Improving the Implementation of Ecological Monitoring and Adaptive Management in the Clark County Multiple Species Habitat Conservation Plan

Final Report for Contract 2005-TNC-574F-P between Clark County and The Nature Conservancy

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Cover photos: left: *Astragalus geyeri var. triquetrus* (threecorner milkvetch) in seed (Dianne Bangle), right: *Arctomecon californica* (Las Vegas bearpoppy) in flower (Sonja Kokos)

Summary of Report

Monitoring is an essential activity to determine the status, detect change and assess the success of management and conservation actions. Monitoring is a core component of adaptive management. The role of monitoring and adaptive management in the Clark County Multiple Species Habitat Conservation Plan (MSHCP) has been prominently recognized in the original Biological Opinion and the biennial Adaptive Management Reports. Implementing a successful monitoring and adaptive management process for conservation projects and programs, however, has proven difficult and Habitat Conservation Plans pose several unique situations for monitoring and adaptive management.

This report summarizes the efforts of the Clark County MSHCP to address some of the hurdles of implementing a monitoring and adaptive management program, with the focus on the low elevation desert plant species that are part of the MSHCP. The ultimate vision is a precise and efficient monitoring effort across Clark County, Nevada that increases knowledge about each species and enhances management and conservation success through knowledgeable and empowered staff in each jurisdiction.

This report specifically summarizes the work done for the three contract tasks.

The first task was to hold a three day monitoring workshop for all the agencies and jurisdictions party to the MSHCP. This workshop was held from September 25 to 27, 2007 and was attended by 12 individuals. Day one focused on a framework for monitoring that included setting objectives, selecting indicators and developing desired ecological conditions and ecological models. Day two focused primarily on sampling design. Day three was in the field, at Ash Meadows National Wildlife Refuge, and included an exercise developing a monitoring protocol and discussions on data analysis and adaptive management. A workbook was produced for the workshop and all workshop powerpoints are available.

The second task was to review monitoring protocols for four covered species developed for Lake Mead National Recreation Area (National Park Service) and recommend improvements. The draft monitoring protocols were produced in 2007 and were reviewed in the field in 2008 and revised to incorporate changes in 2009. This report summarizes the nine recommendations and how the protocols were improved.

The third task was to develop written guidance to help improve monitoring across all agencies and produce two model monitoring protocols. This Implementation Framework for Monitoring and Adaptive Management was presented at a workshop on October 22, 2008. The guidance is the most extensive part of the report and covers information on setting species priorities, developing monitoring objectives and indicators, developing a study and sampling design and a plan for managing data, determining how data will be analyzed, interpreted and communicated, and making the whole process adaptive. We used this as the basis for developing to model monitoring protocols, for *Astragalus geyeri var. triquetrus* (threecorner milkvetch) and *Arctomecon californica* (Las Vegas bearpoppy). The two model monitoring protocols are included in Appendix A.

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Improving the Implementation of Ecological Monitoring and Adaptive Management in the Clark County Multiple Species Habitat Conservation Plan

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Introduction

Monitoring is an essential activity to determine the status or resources, detect change in resources and assess the effectiveness of management and conservation actions (The Nature Conservancy 2009, McEachern et al. 2007, Atkinson et al. 2004, Elzinga et al. 2001, Mulder et al. 2000). Monitoring is a core component of adaptive management, an approach to management that recognizes the inherent complexity and uncertainty in managing natural resources and structures management into a learning process that maximizes management success and reduces uncertainty (The Nature Conservancy 2009). The role of adaptive management in the Clark County Multiple Species Habitat Conservation Plan (MSHCP) has been prominently recognized in the original Biological Opinion (USFWS 2000) and in several reports (Clark County, Nevada 2006, 2008).

Implementing a successful monitoring and adaptive management process for conservation projects and programs, however, has proven difficult (The Nature Conservancy 2009, McEachern et al. 2007). The reasons for these difficulties are related to monitoring design and sampling (Table 1) or to those related to institutional understanding (of the role of monitoring in conservation), support (resources such as funding, staffing, expertise) and implementation (Elzinga et al 2001). A very common situation is one in which the monitoring results are not communicated to decision-makers or integrated into decision-making.

Monitoring and adaptive management has been particularly absent in Habitat Conservation Plans. Only about 5% of HCPs have a “monitoring plan sufficient to evaluate the [HCP’s] success” (Kareiva et al. 1999). While more of an effort to integrate monitoring and adaptive management in HCPs has occurred in the last decade, there is still a lack of monitoring that can be used to assess HCP success (McEachern et al. 2007, Wilhere 2002).

Habitat Conservation Plans do pose several unique situations for monitoring and adaptive management. Many HCPs cover geographic areas that included multiple jurisdictions and ownerships. The different jurisdictions have different levels of support and resources (funding, staff and expertise) available for monitoring. There is commonly a lack of coordination in developing monitoring protocols, sharing data and lessons learned (McEachern et al. 2007). It is also difficult for these multiple jurisdictions to have a perspective of species conservation at the scale of the whole Habitat Conservation Plan.

The Clark County MSHCP is even more unique in that the majority of the land is administered by federal agencies and the Clark County MSHCP mitigates for their activities on federal land. While they all have a similar mandate related like the MSHCP, they each have different missions and varying monitoring and management capabilities.

The Clark County MSHCP is also one of the largest Habitat Conservation Plans, both in terms of area (over 5 million acres, as large as the state of New Jersey) and covered species (78).

This report summarizes the efforts of the Clark County MSHCP to address some of the hurdles of implementing a monitoring and adaptive management program, with the focus on the low elevation desert plant species that are part of the MSHCP. The ultimate vision is a precise and efficient monitoring effort across Clark County, Nevada that increases knowledge about each species and enhances management and conservation success through knowledgeable and empowered staff in each jurisdiction.

This report summarizes the work done on the three contract tasks:

- Holding a three day monitoring workshop for all the agencies and jurisdictions party to the MSHCP. This workshop was held from September 25 to 27, 2007.
- Reviewing monitoring protocols for four covered species developed for Lake Mead National Recreation Area (National Park Service) and recommending improvements.
- Developing guidance to help improve monitoring across all agencies and develop two model monitoring protocols reflecting this guidance. This Implementation Framework for Monitoring and Adaptive Management was presented at a workshop on October 22, 2008.

Each task is summarized separately in this report. The Implementation Framework for Monitoring and Adaptive Management is the most extensive part of the report. From the protocols for the four covered species that we reviewed in Task 2, two of them were developed into model monitoring protocols. These are presented in Appendix A.

Table 1: Sampling Design Reasons for Failed Monitoring Projects
• The objectives of monitoring, the information desired for management and conservation, are not clearly understood • The precision of data does not allow an assessment of status or change • The study design is inappropriate for the objective of monitoring and/or the sampling design does not allow inferences to be made beyond the area sampled. • The results do not provide an conclusive insights on status or change • The sample units can not be accurately relocated • The sampling design and sampling methods are poorly communicated, thus the monitoring lacks repeatability. • The monitoring design or results are not integrated with management actions. • The data is not analyzed

Background on the Clark County Multiple Species Habitat Conservation Plan

Clark County, located in the southern portion of Nevada, encompasses a large and biologically significant portion of the Mojave Desert where many rare plants, animals and unique habitats are found (The Nature Conservancy 2007). Within the county there is extensive variation in elevation, topography, geology (Figure 1) and current and past land use, resulting in much habitat diversity, high species richness and many endemic species. With Las Vegas in the center of the county, there is extensive urban growth and high demand for land.

In response to the listing of the desert tortoise, a widespread but declining species, in the early 1990s, a temporary permit for private lands in Clark County (the Desert Conservation Plan) was developed while permittees and federal agencies developed a more formal Habitat Conservation Plan. The Clark County Multiple Species Habitat Conservation Plan (MSHCP) was completed in early 2001, and is a component of the Section 10 (a) (1) (B) Incidental Take Permit (Permit) issued by the United States Fish and Wildlife Service (FWS) (Clark County 2008).

The intent and purpose of the MSHCP is to establish a means to address the conservation needs of the entire range of biological resources within Clark County, to maximize prospects for long-term protection for habitats located in Clark County, and to minimize economic disruption cause by listing of additional species (RECON, 2000). The MSHCP describes a set of minimization and mitigation activities that may be funded to reduce and/or offset the anticipated habitat loss over the term of the Permit (Clark County, 2008). The MSHCP covers 78 species, of which 37 are vascular plants. Twenty of those 37 vascular plants are located on the Spring Mountains National Recreation Area which is administered by the United States Forest Service (USFS); all activities associated with these species are covered under a separate Conservation Agreement with the FWS and the FS (The Nature Conservancy 2007). Eight species are either covered under land designation, other agreements or likely benefit from the USFS's Conservation Agreement, leaving nine vascular plants not covered by any specific strategy or agreement.

