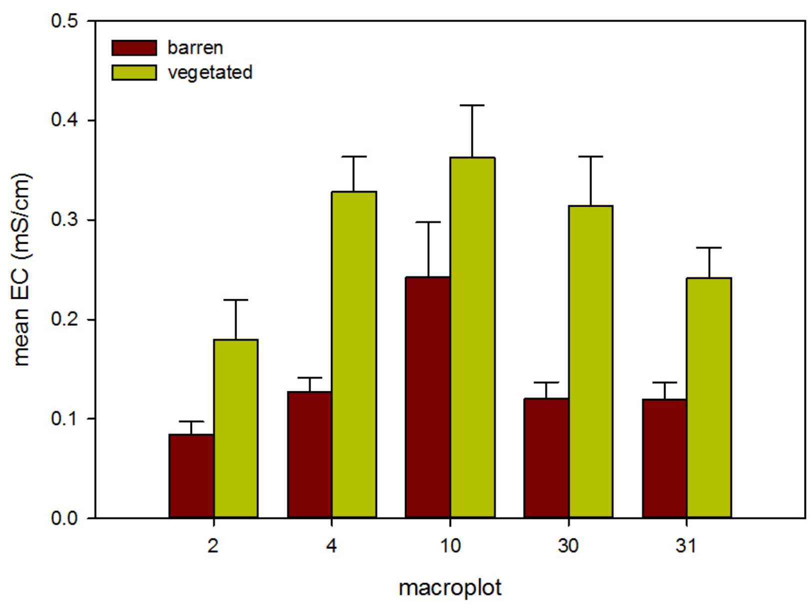


Figure C12. Mean (+SE) values for a) pH and b) electrical conductivity (EC) by macroplot. Macroplot 10 data are from 11 soil sampling points because one sampling point landed on a boulder.

Qualitative soil parameters are shown in Table C4 for barren and vegetated soil samples for each macroplot. For most of the soil parameters, the macroplots were fairly similar and the range of values detected overlapped across macroplots. For example, most macroplots had little to no soil carbonates, but samples on some macroplots ranged from noneffervescent (no carbonates) to slightly effervescent, indicating the presence of carbonates. One exception was rupture resistance, which varied from very loose soils where an intact sample could not be obtained to moderately hard soils where moderate force was required to break the sample.

Table C4. Dominant qualitative soil characteristics for five monitored macroplots in 2012. Range of responses are in parentheses.

Macroplot #	Soil From	Carbonates**	Soil Color	Rupture Resistance***	Stickiness****	Plasticity*****	Texture
2	Barren	NE	Brown (brown-yellowish brown)	L/EW (L/EW-S)	SO	PO	Gravelly sand (gravelly sand-very gravelly loamy sand)
	Vegetated	NE	Brown (brown-yellowish brown)	S/VW (EW-SH)	SO	PO	Gravelly sand (sand-gravelly loamy sand)
4	Barren	NE	Brown (brown-yellowish brown)	L (L-S)	SO	PO	Gravelly sand (sand-gravelly loamy sand)
	Vegetated	NE	Brown (brown- dark yellowish brown)	S (EW-SH)	SO	PO	Loamy sand (sand-gravelly loamy sand)
10*	Barren	NE (NE-SL)	Brown (brown-yellowish brown)	S/VW, SH/W (S/VW-M)	SO (SO-SS)	PO (PO-SP)	Very gravelly loamy sand (Very-extremely gravelly loamy sand)
	Vegetated	NE (NE-SL)	Brown (brown-yellowish brown)	S	SO	PO	Very gravelly loamy sand (very gravelly loamy sand-very gravelly sandy loam)
30	Barren	NE	Brown (brown-yellowish brown)	S/VW (L-S/VW)	SO	PO	Sand (sand-loamy sand)
	Vegetated	NE (NE-VS)	Brown (brown-yellowish brown)	S (S-SH)	SO	PO	Loamy sand (sand-gravelly loamy sand)

Table C4. Dominant qualitative soil characteristics for five monitored macroplots in 2012. Range of responses are in parentheses (continued).

Macroplot #	Soil From	Carbonates**	Soil Color	Rupture Resistance***	Stickiness****	Plasticity*****	Texture
31	Barren	NE (NE-VS)	Yellowish brown (brown-yellowish brown)	S (L/EW-S)	SO	PO	Gravelly sand (sand-gravelly loamy sand)
	Vegetated	NE	Yellowish brown (brown-yellowish brown)	S/VW (EW-SH)	SO	PO	Gravelly loamy sand (sand-gravelly loamy sand)

*Macroplot 10 data are based on 11 soil sampling points because one sampling point landed on a boulder.

**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=soft/very weak, SH/W=slightly hard/weak, MH/M=moderately hard/moderate.

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

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

Joshua Trees Estimates

Although all five macroplots are within what is considered the Joshua tree wooded alliance community, Joshua trees were not recorded on any macroplot, except through the macroplot overview and transect photographs (Appendix D). Although the density of Joshua trees was moderate (2-5 trees per 1000 m^2; Table C5), they were not captured using the current field procedures. Data from the four macroplots in the Joshua tree community at Mojave National Preserve, where there was a higher density of Joshua trees, also supports the finding that the current field procedures will not adequately measure the Joshua tree population.

Table C5. Joshua tree (*Yucca brevifolia* var. *brevifolia*) count within established macroplots.

Macroplot #	# Alive	# Dead	# Fallen Dead	Total
2	20	3	0	23
4	38	6	0	44
10	36	1	0	37
30	41	12	0	53
31	5	2	46	53

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. Joshua trees were documented on each macroplot.

Figure D1. Macroplot overview photo for macroplot 2.

Figure D2. Macroplot overview photo for macroplot 4.

Figure D3. Macroplot overview photo for macroplot 10.

Figure D4. Macroplot overview photo for macroplot 30.

Figure D5. Macroplot overview photo for macroplot 31.

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