National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

A Summary of the Joshua Tree National Park Vegetation Mapping Project

NPS Vegetation Inventory Program

Natural Resource Technical Report NPS/JOTR/NRTR—2013/723

ON THE COVER
Joshua Tree — California Juniper / Nevada Ephedra (*Yucca brevifolia — Juniperus californica / Ephedra nevadensis)* Woodland Association during a spring bloom in Upper Covington Flats of the Little San Bernardino Mountains (northwestern Joshua Tree National Park). The yellow annual groundcover is *Linanthus aureus* ssp. *aureus*; the photo was taken in May of 2008.
Photograph by: Tasha La Doux

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Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the Mojave Desert Inventory and Monitoring Network website (http://science.nature.nps.gov/im/units/mojn/rpts_pubs/rpts_pubs_main.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

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Executive Summary

The U.S. Geological Survey (USGS) and the National Park Service (NPS) Vegetation Characterization Program initiated a project at Joshua Tree National Park (JOTR or Park) in 1996 to classify, describe, and map the vegetation communities of the Park. The project, including the final map, classification, and report, was completed in 2012. Initial mapping, photo-interpretation, and field work was conducted between 1996 and 2005. Final reports for these efforts were generated by 2005, including a map, ecological descriptions, classification, key, and photo-interpretation guide. Following this, a total of 1,313 accuracy assessments were conducted in 2007 and 2008, the results of which spurred additional field relevés and a reworking of the map and classification. An additional 111 relevés were conducted in 2009 targeting problematic associations and alliances; these data were used in conducting additional analyses to produce a revised vegetation map and classification. Photo-interpretation was also redone during this time for a subset of the problematic associations and the classification was updated to match the most recent vegetation classification presented in the Manual of California Vegetation Second Edition (Sawyer et al. 2009). Between 2010 and 2011 data analysis was completed and incorporated into the final map and classification. By February 2012 the ecological descriptions were updated and completed to match (as best as possible) the most recent version of the U.S. National Vegetation Classification and the map was updated to reflect the final nomenclature.

The 2012 version of the vegetation classification for the Park includes 51 Alliances (including Provisional Alliances, Semi-Natural Stands, and Special Stands) and 78 Associations (including Provisional Associations). There are eight map classes that have less than 2% absolute vegetation cover, these include Disturbed/Built-Up, Water, Dunes, Playas, Recent Burns, Rock Outcrops, Desert Pavement, and a generic Non-vegetated Habitat type. The largest amount of land cover is classified under the *Larrea tridentata — Ambrosia dumosa* Shrubland Alliance, which is classified into seven Associations. This Alliance covers a total of 1,130 km^2, representing 35% of the total area within JOTR (3,208 km^2). On the other hand, there are eight Alliances, mostly associated with riparian habitats, which have less than 1 km^2 mapped, these include: *Washingtonia filifera* Woodland Alliance, *Salix gooddingii* Woodland Alliance, *Prosopis glandulosa* Woodland Alliance, *Populus fremontii* Forest Alliance, *Justicia californica* Provisional Shrubland Alliance, *Ericameria nauseosa* Shrubland Alliance, *Cylindropuntia bigelovii* Shrubland Alliance, and *Ambrosia salsola* Shrubland Alliance.

Overall map class accuracies for the JOTR map are 41.0% at the U.S. National Vegetation Classification association level, 61.0% at the alliance level, 82.0% at the group level, 87.3% at the macrogroup level, 92.5% at the formation level, and 92.9% at the class level.

The goals of this report are three-fold: 1) to summarize the events and products that resulted from the 16-year effort; 2) to describe and present the results of the accuracy assessment phase of the project; and 3) to present the final vegetation classification, ecological descriptions, and a geospatial vegetation classification map of the Park.

Final products resulting from the JOTR vegetation mapping project are listed below. Most of these are available online: http://www.usgs.gov/core_science_systems/csas/vip/products.html .

Available as separate PDFs through the NPS Data Store (https://irma.nps.gov/) or on CD upon request to the MOJN Data Manager:

- Appendix A: ***Vegetation Descriptions for Joshua Tree National Park****. Submitted by J. Evens, D. Roach-McIntosh, and D. Stout of the California Native Plant Society in January 2012.* This is the final report of vegetation descriptions for all vegetation types included in the classification.
- Appendix B: ***Vegetation Classification of Joshua Tree National Park****. Submitted by J. Evens, D. Roach-McIntosh, and D. Stout of the California Native Plant Society in January 2012.* This is a hierarchical list of the final vegetation classification for JOTR.
- Appendix C: ***Key to Vegetation of Joshua Tree National Park, California****. Written by T. Keeler-Wolf and T. La Doux.* This is a dichotomous key to be used for field identification of the vegetation types found in JOTR.
- Appendix D: ***Map and Classification Crosswalk, 2005 to 2012****. Prepared by T. La Doux, E. Babich, and M. Harding in July 2011.* This spreadsheet shows the relationship of the 2005 mapped polygons and classification to the final 2012 mapped polygons and classification.
- Appendix E: ***Vegetation Classification of Joshua Tree National Park, Riverside and San Bernardino Counties, California****. Submitted by Todd Keeler-Wolf, Sau San, and Diana Hickman of the California Department of Fish and Game (CDFG) in March of 2005*. This report describes the field and classification efforts by CDFG, including the 2005 version of the vegetation classification for JOTR, ecological descriptions for all vegetation types, and a field key.
- Appendix F: ***Photo-Interpretation Report, USGS-NPS Vegetation and Inventory and Mapping Program, Joshua Tree National Park****. Submitted by Aerial Information Systems, Inc. in December 2004.* This report describes the mapping and photo-interpretation effort (including protocols for data conversion and quality control) conducted by AIS in preparation of the 2005 version of the vegetation map.
- Appendix G: ***USGS-NPS Vegetation Mapping Program, Joshua Tree National Park Mapping Classification****. Submitted by Aerial Information Systems, Inc. in November 2004.* This report includes photos for many of the Alliances, as well as brief descriptions of the Associations or Mapping Units included in the 2005 version of the vegetation map.
- Appendix H: ***Sample and Population Contingency Tables,*** completed by Chris Lea in July 2012. The twelve tables display producer's and user's accuracies at multiple levels: Association, Alliance, Group, Macrogroup, Formation, and Class.
- **Appendix I**: Field forms and related materials.

Retained elsewhere:

- Geodatabase of vegetation map, titled "JOTR_2012_Veg_Classification.gdb". There are four feature classes included within this geodatabase, their titles are as follows:

JOTR_2012_Veg_Classification_Documentation, JOTR_2012_Veg_Classification, JOTR_2005_Veg_Classification, and JOTR_2012_Veg_Classification_ParkSpecials. Geospatial products are in Universal Transverse Mercator (UTM) projection, Zone 11, using the North American datum of 1983.

- All vegetation plot data collected between 1996-2009, including AA plot data and RA plot data with georeferenced photos. Excel and Access databases of plot data are available on the Park sharedrive.
- Original datasheets and field notebooks from the 2007-2009 field efforts are available in the Park archive.

Acknowledgments

The authors would like to thank the efforts of all individuals involved in the process of completing this project. Many skilled individuals from a variety of organizations and agencies came together to execute this project over the course of 16 years. In particular, we would like to thank Aerial Information Systems (AIS) and Todd Keeler-Wolf for their persistence in helping us refine and update the map and classification, even after they were no longer being paid. In addition, we thank Julie Evens (and others) at CNPS for completing the final version of the classification.

In an attempt to acknowledge all that are deserving of recognition, listed below are names of individuals and their respective role(s) in the project. Because the authors of this report were not involved in the beginning phases of the project there are likely many individuals who contributed in some way that are not acknowledged here. We apologize for any gaps or unintentional omissions.

AIS, Inc.

Debbie Johnson, General Manager – Developed work plan and provided overall project management and supervision of the grad sect analysis, vegetation plot sample collection for classification analysis, and map and GIS database development.

Denise Cline, Technical Project Manager – Provided project oversight, quality control, photo interpretation, and geo-referencing the final product.

John Menke, Lead Photo Interpreter – Provided field ecology and photo interpretation expertise, training, and final quality control of the vegetation map and GIS database.

Ed Reyes, Senior Photo Interpreter – Provided photo interpretation expertise, performed final quality control of the vegetation map and GIS database.

Ben Johnson, Senior GIS Analyst – Provided GIS modeling and analysis.

Kumi Rattenbury, Lead Field Ecologist and Photo Interpreter – Provided field coordination and plot sample collection in support of the vegetation classification development and photo interpretation of vegetation units.

Rene Vargo, Field Ecologist and Photo Interpreter – Provided plot sample collection and photo interpretation of vegetation units.

Marcie Young, Field Ecologist and Photo Interpreter – Provided plot sample collection and photo interpretation of vegetation units.

Valerie Cribbs, Photo Interpreter – Provided photo interpretation of vegetation units.

National Park Service

Chris Lea, Botanist, National Park Service Vegetation Inventory – Conducted sampling design and analysis of thematic accuracy assessment and trained park staff in reference (field) data collection methods for thematic accuracy assessment.

Karl Brown, NPS I&M – Provided oversight and funding for project.

Mike Story, USGS/NPS – Project initiation and securing of funds.

Jesse D'Elia – Provided GIS modeling and analysis and photo interpretation of vegetation units.

Gillian Bowser – Project manager before 2003.

Kathie Meyer – Assisted with field data collection.

Hank McCutchen, Resource Division Chief – Assisted in procurement of funding to complete the mapping effort.
Paul DePrey, Resource Division Chief – Project oversight and administration.
Andrea Compton, Resource Division Chief – Project oversight and administration.
Jane Rodgers, Vegetation Branch Manager – Project management (1996 - 2003) for initial phases of classification, mapping, and fieldwork.
Tasha La Doux, Botanist – Project funding and management (2005 – 2012) through completion of final report, including accuracy assessments, field relevés, training field technicians, data analysis, GIS assistance, and rewriting of the final classification and key.
Jeanne Taylor, Vegetation Mapping Coordinator, Mojave Desert I&M Network – Assisted with project management and funding.
Alice Miller, Vegetation Branch Manager – Assisted with fieldwork and data entry.
Josh Hoines, Vegetation Branch Manager – Project oversight and administration.
Erin Babich, Botany Tech. – Lead technician on accuracy assessment and data analysis. Assisted with data collection/management, training of field technicians, and completing the final report.
Mitzi Harding, Botany Tech. – Assisted with completing final report.
Jason Van Warmerdam, Biol. Sci. Tech. – Assisted with fieldwork and data entry.
Michael Bell, Biol. Sci. Tech. – Assisted with fieldwork and data entry.
Amber Holt Biol. Sci. Tech. – Assisted with fieldwork and data entry.
Kathryn Matthews, Biol. Sci. Tech. – Assisted with fieldwork and data entry.
Jane Cipra, Biol. Sci. Tech. – Assisted with fieldwork and data entry.
Jesse D'Elia, Biol. Sci. Tech. – Assisted with field work and GIS modeling.
April Johnson, NPS volunteer – Assisted with fieldwork.
Mark Wheeler, NPS volunteer – Assisted with fieldwork.
Colleen Ely, NPS volunteer – Assisted with fieldwork.
Bill Truesdell, NPS volunteer – Assisted with fieldwork.
Kathleen White, NPS volunteer – Assisted with fieldwork.
Sean P. Murphy, GIS specialist – Provided GIS modeling and analysis for the accuracy assessments, as well asassisted with finalizing the map.

CDFG and CNPS
Todd Keeler-Wolf, CDFG Senior Vegetation Ecologist – Collected and synthesized ecological plot data, produced 2005 version of vegetation classification and field key, and assisted in final analysis and production of final classification and vegetation descriptions.
Diana Hickson, CDFG Vegetation Ecologist – Assisted in development of 2005 vegetation classification, developed crosswalks, and quality checked 2005 final report.
Sau San, CNPS – Assisted in development of 2005 vegetation descriptions.
Julie Evens, Vegetation Program Director, CNPS – Conducted final data analyses and produced final classification and vegetation descriptions.
Deborah Stout, Assistant Vegetation Ecologist, CNPS – Assisted with final classification and vegetation descriptions.
Kendra Sikes, Vegetation Ecologist, CNPS – Assisted with final classification and vegetation descriptions.
Danielle Roach-McIntosh, Vegetation Team Leader, CNPS – Assisted with final classification and vegetation descriptions.

List of Abbreviations and Acronyms

AA	Accuracy Assessment
AIS	Aerial Information Systems, Inc.
CDFG	California Department of Fish and Game
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System(s)
GPS	Global Positioning System
JOTR	Joshua Tree National Park
NPSVIP	National Park Service Vegetation Inventory Program
MMU	Minimum Mapping Unit
NAD	North American Datum
NBS	National Biological Service
NPS	U.S. National Park Service
USNVC	U.S. National Vegetation Classification
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

List of Relevant Links

http://www.usgs.gov/	United States Geologic Survey
http://www.usgs.gov/core_science_systems/csas/vip	USGS-NPS Veg. Mapping Program
http://www.nps.gov/jotr	Joshua Tree National Park
http://www.aisgis.com/	Aerial Information Systems, Inc.
http://www.dfg.ca.gov/	Cal. Dept. of Fish and Game
http://www.natureserve.org/	NatureServe
http://science.nature.nps.gov/im/	NPS Inventory & Monitoring Prog.
http://www.wrcc.dri.edu/index.html	Western Regional Climate Center

1.0 Introduction

1.1 Overview of Joshua Tree National Park

The nearly 800,000 acres known as Joshua Tree National Park (JOTR or Park) is located in southern California, within portions of Riverside and San Bernardino counties (Figure 1). JOTR was declared a U.S. National Park in the California Desert Protection Act of 1994, but had previously been a U.S. National Monument since 1936. Almost three-quarters of the park (593,490 acres) is designated as Federal Wilderness, making much of the park only accessible by foot (Figure 2).

Figure 1. Location of Joshua Tree National Park in southern California.

The Park includes portions of two deserts; the Colorado Desert is restricted to regions of the south and east below 3,000 feet, whereas the higher, moister, and slightly cooler Mojave Desert lies in the western and northern regions of the Park. Aquatic or riparian habitats (e.g., springs, oases, and ephemeral stream corridors) represent a very small, but ecologically important, portion of total land cover in JOTR (Chung-MacCoubrey et al. 2008). And while there are several isolated mountain ranges that serve as "sky islands" throughout JOTR, the Little San Bernardino Mountains on the west end of the Park are unique in that they provide a geographic link to the Transverse and Peninsular ranges of the chaparral habitats of southern California (Figure 2). It is the confluence of these three bioregions, mojavean desert, coloradan desert, and cismontane chaparral, which provides for the rich and diverse flora found in JOTR.

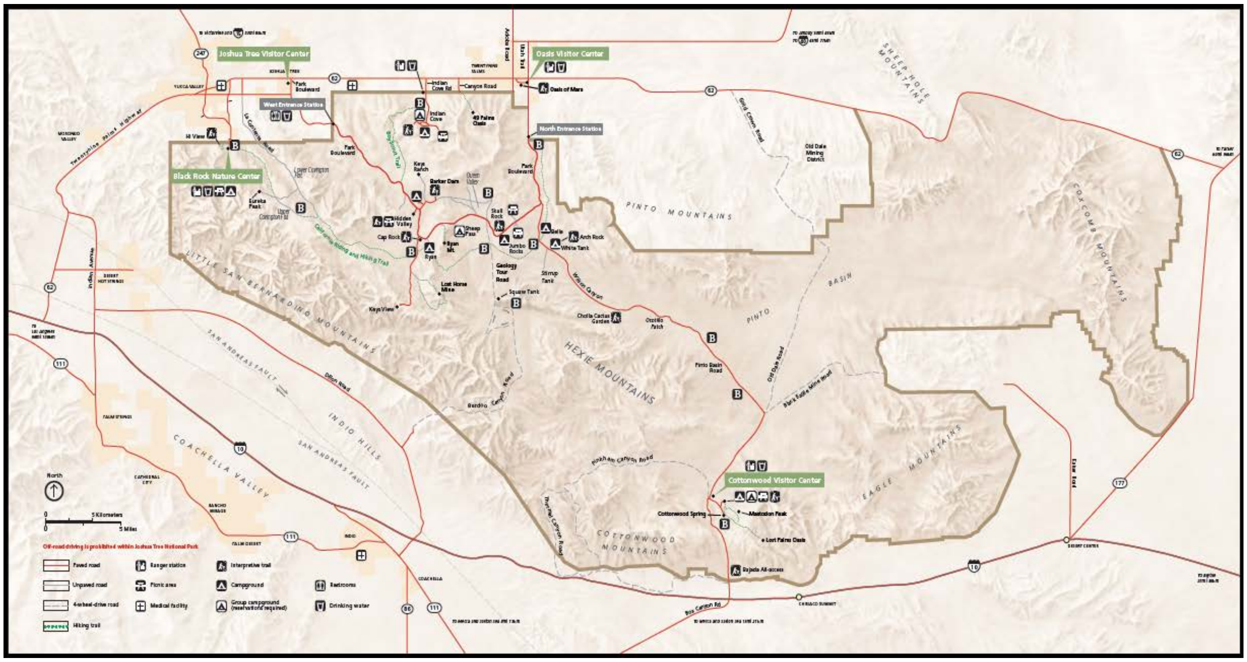

Figure 2. Topographic map of Joshua Tree National Park showing the isolated mountain ranges in the south and east, as well as the Little San Bernardino Mountains to the west (obtained from Joshua Tree National Park Website http://www.nps.gov/jotr). Notice the lack of roads throughout much of the Park.

Nearly 730 vascular plant taxa have been documented and vouchered in the park. The floristic richness of this area is greatly enhanced by the high percentage of annual species, which represent approximately 50% of the flora (La Doux in press). Another important aspect contributing to the floristic diversity are the many species that flower during the summer or fall seasons. For example, 5% of the flora consists of obligate summer annuals, species that only respond to summer rains. In addition, JOTR is host to over 40 rare species protected by the park, two of which are federally listed (*Astragalus tricarinatus* and *Erigeron parishii*). One of the rare plant taxa, *Tetracoccus hallii*, is considered a dominant cover in a restricted area of the park, at the northwest end of the Eagle Mountains. Stands of this species generally occur on colluvial slopes with *Yucca schidigera, Simmondsia chinensis, Nolina bigelovii*, and *Ephedra nevadensis*. Hall's Tetracoccus (*Tetracoccus hallii*) Provisional Shrubland Alliance is known to occur in San Bernardino, Riverside, and Imperial counties of California, as well as in Arizona and Baja California, Mexico.

As is the case for the entire desert bioregion of California, the Park represents a fairly pristine landscape with only 50 non-native plant species (not including ornamentals isolated to park facilities) representing ~7% of the flora. A number of these are considered invasive species, for example Sahara Mustard (*Brassica tournefortii),* Fountain Grass (*Pennisetum setaceum),* and Russian Thistle (*Salsola tragus*) (Cal-IPC 2006). In some cases the non-native species are so prevalent in the ecosystem they have become the dominant cover and are recognized as distinctive vegetation types in California, two examples include: *Bromus rubens* — *Schismus* (*arabicus, barbatus*) Semi-Natural Herbaceous Stands and *Tamarix* spp. Semi-natural Shrubland Stands, both of which have been observed in JOTR (Sawyer et al. 2009). All *Tamarix spp*. stands are being monitored and treated by the Invasive Species Program at the Park; current status of these stands can be obtained from park staff.