Two important goals of the MSHCP are to maintain stable or increase populations of covered species and to maintain no net unmitigated loss or fragmentation of habitat. The primary objectives of the MSHCP are: "a) maintenance of the long-term net habitat value of the ecosystems in Clark County with a particular emphasis on Covered Species and b) recovery of listed species and conservation of unlisted Covered Species" (RECON, 2000).

As required in the Permit, Clark County is required to complete a conservation management strategy or agreement for the remaining nine plant species that identifies monitoring actions required to ensure adequate conservation of covered species. Clark County completed the "Conservation Management Strategy for Nine Low Elevation Rare Plants in Clark County, Nevada" (CMS) in 2007 (The Nature Conservancy 2007). The CMS is designed to address rare species conservation needs within the context of a rapidly expanding urban environment and increased public use of the surrounding Federal landscape (The Nature Conservancy 2007, Figure 2). The top recommendations

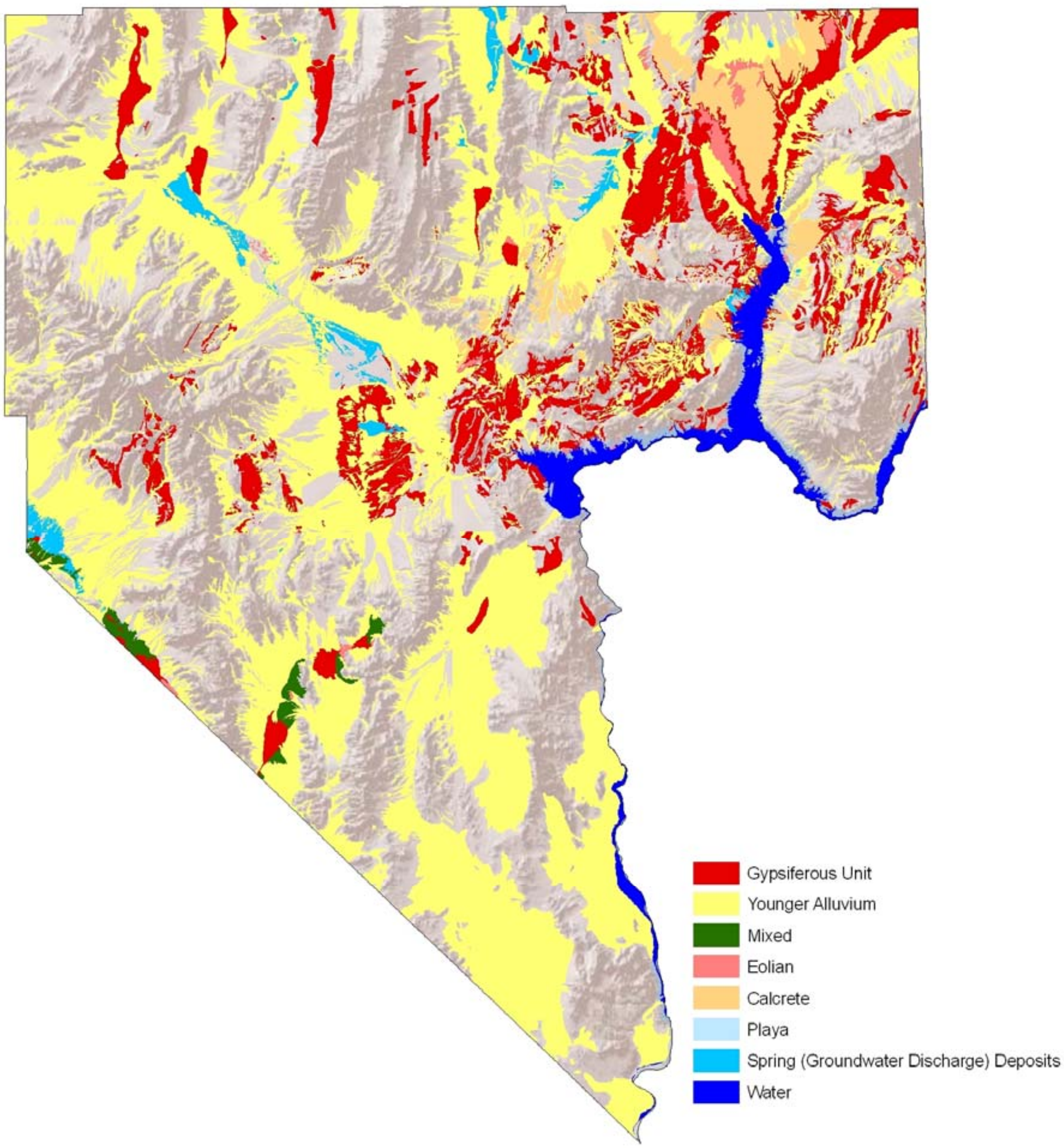

Figure 1. Geology of Clark County

by the CMS are: designate specific rare plant populations for conservation management; coordinate MSHCP communications, funding, projects, monitoring, and adaptive management; continue botanical surveys on federal lands; conduct research on pollinators; and track cumulative loss of rare plant populations and habitats.

All of the nine lower elevation rare plant species covered in the CMS are found in Mojave Desert Scrub. The Mojave Desert Scrub ecosystem includes a number of landforms that are characterized by their soil, erosional features, slope, aspect, and high temperature. Relationships between the hydrological cycle (frequency, duration, and timing of precipitation), soil type, sediment deposition, and erosion create different landforms/habitats that include sand dunes and sites thinly covered with sand, gypsum soils, cliff/rock outcrops, and bajadas (including alluvial fans, washes, and desert pavement) (Clark County 2008). The species discussed in this report are found in sandy, gypsum or calcareous soils.

Table 2: Nine Low Elevation Rare Plants in Clark County, Nevada

Species	Common Name
Anulocaulis leiosolenus var. leiosolenus	Sticky ringstem
Arctomecon californica	Las Vegas bearpoppy
Arctomecon merriamii	White bearpoppy
Astragalus geyeri var. triquetrus	Threecorner milkvetch
Calochortus striatus	Alkali mariposa lilly
Eriogonum bifurcatum	Pahrump Valley wild buckwheat
Eriogonum viscidulum	Sticky buckwheat
Penstemon albomarginatus	White-margined beardtongue
Phacelia parishii	Parish phacelia

While there are nine low elevation covered plant species, four of these occurred on Lake Mead National Recreational Area lands (National Park Service) where they are being actively monitored. These were the four covered species that we reviewed in Task 2. For two of these species, we developed model monitoring protocols. These are presented in Appendix A.