Though the Park is probably most famous for its namesake, the Joshua Tree (*Yucca brevifolia*), the rock formations found in the Wonderland of Rocks region of the Little San Bernardino Mountains has made JOTR a world-famous rock climbing destination. These unique monzogranitic outcrops, called plutonic intrusions, were formed under the surface of the earth as a result of magma formed during the Mesozoic Era, 245 to 60 million years ago (Schoenherr 1992). Compressional and extensional tectonic activity along fault lines, volcanic activity, and continuous erosional and depositional forces have contributed to the interesting geologic features of the desert region. JOTR is located in the southwestern edge of the Basin and Range Province, which explains the characteristic landscape of uplifted mountain ranges ("sky-islands") consisting primarily of thick Paleozoic Mesozoic rock, separated by broad alluvium filled valleys or basins (Schoenherr 1992, USGS - NPS 2000). Basins consist of piedmont slopes, regions of active erosion and deposition, or basin floors characterized by slow run-off and an accumulation of soluble salts (Chung-MacCoubrey et al. 2008). JOTR ranges in elevation from approximately 500 feet along the southeast boundary of the Coxcomb Mountains, to the summit of Quail Mountain in the Little San Bernardino Mountains at 5,813 feet.

The Park receives precipitation biannually. Both summer and winter precipitation events are highly variable from year to year, but the region exhibits a southeastward gradient of increasing temperature, decreasing average elevation, and decreasing precipitation. Summer rains generally occur from July to September, are often characterized by heavy but isolated thunderstorms, and may contribute upwards of 50% of the average annual rainfall (Figure 3). These monsoonal events are created by sub-tropical moisture originating in the Gulf of Mexico that spreads west and is most noticeable in the southern and eastern portions of the Park where the average annual rainfall is approximately 3.5 inches per year (Eagle Mtn station = 3.65 in. based on records from 1933-2012). While the Little San Bernardino Mountains consistently receive summer rains, the winter rains tend to be more reliable and contribute a greater proportion of the annual rainfall. Winter rains are caused by moist air masses originating in the Pacific Ocean that travel eastward. Although most of the rain is dropped on the west side of the Transverse Mountain ranges, a portion of it reaches the leeward side of the San Bernardino Mountains and provides reliable precipitation in the Little San Bernardino Mountains (Chung-MacCoubrey et al. 2008). Depending on elevation (~3,000 – 5,800 feet), the annual rainfall in these western and northern regions of the park can range from 5 to 12.5 inches, some of which falls as snow during the winter months. These averages are based on annual average precipitation for the following Western Regional Climate Center (WRCC) weather stations: Joshua Tree station = 4.68 inches at 2,760 feet; Lost Horse Valley station = 6.4 inches at 4,200 feet; and Black Rock station = 12.5 inches at 4,080 feet (available at: http://www.wrcc.dri.edu/index.html).

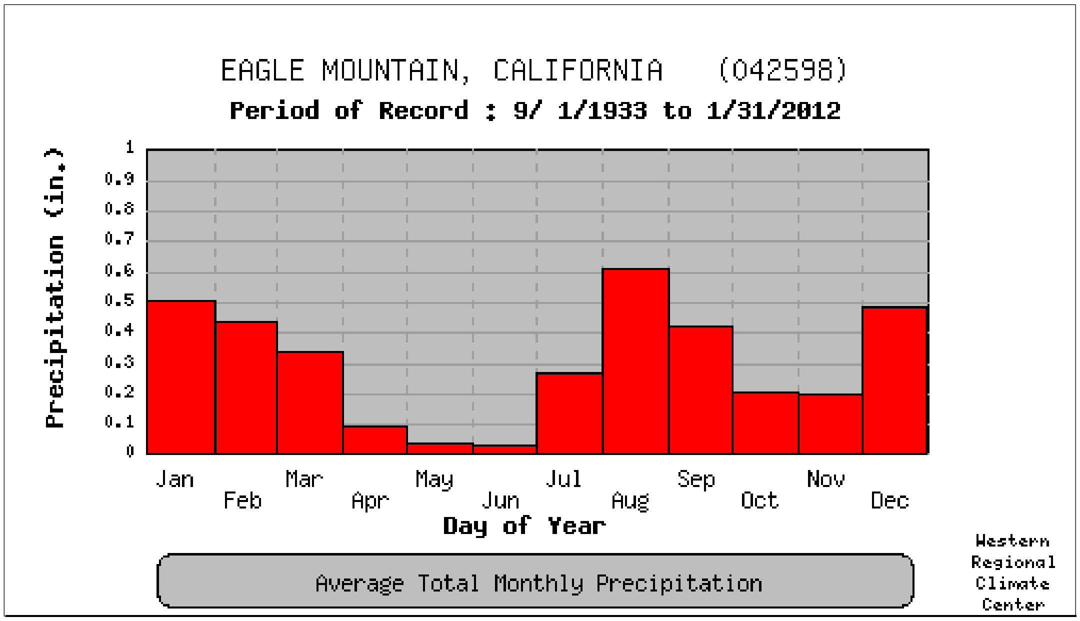

Figure 3. Precipitation data for Eagle Mountain, CA, WRCC weather station (elev. 970 feet) located in the southeastern portion of JOTR. Data are for 1933 through 2012 and nicely demonstrate the bimodal precipitation pattern in this region.

1.2 NPS Vegetation Inventory Program

In 1994, the National Park Service (NPS) initiated a partnership with the U.S. Geological Survey (USGS) Biological Resources Division to classify, describe, and map vegetation communities in more than 250 National Park units across the United States. This landmark program is both the first to provide national-scale descriptions of vegetation for a federal agency and the first to create national vegetation standards for its data products. Later, the program was split into two separately administered and funded programs, though they remain integral to one another and are still considered a collaborative effort. The two programs are now known as the USGS Vegetation Characterization Program and the NPS Vegetation Inventory Program (NPSVIP). The goals of these programs are to provide baseline ecological data for park resource managers, obtain data that can be examined in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities (Grossman et al. 1998, Federal Geographic Data Committee 2008, Lea 2011). To learn more about these programs, visit the websites: (http://science.nature.nps.gov/im/inventory/veg/index.cfm) or (http://www.usgs.gov/core_science_systems/csas/vip/index.html).

Program scientists and partners have developed data collection procedures for classification, mapping, thematic accuracy assessment, and use of existing data (The Nature Conservancy and Environmental Systems Research Institute 1994, Lea and Curtis 2010, Lea 2011). Program products meet Federal Geographic Data Committee (FGDC) standards for vegetation classification and metadata, and national standards for spatial accuracy and data transfer (FGDC 2008).

Each park developing a vegetation map follows a standardized methodology for sampling field data (The Nature Conservancy and Environmental Systems Research Institute 1994) and vegetation classification (Lea 2011). This information is used by photointerpreters to delineate polygons of vegetation communities, which are then subjected to a thematic accuracy assessment process (Lea and Curtis 2010). The final products consist of a vegetation map, descriptions of each vegetation type, a key to each type, and all related data and metadata files (original field forms, plot database, accuracy assessment points, etc.).

1.3 Joshua Tree National Park Vegetation Mapping Project

The purpose for developing vegetation classifications and maps for the National Park Service units is to provide baseline data for park managers. These products can be used to help managers with many aspects of resource management, for example, to build predictive models for rare plant and animal habitat, to track landscape-level changes in vegetation, and to model the spread of wildfires and invasive species. The JOTR classification and mapping project was initiated in 1996 as one of several pilot studies for the newly formed NPS Vegetation Mapping Program; it was the first desert park to initiate a mapping project. Informative summaries and timelines of the initial phases (1996-2005) are provided in the two final reports submitted to JOTR in 2005 (Appendices E and F). Specifically, the title of these reports are: 1) the "Photo-Interpretation Report, USGS-NPS Vegetation and Inventory and Mapping Program, Joshua Tree National Park" submitted by Aerial Information Systems, Inc. (AIS) in December 2004, and 2) "Vegetation Classification of Joshua Tree National Park, Riverside and San Bernardino Counties, California" submitted by Todd Keeler-Wolf, Sau San, and Diana Hickman of the California Department of Fish and Game (CDFG) in March of 2005. In these reports you can find details of the earlier stages of this project, including information on pre-existing datasets used in the analysis, timelines of events, and protocols used for data collection/analysis. This report will not attempt to summarize what is already available in those reports.

The following products were a result of the initial mapping effort (ending in 2005) and accompany this report as Appendices.

- Appendix E: *Vegetation Classification of Joshua Tree National Park, Riverside and San Bernardino Counties, California. Submitted by Todd Keeler-Wolf, Sau San, and Diana Hickman of the California Department of Fish and Game (CDFG) in March of 2005*. This report describes the field and classification efforts by CDFG, including the 2005 version of the vegetation classification for JOTR, ecological descriptions for all vegetation types, and a field key.
- Appendix F: *Photo-Interpretation Report, USGS-NPS Vegetation and Inventory and Mapping Program, Joshua Tree National Park. Submitted by Aerial Information Systems, Inc. in December 2004.* This report describes the mapping and photo-interpretation effort (including protocols for data conversion and quality control) conducted by AIS in preparation of the 2005 version of the vegetation map.
- Appendix G: *USGS-NPS Vegetation Mapping Program, Joshua Tree National Park Mapping Classification. Submitted by Aerial Information Systems, Inc. in November 2004.* This report includes photos for many of the Alliances, as well as brief descriptions of the Associations or Mapping Units included in the 2005 version of the vegetation map.

Ideally, the mapping, classification, ground truthing, and accuracy assessment can all be completed within a concise time frame by a core set of individuals and, perhaps more importantly, with continuous funding to support the completion of the project. Unfortunately, this was not the case for the JOTR effort, which suffered from a lack of funding and a high turnover rate of Park staff. The lack of funding contributed to meager field efforts for the collection of vegetation plot data for initial analysis, as well as in ground-truthing the map and classification. In an effort to make-up for this lack of data, the Accuracy Assessment protocol was modified in 2006 to include more vegetation data for each plot. The additional vegetation data were utilized during the final stages of this project to target problematic vegetation types and refine the classification. Preferably, these final stages of fieldwork would have been done in conjunction with the final stages of producing the map and classification, such that feedback from the Park could have been incorporated into the final products submitted in 2005. However, it wasn't until 2006 that funding was secured for the Accuracy Assessment phase of the project, long after all funding had ended to support the vegetation ecologists at CDFG and photo-interpreters at AIS.

The field component of the Accuracy Assessment (AA) phase of the project was completed in 2008 after two seasons of data collection. In addition, one season of targeted Rapid Assessments (see Appendix I for the protocol and field form) were completed in 2009 to assist in refining 14 problematic vegetation types. By July 2009 all fieldwork was completed and incorporated into the data analysis. Based on these results, the map and classification were updated accordingly, including re-working of the map by photo-interpreters at AIS, and then finalization of the classification and descriptions by CDFG and CNPS. The final stages of completing the classification involved incorporating the most recent (or most appropriate) nomenclature published by Sawyer et al. (2009), USNVC (http://usnvc.org/explore-classification/), NatureServe Explorer (http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol), or in some cases the Vegetation Classification utilized by NatureServe for Grand Canyon National Park (unpublished data, but will be available at http://www.usgs.gov/core_science_systems/csas/vip/products.html).

The following products represent the final Vegetation Classification for JOTR and can be found accompanying this report as Appendices.

- Appendix A: ***Vegetation Descriptions for Joshua Tree National Park****. Submitted by J. Evens, D. Roach-McIntosh, and D. Stout of the California Native Plant Society in January 2012.* This is the final report of vegetation descriptions for all vegetation types included in the classification.
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2.0 Methods

2.1 Timeline

The goals of this report are to present the efforts of the Vegetation Classification project after 2005 as well as provide a summary of the earlier work between 1996-2005. The following timeline depicts major activities for the duration of the project, whereas the remainder of the Methods section will focus on the activities post-2005. Specifically, we will discuss the Accuracy Assessment phase, the additional Rapid Assessment plots completed in 2009, then provide an overview of the reworking of the classification and map that resulted from these efforts.

1996—Initial meeting for project planning and park tour. AIS field reconnaissance trip for Malapai Hill area. Vegetation sampling by Joe Watts and U.S. Army Corps of Engineers (108 plots).

1997—Mapping of pilot area (Malapai Hill quadrangle). Field data collection by Brent Long and his crew from Joshua Tree National Park using large relevés (74 plots).

1998—New color infrared (CIR) aerial photographs acquired (June–November) and vegetation field sampling by Mojave Desert Ecosystem Initiative crews (74 plots).

1999—Review and evaluation of park vegetation classification. Preliminary photo-interpretation performed to aid field sampling.

2000—AIS conducts vegetation field sampling (300 plots) using gradient directed sample stratification.

2001—Vegetation classification for JOTR developed. Aerial photo-interpretation initiated.

2002—Vegetation photo-interpretation completed.

2003—Data automation and rectification commences.

2004—Final vegetation coverage and photo-interpretation report completed by AIS.

2005—Final vegetation classification report completed by CDFG.

2006—Funding secured for Accuracy Assessment phase of project.

2007—Accuracy assessment phase initiated, training of field crew and creation of random sampling points provided. A total of 662 accuracy assessment points completed.

2008—Accuracy assessments continue with 651 additional points completed, for a total of 1,313 points. Initial accuracy assessment analysis and contingency table completed by Chris Lea (NPS). Meeting is held at JOTR headquarters in September 2008 (including AIS, CDFG, and NPS staff) to discuss the results and future needs.

2009—111 Rapid assessment plots executed in problematic vegetation associations to complement accuracy assessment data. Small amount of funding is secured to hire CDFG to incorporate new data into analysis and make recommendations for updating the classification and map. Meeting is held in August 2009 (including AIS, CDFG, and JOTR staff) to review data and make decisions on updating the classification and map.

2010—AIS is contracted to rework the map according to the decisions made at the August 2009 meeting.

2011—CNPS is contracted to provide a final Classification and Descriptions report utilizing the most recent nomenclature from USNVC and NatureServe.

2012—Accuracy assessment analysis and contingency table are redone using more recent methodologies and corrected AA data. Geodatabase of vegetation map is created and finalized by JOTR staff. Final report and data products are completed and published.

2.2 Overview and Purpose of Thematic Accuracy Assessment

Thematic accuracy assessment (AA) for a vegetation map is a test of how well the map represents vegetation on the ground. The AA methodology for JOTR and terminology for this report generally follow Lea and Curtis (2010), which provides more detailed information on sampling design and data analysis within the National Park Service Vegetation Inventory Program. Congalton and Green (2009) and Czaplewski (2003) also provide informative discussions on methodology for calculating various accuracy statistics.

Assessments can be made for each mapped class (individual class accuracy) and/or for the entire map (i.e., all individual classes combined, or overall accuracy). Accuracy is represented by the rate of matches between the map class label and the vegetation type recorded by an observer in the field, using observation plots of a specified size. In practice, a specified number of observation plots are randomly selected within each map class using a Geographic Information System (GIS). Each of these plots is labeled with the geographic location and the corresponding map class, these are referred to as the “sample data label.” Field observers are provided with the locations and size of area to observe (the observation plot), but to avoid influencing the field classification, observers do not know the map class label of the observation plot. The observers navigate to each observation plot and decide which vegetation type best fits the assigned observation location, using a field key of all known vegetation types for the project area. The best choice made from the field key is recorded for each plot, referred to as the “reference data label”, for that observation. Since vegetation attributes can be more easily and accurately observed on the ground than from a remotely sensed perspective, the reference data labels are assumed to be the most accurately classified label for the location (in practice, the field classifications are rarely 100% accurate), and the sample data label must match the reference data label in order for an observation to be considered correctly mapped. Figure 4 shows the location of accuracy assessment points collected in 2007-2008.

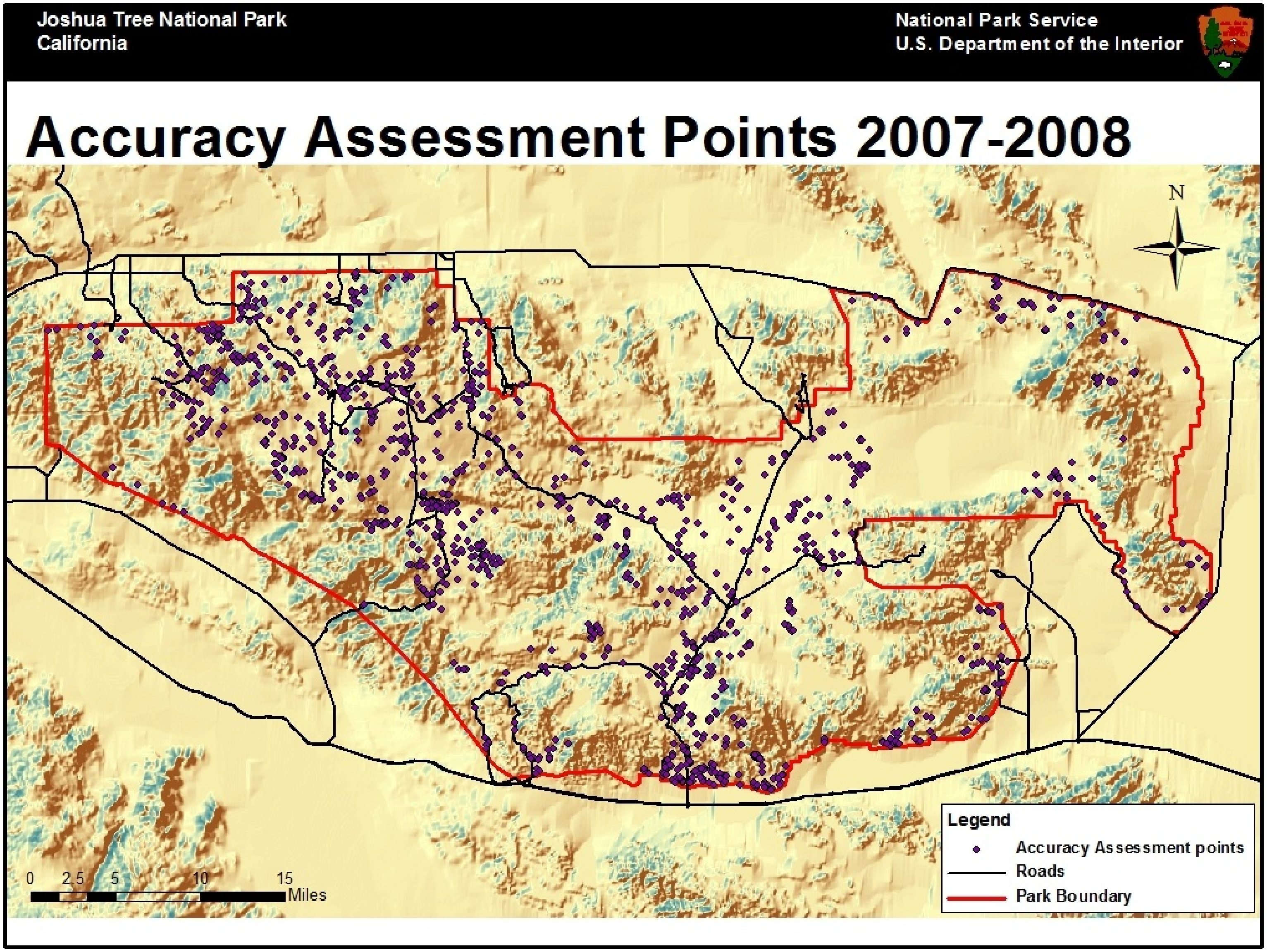

Figure 4. Locations of accuracy assessment points collected in 2007-2008.