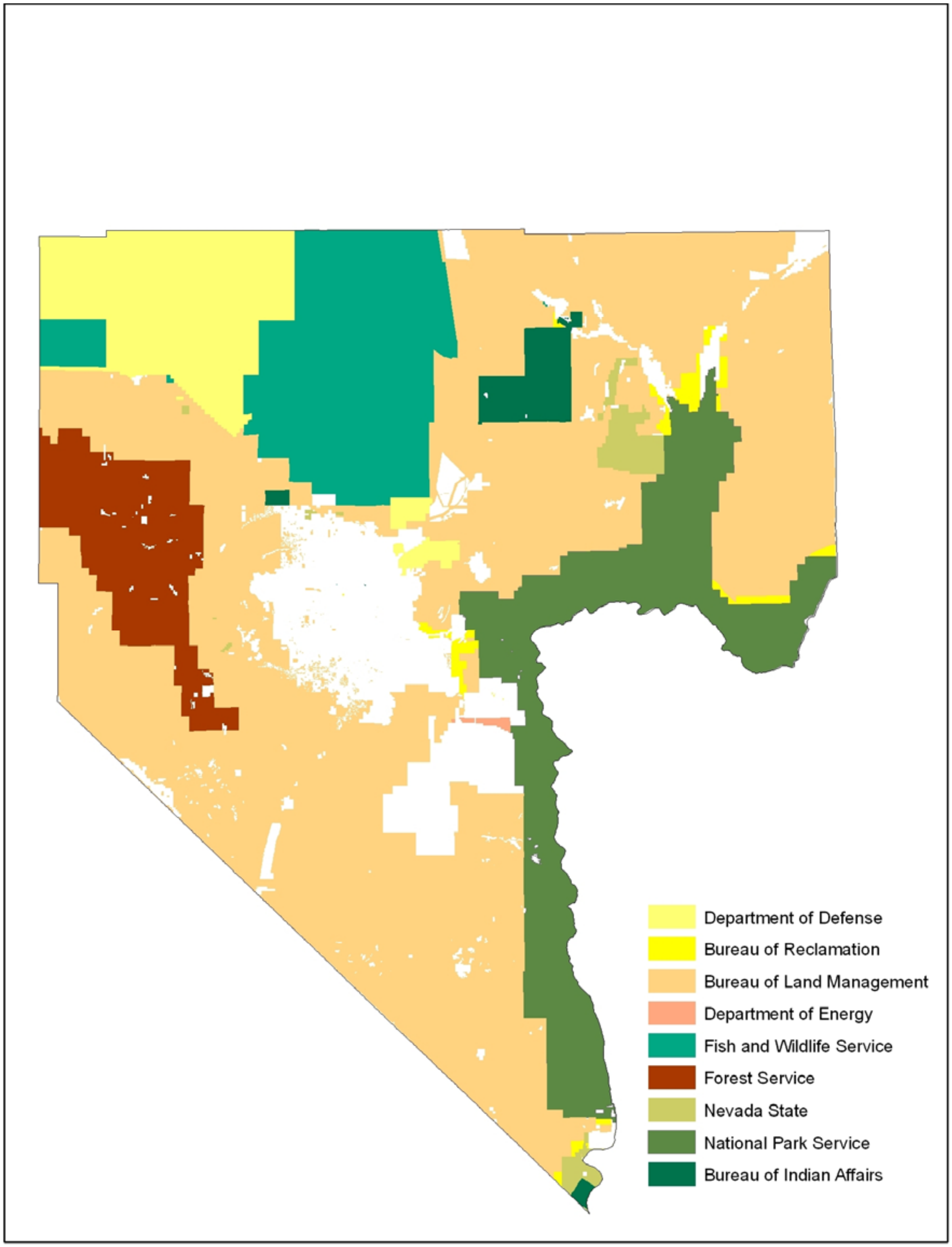

Figure 2. Jurisdictional Ownership in Clark County

Report on the Contract Tasks

Task 1. Monitoring and Adaptive Management Workshop

The Monitoring and Adaptive Management Workshop was held on September 25 to 27, 2007 at the USGS office in Henderson, NV, with field exercises at Ash Meadows National Wildlife Refuge. Lead monitoring staff were invited from all the jurisdictions to the workshop. Attending the workshop were Sonja Kokos, Matt Hamilton and Liz Bickmore (Clark County), Alice Newton (NPS), Dianne Bangle and Scott Abella (UNLV Public Lands Institute), Fred Edwards (USFWS), Kate C. Walker and Bruce Lund (USFS), Leslie DeFalco (USGS), and Don Sada and Dave Mouat (Desert Research Institute).

The workshop was modified from one that has been taught by Nature Conservancy staff for the last 10 years. The standard TNC workshop is 5 days long and integrates lecture sessions on monitoring objectives, sampling design, sampling methods and data analysis with numerous classroom and field exercises.

The Workshop objectives were:

- to empower participants in the design and review of monitoring protocols for T&E species in desert and desert-mountain ecosystems by:
    - introducing a framework for monitoring T&E species including the development of ecological models, desired ecological conditions and results chains
    - developing objective-based monitoring and selecting appropriate indicators
    - presenting the statistical basis of monitoring and sampling design
    - demonstrating the precision of different sampling methods
- To provide an opportunity for participants to develop or improve a monitoring protocol for a project/species that they are working on
- To provide guidance on how to incorporate the concept of adaptive management in monitoring projects

This workshop was three days long. Day one focused on a framework for monitoring that included setting objectives, selecting indicators and developing desired ecological conditions and ecological models. Day two focused primarily on sampling design. Day three was in the field and included an exercise developing a monitoring protocol and discussions on data analysis and adaptive management. A workbook was produced for the workshop. All workshop powerpoints are available at:

http://www.accessclarkcounty.com/depts/daqem/epd/dcp/Pages/dcp_reports.aspx

Task 2. Review of Monitoring Protocols for Four Covered Species at Lake Mead National Recreation Area (National Park Service)

Lake Mead National Recreation Area contains populations of some of the highest priority low elevation covered species in the MSHCP. These include *Anulocaulis leiosolenus var. leiosolenus* (sticky ringstem), *Arctomecon californica* (Las Vegas bearpoppy), *Astragalus geyeri var. triquetrus* (threecorner milkvetch) and *Eriogonum viscidulum* (sticky buckwheat).

Monitoring protocols were developed and pilot monitoring data collected for these four species by one of the authors (Dianne Bangle) in 2007 under a contract with Clark County. The draft monitoring protocols were reviewed in the field in 2008 and revised to incorporate changes in 2009. As a group we developed a list of improvements and recommendations to these protocols.

These are the major findings of the review.

1. Strengthen the linkage between the biology of and threats to the species and the monitoring objectives. Developing appropriate monitoring objectives requires using all available information on the biology and the threats affecting the species and the species habitat. Fortunately, an excellent document, A Conservation Management Strategy for Nine Low Elevation Rare Plants in Clark County, Nevada by The Nature Conservancy, Nevada Field Office, Reno, Nevada (2007) summarizes the biology and ecology of the species and analyses the threats to the species over different ownerships. This information is essential for determining what questions one wants the monitoring to answer. It also provides the basis for the selection of indicators. The linkage also helps to make sure that each monitoring protocol is unique to the species being monitored and not developed through a cut and paste approach.

Improvements made to the monitoring protocols: added more detail on the biology of the species and identified the threats specific to the land ownership being monitored.

Recommended changes to the monitoring protocols: that more quantitative data on trampling, soil disturbance, burros, trails be collected. The monitoring would benefit from a better method of recording these disturbances, both their distribution and intensity.

2. Recognize the threat of investigator impact. In many habitats, such as wetlands and shallow soil communities, the act of monitoring has a disturbance impact on the species and habitat. This is true with the cryptogamic crust in desert communities that may be essential for seedling establishment and survival and providing a source of nutrients for several of the covered species (The Nature Conservancy 2007). All of the protocols were designed with this in mind, but investigator impact was not explicitly discussed.

Improvements made to the monitoring protocols: added a discussion on investigator impact in both the species background and in the sampling methods.

3. Strengthen the clarity and specificity of the monitoring objectives. Clear monitoring objectives focus monitoring on the most important management questions. Monitoring objectives need to have:

- A clear statement of what type of monitoring (status, trend, or effectiveness) is the focus of the protocol. Status monitoring assesses the size or condition of a population at one point in time, comparing it to a threshold. Trend monitoring is designed to be able to detect directional change in size or condition. And effectiveness monitoring is designed to assess the response of the population to one or more specific conservation or management actions, such as invasive species control or trail closure. These different types of monitoring objectives differ by the type of study design, the indicators measured and the precision of the data.
- Biologically realistic baseline measurements and thresholds or level of change detection.

Improvements made to the monitoring protocols: clarified that the baseline density, species richness and cover of native and non-native species will be determined as a average of the first 3 years, that annual sampling will be done only in years with average to above average rainfall, and that the abiotic factors will be correlated with the species density data.

4. Include the management and monitoring response to significant changes in a population. Proactively assessing the potential management and monitoring responses to significant change in a population helps prepare the monitoring program for its next steps and provides insights into what other staff, partners and stakeholders should be involved in the monitoring and management efforts.

Improvements made to the monitoring protocols: added this section to the monitoring protocols.

5. State explicitly what the population of interest is and what the relationship of the plot data is to the population of interest. A monitoring protocol needs to explicitly state the population of interest and whether the plot data will be used to make statistical inferences or considered representative of that population of interest.

Improvements made to the monitoring protocols: added clarity to this section of the monitoring protocols.

6. Assess data for precision. Whenever data is sampled from a population to make inferences about a larger sampling area, that data should be assessed for its precision (for status monitoring) or power (for detecting change). Assessing precision or power can be done at several scales, from quadrats to a plot, from plots to the total population, from multiple populations to all populations within a geographic range. The data collected for three of the four species did not need to be assessed for precision, since they were established to be representative of the sampled population not to make statistical inferences. The subsampling of the plots for *Eriogonum viscidulum* (sticky buckwheat) proved to be relatively precise (+/- 50%) in estimating the total population of the species in the plot after changes after pilot sampling.