Ideally, each sample data (map) class corresponds to a single reference data (vegetation) class in a one-to-one relationship, but, because some vegetation types can be identified with relative ease on the ground, but not from a remote sensing perspective, some sample data classes have a one-to-many relationship with vegetation classes. More rarely, sample data classes may have a many-to-one relationship with the reference data classes. In order to assign sample and reference data labels unambiguously, all map class to vegetation class relationships must be conceptually and spatially non-overlapping for a given level of thematic resolution. Sample and reference data both may be relabeled at coarser levels of thematic resolution to assess accuracy at those levels. For example, observations with a sample data label of *Yucca brevifolia – Juniperus californica* / *Ephedra nevadensis* Association are matches with reference data labels of *Yucca brevifolia* / *Coleogyne ramosissima* Association when accuracy is assessed at the Alliance level because both associations are members of the *Yucca brevifolia* Woodland Alliance, but they would not be matches at the Association level.

The rate of matches between the sample data and reference data, *as grouped by each sample data class*, is the "user's accuracy" for that map class. User's accuracy for an individual map class is an estimate of the probability that the map class represents what was found on the ground and is equal to 100% accuracy minus the rate of "errors of commission." The rate of matches between the sample data and reference data, *as grouped by each reference data class*, is the "producer's accuracy" for that vegetation type. Producer's accuracy for an individual vegetation type is an estimate of the probability that the vegetation type has been mapped correctly, wherever it is found in the project area, and is equal to 100% minus the rate of "errors of omission." Note that the terms user's accuracy and producer's accuracy are applied to and have meaning only in reference to a specific map class or vegetation type.

As an example, the *Yucca brevifolia – Juniperus californica* / *Ephedra nevadensis* Association has a user's accuracy of 53.1% and a producer's accuracy of 48.4% (Table 2, Appendix H). The user's accuracy predicts that one can expect to find the *Yucca brevifolia – Juniperus californica* / *Ephedra nevadensis* Association in 53.1% of all areas mapped as this association, and one will find other associations about 46.9% of the time (the population contingency table (Table H3, Appendix H) shows the estimated contributions of the other associations to the incorrectly mapped proportion of 46.9%). The producer's accuracy predicts that, wherever *Yucca brevifolia – Juniperus californica* / *Ephedra nevadensis* Association occurs in JOTR, about 48.4% of this vegetation will be found in areas mapped as this map class, and 51.6% of the vegetation will fall in areas mapped as a different map class (also listed in the population contingency table). These estimates assume an observation area equal to that used by the AA (0.5 hectare or 0.25 hectare), but are likely to be robust enough for both larger and smaller areas.

User's and producer's accuracies may also be assessed at different levels of thematic resolution, including, different levels of the USNVC hierarchy, as is the case for this project (levels presented in the contingency tables are: Association, Alliance, Group, Macrogroup, Formation, and Class). This is useful because map accuracy and thematic resolution are inversely related to each other and different applications of the map may require more of one attribute than of the other. In the case of JOTR, the sample data and reference data are labeled at the finest level of thematic resolution (e.g., USNVC association) but can be regrouped at higher hierarchy levels (e.g., USNVC alliance and above), as needed.

Ideally, a map (sample data) class or vegetation (reference data) class has both high user's and high producer's accuracy. High producer's accuracy combined with low user's accuracy indicates that the map class is over-mapped (i.e., is rarer on the ground than the map indicates). Conversely, low producer's accuracy combined with high user's accuracy indicates that a vegetation type is under-mapped (i.e., is more abundant on the ground than the map indicates). Producer's accuracies, as calculated from population contingency tables, combined with GIS map class area measurements, allow for estimations of map class areas, as corrected for over-mapping or under-mapping error (Lea and Curtis 2010, Czaplewski 2003). For example, the JOTR map database documents 9,359 hectares mapped as the *Larrea tridentata - Ambrosia dumosa - Senna armata* Association, but from the low producer's accuracy (4.8%) and measurements of map classes in which this type was found, the true area of this association in JOTR is estimated to be more than four times as large (41,118 hectares). See Table H1 in Appendix H for mapped and estimated area differences for all classes mapped and assessed.

User's accuracy is important to anyone using the vegetation map because the "user" can assess the reliability of the map for each map class. Given that individual map classes can vary greatly in accuracy and that there may be consequences in relying on a map that is inaccurate at a given location, these values can be important for the decisions made by land managers that are informed by the map. Despite its name, producer's accuracy can also be important to map users because it is an estimate of how abundant each vegetation type is, within the mapped area (accounting for mapping error). Producer's accuracy can be used to derive a more accurate estimate of the area of a given vegetation type than the map alone indicates, because it enables compensation for mapping errors. The nature of the management focus will usually dictate which type of accuracy measure is more germane to the user: User's accuracy is more often applied when one is concerned about management *at a specific location*; producer's accuracy is more often applied when one is concerned about management *of a specific vegetation type*. As an example of the management value of estimating producer's accuracy, the JOTR AA results suggest that the rare plant dominated *Tetracoccus hallii* Provisional Association is likely to be more abundant at JOTR than the map indicates due to a very low producer's accuracy (0.4%). Although there is sampling uncertainty associated with this estimate (because of the small number of observations), estimates of the true area of this type suggest that it could be as much as nine times as abundant as mapping suggests. The contingency tables in Appendix H indicate the other map classes in which this type may occur undetected.

Beyond the basic value of the user's and producer's accuracies for map classes, the AA data can enable a map user to understand which combinations of map classes have been confused with one another by the mapper. Counts of individual observations and proportions of the map for all possible combinations of sample and reference data labels can be displayed in two different types of contingency tables: a sample table and a population table (Tables H1-H12, Appendix H) (see Lea and Curtis 2010 for further explanation). The sample table documents raw counts of observations within each possible combination of sample data labels and reference data labels; the population contingency table adjusts these counts to estimated proportions of the map that fall into each combination and is the correct table to use when estimating the accuracy of combinations of classes aggregated from the thematically finest classes. Reviewing the data in these tables will reveal commonly confused map classes and provide insight for which combinations of classes could be aggregated to produce more accurate units (at a lower level of thematic resolution). The user, of course, must make an informed decision about the best balance of thematic accuracy and map accuracy that best suits the situation. Combinations of aggregations and assessments of accuracy may be done within a formal hierarchy, as described in this example, or using any *ad hoc* combination of map classes desired.

The entire set of observations may be combined into an estimate of overall accuracy for the map. Overall accuracy is the probability that any location on the ground in the project area is correctly mapped. User's and producer's accuracy do not apply to the overall accuracy estimate, since observations from all classes are combined to derive overall accuracy. Overall accuracy is computed by pooling the individual observations used to assess individual map class accuracy. Since these sets of observations are derived from multiple independent random sampling designs, usually assigned at different sampling densities (because of different map class sizes), the influence of individual observations must be proportionally weighted when pooling the results (Lea and Curtis 2010).

The following sections will describe the three main phases of accuracy assessments completed at JOTR: (1) sampling design, (2) field data collection, and (3) analysis and computation.

2.3 Accuracy Assessment Sampling Design (Sample Data Label Methodology)

2.3.1 Determination of Observation Plot Size

The default size for the AA observation plot was 0.5 hectare (5,000 m^2); this was used for most JOTR map classes, including the majority of upland map classes. The shape of the AA plot was circular (39.9 meter radius) and centered on the observation point generated in the sampling design phase. Circular plots are logistically convenient because the observer can often estimate the boundaries from the center point. In addition, circular plots are less likely than plots of other shapes to encroach upon polygon boundaries with other map classes, which could cause ambiguity in field observations. A disadvantage of circular plots, compared to elongated plots of the same size, is that individual plant species distributions in individual stands (and, therefore, in the map class) is often clustered, so that isodiametric plots have a greater tendency to either underestimate the contribution of clusters within the stand that happen to be missed by the plot or overestimate the contribution of clusters that happen to be captured by the plot (Daubenmire 1968).

A number of map classes, mostly representing vegetation types associated with riparian washes, were mapped as small or narrow polygons, often less than 80 meters in width (the diameter of a 0.5 hectare circular plot). This condition was problematic because placing a 0.5 hectare circular plot in these map classes would decrease the available inference area, often to below the recommended sample size and, in some cases, eliminate all areas of the class (Lea and Curtis 2010). Therefore, we employed a 0.25 hectare or 2,500 m^2 circular (28.2 meter radius) plot in these map classes. A smaller observation area is appropriate in these cases because the ability to map small areas is limited by the narrowest dimension of the polygon. As a general rule, map classes with an overall area ($meters^2$) to edge (meters) ratio of 15:1 or less were assigned the smaller 0.25 hectare observation area (overall area = total map class area; edge = total perimeter of all map class polygons). To decrease possible observer bias, from linking a type to an observation area size in difficult assessments between similar types, we also evaluated all ecologically similar types at a common observation area size, regardless of this ratio for an individual class (e.g., since most wash riparian types had a $meters^2$/meters of edge ratio of less than 15:1, all wash types were assessed at the observation size). This possible bias from knowing the observation area size remained between riparian and upland types, but we assumed that major differences between riparian and non-riparian types would influence the field assessment strongly enough to override this bias.

2.3.2 Map Class Sample Sizes

Using ArcView ® 3.2, we calculated total areas (in hectares) for all original (2005 version) map classes in the JOTR map in order to determine how many observation plots to assign within each map class. The sample size for each map class was allocated at a density of 0.6 AA plots per hectare of the map class, up to a maximum of 30 samples per map class and a minimum of 5 (where possible) per map class (Table 1).

Table 1. Standard sample size allocations for thematic accuracy assessment, based on map class area (from Lea and Curtis 2010).

MAP CLASS TOTAL AREA*	NUMBER OF OBSERVATIONS PER MAP CLASS
>50 hectares	30**
8.33 to 50 hectares	0.6 per hectare**
<8.33 hectares	5**

* - as measured before buffering for cost surface (access buffer) or for map class boundary buffer.

** - or as many spatially independent (non-overlapping) observation sites as map class area, MMU size, and other considerations will allow.

2.3.3 Inference Area Determination

In order to assure that observations can be unambiguously assigned to a map class label, the edge of the circular plot should be far enough away from the polygon edge to eliminate the chance of overlapping the observation plot with a neighboring polygon. The radius of a 0.5 hectare circular plot is approximately 40 meters, whereas the radius of a 0.25 hectare circular plot is approximately 30 meters. To accommodate the placement of the entire observation area of the AA plot within the assigned map class, we used ArcView ® 3.2 to exclude areas within each polygon near boundaries with other map classes as follows:

(1) We created a 40 meter buffer inside the boundary of all polygons in map classes for which 0.5 hectare was designated as the observation area size.

(2) We created a union theme of the original map classes and this buffer theme.

(3) We selected the portions of all polygons that were within the 40 meter buffer and deleted them from this union theme. The result of this geoprocessing step was a polygon theme (sampling population) that was comprised of the interiors of all polygons (all areas more than 40 meters from a boundary with a different map class).

(4) We repeated the above process using a 30 meter buffer for all map classes designated to be evaluated at the 0.25 hectare observation area size. The result of this geoprocessing step was a polygon theme that was comprised of the interiors of all polygons (all areas more than 30 meters from a boundary with a different map class).

Excluding the edge of a polygon may create a bias of reporting more favorable map class accuracies. This would be true if the boundary areas represent more transitional vegetation between two neighboring map classes and may therefore be more difficult to diagnose, both in mapping and in field assessment. If present, this bias would not be expected to distort accuracy reporting overly since the buffered areas were excluded from central plot position selection, but may still be included in the plot. In addition, there are two benefits for excluding the edges: (1) retaining the ability to unambiguously label more individual observation points within a single map class; and (2) a time savings for field crews by reducing the chance of needing to move the center point of the AA plot when near a map class boundary (Lea and Curtis 2010).

Using the appropriate inference area for each map class, we located individual accuracy assessment center plot positions by allocating the specified number of observation points for each map class to the modified union theme derived from the operations above. This was done using the “Select Random Features” function in the National Park Service Alaskapak tools package for ArcView® 3.2 (NPS 2002). This feature achieves the requirement of simple random sampling within each individual inference area.

When two or more randomly selected observation points were near enough to one another to produce overlapping observation areas (i.e., within 80 meters of one another for classes to be observed at the 0.5 hectare scale or within 60 meters of one another for classes to be observed at the 0.25 hectare scale), we randomly selected one of the points (using the random numbers function in Microsoft® Excel 2003), retained it in the sample, and deleted the other positions. These overlapping plots would not be mutually independent observations because observers would likely approach positions in geographical sequence on the same day such that their assessment on the prior observation would tend to influence their assessment of the next observation (Lea and Curtis 2010). A replacement site was generated for each site so deleted, using the “Select Random Features” function (as above). If the replacement site was near enough to a previously located site, so as to produce an overlapping observation area, it was rejected, and the process repeated, until either (1) the full complement of sites for the map class was assigned or (2) it was determined that the map class was saturated (could not accommodate more positions without observation area overlap between one or more plots).

After the observation points were determined and saved to a GIS shapefile, easting and northing coordinates were assigned to the data table using the National Park Service Alaskapak tools package for ArcView® 3.2 (“ x, y coordinates” function). In addition, each plot was assigned a six-digit label; the first two digits were either 50 or 25 depending on which size observation plot was to be employed at the point (e.g., 25-0034 or 50-1223).

While we originally were optimistic that the entire map (all of JOTR) could be used as an inference area, field crews had not reached observation positions more than 4 kilometers from a road or trail after the first year of field work, and it became apparent that they would not obtain an adequate sample size if they would need to traverse long distances to some sites originally selected. Therefore we reduced the inference area to all areas represented by the JOTR vegetation map within 4 kilometers of a road or trail. We eliminated all locations farther than 4 kilometers and replaced them, using the methods described above, with new random positions. The selection order of pre-determined observation positions was done opportunistically by the crew, so that the observations made were not an unbiased sample from the revised inference area for the 2008 field campaign (the portion of the JOTR map representing all areas of JOTR within 4 kilometers of a road or trail) or the original sample selected for the 2007 field campaign (the entire JOTR map). However, since there is no reason to believe that areas more distant than 4 kilometers from a road or trail would be substantially different from those within 4 kilometers of these features and, since the crew observed a large proportion of the 2008 campaign revised sample, we treat the sample as a random selection from the 2008 campaign revised inference area.

Table 2 lists the original (fine level) map classes assessed, with the observation area size assigned to the class, the number of observations assigned to the class, the number of observations actually made within the class, the number of hectares mapped in the class, the numbers of hectares mapped within the 2008 campaign revised inference area, and the proportion of the entire map class contained within the 2009 campaign revised inference area. For 63 of the 74 original map classes considered for sampling, the revised 2009 campaign inference area (representing areas within 4 kilometers of a road or trail) for the map class represented at least 50% of the entire area mapped for the class (representing all of JOTR).

2.4 Accuracy Assessment Field Protocol (Reference Data Label Methodology)

After three days of training in January of 2007, data collection for Accuracy Assessment plots started and continued through June 2008. The field observers were trained for the following: 1) how to use a Global Positioning System (GPS) receiver for navigation to an AA point; 2) how to use the JOTR field key; 3) how to estimate absolute and relative canopy cover; 4) how to determine the boundary of the AA plot; 5) species identification for common perennial species; and 6) how to record and enter data collected in the field. All data were collected in Universal Transverse Mercator (UTM) projection, Zone 11, using the North American datum of 1983.

There was not a preconceived order in which the field observers went about visiting points, however consideration was given to completing as many of the low elevation points in the cooler months as possible, then move up in elevation as temperatures increased into the warmer seasons. Slight bias may have resulted from the selection process of points on a daily basis. First, in order to visit as many points as possible in a day, the field observer would choose points close to one another geographically. This would increase the chance of the observer visiting several points within a given polygon or map class due to geographic proximity. As discussed above, this could potentially cause the observer to make similar calls that are not entirely independent of one another. Second, because the plot label contains the size of the plot to be used, the observer may have increased accuracy for those vegetation types that required the 0.25-hectare plots because they were often associated with a limited subset of vegetation types. This bias was deemed to be insignificant, particularly, at the thematically finest levels because many map classes were represented in each observation size. To reduce any bias in making correct field calls for the AA plots, the field observers were not aware of the vegetation type the AA point was representing, nor were they given a map depicting the shape of the polygon the point was located within.

When field observers were ready to navigate to the AA point, the center point coordinates were entered into GPS receivers and the observer then attempted to find the most parsimonious path to the AA plot. Once at the predetermined point, the observer would collect information within a 40 meter or 30 meter radius, depending on the size of the AA plot (0.5- or 0.25-hectare, respectively). Data collected included date, observer(s) name, AA plot label, GPS coordinates, accuracy of position, type of GPS unit, elevation, absolute percent cover of all perennial species in the plot, and any other relevant notes about the point. The observers always collected a GPS position in the field and these coordinates were considered more accurate than the randomly created coordinates assigned by ArcGIS.

Once the observer was familiar with the observational area inside the AA plot, they consulted the JOTR field key and recorded their first call for the vegetation type that most closely represented their observations. If necessary, a second call was recorded when more than one vegetation type represented what they observed. The field key presents a succession of mutually exclusive vegetation conditions, for example, abundance of certain plant species or species combinations, the presence or absence of diagnostic plant species, minimum percent cover for diagnostic species, etc., for the observer to choose from.

During the 2007 field season, the field observers used the key found in the 2005 vegetation classification report produced by Todd Keeler-Wolf et al. of the California Department of Fish and Game in 2005 (Appendix E, p28-48). At the end of the 2007 field season the original key was modified (see Appendix I) with three significant changes. First, the unmapped vegetation types that were represented in the key were moved to the last page of the key. By moving the unmapped vegetation types to a list at the end of the key it allowed the field observer to consider these types as options but yet choose a mapped type for their AA call. This favors the User's accuracy rate, which supports the management goal of testing the map for on-the-ground accuracy. If the goal of the accuracy assessment is to test the map, then the key should present only map classes that are actually mapped. Secondly, there were a number of map classes that were not listed in the key that were represented on the map, so these were added to the key. The key was written by CDFG and did not account for the differences between the AIS mapping classification and the CDFG ecological classification. Unfortunately, due to the lack of continuity and funding for this project, these differences were not obvious to park staff when the AA process began in 2006. Finally, the field observers substituted a 3-digit code to represent each vegetation type rather than the 5-digit mapping code assigned by the photo-interpreters at AIS (PI code). This was done to reduce the likelihood of transposition errors during data entry, particularly into the GPS receivers. The 3-digit code was transcribed back to the original 5-digit PI code after data were entered.

While a datasheet (see Appendix I) was created to record the field observations, field observers found that pocketsize Rite-in-the-Rain notebooks were more practical due to the long, arduous hikes of up to 8 miles over rough terrain. Carrying a light backpack allowed them to move more quickly and safely. These notebooks are available in the park archive. All data were entered into an excel spreadsheet once the field observer was back in the office.

In cases where two or more distinctly different vegetation types occupied the plot area, observers were given latitude to move the center point a minimum distance in a direction perpendicular to the perceived boundary until the observation area appeared to be within one vegetation type. Observers were instructed to consider significantly steep environmental gradients such as a combination of a wash channel and an upland slope or an abrupt change in stand physiognomy (e.g., regularly spaced trees to no trees) as justification for moving the center position. Because vegetation keys are designed to work in relatively homogeneous vegetation, excessive heterogeneity can be a justification for rejecting or adjusting an observation area; on the other hand, atypical (but homogeneous) vegetation constitutes a valid observation and should always be assessed as it is encountered (Lea and Curtis 2010). The field observers did not choose to move any of the AA plots using this methodology. This could be due to desert vegetation often being relatively patchy with several ostensibly co-dominant species, therefore the method of moving the center point would not necessarily remedy the seeming lack of homogeneity within the plot.