Improvements made to the monitoring protocols: Assessed the precision of the *Eriogonum viscidulum* (sticky buckwheat) data and implemented improvements to the sampling design.

7. Strengthen data accuracy and repeatability. Any long-term monitoring effort needs to insure that the locations of the plots and the sampling methods can be repeated over different sampling times (McEachern and Sutter in prep., McEachern et al. 2007, Govus et al. in prep.). This is important in all monitoring, but even more important for monitoring objectives that requires a long time period to measure changing status, detect change or discern the effectiveness of a conservation or management action. For the NPS study, an effort to locate one of the sampling plots using the GPS data failed.

Recommended changes to the monitoring protocols: we recommend that the location of plots and the sampling methods be tested by an individual knowledgeable about monitoring but independent from the work done on these species in the Lake Mead National Recreation Area.

8. Strengthen the detail on data management. The management of the data is an essential stage between data collection and the analysis and archiving of the data. It is also a stage in monitoring that usually is not explicitly discussed.

Improvements made to the monitoring protocols: added information from the report from the Data Management Plan (National Park Service 2007) and from Palmer and Landis (2002) that helps to insure the accuracy of the data collection and the management of the data

9. Strengthen the planning section on data analysis, interpretation and communication. While it is challenging to plan for these components of the monitoring protocol, it greatly helps thinking about the outcomes of the monitoring effort and essential for adaptive management. This is a component of monitoring that is often lacking, especially the communication of monitoring results to decision-makers.

Improvements made to the monitoring protocols: added more detail to the data analysis and added sections on data interpretation and communication.

Task 3. Implementation Framework for Monitoring and Adaptive Management

While reviewing the monitoring protocols for one agency and four species within the MSHCP is valuable, the authors wanted to provide support for monitoring across all the jurisdictions. The monitoring workshop was one means to do this. Another was to capture the available knowledge and lessons learned from the monitoring protocols to develop an Implementation Framework for Monitoring and Adaptive Management (Table 3).

The impetus for this framework also grew out of the piecemeal approach that is seen in monitoring, and the lack of a comprehensive big picture that includes all the steps necessary for a good monitoring and adaptive management protocol. Many times the focus of monitoring staff is on the sampling design, but not on objectives and indicators, data management, or on analysis, communication, and learning. This can result in expensive monitoring programs with no link to actual objectives or to an adaptive management feedback loop.

The implementation framework is structured by five components:

1. **Priorities** – is the monitoring focused on priority species and species locations?
2. **Objectives and Indicators** – is the monitoring addressing the most important objectives for each species and are the most effective indicators selected to detect status, change or effectiveness?
3. **Study and Sampling Design** – is the design of the study adequate to assess the monitoring objectives?
4. **Data Analysis, Interpretation and Communication** – will the data be analyzed, interpreted, communicated, made available, and archived in ways to maximize its impact on decision making?
5. **Adaptive Management** – are the processes and structure present to allow the monitoring data to be used to learn and adapt conservation actions?

Some of the more significant components of the framework are:

- Determining whether the most important monitoring question is a status, trend or effectiveness question
- Insuring the accuracy of data collection, the ability to repeat the monitoring in the future and the management of data
- Identifying the best available information and experts to assist in the interpretation of the data
- Identifying at the beginning of the project the audience of decision-makers and presenting the data in a manner appropriate to maximize their understanding and ability to make decisions that will influence conservation actions and management
- The multiple roles of communication and publishing
    - to communicate results to improve the work of others
    - to facilitate peer review and improvement of your work
    - to archive the methods and results
- To identify early in the process how the results will be used to adaptively manage the target or conservation area

Table 3. An Implementation Framework for Monitoring and Adaptive Management

1. Determine Priorities for Monitoring	2. Focus Monitoring through Objectives and Indicators	3. Develop a Monitoring Protocol that Assesses the Monitoring Objectives	4. Use Monitoring Data to Improve Decision Making
What are the most important species and species locations to use limited monitoring resources?	***What are the most important monitoring objectives?*** ***What information is needed to determine the most important monitoring objectives?*** ***What are the most effective indicators to assess the monitoring objectives?***	***What level of certainty is needed to determine whether the conservation objective is being met?*** ***What study design will effectively and efficiently assess status, trend or effectiveness?*** ***What sampling design will effectively and efficiently answer the monitoring objectives?*** • ***Population of interest*** • ***Appropriate sample unit (SU) and sampling method*** • ***Spatial allocation of SUs*** • ***Temporal allocation of SUs*** • ***Number of SUs*** ***How will accuracy be insured for repeat sampling and the collecting and compiling of data?***	***Analysis and Interpretation of Data:*** ***How will the data be analyzed?*** ***What assistance will be obtained to help with the analysis?*** ***Will the interpretation of the data being done with the best available information and expertise?*** ***Communicating Results:*** ***How will the monitoring results be presented to and used by the appropriate decision-makers?*** ***How will the monitoring results be communicated to improve the work of others?*** ***How will the monitoring results be communicated to facilitate peer review and improvement of your work?*** ***Archiving Data and Results:*** ***Does your organization effectively archive data and project reports?*** ***Is publishing the best archiving option?***
5. Integrate Monitoring and Adaptive Management ***How will adaptive management be implemented for this project?*** ***Does the institution support adaptive management?***			

The Implementation Framework was presented at a workshop on October 22, 2008 in Las Vegas. Attending were:

Aaron Ambos - Southern Nevada Water Authority
Marisa Anderson - US Forest Service
Tanya Anderson - The Nature Conservancy
Derek Babcock - Southern Nevada Water Authority
Mauricia Baca - The Nature Conservancy
Nancy Beecher - Southern Nevada Water Authority
Joseph Betzler – Parsons
Liz Bickmore - Clark County Desert Conservation Program
Jennifer Brickey - US Forest Service
Fred Edwards - US Fish and Wildlife Service
Matt Hamilton - Clark County Desert Conservation Program
Ryan Hewitt – Parsons
Robert Johnson - Southern Nevada Water Authority
Jeri Krueger - US Fish and Wildlife Service
Zane Marshall - Southern Nevada Water Authority
Alice Newton - National Park Service -Lake Mead National Recreation Area
Tim Ricks - Southern Nevada Water Authority
Maria Ryan - Southern Nevada Water Authority
Amber Shanklin - The Nature Conservancy
David Syzdek - Southern Nevada Water Authority
Sue Wainscott - Clark County Desert Conservation Program

The powerpoint presentation for this workshop is available at:

http://www.accessclarkcounty.com/depts/daqem/epd/dcp/Pages/dcp_reports.aspx

The following is a detailed description of the Implementation Framework. Most components of the framework have a level of complexity that limit the ability to summarize the topic in one document or one workshop. We do not pretend to be comprehensive in this description.

1. Priorities for Management and Monitoring

What are the most important species and species locations to focus management and monitoring resources?

Most natural resource managers have more significant species, natural communities or ecosystems to manage and monitor than they have resources. This is true for any land managing agency (National Forests, National Park Service units, National Wildlife Refuges, Bureau of Land Management lands, Department of Defense installations or a Nature Conservancy preserve) and is also true within the context of most Habitat Conservation Plans. This is illustrated well by the Clark County MSHCP which has 78 covered species.

The primary reasons to establish priorities are to make the best decisions on the allocation of time, money and staff. It becomes the basis of using resources and making decisions to obtain the greatest conservation impact. Establishing priorities allows staff to answer questions about where resources are spent and why decisions are made.

Establishing species priorities at the state, national and global scales (www.natureserve.org, USFWS, IUCN) has received substantial attention. It was from a list of national priority species that was the basis of the selection of the 78 covered species in the MSHCP. But the process to set priorities at more local scales, such as ownership by a land managing agency or an area covered by a habitat conservation plan, are less clearly established. While setting priorities at local scales is done often (and should be done more) very little has been written on a process to do it. Elzinga et al (2001) provide a published example, but most efforts are documented in the gray literature.

Clear criteria should be developed to make the process as objective and consistent as possible. Usually the suite of species being considered at a local scale is determined by legal mandate and rarity status. Assessment for management and monitoring would include the condition of the population, active or proposed management, threats to populations (immediacy, intensity and scope of threats) and known decline of populations. The ecological characteristics of the species (life history) or habitat (disturbance frequency) may also be valuable to include. Elzinga et al. (2001) has a comprehensive list.