2.5 Accuracy Assessment Analysis

2.5.1 Quality Control for Positioning Relative to Map Class Label

An analysis of the recorded field positions was made in order to determine whether ambiguity in the map class label might exist for any observations, as a result of GPS error, movement of the plot to avoid excessive heterogeneity in assigning the reference data value (as described in Section 2.4), or other reasons:

First, the position (as collected by GPS in the field) of each observation was buffered by a distance according to the following equation (Lea and Curtis 2010):

$$\text{Buffer Distance} = \sqrt{R^2 + F^2 + M^2}$$

where R is the radius distance of the observation area (either 30 meters or 40 meters, for individual JOTR observations), F is the expected (e.g., 90^{th} percentile field positioning) GPS error distance (assumed to be 10 meters for all observations at JOTR), and M is the expected maximum positional error distance in the map (12 meters for all observations, as the map was assumed to meet National Map Accuracy Standard (NMAS) requirements for positional accuracy of 1:24,000 scale products). Observations were buffered by 43 meters for all 0.5 hectare observations or by 34 meters for all 0.25 hectare observations.

Using ArcGIS 8.3, the buffer function was used to create polygons of the appropriate radius around each observation. These individual polygons effectively represented the maximum possible extent of any position within the corresponding field plot. Using the spatial join function, these buffered polygons were joined to the JOTR map polygons in order to assign a map class to the buffered observation area. Buffered polygons that received more than one label were removed temporarily from the sample of all observations as having suspected positional ambiguity (due to GPS positioning error).

The position of these buffered polygons, relative to the JOTR map class polygons, showed that 1286 of 1311 observation plots were contained unambiguously within a single map class, in other words the buffered polygon map class was the same as the unbuffered AA observation point. All buffered polygons were labeled with the predominant map class and raw (sample) accuracy was calculated. Of the 25 buffered observation polygons that overlapped more than a single map class, 10 of 25 (40%) had reference labels that matched the sample labels, which exceeds the accuracy of the “unambiguous” positions by almost 10%; only 414 of 1286 (40%) reference labels matched the sample label. Therefore, the 25 suspected “ambiguous” plots were labeled with the predominant map class and retained in the analysis as unambiguous.

During this analysis we found that in two instances the buffered observation area overlapped with two other buffered observation areas, in both cases with more than 75% overlap. We assume that one of the overlapping observations in each case can be considered redundant and removed from the analysis. For one pair, the overlapping observations were labeled with the same unique identifier and therefore considered to have been made in error; one observation was randomly selected and discarded. For the other pair, one observation was randomly selected to be retained in the analysis, and the other overlapping observation was discarded.

2.5.2 Thematic Accuracy Calculations

Following collection and analysis of the accuracy of the original (2005) map, the classification for JOTR was revised (Evens et al. 2012, Appendix A) and the map modified to coincide with the revised classification. These modifications affected the AA in several ways. First, some original associations were deemed too narrowly defined and were merged with other associations (after the map classes representing the original associations had been sampled individually). Second, some original map classes had been mapped as units that had overlapping relationships with other map classes or were ambiguous as to level of thematic resolution (e.g., unique stands of plant species not labeled as to USNVC membership and multiple alliance mapping units). These were assigned a USNVC label. Third, the revised classification defined associations and alliances within the revised USNVC hierarchy (Federal Geographic Data Committee 2008, Evens et al. 2012), enabling aggregations to be done to higher levels of the newer version of the USNVC. Finally, some individual polygons with AA plots were relabeled to match the reference data in the AA plot (i.e., some parts of the map classes were corrected using the AA data).

The first three *post hoc* modifications to the classification and map required that a population contingency table be created for the original map classes prior to merging the cell proportions to derive representative accuracy rates for the user's accuracies of a number of associations using a stratified design (Lea and Curtis 2012). Some associations recognized by Evens et al. (2012) had been sampled in the original field efforts for the project, but were not recognized in the 2005 version of the classification, perhaps due to lack of resolution or too few data points. In addressing the fourth *post hoc* modification to the map (relabeling polygons to match reference data collected within them), we could not apply the new sample data labels (map classes) because of the obvious circular reasoning that would be involved (sample data labels matched reference data labels because they were changed to fit reference data labels). However, the sample error rates derived from the original labels can be expected to be largely representative of population error rates that still exist throughout the uncorrected parts of the map and map classes, and for most map classes these represent most of the map. The reason for this is that entire polygons were relabeled on the basis of a relatively small area observed (0.5 or 0.25 hectare) and a polygon cannot be assumed to be internally homogeneous (as mapped) unless observed in its entirety. This assumption would be less true for smaller map classes, for which larger proportions of the class were corrected, than for extensive map classes. A further consideration is that some polygon relabeling may have reduced map class accuracy because rarely has an entire polygon been ground-truthed. We consider the reported sample accuracy rates to be somewhat conservative, but relatively accurate representations of the current JOTR map (population) accuracy rates.

We attributed the reference (field observation calls) labels to the AA observation point as recorded in the field by GPS. Using a spatial join of this point theme with the JOTR vegetation map polygon theme, we applied the JOTR map class label to yield a table of all observations with three values (columns): a unique identifier, a map class label, and a reference data label. We applied the Microsoft Excel ® 2007 pivot table function to yield a map class value by reference data value table, with each cell representing a unique combination of map class X reference data value. Each cell contains the number of observations with that combination of values. This pivot table was the raw sample contingency table for the original map and vegetation classes (Lea and Curtis 2010).

From the sample contingency table and map class area calculations, we created a population (proportional) contingency table for all original map classes, as specified by Lea and Curtis (2010), using Microsoft Excel ® 2007.

To report USNVC association level user's, producer's, and overall accuracies in terms of the revised classification (Evens et al. 2012) and map (see Table 2), we relabeled the applicable proportions for rows and columns of individual map classes that underwent global recodes (i.e. either renaming a vegetation type or merging together two or more vegetation types). Observations that were assigned either sample data labels, reference data labels, or both, at a higher level of the USNVC hierarchy (i.e., at a coarser thematic resolution) were not included in the association level analysis. We summed population table rows and columns to derive individual user's and producer's accuracy rates, respectively, and diagonal cell proportions in the population contingency table were summed to derive overall accuracy (Lea and Curtis 2010). We used vegetation type producer's accuracies and the area mapped within each map class to derive estimated areas of all associations (see Table 4), as corrected for overmapping or undermapping (Czaplewski 2003, Lea and Curtis 2010).

To report USNVC alliance level user's, producer's, and overall accuracies in terms of the revised classification and map, we relabeled association level classes with their appropriate alliance membership, and combinations of rows and columns were made, accordingly. Observations that were assigned either sample data labels, reference data labels, or both, at a higher level of the USNVC hierarchy (i.e., at a coarser thematic resolution) were not included in the alliance level analysis.

We repeated this process to report user's, producer's, and overall accuracies at the higher USNVC levels of group, macrogroup, formation, and class, as assigned by Evens et al. (2012). We did not calculate USNVC division and subclass level accuracies because division units are 1:1 with formation units within JOTR and subclass units are nearly 1:1 with class units, and in both cases the respective overall accuracies are identical.

2.6 Rapid Assessments

In September 2008, a meeting was held to discuss and analyze the results of the accuracy assessment. Attendees included JOTR staff members and field observers, AIS representatives, Todd Keeler-Wolf representing CDFG, and Chris Lea representing the NPS vegetation mapping program. As a result of this meeting it was decided to collect additional vegetation data to help define the ecological signature of 14 problematic vegetation types or polygons. The goal was to complete a minimum of 10 Rapid Assessments (RA) within the map classes lacking good ecological information (i.e. problematic vegetation types), with a focus on visiting polygons that were not sampled during the AA process, whereas for each of the problematic polygons only one

RA was needed. The 10 vegetation types that were targeted for better ecological definition include (2005 PI code in parentheses): 1) *Yucca brevifolia* Wooded Shrubland Alliance (13010); 2) *(Ephedra nevadensis – Pleurocoronis pluriseta – Encelia farinosa - Trixis californica – Bebbia juncea – Eriogonum fasciculatum – Lycium andersonii – Acacia greggii)* Low-Elevation Rocky Mountain Type (24001); 3) *Salazaria mexicana – Krameria* spp*. – Encelia farinosa – Hyptis emoryi – Eriogonum fasciculatum – Hymenoclea salsola – Acacia greggii – Tetracoccus hallii* Dense Rivulet/Desert Pavement Type (27001); 4) *Larrea tridentata – (Ambrosia dumosa – Viguiera parishii)* Higher-Elevation Type (27046); 5) *Coleogyne ramosissima* — (mixed shrub) Super Association (28023); 6) *Viguiera parishii – (Ephedra nevadensis – Eriogonum fasciculatum – Nolina bigelovii)* High-Elevation Rocky Mountain Type (28133); 7) *Ambrosia dumosa – Senna armata – (Psorothamnus schottii)* Eastern Pediment Type (43013); 8) *Ambrosia dumosa – (Eriogonum fasciculatum – Lycium andersonii/Pleuraphis rigida)* Western Mountain Type (43014); 9) *Bromus tectorum* fire plot (60001); and 10) Desert Pavement (90100). The four vegetation types represented by problematic polygons were: 1) *Prosopis glandulosa* Woodland Shrubland Alliance (16040); 2) *Larrea tridentata* Clones (27022)*;* 3) *Larrea tridentata — Encelia farinosa — Fouquieria splendens* Shrubland Association (27056)*;* and 4) *Acacia greggii* — (*Viquieria parishii — Eriogonum fasciculatum*) Upland Slope Type (36017). A total of 111 relevé plots were completed in 2009 (Figure 5). There are other vegetation types and polygons that will benefit from additional information; however, it was not feasible to include all of them in the 2009 field effort. See the discussion under "Future Work" for suggestions on which vegetation types could benefit most from additional plot data.

The RA protocol developed by CNPS (http://cnps.org/cnps/vegetation/sampling.php) was chosen for data collection because it provides more detailed ecological information than the AA protocol. In particular, the RA plots are meant to sample the entire stand, or polygon, and the observer chooses a representative spot within the polygon to record their observations. Field observers were instructed to walk around in the polygon before choosing a representative location to record data. This is in contrast to the AA protocol, which requires that the point is fixed (randomly assigned to a location inside the polygon) and the observer does not know where the borders of the polygon lie or have the opportunity to move the point to a more representative location. The following guidelines from the CNPS protocol (see Appendix I) were to be considered in choosing an area to represent the stand:

1) It has compositional integrity. Throughout the site, the combination of species is similar. The stand is differentiated from adjacent stands by a discernible boundary that may be abrupt or indistinct.
2) It has structural integrity. It has a similar history or environmental setting that affords relatively similar horizontal and vertical spacing of plant species. For example, a hillside forest originally dominated by the same species that burned on the upper part of the slopes, but not the lower, would be divided into two stands. Likewise, sparse woodland occupying a slope with very shallow rocky soils would be considered a different stand from an adjacent slope with deeper, moister soil and a denser woodland or forest of the same species.

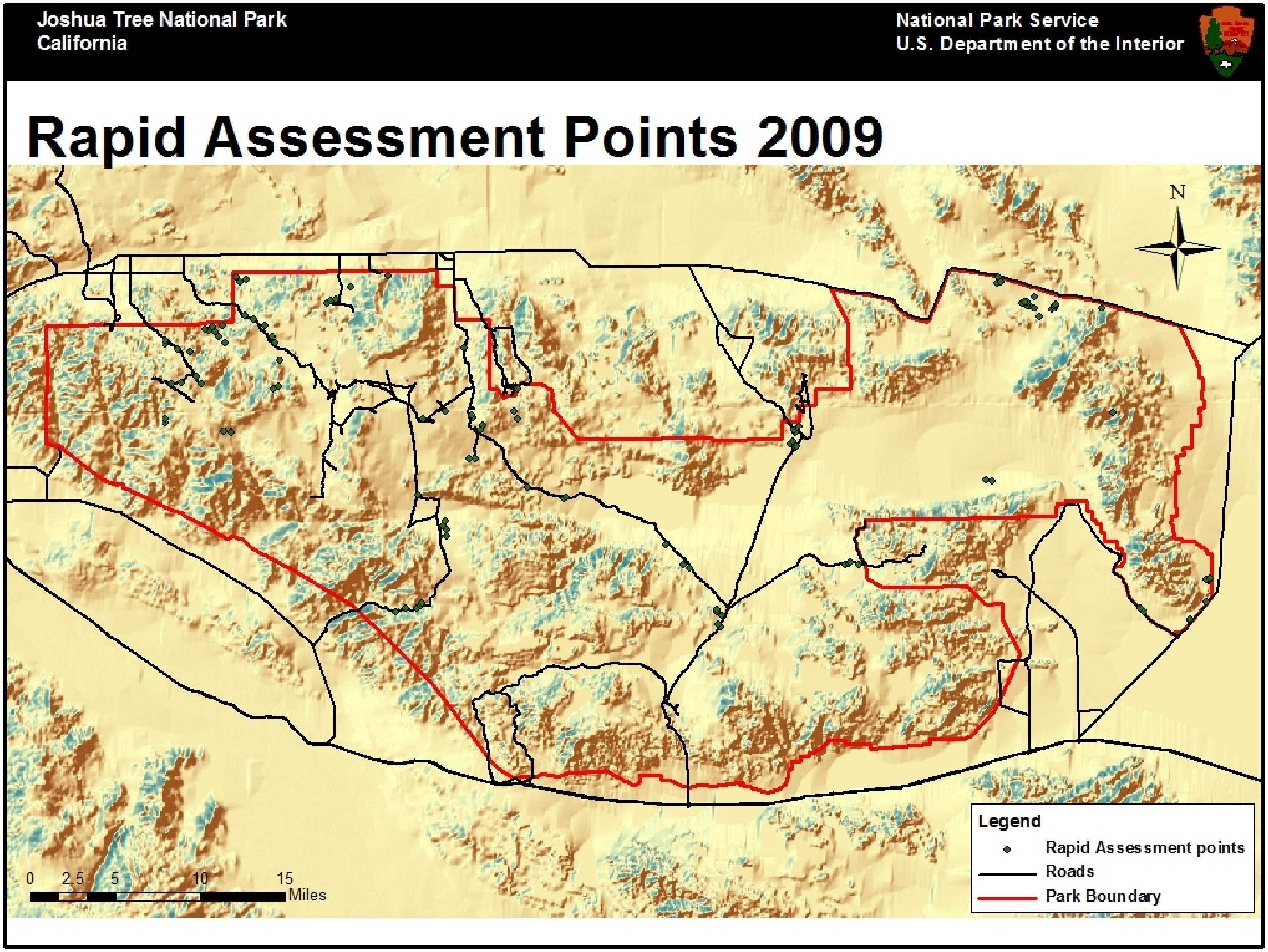

Figure 5. Locations of rapid assessment points collected in 2009.

The CNPS Combined Rapid Assessment and Relevé Field Form (Appendix I) was used for data collection in the field (datasheets are available in the Park archive). Upon returning to the office, data were entered into an Access database provided by CNPS (Access database is available on the JOTR sharedrive, "JOTR_2009_PLOTDATA.mdb"). At each RA plot, photographs were taken in each of the cardinal directions; a file geodatabase containing the embedded photos was created in ArcGIS Desktop 9.3.1 and is available on the Park sharedrive (RA_Photos.gdb).

2.7 Vegetation Mapping and Classification

The vegetation mapping portion of the project was contracted to Aerial Information Systems, Inc. (AIS) out of Redlands, CA. The mapping effort began in 1996 and by 2004 they had produced a vegetation map (referred to as the 2005 version of the map), along with two reports (see Appendix F and G) titled, *Photo-Interpretation Report, USGS-NPS Vegetation and Inventory and Mapping Program, Joshua Tree National Park* and *USGS-NPS Vegetation Mapping Program*, *Joshua Tree National Park Mapping Classification.* AIS was hired again in 2009-2010 to assist in updating the map; they hosted the meeting in August 2009, then proceeded to make changes to the map as discussed at the meeting. For the most part, this involved revisiting aerial photos and reevaluating the map class assigned to each problematic polygon, as well as correcting any global recodes and minor edits to the nomenclature. Aerial imagery used for the project was from 1998, including the revisits in 2009, and the minimum mapping unit was defined as 0.50 hectares. For more detail on methods used by AIS to produce the map and a summary of the project pre-2005, refer to the reports mentioned above. All changes made to the map after 2010 were done by JOTR staff, specifically Tasha La Doux and Sean Murphy.

The 2005 version of the vegetation classification was completed by the California Department of Fish and Game (CDFG) in March of 2005. This report, titled "*Vegetation Classification of Joshua Tree National Park, Riverside and San Bernardino Counties, California",* included ecological descriptions, a key, and an overview of the project (see Appendix E). The lead author, Todd Keeler-Wolf, continued to work with Park staff once the Accuracy Assessment phase started in 2007. He attended both the 2008 and 2009 meetings in which results from the 2007-2009 field seasons were discussed and incorporated into the 2012 version of the classification, largely based on his analyses. In 2011, Julie Evens of the California Native Plant Society (CNPS) was hired to produce a report containing ecological descriptions for the final classification; this report is titled "*Vegetation Descriptions for Joshua Tree National Park"* (see Appendix A). Leading up to this, Todd Keeler-Wolf, Julie Evens, and Tasha La Doux worked together to update the classification to reflect the most recent nomenclature supported by NVC and Sawyer et al. (2009). In addition, newly acquired datasets from nearby areas (e.g., northern and eastern Colorado Desert) were utilized to help clarify some of the vegetation types that had previously been difficult to describe due to lack of data. All statistical analyses were performed by Todd Keeler-Wolf (CDFG) and the methods are described in Appendix E. For more detailed information on these analyses, contact Todd Keeler-Wolf (CDFG) directly. Finally, using a draft version of an ecological key produced by Todd Keeler-Wolf, the final vegetation key was completed by Tasha La Doux (see Appendix C). This key is meant to be an ecological key, such that observations should be based on the stand and not limited to any given plot size. Any plot data obtained by using the key should consider placing the plot in a location that is representative of the surrounding stand (within the mapped polygon).

The final classification was based on vegetation data from a total of 689 plots derived from six different projects. Four of these projects were not directly related to this effort; however, they contributed 278 vegetation plots to the analysis. The majority of the plots (411) were sampled for the purpose of this project, including 300 plots completed by AIS in 2000 and 111 plots sampled by JOTR staff in 2009. All of these plots used the CNPS Relevé protocol (CNPS 2004). The other four data sets with useful vegetation data for this analysis are referred to as Watts, MDEI, NECO, and Long. More specifically, 108 plots collected by Joe Watts of the Army Corps of Engineers in 1996; 76 plots sampled for the Mojave Desert Ecosystem Initiative Program (MDEI) in 1997; 20 plots were utilized from a much larger project referred to as the Northeast Colorado Desert vegetation survey completed by CNPS and CDFG; and 74 plots sampled for the purpose of monitoring restoration effects on desert tortoise habitat in 1997 by Brent Long, an ecologist at Joshua Tree National Park. In addition to these data sets, two reports were utilized in developing the preliminary classification at the beginning of the project, these were 1) “The Ecology of the Joshua Tree in Joshua Tree National Monument,” which was a master's thesis by James Hogan of the University of Nevada, Las Vegas, and 2) “Investigation of the Vegetational Communities of Joshua Tree National Monument”, a National Park Service technical report by Patrick Leary in 1977. A more complete summary of these data sets (with the exception of the JOTR relevé plots from 2009) is available in Keeler-Wolf et al. (2005), which is attached to this report as Appendix E. In addition, the 1,313 Accuracy Assessment plots were helpful during the discussions in 2008 and 2009 to assess presence/absence of species within vegetation types and were useful in corroborating the presence or absence of certain vegetation types within the Park. All data are available on the Park sharedrive.

3.0 Results

3.1 Thematic Accuracy Assessment

Overall map class accuracies for the JOTR map are 41.0% at the USNVC association level (41 map classes, number of observations = 1070), 61.0% at the alliance level (32 map classes, n= 1278), 82.0% at the group level (13 map classes, n= 1281), 87.3% at the macrogroup level (10 map classes, n= 1281), 92.5% at the division and formation levels (8 map classes at each level, n= 1285), and 92.9% at the subclass and class level (4 map classes at class level and 5 map classes at subclass level, n= 1290).

Table 2 reports map class user's and producer's accuracies. Because of the complex variance calculations with the large number of aggregations, confidence intervals are not reported; instead, numbers of observations with sample and reference data labels for each class are listed. GIS-calculated areas and estimated areas for each class, as adjusted for mapping error, are listed. Table 4 reports areas for each association and alliance level class as mapped and the estimated areas for each of these classes as adjusted for mapping error (Czaplewski 2003, Lea and Curtis 2010).

Tables H1 through H12 (Appendix H) are sample and population contingency tables for multiple levels of the USNVC hierarchy, as assessed for the JOTR vegetation map. The proportions in the population contingency tables allow patterns of map class confusion not summarized by aggregation within the USNVC hierarchy (Table 2) to be assessed. The numbers in the cells within the sample contingency tables are sums of observations originally assigned to the different map classes, cell counts are from a stratified random design. They are presented to show general patterns of error frequency, but cannot be used for precise estimation of individual class or overall accuracy rates.

3.2 Accuracy Assessment Vegetation Data

In August 2009, a meeting was held in Redlands, CA, to review and discuss all the new vegetation data collected during the 2007 – 2009 field seasons. Present at the meeting were Todd Keeler-Wolf (CDFG), Debbie Johnson (AIS), Ed Reyes (AIS), John Menke (AIS), Erin Babich (JOTR), Tasha La Doux (JOTR), and Sean Murphy (JOTR). Prior to the meeting Park staff prioritized the vegetation types to be discussed and made suggestions for how each of these might be affected after reviewing the new data. Todd Keeler-Wolf had also done additional cluster analyses incorporating the new data, which he presented during the meeting. Specifically, the following aspects of each vegetation type were considered and changed if necessary: 1) nomenclature should follow Manual of California Vegetation Second Edition (Sawyer et al. 2009) and/or NVC standards; 2) assignment of a proper PI code; 3) if possible, polygons mapped at the Alliance level were assigned an Association; and 4) any problematic vegetation types (or polygons) were assessed and either left unchanged or reclassified. Major changes made to the map and classification are discussed below, however, the 14 types targeted by the RA effort in 2009 are discussed in the following Section (3.3). To view all changes made to the 2005 version of the map, see the excel document titled "Map and Classification Crosswalk, 2005 to 2012" (Appendix D), as well as the attribute table of the geodatabase feature class titled "JOTR_2012_Veg_Classification_Documentation".

Table 2. Accuracy assessment statistics for JOTR, by National Vegetation Classification class, formation, macrogroup, group, alliance, and association assignments. N_{i+} and N_{+j} denote the numbers of sample data observations and reference data observations for each map class, respectively. Overall map accuracies are: at USNVC Class (and USNVC Subclass): 92.9%; at USNVC Formation (and USNVC Division): 92.5%; at USNVC Macrogroup: 87.3%; at USNVC Group 82.0%; at USNVC Alliance: 61.0%; at USNVC Association: 41.0%.

MAP CLASS NAME AND NUMBER	USERS ACCURACY	N_{i+}	PRODUCERS ACCURACY	N_{+j}
Forest & Woodland Class	**72.0%**	**38**	**73.6%**	**41**
Cool Temperate Forest Formation	***72.1%***	***26***	***73.6%***	***31***
Intermountain Singleleaf Pinyon-Western Juniper Woodland Macrogroup	**72.1%**	**26**	**73.6%**	**31**
Great Basin Pinyon-Juniper Woodland Group	**72.1%**	**26**	**73.6%**	**31**
***Pinus monophylla* Woodland Alliance (10160)**	**72.1%**	**26**	**74.4%**	**30**
Pinus monophylla / Quercus cornelius-mulleri Association (10161)	72.1%	26	75.8%	28
Temperate Flooded & Swamp Forest Formation	***0.0%***	***12***	***0.0%***	***10***
Warm Mediterranean & Desert Riparian, Flooded & Swamp Forest MG	**0.0%**	**12**	**0.0%**	**10**
Southwestern North American Warm Desert Riparian Group	**0.0%**	**12**	**0.0%**	**10**
***Populus fremontii* Forest Alliance (15040)**	**0.0%**	**3**	**0.0%**	**0**
***Salix gooddingii* Woodland Alliance (15030)**	**100.0%**	**4**	**37.7%**	**6**
***Washingtonia filifera* Woodland Alliance (15110)**	**80.0%**	**5**	**100.0%**	**4**
Shrubland & Grassland Class	**44.4%**	**39**	**52.6%**	**44**
Mediterranean Scrub Formation	***41.2%***	***17***	***31.0%***	***38***
California Chaparral Macrogroup	**41.2%**	**17**	**31.0%**	**38**
California Mesic North-Slope Chaparral Group	**41.2%**	**17**	**31.0%**	**38**
***Quercus cornelius-mulleri* Shrubland Alliance (21230)**	**41.2%**	**17**	**31.0%**	**38**
Quercus cornelius-mulleri - Eriogonum fasciculatum - Ericameria linearifolia Association (21234)	41.2%	17	39.9%	17
Mediterranean Grassland & Forb Meadow Formation	***0.0%***	***18***	***0.0%***	***0***
California Annual & Perennial Grassland Macrogroup	**0.0%**	**18**	**0.0%**	**0**
Mediterranean California Naturalized Annual & Perennial Grassland Group	**0.0%**	**18**	**0.0%**	**0**
***Bromus rubens - Schismus* (*arabicus, barbatus*) Semi-Natural Herbaceous Stands (60010)**	**0.0%**	**16**	**0.0%**	**0**
Salt Marsh Formation	***75.0%***	***4***	***19.6%***	***6***
Warm Semi-Desert & Mediterranean Alkaline-Saline Wetland MG	**75.0%**	**4**	**19.6%**	**6**
North American Warm Desert Alkaline Scrub & Herb Playa & Wet Flat Group (90400)	**75.0%**	**4**	**19.6%**	**6**

Table 2. Accuracy assessment statistics for JOTR, by National Vegetation Classification class, formation, macrogroup, group, alliance, and association assignments. N_{i+} and N_{+j} denote the numbers of sample data observations and reference data observations for each map class, respectively. Overall map accuracies are: at USNVC Class (and USNVC Subclass): 92.9%; at USNVC Formation (and USNVC Division): 92.5%; at USNVC Macrogroup: 87.3%; at USNVC Group 82.0%; at USNVC Alliance: 61.0%; at USNVC Association: 41.0% (continued).

MAP CLASS NAME AND NUMBER	USERS ACCURACY	N_{i+}	PRODUCERS ACCURACY	N_{+j}
Xeromorphic Scrub & Herb Vegetation (Semi-Desert) Class	**96.1%**	**1179**	**97.7%**	**1183**
Warm Desert Scrub & Grassland Formation	***96.0%***	***1172***	***97.7%***	***1151***
Mojave-Sonoran Semi-Desert Scrub Macrogroup	**90.6%**	**868**	**97.9%**	**876**
Mojave Mid-Elevation Mixed Desert Scrub Group	**77.8%**	**492**	**88.3%**	**430**
***Coleogyne ramosissima* Shrubland Alliance (28020)**	**28.6%**	**28**	**9.5%**	**23**
Coleogyne ramosissima - Ephedra nevadensis Association (28023)	28.6%	28	10.1%	22
***Eriogonum fasciculatum - Viguiera parishii* Shrubland Alliance (28130)**	**33.3%**	**35**	**63.7%**	**42**
Viguiera parishii - Ambrosia dumosa - Simmondsia chinensis Association (28134)	22.2%	18	47.4%	28
Viguiera parishii - Eriogonum fasciculatum - Simmondsia chinensis Association (28133)	23.5%	17	41.6%	12
***Juniperus californica* Woodland Alliance (10020)**	**72.1%**	**175**	**66.1%**	**140**
Juniperus californica / Yucca schidigera / Pleuraphis rigida Association (10031)	24.9%	27	20.4%	24
Juniperus californica / Coleogyne ramosissima Association (10025)	69.4%	106	61.9%	103
Juniperus californica / Quercus cornelius-mulleri – Coleogyne ramosissima Association (10032)	25.0%	24	38.3%	12
***Pleuraphis rigida* Herbaceous Alliance (59010)**	**53.3%**	**30**	**17.4%**	**20**
***Salazaria mexicana* Shrubland Alliance (28140)**	**0.0%**	**0**	**0.0%**	**5**
***Tetracoccus hallii* Provisional Shrubland Alliance (28180)**	**20.0%**	**5**	**0.4%**	**10**
Tetracoccus hallii Provisional Association (28181)	100.0%	1	0.4%	10
***Yucca brevifolia* Woodland Alliance (13010)**	**83.4%**	**139**	**78.5%**	**145**
Yucca brevifolia - Juniperus californica / Ephedra nevadensis Association (13015)	53.1%	32	48.4%	40
Yucca brevifolia / Coleogyne ramosissima Association (13012)	37.0%	27	7.4%	22
Yucca brevifolia / Larrea tridentata - Yucca schidigera / Pleuraphis rigida Association (13016)	71.4%	28	70.4%	40
Yucca brevifolia / Pleuraphis rigida Association (13021)	66.7%	24	71.4%	34
***Yucca schidigera* Shrubland Alliance (29030)**	**34.9%**	**79**	**58.3%**	**43**
Yucca schidigera - Coleogyne ramosissima Association (29032)	5.6%	18	10.5%	10
Yucca schidigera - Larrea tridentata - Ambrosia dumosa Association (29033)	16.1%	35	28.3%	23
Yucca schidigera / Pleuraphis rigida Association (29034)	8.0%	25	3.9%	5

Table 2. Accuracy assessment statistics for JOTR, by National Vegetation Classification class, formation, macrogroup, group, alliance, and association assignments. N_{i+} and N_{+j} denote the numbers of sample data observations and reference data observations for each map class, respectively. Overall map accuracies are: at USNVC Class (and USNVC Subclass): 92.9%; at USNVC Formation (and USNVC Division): 92.5%; at USNVC Macrogroup: 87.3%; at USNVC Group 82.0%; at USNVC Alliance: 61.0%; at USNVC Association: 41.0% (continued).

MAP CLASS NAME AND NUMBER	USERS ACCURACY	N_{i+}	PRODUCERS ACCURACY	N_{+j}
Xeromorphic Scrub & Herb Vegetation (Semi-Desert) Class (cont.)				
Warm Desert Scrub & Grassland Formation (cont.)				
Mojave-Sonoran Semi-Desert Scrub Macrogroup (cont.)				
Sonoran – Mojave Creosotebush – White Bursage Desert Scrub Group	**86.9%**	**376**	**92.6%**	**446**
***Ambrosia salsola* Shrubland Alliance (28110)**	**0.0%**	**0**	**0.0%**	**13**
***Cylindropuntia bigelovi*i Shrubland Alliance (29050)**	**84.0%**	**25**	**41.1%**	**23**
*Cylindropuntia bigelovi*i Association (29051)	100.0%	25	41.1%	23
***Encelia farinosa* Shrubland Alliance (28030)**	**33.3%**	**9**	**7.0%**	**13**
Encelia farinosa - Ambrosia dumosa Association (28033)	33.3%	9	7.0%	13
***Larrea tridentata - Ambrosia dumosa* Shrubland Alliance (27030)**	**72.3%**	**223**	**81.7%**	**253**
Larrea tridentata - Ambrosia dumosa - Psorothamnus arborescens Association (27044)	0.0%	10	0.0%	0
Larrea tridentata - Ambrosia dumosa - Krameria grayi Association (27034)	0.0%	26	0.0%	0
Larrea tridentata - Ambrosia dumosa - Senna armata Association (27047)	49.1%	51	4.8%	99
Larrea tridentata - Ambrosia dumosa - Simmondsia chinensis Association (27046)	25.0%	20	19.9%	19
Larrea tridentata - Ambrosia dumosa - Yucca schidigera Association (27045)	75.6%	48	59.3%	57
Larrea tridentata - Ambrosia dumosa Association (27031)	23.8%	47	74.5%	54
***Larrea tridentata - Encelia farinosa* Shrubland Alliance (27050)**	**52.8%**	**55**	**75.7%**	**82**
Larrea tridentata - Encelia farinosa - Ambrosia dumosa Association (27057)	50.0%	12	70.1%	51
Larrea tridentata - Encelia farinosa - Fouquieria splendens Association (27056)	27.6%	29	4.1%	15
Larrea tridentata - Encelia farinosa - Pleurocoronis pluriseta Association (27059)	0.0%	13	0.0%	10
***Larrea tridentata* Shrubland Alliance (27010)**	**49.9%**	**59**	**23.7%**	**62**
Larrea tridentata - Atriplex hymenelytra Association (27023)	0.0%	4	0.0%	0
Larrea tridentata / Pleuraphis rigida Association (27021)	46.2%	26	39.2%	31
Larrea tridentata Association (27019)	35.7%	28	5.5%	25

Table 2. Accuracy assessment statistics for JOTR, by National Vegetation Classification class, formation, macrogroup, group, alliance, and association assignments. N_{i+} and N_{+j} denote the numbers of sample data observations and reference data observations for each map class, respectively. Overall map accuracies are: at USNVC Class (and USNVC Subclass): 92.9%; at USNVC Formation (and USNVC Division): 92.5%; at USNVC Macrogroup: 87.3%; at USNVC Group 82.0%; at USNVC Alliance: 61.0%; at USNVC Association: 41.0% (continued).

MAP CLASS NAME AND NUMBER	USERS ACCURACY	N_{i+}	PRODUCERS ACCURACY	N_{+j}
Xeromorphic Scrub & Herb Vegetation (Semi-Desert) Class (cont.)				
Warm Desert Scrub & Grassland Formation (cont.)				
North American Warm-Desert Xero-Riparian Macrogroup	**79.9%**	**304**	**16.5%**	**275**
Sonoran-Coloradan Semi-Desert Wash Woodland / Scrub Group	**77.7%**	**254**	**18.4%**	**213**
***Chilopsis linearis* Woodland Alliance (15010)**	**54.2%**	**24**	**93.6%**	**15**
Chilopsis linearis Association (15013)	56.5%	23	93.6%	15
***Hyptis emoryi* Shrubland Alliance (28200)**	**52.9%**	**17**	**0.0%**	**24**
Hyptis emoryi Association (28203)	60.0%	15	0.0%	24
***Justicia californica* Provisional Shrubland Alliance (28171)**	**0.0%**	**30**	**0.0%**	**0**
***Parkinsonia florida - Olneya tesota* Woodland Alliance (16010)**	**84.1%**	**139**	**28.8%**	**162**
Parkinsonia florida – Olneya tesota / Cylindropuntia sp. Association (16024)	50.0%	28	8.0%	32
Parkinsonia florida - Olneya tesota / Hyptis emoryi Association (16025)	69.0%	29	52.2%	33
Parkinsonia florida / Hyptis emoryi Association (16015)	53.1%	51	61.5%	41
Parkinsonia florida / Larrea tridentata - Peucephyllum schottii Association (16013)	37.1%	28	31.9%	24
***Prosopis glandulosa* Woodland Alliance (16040)**	**100.0%**	**5**	**100.0%**	**5**
***Psorothamnus spinosus* Woodland Alliance (16030)**	**17.8%**	**49**	**51.3%**	**17**
Psorothamnus spinosus / Hyptis emoryi - Acacia greggii Association (16035)	19.1%	45	51.3%	17
Warm Semi-Desert Shrub & Herb Wash-Arroyo Group	**19.5%**	**50**	**0.8%**	**62**
Acacia greggii Shrubland Alliance (36010)	**19.5%**	**50**	**0.9%**	**53**
Acacia greggii - (*Bebbia juncea - Hyptis emoryi*) Association (36015)	5.9%	17	0.2%	21
Acacia greggii - Prunus fasciculata Association (36016)	40.7%	27	2.9%	21
***Prunus fasciculata* Shrubland Alliance (32010)**	**0.0%**	**0**	**0.0%**	**9**
Prunus fasciculata Association (32013)	0.0%	0	0.0%	3
Cool Semi-Desert Scrub & Grassland Formation	***100.0%***	***7***	***6.2%***	***23***
Great Basin & Intermountain Semi-Desert Shrubland & Steppe MG	**100.0%**	**1**	**100.0%**	**1**
Intermountain Semi-Desert Shrubland & Steppe Group	**100.0%**	**1**	**100.0%**	**1**
***Ericameria nauseosa* Shrubland Alliance (28210)**	**100.0%**	**1**	**100.0%**	**1**

Table 2. Accuracy assessment statistics for JOTR, by National Vegetation Classification class, formation, macrogroup, group, alliance, and association assignments. N_{i+} and N_{+j} denote the numbers of sample data observations and reference data observations for each map class, respectively. Overall map accuracies are: at USNVC Class (and USNVC Subclass): 92.9%; at USNVC Formation (and USNVC Division): 92.5%; at USNVC Macrogroup: 87.3%; at USNVC Group 82.0%; at USNVC Alliance: 61.0%; at USNVC Association: 41.0% (continued).

MAP CLASS NAME AND NUMBER	USERS ACCURACY	N_{i+}	PRODUCERS ACCURACY	N_{+j}
Xeromorphic Scrub & Herb Vegetation (Semi-Desert) Class (cont.)				
Cool Semi-Desert Scrub & Grassland Formation (cont.)				
Great Basin Saltbrush Scrub Macrogroup	**100.0%**	**6**	**1.8%**	**22**
Intermountain Shadscale-Saltbush Scrub Group	**100.0%**	**6**	**1.8%**	**22**
***Atriplex canescens* Shrubland Alliance (28080)**	**100.0%**	**6**	**1.9%**	**21**
Atriplex canescens Association (28083)	100.0%	6	3.7%	12
Nonvascular & Sparse Vascular Rock Vegetation Class	**32.7%**	**25**	**15.7%**	**22**
Warm Semi-Desert Cliff, Scree, & Rock Vegetation Formation	***32.7%***	***25***	***15.7%***	***22***
North American Warm Semi-Desert Cliff, Scree & Rock Vegetation Macrogroup	**32.7%**	**25**	**15.7%**	**22**
North American Warm Desert Dunes & Sand Flats Group	**0.0%**	**0**	**0.0%**	**0**
***Dicoria canescens - Abronia villosa* Sparsely Vegetated Alliance (60020)**	**0.0%**	**0**	**0.0%**	**0**
North American Warm Semi-Desert Cliff, Scree & Pavement Group	**32.7%**	**25**	**15.7%**	**22**
***Geraea canescens - Chorizanthe rigida* Desert Pavement Annual Herbaceous Alliance (90100)**	**33.3%**	**24**	**16.2%**	**19**
Rock Outcrops (90200)	**0.0%**	**1**	**0.0%**	**3**
Unvegetated - Disturbed/Built-Up (90600)	**35.7%**	**14**	**100.0%**	**5**
Unvegetated – Water (90900)	**100.0%**	**3**	**100.0%**	**3**

In the 2005 version of the map, there were seven Associations (including "mapping units") under the Juniper Alliance (10020), whereas in the final version there are only three. The diversity that was represented in the original classification was not supported by the vegetation data collected during the AA process. While the diversity of species represented in the original classification was present, it didn't support individual Associations based on the presence or absence of these species. It seemed that the Alliance was better described by splitting it into two major groups based on presence/absence of *Coleogyne ramosissima*. The final three Associations include: *Juniperus californica / Coleogyne ramosissima* Association (2012 PI code: 10025), *Juniperus californica / Quercus cornelius-mulleri — Coleogyne ramosissima* Woodland Association (2012 PI code: 10032), and *Juniperus californica / Yucca schidigera / Pleuraphis rigida* Woodland Association (2012 PI code: 10031).