Clear species priorities allow a managing entity to confidently allocate resources for management and monitoring. The Clark County MSHCP has begun this by their efforts to develop a predictive model of species occurrence for the low elevation desert plant species. It would benefit the MSHCP to establish species priorities, both throughout Clark County, Nevada and within each jurisdiction.

2. Objective-based Management and Monitoring

What are the most important management and monitoring objectives? What information is needed to determine the most important management and monitoring objectives? What are the most effective indicators to assess these objectives?

Important Monitoring Objectives

For any monitoring situation, there are many management and conservation questions that can be asked. One needs to determine which of these questions are the most important to answer with the monitoring. Attempting to answer too many questions will result in poor answers to all of them. The important questions are best determined by active management and current threats.

First there needs to be clarity of what type of monitoring is desired. There are three general types of monitoring objectives:

- Status monitoring is an assessment of the size and condition of a population, from presence/absence and mapping the extent of the population or a qualitative estimate of numbers to a quantitative count. Status assessments are usually compared to a threshold at one point in time, but can be compared over time.
- Trend monitoring is designed to be able to detect directional change in size or condition and requires a quantitative assessment over time.
- Effectiveness Monitoring attempts to determine a correlation or cause and effect between the response of a population and a management (removal of nonnative species, prescribed fire) or conservation action (closing a trail, protective land ownership). The objective is to determine if the action has been effective.

These different types of monitoring objectives require different study designs and potentially different indicators and levels of precision.

Secondly, one needs to be a clear what information the monitoring data needs to provide. Do you want to detect changes in the numbers of individuals in the population, the changes by age or stage class, the spatial extent of the population, the condition of individuals or predict future conditions by gathering the whole set of information needed to develop demographic models? Also what ecological information is valuable to collect with the population data? Obviously, one wants the monitoring data to provide the appropriate information at the desired level of precision to be able to make management and conservation decisions.

Clarity in developing monitoring objectives has many values. They:

- focus and sharpen thinking about the desired state or condition of the resource
- allow the description to others the desired condition of the resource, providing the basis for understanding and collaboration
- determine the conservation actions that will be implemented
- provide direction for the appropriate type of monitoring and the basis for evaluating management success
- identify resource needs for monitoring

Information for Monitoring Objectives

To develop the most appropriate management and monitoring objectives one needs to use the best available information, both from written sources and working with experts. Fortunately, a document, A Conservation Management Strategy for Nine Low Elevation Rare Plants in Clark County, Nevada by The Nature Conservancy, Nevada Field Office, Reno, Nevada (2007) summarizes the biology and ecology of the species and analyses the threats to the species over different ownerships. The approach used in this document is one developed by The Nature Conservancy to identify the highest priority conservation strategies for a single target (species or ecosystem) to multiple targets within an identified conservation area. The process is called Conservation Action Planning (CAP), and provides a structured planning process to assess the ecological needs of a species, threats and barriers, priority conservation actions and monitoring to assess changing status or the effectiveness of the conservation action. Many tools can be integrated into the CAP process, including ecological models, desired future conditions, situation diagrams (adding the human dimension to the ecological model) and results chains (a diagram of expected outcomes from a set of actions).

Effective Indicators

Determining the most appropriate indicators for effectively assessing a monitoring objective is challenging. The complications arise from the number of potential indicators. One way to structure thinking about indicators is to assess them along a continuum of how directly they measure changes in the species of interest. For example, indicators can measure:

- The implementation of management or a conservation action. This would include the area controlled for an invasive species or the area burned under different fire intensities.
- The immediate response of the site to a conservation or management action. This would include changes in the ratio of native to non-native cover and the change in the structure of the vegetation.
- The longer term impact on the species of interest, measuring changes in the size (number of individuals, the number of seedlings) and condition (the number of individuals flowering and producing seed, the vigor of individuals) of the population.

Because of the temporal nature of these indicators, the immediate changes related to management versus the much longer time frame for a population to respond, requires indicators to be chosen at several points along this temporal continuum. It is also challenging to find the minimal set of indicators that provide the manager the information needed to assess the monitoring objective.

3. Monitoring Design

What level of monitoring certainty is needed to determine whether management is meeting its conservation objective? What study design and sampling design will effectively and efficiently answer the management and monitoring objectives? How will accuracy be insured in the relocating the sampling sites, repeating the sampling method and collecting and compiling the data?

Monitoring Certainty

One of the more difficult decisions facing natural resource staff is determining the type and level of ecological monitoring needed to assess the management and monitoring objectives. From the experience of the first author he has found that the key decision that determines the type and level of ecological monitoring is the level of confidence that project or program staff need to have in assessing the conservation or management objectives.

The level of confidence is determined by weighing several factors:

- The uncertainty of the outcomes of the conservation actions– the more uncertain the outcome from the conservation and management actions the more important it is to have a level of monitoring that will detect the direction and extent of change.
- The risk that those actions have to the conservation target – the higher the risk the more important it is to have a level of monitoring that will detect the direction and extent of change.
- The risk that the conservation actions have for the project, program or organization as a whole – the higher the risk the more important it is to have a level of monitoring that assesses the outcomes of those conservation actions.
- Level of financial investment – the higher the financial investment in the property or management actions will increase the potential for a higher level of monitoring.

Other factors to consider in determining the type and level of ecological monitoring include:

- Partnerships – may be able to spread the costs or create demands for higher levels of monitoring.
- Resources – will determine what level and how extensive the monitoring can be.
- Opportunities – to learn significant lessons about management and restoration may determine a higher level of monitoring and potentially generate more funding.

The level of monitoring needed to meet a desired level of confidence is an iterative process. Data from an implemented monitoring protocol may not meet the level of confidence desired by managers, or monitoring data may suggest that a surrogate is an adequate indicator of status or change. Ultimately, the level of monitoring has to be balanced with the resources needed across all of the monitoring that a project or a program desires to do.

Study Design and Sample Design

Once there is a clear monitoring objective and level of desired certainty, then one needs a study and sampling design that can answer the monitoring objective as effectively and efficiently as possible. This has been the focus of most monitoring courses and there is substantial literature on the subject (Elzinga 2001, Fiensinger 2001, Mulder et al. 2000). What differs between the academic and the conservation approach to monitoring that is in conservation one needs to answer specific conservation management questions with minimum resources.

The objectives of a sampling design are to minimize data variability and maximize the detection of status or change. These include the concepts of:

- **Precision**: describes the closeness of repeated measurements (of the same quantity) to one another
- **Repeatability**: ability of measurements to be repeated over time with limiting errors related to taking the measurements
- **Efficiency**: ability of making the measurements easily and quickly, durability of project

There are five decisions that need to be made in developing a sampling design:

- **What is the population of interest?** What is the spatial extent of the population that you want the question answered? What part of that population can you sample?
- **What is the appropriate sample unit and sampling method?** Sample units are the unit used to collect data, such as individual species, quadrates of a certain size, transects of a certain length. The size and shape of the sample unit influences the precision of the data. What sampling method best collects the data needed to answer the monitoring objective?
- **What is the spatial allocation of sample units?** How are the sample units allocated within the spatial area of the population of interest? There are many ways to allocate sample units within an area (stratified, restricted random, two-stage sampling, etc.). All of these methods of allocating sample units are random, but some are better at interspersion (equal distribution throughout the population of interest), implementation, repeatability and efficiency.
- **What is the temporal allocation of sample units?** How often should the sampling units be sampled? Should the sampling unit positions be permanent or temporary?
- **How many sample units should be included in the sample?** There are sample size equations that help determine how many samples are needed to provide a selected level of precision.

More information on each of these decisions can be found in the lecture notes from the 2007 monitoring workshop.

Data Accuracy and Management

Any long-term monitoring effort needs to insure that the locations of the plots and the sampling methods can be repeated over different sampling times. This is important for all monitoring, but even more important for monitoring objectives that will require a long time period and/or multiple individuals to measure status, detect change or discern the effectiveness of a conservation or management action.

In addition it is essential that the data collection insure the accuracy of both spatial and tabular data. For spatial data this includes where the GPS data is collected (what corners, etc.), what data is collected at each coordinate location (including accuracy), what instrumentation is used and the use of standardized data dictionaries. It is recommended that the GPS data be supplemented by hand-drawn maps, identification of reference points, photopoints and a text description of the location. For tabular data, standardized datasheets should be developed that list all the data collected at each site, with procedures for their entry into electronic databases and how the data entry will be assessed for accuracy. Metadata should accompany all spatial and tabular data.