Both the *Pinus monophylla* Alliance and *Quercus cornelius-mulleri* Alliance were changed to include one Association rather than two. *Pinus monophylla* (PIMO) is never very dense in JOTR, unlike other higher elevation areas in the Mojave Desert, and therefore does not have a strong expression as a dominant cover. It generally co-occurs with *Quercus cornelius-mulleri* (QUCO) and sometimes *Juniperus californica* (JUNCAL), and can even be at lower cover than these species. Despite the low cover, these PIMO stands are to be considered part of the PIMO Alliance unless QUCO or JUNCAL cover is >2 times that of PIMO <u>and</u> PIMO has <3% absolute cover. The *Pinus monophylla — (Juniperus californica) / Achnatherum speciosum* Woodland Association (2005 PI code: 10162) was eliminated from the classification and all polygons were changed to *Pinus monophylla / Quercus cornelius-mulleri* Woodland Association (PI code: 10161). The difference between these two Associations was based on a perceived geomorphic difference (north-facing rockier sites with QUCO versus south-facing drier sites with JUNCAL), however, based on the AA data, the presence of *Pinus monophylla — (Juniperus californica) / Achnatherum speciosum* Woodland Association was not corroborated for JOTR. In addition, the final version of the classification has only one association in the *Quercus cornelius-mulleri* Alliance, which is *Quercus cornelius-mulleri — Eriogonum fasciculatum — Ericameria linearifolia* Association (2012 PI code: 21234). The other association, *Quercus cornelius-mulleri — (Juniperus californica / Coleogyne ramosissima* Association (2005 PI code: 21233) was moved to the *Juniperus californica* Alliance under *Juniperus californica / Quercus cornelius-mulleri — Coleogyne ramosissima* Woodland Association (2012 PI code: 10032). Data from other desert regions, as well as from JOTR, supported this Association being a JUNCAL dominated type rather than QUCO dominated.

A reworking of the vegetation types dominated by *Parkinsonia florida* (PAFL) and *Olneya tesota* (OLTE) was done in part to bring them into accordance with the more recent nomenclature used in Sawyer et al. (2009). Rather than two distinct Alliances, these two types have been combined into one Alliance, *Parkinsonia florida — Olneya tesota* Woodland Alliance. This Alliance includes Associations that have only one of the characteristic species, in addition to having Associations with both species present. In the 2005 version of the map, there were two vegetation types mapped under the *Cercidium floridum* Alliance, *Cercidium floridum / Larrea tridentata* (PI code: 16013) and *Cercidium floridum / Hyptis emoryi* (PI code: 16015). After reviewing the vegetation plot data in the context of the most recent descriptions, these two types were renamed as *Parkinsonia florida / Larrea tridentata — Peucephyllum schottii* Association and *Parkinsonia florida / Hyptis emoryi* Association, respectively. Furthermore, based on AA data one polygon has been relabeled as 16013 (previously labeled to the Alliance level in the 2005 version of the map), as well as one polygon previously labeled as 16015 has been changed to the new *Olneya tesota* Association (2012 PI code: 16016). In addition, in the 2005 version there were two vegetation types mapped under the *Olneya tesota* Alliance: *Olneya tesota / (Larrea tridentata - Encelia farinosa* Fan Type (2005 PI code: 16024) and *Olneya tesota - (Cercidium floridum / Hyptis emoryi*) Wash Type (2005 PI code: 16025). The latter was renamed *Parkinsonia florida — Olneya tesota / Hyptis emoryi* Association (2012 PI code: 16025), whereas the first one was renamed *Parkinsonia florida — Olneya tesota / Cylindropuntia* sp. Association (2012 PI code: 16024). The expression of this Alliance in JOTR is largely determined by geomorphology. The active wash channels, particularly within the south-facing canyons along the southern boundary of the park, are usually dominated by the *Parkinsonia florida / Hyptis emoryi* Association (16015), however as the wash channel widens and fans out onto the bajada, *Olneya tesota* becomes more prominent and 16025 becomes the dominant Association within the wash channels. Further upland, above the active wash channels, *Parkinsonia florida / Larrea tridentata — Peucephyllum schottii* Association (16013) generally dominates on the sandy benches within the canyons and on dissected alluvial fans and flats. Similarly, *Parkinsonia florida — Olneya tesota / Cylindropuntia* sp. Association (16024) occurs slightly above 16025 on the open alluvial fans and flats. Finally, the *Olneya tesota* Association (16016) can be found in isolated stands above the wash channels on flat alluvial bajadas.

Additional riparian vegetation types that required refinement after the AA data were assessed in 2008 were *Chilopsis linearis - Psorothamnus spinosus - (Cercidium floridum / Acacia greggii)* Mapping Unit (2005 PI code: 15012) and *Chilopsis linearis / (Prunus fasciculata- Acacia gregii)* Super Association (PI code: 15013). The AA data and field observations by park staff did not support a vegetation type co-dominated by the three species, *Chilopsis linearis* (CHLI), *Psorothamnus spinosus* (PSSP), and *Cercidium floridum* (CEFL). In JOTR, the riparian corridors with PSSP rarely, if ever, included these other two species. In addition, while CHLI could be found with CEFL in low densities in the lower elevation Sonoran zones, it is more often found as the dominant tree layer in the higher elevation riparian zones. Based on this discussion, it was decided that the expression of CHLI in the Park is best represented by the CHLI Association described by Sawyer et al. (2009) and that many of the polygons previously labeled as 15012 should be reassessed. Therefore, 15013 was given a global name change to *Chilopsis linearis* Association whereas all 49 polygons labeled as 15012 in the 2005 version of the map were revisited and recalled by AIS in 2009. This vegetation type, for the most part, was split into one of three Alliances: *Chilopsis linearis* Woodland Alliance, *Psorothamnus spinosus* Woodland Alliance, or *Parkinsonia florida — Olneya tesota* Woodland Alliance.

All 92 polygons represented by *Larrea tridentata* Undifferentiated Playa and Sandy Dune Top Type (2005 PI code: 27019) in the 2005 version of the map were revisited by the photo-interpreters at AIS in 2009. This map class was being used to lump two different habitats with distinctive plant communities, namely the *Larrea tridentata* dominated playas versus sparsely vegetated sand dunes and flats. The latter is a fairly prominent habitat at lower elevations and is distinguished from Sand Dunes (2012 PI code: 90300) by having >2% vegetative cover. The majority (63%) of the polygons that were labeled as 27019 were relabeled as *Dicoria canescens — Abronia villosa* Sparsely Vegetated Alliance (Desert Dunes & Sand Flats) (2012 PI code: 60020). Twenty of the polygons remained as 27019, and the remainder were assigned new

Associations within the *Larrea tridentata* Shrubland Alliance or *Larrea tridentata — Ambrosia dumosa* Shrubland Alliance.

Another map class that was revisited by AIS in 2009 was Annual Grassland (2005 PI code: 60000), this map class was used by AIS in the 2005 version of the map for areas with smooth pediment surfaces or playas without a shrub layer. At the meeting in Redlands in 2009, it was decided to remove this map class because it was capturing a variety of habitats that are better represented by other map classes available in the classification. AIS reviewed all 155 polygons and relabeled 59 with a more specific map class. Of those polygons that were changed, 49 were relabeled as one of the non-vegetated types with <2% cover (25 were relabeled as Playa (PI code: 90400), 19 were relabeled as Dune (PI code: 90300), and five became *Geraea canescens — Chorizanthe rigida* Desert Pavement Annual Herbaceous Alliance (2012 PI code: 90100)), whereas ten were moved into completely different Alliances (2012 PI codes: 28134, 28083, 27031, and 27019). In some cases it was not possible to ascertain a more accurate map class for the polygons labeled 60000, in which case the polygon was relabeled with 90000 (2012 PI code) Non-vegetated habitat (<2% absolute cover) until more data are available.

In some cases the vegetation type was relabeled with a new PI mapping code and/or new name; this action is referred to as a "global recode". There were three Associations in the 2005 version of the map that received global recodes but were also assigned the "Park Special" status: 1) *Larrea tridentata - (Ambrosia dumosa) - Tetracoccus hallii - (Yucca schidigera)* (2005 PI code: 27043) was changed to *Larrea tridentata — Ambrosia dumosa — Yucca schidigera* Association (2012 PI code: 27045); 2) *Yucca schidigera - Tetracoccus hallii* (2005 PI code: 29035) was relabeled as *Yucca schidigera — Larrea tridentata — Ambrosia dumosa* Association (2012 PI code: 29033); and 3) *Larrea tridentata* Clones, which will be discussed in the next section (3.3 Rapid Assessments). The first two Associations were created because the rare plant *Tetracoccus hallii* (CNPS List 4.3) was present in the stand. However, maintaining these Associations based on this distinction was not supported by the vegetation data, not because it was not present but because it did not stand out as a characteristic species. Therefore, it was decided that retaining the locality information for the species might prove useful for the JOTR rare plant program or for future research on the species; for this reason these polygons were retained in the Park Specials map layer. A separate shapefile labeled "JOTR_2012_Veg_Classification_ParkSpecials" was created to display these three map classes, in which the 2005 PI code is retained under the "Park Specials" field.

3.3 Rapid Assessments

Results of the RA plot data were discussed during the August 2009 meeting. A total of 111 RA plots were completed, the results of which are discussed below (Figure 5). A record of all changes made to the 2005 version of the map can be found by looking at the excel document titled "Map and Classification Crosswalk, 2005 to 2012" (Appendix D), as well as in the attribute table of the geodatabase layer titled "JOTR_2012_Veg_Classification_Documentation". In addition, the classification was updated to match the newest nomenclature available in the Manual of California Vegetation Second Edition (Sawyer et al. 2009) and/or NVC standards.

In the 2005 version of the map, eight polygons were labeled as *Prosopis glandulosa* Woodland Shrubland Alliance (2005 PI code: 16040) and no Associations were defined for the Park due to lack of data. In order to clarify which Associations are present in the Park, an assessment of any previous plot data and prior knowledge of vegetation near or at the site was considered. It was determined that six of the eight polygons could be relabeled as the *Prosopis glandulosa* Association (2012 PI code: 16041) and the other two were relabeled as *Prosopis glandulosa / Atriplex spp. — Suaeda moquinii* Association (2012 PI code: 16043). These latter two polygons are located along the southeastern edge of the park boundary and clearly represent the western edge of a large stand of this vegetation type, which surrounds Palen Dry Lake east of JOTR. One RA plot was done to confirm that the stand contains the characteristic species for this Association.

The *Acacia greggii —* (*Viguiera parishii — Eriogonum fasiculatum*) Upland Slope Type (2005 PI code: 36017) was only represented by one polygon in the 2005 version of the map, and this polygon had not been visited during any stage of the project. One RA plot was completed within this polygon, the results of which supported changing the vegetation type to *Larrea tridentata — Encelia farinosa — Pleurocoronis pluriseta* Association (2012 PI code: 27059). The original *Acacia greggii —* (*Viguiera parishii — Eriogonum fasiculatum*) Upland Slope Type (2005 PI code: 36017) is no longer included in the classification, however a similar Association (*Acacia greggii – Eriogonum fasciculatum* Association*)* was added to the classification based on previous plot data (see page 196 of Appendix A).

The Park has an isolated stand of *Cylindropuntia bigelovii* within the Pinto Basin (referred to as the "Cholla Garden") that was represented by two polygons on the 2005 version of the map. One of these polygons was mislabeled as *Larrea tridentata — Encelia farinosa — Fouquieria splendens* Shrubland Association (2005 PI code: 27056) and no AA points were completed during the 2007-2008 field season within this polygon. The other polygon was labeled correctly, as *Opuntia bigelovii* Shrubland Association (2005 PI code: 29050) and a total of six AA points were completed within this polygon. Two RA plots were completed within the mislabeled polygon during the 2009 field season corroborating that the entire stand does in fact belong to the *Cylindropuntia bigelovii* Shrubland Association (2012 PI code: 29051).

During the initial photo-interpretation effort the photo-interpreters were able to delineate 11 polygons where *Larrea tridentata* Clones (2005 PI code: 27022) are located. However, it was decided later that this feature should be considered separately from the type of vegetation represented in the stand, in other words *Larrea tridentata* Clones are not considered a vegetation type but rather a special feature that is ecologically interesting. These polygons have retained the 2005 PI code under the "Park Specials" attribute but have been relabeled as *Dicoria canescens — Abronia villosa* Sparsely Vegetated Alliance (Desert Dunes & Sand Flats) (2012 PI code: 60020) in the 2012 version of the map (see the geodatabase layer titled "JOTR_2012_Veg_Classification_Documentation" to find the Park Specials attribute). Of note, however, is that only two of the eleven polygons have ever been visited due to their remoteness. The two that were visited each have an RA plot confirming that the Desert Dunes & Sand Flats map label is best suited for those stands; however the other nine polygons should eventually be visited to confirm their status.

There were 14 polygons in the 2005 version of the map labeled as *Yucca brevifolia* Wooded Shrubland Alliance (2005 PI code: 13010), whereas in the 2012 version only 4 of these remain at the Alliance level. Each of the 14 polygons was assessed to determine if the data could support a new call to the Association level. There were 10 RA plots completed in 9 of the polygons plus 28

AA points within 7 of the polygons; this information combined with proximity to other polygons and familiarity with the site allowed 10 of the 14 polygons to be relabeled to an appropriate Association. The polygons that were renamed within the Alliance became either *Yucca brevifolia / Prunus fasciculata* Association (2012 PI code: 13014) or *Yucca brevifolia / Coleogyne ramosissima* Woodland Association (2012 PI code: 13012). Seven of these polygons were changed to an Association within a completely different Alliance; this was, in part, due to fires occurring in this area between 1998 (the year the aerial photos used by the PI's were taken) and 2009 when the RA plots were completed. These seven polygons were relabeled as *Acacia greggii — Eriogonum fasciculatum* Association (2012 PI code: 36018), *Prunus fasciculata* Association (2012 PI code: 32013) or *Quercus cornelius-mulleri — Eriogonum fasciculatum — Ericameria linearifolia* Association (2012 PI code: 21234).

There were 114 polygons of the *Coleogyne ramosissima* — (mixed shrub) Super Association (2005 PI code: 28023) in the 2005 version of the map that either retained the same map code (but a new name) or were changed to one of seven different associations in the final version of the map. Apparently the dense stands of *Coleogyne ramosissima* at higher elevations were easier to map than the lower elevation stands, which often had co-dominant species in the stand making correct field calls difficult for the AA plots. A total of ten RA plots were completed in 2009 within ten different polygons to complement the 35 AA plots that were completed in 16 different polygons. Each of the 114 polygons was reviewed a second time by photo-interpreters at AIS in 2009 and a mapping decision was made based on the newest classification and new vegetation data. The majority (51) of the changes were to *Viguiera parishii — Ambrosia dumosa — Simmondsia chinensis* Association (2012 PI code: 28134), whereas 35 were retained as 28023 but given the new name *Coleogyne ramosissima — Ephedra nevadensis* Association. In addition, 16 polygons were renamed as *Viguiera parishii — Eriogonum fasciculatum — Simmondsia chinensis* Association (2012 PI code: 28133) and six polygons were changed to *Yucca brevifolia / Larrea tridentata — Yucca schidigera / Pleuraphis rigida* Woodland Association (13016). Finally, two polygons were changed to *Juniperus californica / Coleogyne ramosissima* Association (10025) and one polygon was changed to each of the following: *Yucca brevifolia / Coleogyne ramosissima* Woodland Association (2012 PI code: 13012), *Larrea tridentata — Ambrosia dumosa — Simmondsia chinensis* Association (2012 PI code: 27046), *Larrea tridentata — Encelia farinosa — Ambrosia dumosa* Shrubland Association (2012 PI code: 27057), and *Yucca schidigera — Larrea tridentata — Ambrosia dumosa* Association (2012 PI code: 29033).

In the original 2005 version of the map, there were 513 polygons of *Ambrosia dumosa – (Eriogonum fasciculatum – Lycium andersonii/Pleuraphis rigida)* Western Mountain Type (43014), which was not identified in the CDFG 2005 Classification (Appendix E), but was added to the classification by AIS during their mapping efforts. Due to the lack of an ecological description and supporting information, this vegetation type was difficult to identify in the field. Therefore, in addition to the 18 AA plots completed within 15 polygons, ten RA plots within 10 different polygons were completed in 2009. The mapping code 43014 does not occur in the 2012 version of the map, all polygons were changed to one of the following: *Viguiera parishii — Eriogonum fasciculatum — Simmondsia chinensis* Association (2012 PI code: 28133) or *Viguiera parishii — Ambrosia dumosa — Simmondsia chinensis* Association (2012 PI code: 28134).

In seven cases all polygons of the problematic vegetation type received a global recode. These were done based on an assessment of data from previous plot data, including AA plots, as well as the new RA plots completed in 2009. There were four that required both name and code changes, these include: 1) 21 polygons of *Ambrosia dumosa – Senna armata – (Psorothamnus schottii)* Eastern Pediment Type (2005 PI code: 43013) are now called *Larrea tridentata — Ambrosia dumosa — Psorothamnus arborescens* Association (2012 PI code: 27044); 2) 643 polygons of *(Ephedra nevadensis – Pleurocoronis pluriseta – Encelia farinosa - Trixis californica – Bebbia juncea – Eriogonum fasciculatum – Lycium andersonii – Acacia greggii)* Low-Elevation Rocky Mountain Type (2005 PI code: 24001) were changed to *Larrea tridentata — Encelia farinosa — Pleurocoronis pluriseta* Association (2012 PI code: 27059); 3) 618 polygons of *Salazaria mexicana – Krameria* spp. *– Encelia farinosa – Hyptis emoryi – Eriogonum fasciculatum – Hymenoclea salsola – Acacia greggii – Tetracoccus hallii* Dense Rivulet/Desert Pavement Type (2005 PI code: 27001) were changed to *Larrea tridentata — Ambrosia dumosa — Krameria grayii* Association (2012 PI code: 27034); and 4) 57 polygons of *Bromus tectorum* fire plot (2005 PI code: 60001) were globally recoded to *Bromus rubens — Schismus (arabicus, barbatus)* Semi-Natural Herbaceous Stands (2012 PI code: 60010). The other three problematic types received global name changes only, these include: 1) 1,301 polygons of Desert Pavement (PI code: 90100) were renamed to *Geraea canescens — Chorizanthe rigida* Desert Pavement Annual Herbaceous Alliance; 2) 142 polygons of *Larrea tridentata – (Ambrosia dumosa – Viguiera parishii)* Higher-Elevation Type (PI code: 27046) were renamed to *Larrea tridentata — Ambrosia dumosa — Simmondsia chinensis* Association; and 3) 305 polygons of *Viguiera parishii – (Ephedra nevadensis – Eriogonum fasciculatum – Nolina bigelovii)* High-Elevation Rocky Mountain Type (PI code: 28133) were changed to *Viguiera parishii — Eriogonum fasciculatum — Simmondsia chinensis* Association. In each of these problematic vegetation types ten RA plots were completed, with the exception of the *Ambrosia dumosa – Senna armata – (Psorothamnus schottii)* Eastern Pediment Type (2005 PI code: 43013), in which 14 were completed.

3.4 Vegetation Mapping and Classification

The 2012 version of the vegetation map for the Park includes a total of 130 map classes, consisting of 51 Alliances (including Provisional Alliances, Semi-Natural Stands, and Special Stands), 78 Associations (including Provisional Associations), and eight non-vegetated map classes (Table 3). Forty-three vegetation types were not mapped due to lack of data. These unmapped vegetation types were documented or observed during vegetation sampling but the plot data lacked enough information to fully describe the vegetation type and in many cases occur in small enough stands (<MMU) that the PI could not pick them up in the aerial photos.

Table 3. Comparison of JOTR's vegetation classification from 2005 to 2012.

Year	Number of vegetation alliances	Number of vegetation associations	Number of non-vegetated classes
2005	47	52	7
2012	51	78	8

The largest amount of land cover in JOTR is classified under the *Larrea tridentata — Ambrosia dumosa* Shrubland Alliance, which is classified into seven Associations (see Table 4). This Alliance covers a total of 1,130 km^2 (279,229 acres), representing 35% of the total area (3,208

km^2 or 792,714 acres) within JOTR. The second largest Alliance in terms of land cover is the *Larrea tridentata — Encelia farinosa* Shrubland Alliance; it covers a total of 708 km^2 (174,951 acres), or 22% of the total area and is classified into three Associations. On the other end of the spectrum, there are eight Alliances, mostly associated with riparian habitats, that have less than 1 km^2 (<247 acres) mapped, these include: *Washingtonia filifera* Woodland Alliance, *Salix gooddingii* Woodland Alliance, *Prosopis glandulosa* Woodland Alliance, *Populus fremontii* Forest Alliance, *Justicia californica* Provisional Shrubland Alliance, *Ericameria nauseosa* Shrubland Alliance, *Cylindropuntia bigelovii* Shrubland Alliance, and *Ambrosia salsola* Shrubland Alliance.

There are 16,499 total polygons on the map, containing 67 map classes. The three most frequent map classes are as follows: 1) *Larrea tridentata — Ambrosia dumosa* Association (PI code: 27031) with 1,718 polygons covering 693 km^2 (171,244 acres); 2) *Larrea tridentata — Encelia farinosa — Ambrosia dumosa* Association (PI code: 27057) which covers 599 km^2 (148,016 acres) within 1,706 polygons; and 3) *Geraea canescens — Chorizanthe rigida* Desert Pavement Annual Herbaceous Alliance (PI code: 90100) for which there are 1,306 polygons covering 116 km^2 (28,664 acres). The first two are also the most abundant Associations in terms of cover. The third largest Association in cover is the *Larrea tridentata — Ambrosia dumosa — Yucca schidigera* Association, with an area of 276 km^2 (68,201 acres). See Table 4 for a complete list of map classes and their respective covers.

There are eight map classes that have less than 2% absolute vegetation cover, these include Disturbed/Built-Up, Water, Dunes, Playas, Rock Outcrops, Recent Burns, Desert Pavement, and a generic Non-vegetated Habitat type (which was only used in cases where a lack of data did not allow a better assignment). With the exception of the first one, all of these are ecologically important for the Park. In particular, the Dune habitat found within JOTR is highly restricted (0.5 km^2 or 124 acres) but supports a unique assemblage of plant species found only on fine sand habitats. For example, *Astragalus aridus, Eriastrum harwoodii*, and *Cryptantha costata* are only found on the sand ramps along the southeastern Eagle Mountains. In addition, Rock Outcrops, which consist of monzogranitic plutons and boulder outcrops, are part of the signature habitat found in the Wonderland of Rocks and one of the reasons JOTR is world famous for rock climbing. This map class covers 6.6 km^2 (1,631 acres) and hosts a number of rock-dwelling species such as *Ericameria cuneata*, *Phacelia rotundifolia*, and *Ivesia saxosa*. In addition, Desert Pavement, though by definition has less than 2% perennial cover, is listed as a distinct Alliance (*Geraea canescens — Chorizanthe rigida* Desert Pavement Annual Herbaceous Alliance) rather than a generic type (as is the case for the other non-vegetated types) and can be found on 116 km^2 (28,664 acres) in the lower elevations of the southern and eastern areas of the Park. Species such as *Phacelia neglecta*, *Erodium texanum*, and *Gilia latifolia* are often found on these surfaces.

Table 4. Total area mapped and estimated areas (accounting for mapping error from accuracy assessment data) (Czaplewski 2003; Lea and Curtis 2010) within Joshua Tree National Park for all map classes represented on the 2012 version of the map. Total area mapped under each Alliance, including all Associations under that Alliance, are shown in the first row in bold. Only in cases where there is at least one polygon labeled at the Alliance level will there be an additional row showing total area mapped with that particular map code.

ALLIANCE	ASSOCIATION	PI MAPPING CODE	MAPPED AREA (km2)	ESTIMATED AREA (km2)
***Acacia greggii* Shrubland Alliance**			**78.93**	**27.69**
	Acacia greggii — (Bebbia juncea — Hyptis emoryi) Association	36015	51.98	19.93
	Acacia greggii — Eriogonum fasciculatum Association	36018	2.60	0.00
	Acacia greggii — Prunus fasciculata Association	36016	24.35	7.76
***Ambrosia salsola* Shrubland Alliance**		**28110**	**0.03**	**1.30**
***Atriplex canescens* Shrubland Alliance**			**0.67**	**0.75**
	Atriplex canescens Association	28083	0.67	0.75
***Bromus rubens — Schismus (arabicus, barbatus)* Semi-Natural Herbaceous Stands**		**60010**	**23.64**	**0.00**
***Chilopsis linearis* Woodland Alliance**			**6.57**	**1.67**
	Chilopsis linearis Association	15013	6.57	1.67
***Coleogyne ramosissima* Shrubland Alliance**			**2.52**	**29.30**
	Coleogyne ramosissima — Ephedra nevadensis Association	28023	2.52	29.30
***Cylindropuntia bigelovii* Shrubland Alliance**			**0.62**	**0.89**
	Cylindropuntia bigelovii Association	29051	0.62	0.89
***Dicoria canescens — Abronia villosa* Sparsely Vegetated Alliance (Desert Dunes)**		**60020**	**15.44**	**15.44**
***Encelia farinosa* Shrubland Alliance**			**30.81**	**132.17**
	Encelia farinosa — Ambrosia dumosa Association	28033	30.81	132.17
***Ericameria nauseosa* Shrubland Alliance**		**28210**	**0.02**	**0.03**
***Eriogonum fasciculatum — Viguiera parishii* Shrubland Alliance**			**182.68**	**94.43**
	Viguiera parishii — Ambrosia dumosa — Simmondsia chinensis Association	28134	123.50	63.84
	Viguiera parishii — Eriogonum fasciculatum — Simmondsia chinensis Association	28133	59.18	30.59
***Geraea canescens — Chorizanthe rigida* Desert Pavement Annual Herbaceous Alliance**		**90100**	**115.81**	**114.48**
***Hyptis emoryi* Shrubland Alliance**			**19.25**	**76.27**
	Hyptis emoryi Association	28203	19.25	76.27

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***Juniperus californica* Woodland Alliance**			**198.36**	**174.63**
	Juniperus californica Woodland Alliance	**10020**	0.09	0.00
	Juniperus californica / Yucca schidigera / Pleuraphis rigida Association	10031	21.19	55.25
	Juniperus californica / Coleogyne ramosissima Association	10025	158.45	110.67
	Juniperus californica / Quercus cornelius-mulleri — Coleogyne ramosissima Association	10032	18.63	8.71
***Justicia californica* Provisional Shrubland Alliance**		**28171**	**0.57**	**0.00**
***Larrea tridentata — Ambrosia dumosa* Shrubland Alliance**			**1129.64**	**1142.55**
	Larrea tridentata — Ambrosia dumosa — Psorothamnus arborescens Association	27044	1.46	0.00
	Larrea tridentata — Ambrosia dumosa — Fouquieria splendens Association	27049	0.67	0.67
	Larrea tridentata — Ambrosia dumosa — Krameria grayi Association	27034	13.72	0.00
	Larrea tridentata — Ambrosia dumosa — Senna armata Association	27047	94.47	411.88
	Larrea tridentata — Ambrosia dumosa — Simmondsia chinensis Association	27046	50.43	69.91
	Larrea tridentata — Ambrosia dumosa — Yucca schidigera Association	27045	276.25	389.85
	Larrea tridentata — Ambrosia dumosa Association	27031	692.65	270.24
***Larrea tridentata — Encelia farinosa* Shrubland Alliance**			**707.63**	**572.67**
	Larrea tridentata — Encelia farinosa — Ambrosia dumosa Association	27057	599.36	474.76
	Larrea tridentata — Encelia farinosa — Fouquieria splendens Association	27056	8.60	66.52
	Larrea tridentata — Encelia farinosa — Pleurocoronis pluriseta Association	27059	99.67	31.39
***Larrea tridentata* Shrubland Alliance**			**94.10**	**288.38**
	Larrea tridentata — Atriplex hymenelytra Shrubland Association	27023	0.11	0.00
	Larrea tridentata / Pleuraphis rigida Association	27021	91.99	139.12
	Larrea tridentata Association	27019	1.99	149.26
***Parkinsonia florida — Olneya tesota* Woodland Alliance**			**54.96**	**98.15**
	Olneya tesota Association	16016	0.02	0.02
	Parkinsonia florida — Olneya tesota / Cylindropuntia sp. Association	16024	9.08	66.89
	Parkinsonia florida — Olneya tesota / Hyptis emoryi Association	16025	7.52	7.85
	Parkinsonia florida / Hyptis emoryi Association	16015	25.87	7.52
	Parkinsonia florida / Larrea tridentata — Peucephyllum schottii Association	16013	12.48	15.89

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***Pinus monophylla* Woodland Alliance**			**130.48**	**107.68**
	Pinus monophylla Woodland Alliance	**10160**	0.15	19.04
	Pinus monophylla / Quercus cornelius-mulleri Association	10161	130.33	88.64
***Pleuraphis rigida* Herbaceous Alliance**			**1.20**	**3.63**
	Pleuraphis rigida / Ambrosia dumosa Association	59011	0.16	0.49
	Pleuraphis rigida / Atriplex canescens Association	59012	1.03	3.14
***Populus fremontii* Forest Alliance**		**15040**	**0.06**	**0.00**
***Prosopis glandulosa* Woodland Alliance**			**0.05**	**0.05**
	Prosopis glandulosa / Atriplex spp. Association	16043	0.02	0.02
	Prosopis glandulosa Association	16041	0.03	0.03
***Prunus fasciculata* Shrubland Alliance**			**1.65**	**4.64**
	Prunus fasciculata Association	32013	1.65	4.64
***Psorothamnus spinosus* Woodland Alliance**			**27.47**	**2.50**
	Psorothamnus spinosus / Hyptis emoryi — Acacia greggii Association	16035	27.47	2.50
***Quercus cornelius-mulleri* Shrubland Alliance**			**58.90**	**63.74**
	Quercus cornelius-mulleri - Eriogonum fasciculatum - Ericameria linearifolia Association	21234	58.90	63.74
***Salazaria mexicana* Shrubland Alliance**		**28140**	**0.00**	**3.46**
***Salix gooddingii* Woodland Alliance**		**15030**	**0.03**	**0.12**
***Tetracoccus hallii* Provisional Shrubland Alliance**			**0.10**	**8.83**
	Tetracoccus hallii Provisional Association	28181	0.10	8.83
***Washingtonia filifera* Woodland Alliance**		**15110**	**0.10**	**>0.01**
***Yucca brevifolia* Woodland Alliance**			**166.50**	**188.04**
	Yucca brevifolia Woodland Alliance	**13010**	0.10	0.00
	Yucca brevifolia — Juniperus californica / Ephedra nevadensis Association	13015	49.77	54.94
	Yucca brevifolia / Coleogyne ramosissima Association	13012	6.65	22.93
	Yucca brevifolia / Larrea tridentata — Yucca schidigera / Pleuraphis rigida Association	13016	56.77	54.80
	Yucca brevifolia / Pleuraphis rigida Association	13021	53.04	55.20
	Yucca brevifolia / Prunus fasciculata Association	13014	0.17	0.17

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***Yucca schidigera* Shrubland Alliance**			**148.92**	**76.68**
	Yucca schidigera — Coleogyne ramosissima Association	29032	57.55	22.94
	Yucca schidigera — Larrea tridentata — Ambrosia dumosa Association	29033	87.40	46.41
	Yucca schidigera / Pleuraphis rigida Association	29034	3.96	7.33
Sparse Vegetation & Non-Vegetated Habitat (less than 2% absolute cover			**10.17**	**5.49**
		90000	2.00	2.00
	North American Warm Semi-Desert Cliff, Scree & Pavement Group (“Rock Outcrops”)	90200	6.63	3.22
	North American Warm Desert Dunes & Sand Flats Group (“Dunes”)	90300	0.53	0.00
	North American Warm Desert Alkaline Scrub & Herb Playa & Wet Flat Group (“Playa”)	90400	0.50	0.22
	Disturbed / Built-up	90600	0.50	0.02
	Water	90900	0.01	0.03
Grand Total			**3207.87**	

Several vegetation types are uncommon within JOTR for ecological reasons such as elevation or habitat limitations. For example, *Parkinsonia florida* and *Olneya tesota* are geographically restricted to the very southern and eastern boundary of the Park, but are more common to the east and south of JOTR in the Sonoran portions of the California desert, for this reason, the *Parkinsonia florida — Olneya tesota* Woodland Alliance is uncommon in the Park. On the other hand, *Pinus monophylla* is limited ecologically to the highest elevations in the Park; therefore the *Pinus monophylla* Woodland Alliance is mainly restricted to elevations above 4,300 feet in the Little San Bernardino Mountains in the western portion of the Park. So, while these vegetation types are uncommon in JOTR, they are not uncommon throughout their geographic range.

However, twenty-six Associations are considered rare within California, and a number of these are unique to JOTR. For example, *Achnatherum speciosum — Sphaeralcea ambigua* Association, *Washingtonia filifera / Salix exigua / Muhlenbergia rigens* Provisional Association, and *Lycium andersonii — Simmondsia chinensis / Pleuraphis rigida* Association have only been documented in JOTR, however, it is possible that with more inventory throughout the desert bioregion (currently underway by NPS and CDFG) these vegetation types will be found to be more common. On the other hand, some of these rare vegetation types, such as *Juniperus californica — Coleogyne ramosissima* Association and *Yucca brevifolia — Coleogyne ramosissima* Woodland Association, are considered rare and threatened throughout their range as a result of environmental degradation due to factors such as increased fire frequency (Evens et al. 2012).

4.0 Discussion

4.1 Summary

In 1996 AIS and CDFG were contracted to work with NPS staff on completing a vegetation map of the Park. Unfortunately, this project was not completed until 2012 due to lack of funding and inconsistent staffing. During the first phase of the project, 1996-2005, a classification and map were produced (referred to as the 2005 version) based on 556 vegetation plots. Details of these efforts can be found in the final reports produced by AIS and CDFG (Appendices E, F, and G), and the 2005 version of the map can be found in the geodatabase ("JOTR_2005_Veg_Classification.gdb") available online at: http://www.usgs.gov/core_science_systems/csas/vip/parks.html.

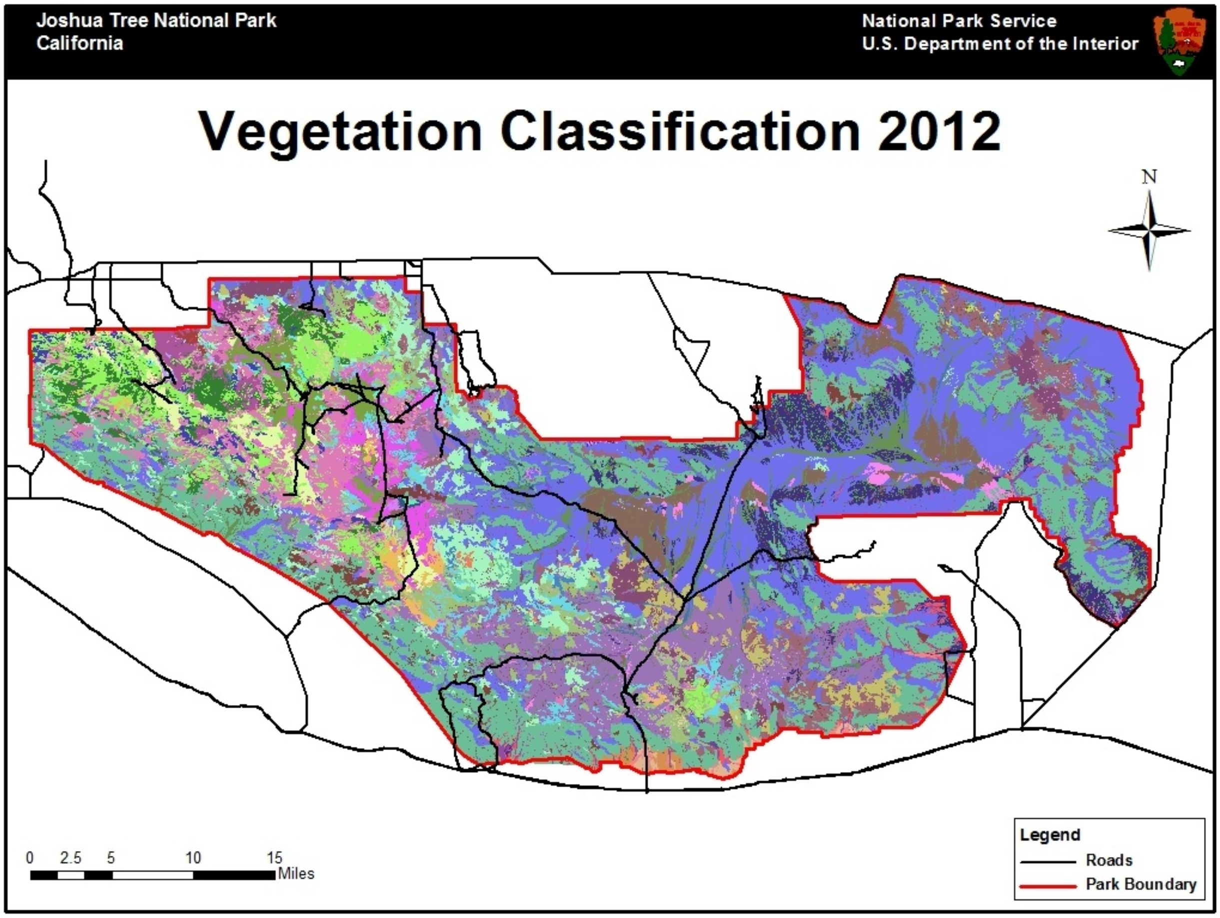

Figure 6. Overview of Joshua Tree National Park final vegetation map containing 67 map classes (map classes not included in the legend for lack of space).