4. Using Monitoring Data to Improve Decision Making

Monitoring is not valuable unless the monitoring data are used to improve decision making. This is the core concept of adaptive management, that monitoring data will be used to adapt and improve conservation actions. This improved decision making can take place at all levels of an organization: not only the direct management of a population or a habitat, but also with law enforcement, environmental education, recreation, land use planning, and the distribution of funding for organizational actions.

To move monitoring data into decision making requires that the data be analyzed and interpreted and that the results are presented and communicated.

Analysis and Interpretation of Data

How is or will the data be analyzed? Is this analysis appropriate for the data collected? What assistance is or being obtained to help with the analysis? Is the interpretation of the data being done with the best available information and expertise?

While statistical analysis is daunting to most biologists, it is essential to analyze and interpret the data that has been collected. There are many types of analyses, although there are some basic ones that are used most often. The simplest analysis, however, has proven its effectiveness for monitoring data: the summary of data with confidence intervals (Stewart-Oaten 1996). Confidence intervals clearly communicate the variability of the data around a central mean and comparing confidence intervals over different sampling periods can show trends or change. Confidence intervals can present complex results clearly, with without oversimplification, to audience of non-scientist decision makers (Stewart-Oaten 1996).

It is essential to get statistical assistance with this phase of monitoring, not when you have data, but as you are developing the sampling design.

The interpretation of data should be done with the best available information and expertise. Monitoring data needs to be interpreted within the context of the biology of the species and with knowledge of the dynamics of the habitat and site specific threats. The results of monitoring should include both the “internal” evidence represented by the data, and with “external” evidence from other studies and knowledge of the biology, ecology and threats to the species.

Communicating Results

How will the monitoring results be presented to and used by the appropriate decision-makers? How will the monitoring results be communicated to improve the work of others? How will the monitoring results be communicated to facilitate peer review and improvement of your work?

To have the greatest impact on decision-making, one needs to know who those decision makers are and what format the information should be present to maximize impact and their use of the data. If one is truly interested in making the best decisions for their own projects and for the resource across its range, they would make the data widely available. Sharing the data and the documentation of adaptive management at your own project will assist others in decision-making for the same or similar resource. In addition, your data can be assessed by others and their input may help you interpret the data and manage the resource better.

Archiving Data and Results

Do the agencies that are party to the MSHCP effectively archive data and project reports? Is there a central depository for the MSHCP for archiving data and project reports? Is publishing the best archiving option?

A common and unfortunate situation among many conservation agencies is the poor archiving of monitoring data and project reports. The first author has several examples of this, where agencies have come back to him to get data and reports from work done in the past. It is the responsibility of the project to insure that the data and report are archived in an accessible location.

One way to insure that results (and sometimes data) are archived is to publish in a peer reviewed journal. There are many journals that accept or focus on conservation data, including Natural Areas Journal, PLoS 1, Conservation Biology and Ecological Applications. When deciding on a peer reviewed journal, think about the journals that other land managers in the same geographic and ecological system are reading. Most often that will be a regional journal such as Madrono or Southwestern Naturalist. Publishing insures that the information will be available and accessible in the future.

Note that the emphasis here is publication to communicate results. Publication for organizational or ego purposes adds another layer and many times distorts the publication process, shifting the monitoring focus from what is best for conservation to what attracts publication attention. This also extends the time to publication as more selective journals have long review processes.

5. Adaptive Management

How will adaptive management be implemented for this project? Does the institution support adaptive management?

Adaptive Management (or Adaptive Resource Management) is an approach that recognizes the inherent complexity and uncertainty in managing natural resources and structures management into a learning process that maximizes management success and reduces uncertainty (The Nature Conservancy 2009). Thus, it is resource management in the context of uncertainty. It is the process of linking ecological management within a learning framework that adapts to the gain of information. It is often shown as an iterative process of planning, management, monitoring, evaluation and adjusting management.

Adaptive Management is more than just management and monitoring with feedback. The successful implementation of adaptive management requires:

- a thoughtful approach to the development and implementation of conservation and management actions
- a well designed process of monitoring the effects of conservation and management
- a formal process of analyzing and interpreting data and using the data and results in decision making
- an institutional structure that allows for adaptive action and active learning

While the above are the core steps in measuring success they are commonly thwarted by lack of institutional support and culture. One of the authors of the conservation plan has done three adaptive management reviews for different agencies, and institutional support was the primary hurdle in all cases.

It is clear that measuring success through monitoring is an institutional commitment, not just project staff or scientists. It requires support and integration and a learning culture. Leadership needs to insure adequate resources, skilled personnel and clear management objectives. The institution has to support sequential decision making, integration and communication across programs and projects and a learning culture, that allows the questioning of the way conservation and management is done.

Format for Developing a Monitoring Protocol

The following format for a monitoring protocol captures the components outlined in the Implementation Framework for Monitoring and Adaptive Management. It was developed and tested on two of the covered species in this project. Monitoring protocols, using this format, are presented for these two covered plant species in Appendix A.

The format is not meant to be a strict template, rather it provides an example of how the components from the Implementation Framework can be incorporated into a protocol. This comprehensive protocol will help avoid several widespread and significant sources of failure in monitoring projects, including the lack of clear communication of monitoring objectives, the lack of repeatability of sampling methods, and lack of planning for data management, analysis and communication.

The development of a monitoring protocol is a collaborative effort. It is not just an exercise for biologists, but requires the involvement of experts in the biology and ecology of the species and individuals knowledgeable about resource management and the planning and structure of the organization.

Species Background and Monitoring Objectives

The need for monitoring

A clear statement of why monitoring, and the resources required for long-term monitoring, is necessary. This should focus on both the species itself (status, priority, ecology) and on the legal and management and/or restoration reasons for monitoring.

Background on the species being monitored

A summary of what is known of the biology, demography, ecology, threats, history of monitoring and the past, present and proposed implementation of management and conservation actions. This section should also discuss the physical impact of monitoring on the species and if there are actions that need to be taken to minimize investigator impact.

Indicators selected for assessing the monitoring objectives

A list of the indicators, with rationale, that will be measured to assess the monitoring questions. The indicators could be categorized by population size (abundance, density), population condition (stage/size classes, vigor, reproduction, demography), habitat condition (invasive species, cryptogamic soils), ecological processes (drought, fire) and landscape context (fragmentation, sources of invasive species).

Monitoring and sampling objectives

Clear objectives stating the type of monitoring (status, trend, or effectiveness), the specific questions the monitoring is intended to answer and the desired precision of the data.

Management Response

A statement of the management or conservation response if a specified threshold or change is detected from the monitoring.

Monitoring Plan

Sampling Intensity/Level of Certainty
A statement of what sampling intensity is needed to evaluate the monitoring objective at a level of certainty appropriate for the project.

Study Design
A detailed study design describing the arrangement and grouping of sample units across population and/or habitat variability or among different management treatment. This includes grouping sample units into controls, paired plots or comparisons and the replication of treatments or units of variability.

Sampling Design
The plan of sampling that minimizes data variability and maximizes the detection of status, trend or effectiveness. A sampling design is needed only if one is sampling a population (versus a total count), when one is selecting a part of the population or community with the intent of showing the quality or nature of the whole. There are five major sampling design decisions that need to be made:

- What “population” do you want to make inferences to?
- What sample unit and sampling method best obtains data on the indicators?
- How will the sample units be spatially allocated?
- How will the sample units be sampled over time?
- How many sample units will be sampled?

Sampling Method
A detailed description of the methods used to sample the population, written so that other individuals can repeat the methods.

Data Accuracy, Repeatability and Management
A description of how the data will be handled in the field and in preparation for analysis. Including:

- How to insure accuracy of repeating the sampling methods, and species identification, spatial data (GPS coordinates)
- Data management includes data dictionaries, spreadsheets, metadata

Protocol Logistics
This summarizes the logistical issues related to implementing the monitoring plan, including:

- What experience and training is needed for personnel to complete the monitoring?
- What is the monitoring schedule and how much time is needed to complete the monitoring and data management during one sampling period?
- What equipment is needed?
- What is the best design for the data sheets/worksheet and how will data be taken in the field?
- How will you insure repeatability in locating plots, repeating the sampling methods and identifying species?

Using Monitoring Data to Improve Decision Making

Data Analysis
A summary of how the data will be analyzed, who will be analyzing it, and how the data will be summarized and presented.

Data Interpretation
A listing of the experts that will assist in the interpretation of the data.

Data Communication
The communication of monitoring data is the essential link to improving decision making and conservation. This section summarizes the answers to these questions:

- Who are the appropriate decision makers that need to know the results of monitoring? How will the data be presented to them?
- How and to whom will the monitoring results be communicated to improve the work of others?
- How and to whom will the monitoring results be communicated to facilitate peer review and the improvement of your work?

Data Archiving
A statement of where the data will be archived in its home organization and where it will be distributed outside of its home organization.

Adaptive Management

To add the dimension of adaptive management to a monitoring project requires proactive linking of all appropriate audiences. This section addresses these questions:

- How will the data be used to improve management and conservation?
- How will the data be used to reduce management and science uncertainty?
- Who is responsible to adapt conservation and management actions and to revise the management and monitoring protocol?
- Does leadership provide the necessary funding and skilled personnel?
- Does the institution support changing management in response to monitoring data?
- Does the institution support integration of programs and projects?
- Does the institution support a learning culture?

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Appendix A.

Model Monitoring and Adaptive Management Protocols for Two Covered Plant Species at Lake Mead National Recreation Area, National Park Service and adjacent Bureau of Land Management Lands

Legal and Regulatory Background

National Park Service (NPS) Management Policies direct managers at Lake Mead National Recreation Area (LMNRA) to survey for, protect, and manage state and locally listed species and other native species that are of special concern to the parks in order to maintain the species' natural distribution and abundance (National Park Service 2002). An additional concern of park managers is maintaining ecosystem health and stability by protecting habitat that supports high biodiversity areas including rare plant sites thus allowing natural processes to occur (i.e. energy flow through the system, natural fluctuations in species abundance). The Clark County Multiple Species Habitat Conservation Plan (MSHCP) lists specific goals for the management of rare plant species as outlined in the A Conservation Management Strategy for Nine Low Elevation Rare Plants in Clark County, Nevada (The Nature Conservancy 2007). The key purposes of the MSHCP are to achieve a balance between 1) long-term conservation and recovery of the diversity of natural habitats and native species of plants and animals, 2) the orderly and beneficial use of land in order to promote the economy, health, well-being, custom and culture of Clark County residents (The Nature Conservancy 2007), as well as, having no net unmitigated loss or fragmentation of habitat in intensively managed areas and maintain stable or increasing plant populations.

Species Selected

The two species for which model monitoring and adaptive management protocols are developed for, *Arctomecon californica* (Las Vegas bearpoppy) and *Astragalus geyeri* var. *triquetrus* (threecorner milkvetch), are two of the rarest and highest priority covered species in the Clark County MSHCP. Some of their most significant populations occur in and around the Lake Mead National Recreation Area.

Monitoring Protocol for *Arctomecon californica* (Las Vegas bearpoppy)

SPECIES BACKGROUND

Arctomecon californica (Las Vegas bearpoppy) is a rare endemic plant found on gypsum soils within southern Nevada and adjacent portions of Arizona. It is one of only three species in the genus, all of which are considered rare and one is listed as Federally-Endangered. The Las Vegas bearpoppy is currently listed by the State of Nevada as critically endangered and is on the Nevada Natural Heritage Programs Sensitive List (ranked as G3S3 -defined as very rare and local throughout its range). It is listed as a covered species under the MSHCP.

The Las Vegas bearpoppy has been documented from 108 locations in east-central Clark County, Nevada, and from 8 sites in the Lake Mead and lower Grand Canyon areas of northwestern Mohave County, Arizona (Mistretta et al. 1996, The Nature Conservancy 2007). The species' distribution ranges from south of the Temple Bar area of Lake Mead to near the southern base of the Virgin Mountains, and from lower Grand Canyon to Las Vegas Valley. Within its range, the species can be grouped into 13 geographically clumped populations (The Nature Conservancy 2007, Figure 1). According to the last major review of this species conducted by Mistretta et al. (1996), the currently known global population of *Arctomecon californica* consisted of at least 830,000 plants restricted to less than 39,500 acres of publicly and privately owned land divided among 99 populations – 91 in east-central Clark County and 8 in adjacent northwestern Mohave County. Other partial surveys done since that time have found some new populations, but no new complete assessment has been completed.

Las Vegas bearpoppy is restricted to dry soils with high gypsum content, and is entirely dependent on incident precipitation. The fine textured, crusted gypsic soils are sparsely inhabited by plants, with those that are present also being unique gypsum-tolerant species (Meyer, S.E. 1980; The Nature Conservancy 2007). High cryptogamic or gypsum crust cover is present at many sites (Meyer, S.E. 1986; The Nature Conservancy 2007) and may be important for seed germination and increasing nutrients and protecting the soil from erosion (The Nature Conservancy 2007)

Dependence on rainfall has been linked to increased germination in addition to increased vigor and survivability. This dependence on fluctuations in regional rainfall patterns results in wide yearly population fluctuations (Mistretta et al. 1996). Las Vegas bearpoppy appears to remain present on some sites over many years while disappearing and reappearing on other sites. Powell (1999) suggested that the sites on which Las Vegas bearpoppy plants remain active over long periods of time may be more important for the survival of pollinators or other associated species than the sites on which Las Vegas bearpoppy plants are ephemeral.

The Las Vegas bearpoppy is a relatively short-lived perennial species (Meyer 1987). Its reproductive biology is similar to an annual plant species, with extensive seed production (Meyer 1987, The Nature Conservancy 2007). Germination is high is wet years, but populations slowly decline over time without additional recruitment. Seeds do persist in the soil seed bank. It is hypothesized that the presence of a cryptogamic crust creates a favorable environment for seedling establishment and survival (The Nature Conservancy 2007)

An assessment of threats by The Nature Conservancy (2007) resulted in 6 threats being ranked as High or Very High. These include: OHV use and trail development, highway and road construction and maintenance, urban development, legal OHV use, military activities and gypsum mining. Several of these threats are geographic specific (military activities, mining, legal OHV use), while others are more widespread. Specifically on the lands that this monitoring protocol is designed for, the primary threats are damage from OHVs, trampling and grazing by cattle, burros and horses, competition from invasive species and potential recreational development.

Many of the fragmented populations within the urban areas of Las Vegas Valley have likely been extirpated in recent years. At the time of the Nevada Natural Heritage Program report in 1996 only 48 (44%) of the Nevada subpopulations of bearpoppy were relatively unimpacted and were considered secure from future development or encroachment (Mistretta et al. 1996). These 48 subpopulations, however, comprised a large majority of the known habitat and numbers of plants. This statistic stresses the importance for an accurate, well-designed monitoring approach for Las Vegas bearpoppy habitat and populations within Clark County.

Prior monitoring for Las Vegas bearpoppy at LMNRA was conducted along 8 transects spread throughout poppy habitat. This study increased knowledge about the population structure and demography of and the threats to the Las Vegas bearpoppy. The major threats to the eight transect sites monitored during the project were from trampling by feral burros and wild horses particularly within the Northshore area and by off-road vehicles on the Bureau of Land Management (BLM) lands. The removal of burros in LMNRA by the

NPS has been ongoing and aggressive. In the 2005 surveys, most of the LMNRA transect sites showed evidence of old disturbance (i.e. motorcycle tracks, burro, horse, and foot prints) but little new disturbance. This may be attributed to the previous burro removals within LMNRA as well as other management actions to reduce off-road vehicles.

Although valuable information was gathered from this long-term study, it did not provide a statistically valid method for monitoring population density and habitat characteristics of Las Vegas bearpoppy and its habitat. A new monitoring plan, reported here, is necessary to evaluate changes within and across populations and monitor progress towards our goal of no unmitigated loss or fragmentation of habitat plus maintaining stable or increasing populations.

The impacts to the habitat caused from scientific field studies can be similar to impacts caused by the general public or trespass animals, but in most cases to a lesser degree. The amount of disturbance from investigators varies depending on the habitat. Individual field oriented research projects and monitoring studies should include an evaluation of investigator impact to the particular habitat upon which the research will be conducted especially if it includes long term monitoring. See the discussion in Sampling Methods on how to limit disturbance of the investigators.