In 2006, funding was secured to begin the accuracy assessment phase of the project. A total of 1,313 accuracy assessment points were completed between 2007-2008, followed by 111 rapid assessment plots in 2009. The data collected during these field efforts were then used to refine the 2005 version of the map and classification. In total, 792,700 acres were mapped within the boundary of Joshua Tree National Park (see Figure 6). There are 130 map classes in the final classification for the park, consisting of 51 Alliances, 78 Associations, and 8 non-vegetated map classes. The final version of the map (referred to as the 2012 version) was completed by AIS and Park staff between 2009-2012. The final classification, which was completed by CDFG, CNPS, and Park staff between 2008-2012, is based on vegetation data from 689 vegetation plots. A geodatabase, titled "JOTR_2012_Veg_Classification.gdb," which includes four feature classes (JOTR_2012_Veg_Classification_Documentation, JOTR_2012_Veg_Classification, JOTR_2005_Veg_Classification, and JOTR_2012_Veg_Classification_ParkSpecials) and all associated vegetation plot data can be found at: http://www.usgs.gov/core_science_systems/csas/vip/parks.html. In addition to this summary report, ecological descriptions of each map class are available in a separate report (Appendix A), a classification list (Appendix B), an ecological key (Appendix C), and a crosswalk showing the relationship between the 2005 and 2012 map classes (Appendix D).

4.2 Lessons Learned

There were several challenges that presented themselves during the 16-year effort to produce the vegetation classification for this Park; some were unforeseen and others could have been avoided with better planning. As is customary, we would like to learn from our mistakes and hope that future projects will benefit from the lessons learned at JOTR. Because the authors of this report were not a part of earlier planning and operational stages (i.e. pre-2005), we recognize that our insights may not reflect the full spectrum of issues.

The most obvious and critical issue affecting this project was the lack of continuous funding and the resulting turnover in Park staff over the duration of the project. This project was part of the prototype phase of the precursor of the NPSVIP, the USGS Vegetation Characterization Program—NPS Vegetation Mapping Program. In this phase, many aspects of the program were being tested, including photo-interpretation, field sampling, and accuracy assessment procedures. It is possible that a clear understanding of the cost and necessary oversight for the project to be successful in JOTR was underestimated from the beginning. We note that experience with the JOTR project was a major influence on improving the operations of the NPSVIP (NPS 2010, Lea and Curtis 2010, Lea 2011).

Another negative outcome of the discontinuity in funding and staffing was that the ecologists from CDFG and the photo-interpreters from AIS were not able to coordinate their findings as effectively as they would have liked (and is now considered a normal expectation of current NPSVIP projects). Because of this, any ground-truthing that might have resolved conceptual differences between remotely sensed classes (by AIS) and field-derived classes (by CDFG) did not occur. Reasonably intensive testing of the field key prior to collecting reference data might have revealed these differences earlier. This was one of the reasons it was decided to collect vegetation data while sampling the accuracy assessment plots in 2007-2008. The AA data were useful in resolving some of these issues for the 2012 version of the map and classification.

4.3 Future Work

As with any project of this nature there are always unresolved issues that need to be reconciled and new questions that arise as a result. This is certainly true for this project. Listed below (not in any particular order) are a number of recommendations that the Park will consider when time and funding become available.

1) The final field key should be tested and refined. The key provided with this report has not been used in the field, and as with any document of this nature, it should be considered a working document. The final key provided here is based on the new classification and aimed to resolve some of the issues encountered by field staff using the 2005 key during the AA process.

2) There are three polygons of *Prosopis glandulosa* Association (PI code: 16041) that do not have any plot data. Vegetation plots should be done in each polygon to verify they are labeled correctly, and if not, relabeled accordingly. In addition, there are a number of *Prosopis glandulosa* stands that are smaller than the minimum mapping unit and have been encountered in the process of doing fieldwork. These stands are of high priority to the Park, as are any stands with obligate riparian species, so an effort to map these stands should be considered. In particular, the following four plots, which were part of the AIS field effort in 2000 (indicated by the prefix JOTRA), should be visited again with the intention of mapping the *Prosopis glandulosa* stand: JOTRA116, 196, 092, 027.

3) Only two of the eleven polygons that are labeled as *Larrea tridentata* Clones (Park Special code: 27022) under the Park Specials field have ever been visited due to their remoteness. The two that were visited each have an RA plot, these data support those polygons being labeled as *Dicoria canescens — Abronia villosa* Sparsely Vegetated Alliance (Desert Dunes) (2012 PI code: 60020), but for lack of any data to accurately label the other nine polygons, all eleven were assigned the same map class. The other nine polygons should be visited to collect vegetation data, then an appropriate map class can be assigned or confirmed if no change is required.

4) Additional vegetation data would be beneficial for the *Dicoria canescens — Abronia villosa Sparsely Vegetated Alliance (*Desert Dunes & Sand Flats*)* (PI code: 60020), in JOTR and throughout the desert region. Currently, this Alliance lacks enough data to describe the variation found across its range and according to Sawyer et al. (2009) the Alliance is best described by the sandy substrate than by the presence of any particular species. With additional data, compositional patterns may begin to emerge and reveal Association level differentiation. Any sampling that is done should be conducted during a good rainfall season such that the ephemeral components of the vegetation can be captured by the data. Also, for sparsely vegetated habitats, such as this, altering the sampling protocol to a belt transect instead of circular plots might decrease the chance of overestimating total cover and improve estimates for relative contributions of the characteristic species to cover.

5) All *Non-vegetated habitats (less than 2% absolute cover)* (PI code: 90000) polygons should be visited and vegetation plots should be done to determine which map class is most appropriate. Again, for sparsely vegetated habitats, altering the sampling protocol to a belt transect instead of circular plots might decrease the chance of overestimating total cover and improve estimates for relative contributions of the characteristic species to cover. In the 2005 version of the map, these polygons were all labeled as *Annual Grassland* (PI code: 60000). It should not be assumed that all 96 polygons are of the same vegetation type because the 90000 map class was only used for lack of any data within the polygon and lack of resolution on the aerial imagery. There were seven

different map classes that 60000 was changed to (see discussion in Results section), not including 90000, so it is possible that the remaining polygons could also be represented by a variety of vegetation types.

6) There are five polygons labeled as *Pinus monophylla* Woodland Alliance (PI code: 10160) in the highest elevations of the Coxcomb Mountains. Ideally, vegetation plots should be completed in each of these polygons, then relabeled to the Association level. Based on the aerial imagery this area did not seem to fit the one Association described for the Park (*Pinus monophylla / Quercus cornelius-mulleri* Woodland Association), if this is true we may be able to add another Association to the classification. Other possibilities might include: *Pinus monophylla / Prunus fasciculata — Rhus trilobata* Association or if Juniper is present, *Pinus monophylla — Juniperus californica / Achnatherum speciosum* Association.

7) In the 2005 version of the map, there were 50 polygons labeled as *Larrea tridentata* Alliance (PI code: 27010), all of which were recoded to *Larrea tridentata — Ambrosia dumosa* Association (PI code: 27031). This global recode was based on vegetation data from 13 AA plots within 11 polygons. Ideally, additional data could be collected with a focus on visiting polygons that have not been field checked. Specifically those that were labeled 27010 in the 2005 version of the map could be targeted, but overall the 27031 map class could benefit from additional plot data because <5% of all polygons have been field checked.

8) An effort to refine the polygons in which *Washingtonia filifera* occur could be beneficial because the polygons drawn around these stands encompass portions of the riparian corridor lacking the species all together. Stands of *Washingtonia filifera* tend to be in small isolated patches that are smaller than the minimum mapping unit (0.5 hectares), making it difficult to map without ground-truthing each site. Also, additional vegetation plots should be conducted within these polygons in an effort to define the stands at the association level. Based on vegetation data collected in 2000 by AIS (JOTRA points) there is support for these stands to be called *Washingtonia filifera / Salix exigua / Muhlenbergia rigens* Provisional Association and the AA data seems to corroborate the presence of this association. After field checking the 10 polygons labeled as *Washingtonia filifera* Woodland Alliance (PI code: 15510), they could potentially be relabeled at the Association level.

9) More thorough surveys of any riparian corridors with stands of *Salix spp*. and/or *Populus fremontii* are of high priority for the Park. Additional data from these areas may help refine the map, as well as provide insight for the Classification. Currently, two of these map classes (PI codes: 15030 and 15040) are mapped to the Alliance level, and in the case of *Populus fremontii*, an Association has not been identified for the Park. We included the *Salix exigua* Alliance and Association (PI code: 15020 and 15021) in the Classification because this seemed to be supported by the vegetation data collected during the AA process. However, these data weren't incorporated into the statistical analyses for the Classification and therefore we have not identified specific plots that might represent this map class. For example, it is possible that the areas surrounding the *Washingtonia filifera* stands (PI code: 15112), upon closer look, could be best

represented by the *Salix exigua* Association (see discussion point #7 above). In addition, anecdotal observations by the field technicians and botanist for the Park seem to support the presence of this vegetation type. Regardless, additional vegetation data and a more detailed approach to mapping these riparian corridors, will undoubtedly reveal the variation in these stands and aid in reclassifying the polygons.

10) Although the *Baccharis sergiloides / Muhlenbergia rigens* Association (PI code: 22031) is not mapped, it is included in the classification due to vegetation data from one plot (JOTRA151). This stand should be revisited, verified, and a polygon could be drawn around the stand. In addition, it is likely that other stands of this Association occur in the riparian corridors throughout the Park, a detailed survey of the riparian corridors would allow these stands to be identified and mapped.

11) Currently, the *Larrea tridentata — Ambrosia dumosa — Fouquieria splendens* Association (PI code: 27049) is only documented by one polygon in JOTR. This area is referred to as the "Ocotillo Patch" by the Park and represents a northern edge of the distribution of *Fouquieria splendens* within California. This stand is unique because it lacks *Encelia farinosa*, which is a characteristic shrub in the more commonly encountered (in JOTR) Associations including *Fouquieria splendens*. No vegetation plots have been completed within this polygon. In addition, there are other isolated stands of this species in the park that may well be repesented by this association.

12) There were three polygons labeled as *Pleuraphis rigida* Herbaceous Alliance (PI code: 59010) in the 2005 version, all three have been renamed at the Association level. Two of these were renamed *Pleuraphis rigida / Ambrosia dumosa* Association (PI code: 59011); one of these is located on the Sand Hill in Pinto Basin and the other is on the eastern flanks of the Coxcomb Mountains. The recall was based on vegetation data collected from the Sand Hill polygon only, so ideally the polygon in the Coxcombs (AIS_ID_2012 = 10043) should be field checked.

13) More plot data for *Chorizanthe rigida — Geraea canescens* Desert Pavement Annual Herbaceous Alliance (PI code: 90100) is needed to better describe the Alliance and potentially define any compositional variation at the Association level. Specifically, in JOTR there are 44 vegetation plots that have been completed within 38 polygons, only 3% of the total number of polygons.

14) Additional plot data for *Viguiera parishii — Eriogonum fasciculatum — Simmondsia chinensis* Association (2012 PI code: 28133) and *Viguiera parishii — Ambrosia dumosa — Simmondsia chinensis* Association (2012 PI code: 28134) should be collected (see the discussion under the Results section). Both of these Associations are only known from JOTR, they were described as a result of this project. With more plot data, from outside the Park as well, these vegetation types may become better defined, in particular, their relationship to closely allied Associations such as, *Viguiera parishii – Eriogonum fasciculatum* Association found in Lake Mead Recreation Area and in the Newberry Mountains of Nevada, may be clarified.

15) Finally, there are a number of polygons labeled as *Bromus rubens — Schismus (arabicus, barbatus*) Semi-Natural Herbaceous Stands (PI code: 60010) that were labeled as *Bromus tectorum* fire plots (2005 PI code: 60001) in the 2005 version of the map. Most of these polygons were burned during the 1995 or 1999 fires in the Covington Flats region of the Park, and many of them had burned at least once in the previous 10 years as well. The PI work that was completed for the 2005 version of the map used images from 1998 and mapping was still in progress during the 1999 fire, therefore many of these polygons were completely burned at the time the area was being mapped for this project. However, by the time we were conducting the AA fieldwork, many of these areas had developed a post-fire vegetation community and would be more accurately defined by a different vegetation type. We did not try to update any of the polygons after our 2007-2009 field efforts for two reasons. First, in this case it is important for the history of the vegetation change to be recorded in the map, and secondly, in order to reclassify all of these polygons accurately, an effort to collect data should take into consideration the boundaries of the various fires. More plot data in these polygons would be of great value to the Park, not only for the purpose of the vegetation map, but because it would help Resource Management understand the progression of post-fire vegetation development.

There are many polygons that have never been field checked, and while this is certainly an unrealistic goal for a Park as large as JOTR, it would be a worthy effort to conduct vegetation plots in as many as possible. Only 3.5% of all polygons have had any type of vegetation plot conducted within it and of the 67 map classes currently on the map, only 28 have vegetation data from >20% of polygons (see Table 5 and Figure 7).

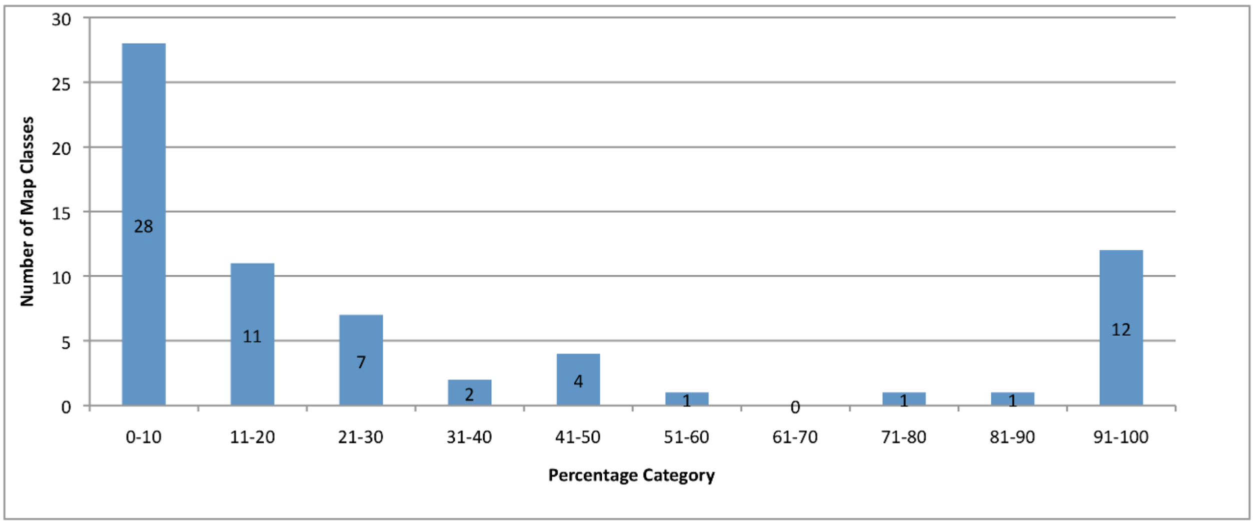

Figure 7. Percentage of mapped polygons (per map class) with vegetation data. Only 15 map classes have vegetation data from over half of the mapped polygons.

Particular attention should be given to any map classes where none of the polygons have been visited, these include PI codes: 10160, 13010, 16016, 27049, 90000, and 90300. An attempt to bring more than half of the map classes above the 50th percentile, in terms of number of polygons with vegetation plots, would be an enormous step in the right direction. Any additional plots that are completed in an effort to advance the vegetation classification should follow the

CNPS combined rapid assessment and relevé protocol (Appendix I). These plots should be placed in a location that is subjectively assessed to be representative of the stand (within the polygon) rather than randomly placing the plot as was done for the AA analysis. More importantly, this new relevé data should be included in any future statistical analyses. And although they are not floristically complete, the data from the AA observations from this project could provide supplementary data that could be used to better circumscribe the vegetation types and could therefore be included, to whatever extent possible, in future classification analyses.

Table 5. Total number of polygons per map class (2012 PI Code), total number of vegetation plots completed within that map class, the number and percentage of polygons with vegetation data collected within it.

2012 PI Code	# Polygons	# Veg Plots	# Polygons w/ Plot	% Polygons w/ Plot
10160	5	0	0	0.0%
13010	4	0	0	0.0%
16016	1	0	0	0.0%
27049	1	0	0	0.0%
90000	96	0	0	0.0%
90300	19	0	0	0.0%
28203	612	19	7	1.1%
90200	389	6	5	1.3%
27057	1706	60	44	2.6%
36015	867	32	25	2.9%
90100	1306	44	38	2.9%
27034	618	23	20	3.2%
27059	644	33	25	3.9%
10161	916	56	38	4.1%
36016	537	41	24	4.5%
27045	973	106	45	4.6%
27031	1718	128	80	4.7%
28033	133	14	7	5.3%
29032	427	36	24	5.6%
27047	778	75	48	6.2%
28134	565	71	39	6.9%
21234	324	39	24	7.4%
13016	319	65	24	7.5%
29033	417	59	32	7.7%
60020	70	13	6	8.6%
10025	785	142	73	9.3%
28133	298	42	28	9.4%
27019	21	11	2	9.5%
27021	201	44	22	10.9%
90400	27	5	3	11.1%
13015	215	67	24	11.2%
16015	140	48	16	11.4%
13021	138	39	16	11.6%
10032	152	31	19	12.5%
16013	190	33	24	12.6%
27046	143	37	22	15.4%
10031	99	32	17	17.2%
90600	63	14	11	17.5%
15013	87	33	17	19.5%
16035	96	57	20	20.8%

Table 5. Total number of polygons per map class (2012 PI Code), total number of vegetation plots completed within that map class, the number and percentage of polygons with vegetation data collected within it (continued).

2012 PI Code	# Polygons	# Veg Plots	# Polygons w/ Plot	% Polygons w/ Plot
60010	57	31	13	22.8%
28023	35	11	8	22.9%
13012	71	32	18	25.4%
16025	40	39	11	27.5%
27056	39	30	11	28.2%
29034	27	27	8	29.6%
16024	36	31	11	30.6%
28181	11	5	4	36.4%
15110	10	5	5	50.0%
16041	6	3	3	50.0%
28171	6	30	3	50.0%
59011	2	2	1	50.0%
27023	7	5	4	57.1%
15030	5	4	4	80.0%
29051	6	27	5	83.3%
27044	21	42	20	95.2%
10020	1	4	1	100.0%
13014	1	1	1	100.0%
15040	3	3	3	100.0%
16043	2	3	2	100.0%
28083	1	18	1	100.0%
28110	1	2	1	100.0%
28210	1	2	1	100.0%
32013	3	10	3	100.0%
36018	3	23	3	100.0%
59012	1	35	1	100.0%
90900	3	3	3	100.0%
All Polygons	**10972**	**598**	**382**	**3.5%**

In conclusion, the authors recommend that the Park continue to work on the vegetation classification by supporting staff within the Resource Division dedicated to this purpose. Management of Park resources can only benefit by having an active vegetation program, as there are many facets of land management that rely heavily on having an accurate vegetation map. For this reason, it is important that both the map and classification remain current by continuing to build upon the existing data.

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