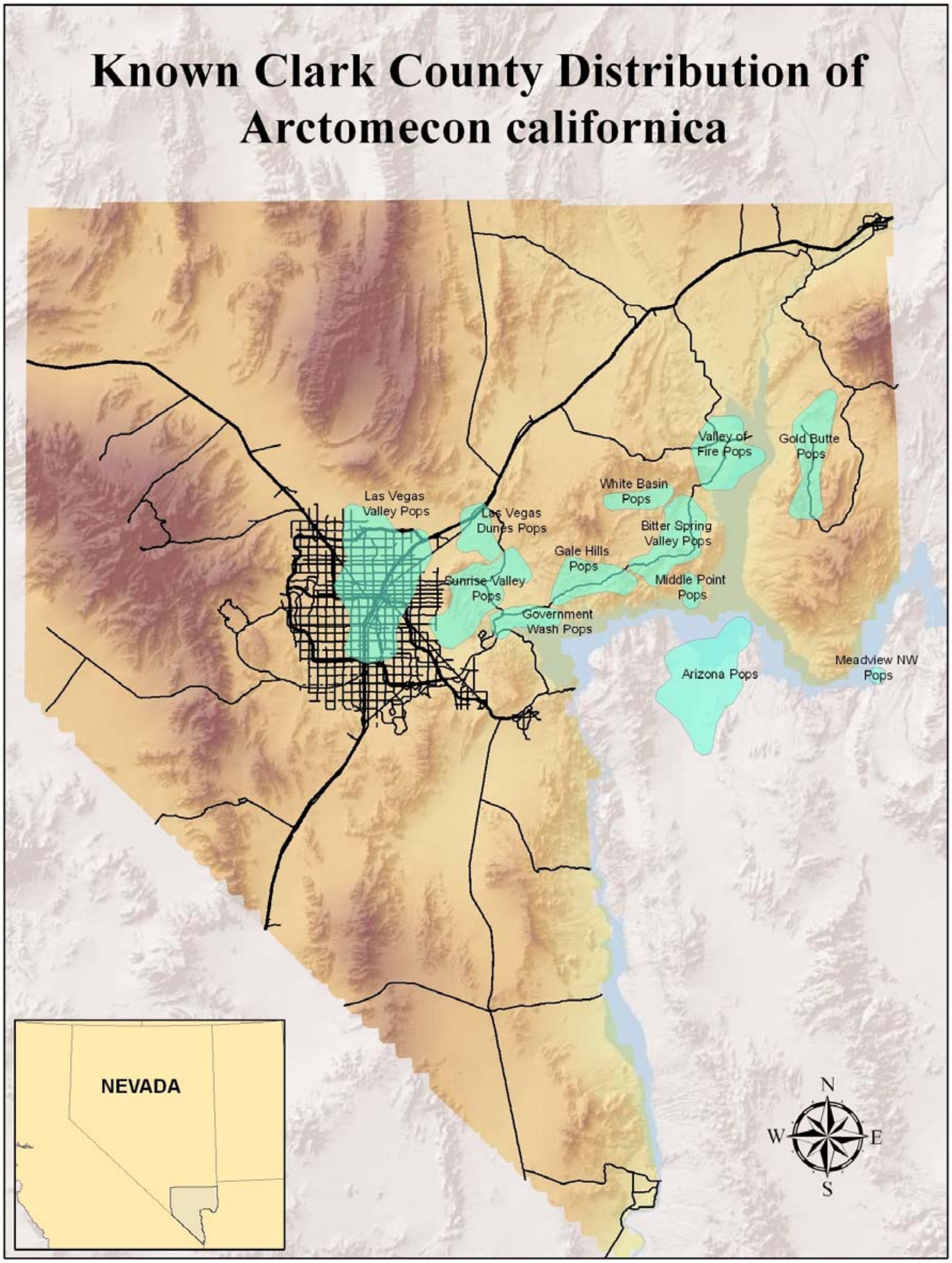
INDICATORS

Species Indicators

- Population density of plants in size classes 2 and above
- Size (age) class of individuals in the population, using these classes (Powell 1999): Size Class 1) 0-5 cm-seedling; SC2) 6-12 cm- juvenile plant 2nd yr; SC3) 13-19 cm-juvenile 3rd yr; SC4) 20-26 cm - adult plant 3rd yr; SC5) 27-32 cm - adult plant 4th yr; SC6) >32 cm - large adult plant)

Habitat Indicators

- Cover of native and non-native plant species
- Species richness
- Soil erosion (potential, if needed)
- Soil compaction
- Cover of cryptogamic crust
- Presence/absence of tracks including, vehicle tracks (OHV, other vehicles), cattle, burros, horses, drainage channels.
- Presence/absence of animal dung (burro, cattle, horse)


Known Clark County Distribution of
Arctomecon californica
Las Vegas
Valley Pops
Las Vegas
Dunes Pops
Valley of
Fire Pops
Gold Butte
Pops
White Basin
Pops
Bitter Spring
Valley Pops
Gale Hills
Pops
Sunrise Valley
Pops
Middle Point
Pops
Government
Wash Pops
Arizona Pops
Meadview NW
Pops
NEVADA
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W
E
S

Monitoring and Sampling Objectives

The objective of the monitoring is to assess the status of selected population of Las Vegas bearpoppy and to gain a greater understanding of the important abiotic and biotic factors that influence population condition. The monitoring objectives for the six monitored populations occurring on BLM and NPS lands within Clark County are:

1. Maintain the current density (within 30% of the baseline measurement calculated from an average of the first 3 years) of stage classes two to six over the next 10 years. Sampling Objective is to be 80% sure of detecting a 30% change in density of Las Vegas bearpoppy in average or above average rainfall years.

2. Correlate the abiotic factors of rainfall, temperature, relative humidity, soil chemistry, soil crust presence and depth, and soil compaction with the density of Las Vegas bearpoppy over the next 10 years.

3. Detect changes in species richness and cover of native and non-native plant species over the next 6 years. For species richness - within 30% of the first measurement and for species cover – within 30% of the baseline measurement calculated from an average of the first 3 years. Sampling Objective is to be 80% sure of detecting a 30% change in species richness and cover of native and non-native plant species in average or above average rainfall years.

Management Response

If change is > 30% of target species population density, native species richness or cover of native and non-native plant species, monitoring will shift from status monitoring to assessing the effectiveness of one or more threat abatement actions such as, invasive species control, limiting OHV access and limiting trespass cattle/burros/horses.

MONITORING PLAN

PILOT YEAR STUDY

Monitoring protocols were developed and plans implemented in 2006 to determine an appropriate experimental design for monitoring Las Vegas bearpoppy. After evaluating the pilot year data (descriptive statistics, power analysis and sample size calculations), it was determined that a modified sampling design was necessary to decrease variability among sampling units and increase power. We determined that increasing the number of study sites, changing the size of the plots, and decreasing the number of plots per site would provide a better representation of overall status and trends of the species throughout its range, while still providing valuable data at the population level.

SAMPLING DESIGN

POPULATION OF INTEREST

The population of interest (as described in the TNC document 'Low elevation rare plants conservation management strategy', Figure 1) to which we want to make inferences to are the combined Bitter Spring Valley, Gale Hills, Gold Butte, Sunrise Valley, and Valley of Fire. The Government Wash and the Las Vegas Dunes populations that occur on public land and were not dormant during recent surveys. Populations that occur on private land or were dormant at the time of modern surveys are not included in the sampling universe. The Las Vegas Valley population was not considered for this project because it has been largely extirpated. The White Basin and Middle Point populations did not qualify for monitoring based on criteria listed below. The Arizona and Meadview NW populations do not occur in Clark County; and were not part of this project.

Within each of the identified populations, patches of Las Vegas bearpoppy are considered sub-populations. The sub-populations selected for monitoring were based on the following criteria: topographic location (not on steep slopes and cliffs), accessibility (within 1km from a road or shoreline), and size (greater than 300 plants). One or two subpopulations within a population were chosen for monitoring.

SAMPLING UNIT AND SAMPLING METHOD

A three-tiered approach to monitoring was employed to address the management objectives. We placed a permanent 100 m transect at each selected sub-population. To address the trends in density of Las Vegas bearpoppy we placed. three permanent plots (10 X 40m) along the transect.

To address community dynamics we placed one large permanent plot (50 x 50m), divided into smaller quadrats (10 x 10m) along the transect, which includes at least one Las Vegas bearpoppy plot.

Abiotic data will be collected in separate 1 x 1m temporary plots spaced along a 2nd transect placed so that it runs in and out of the habitat patch. Abiotic data will be collected in the first year of monitoring and then as determined necessary based on changes in climate patterns or dramatic shifts in species composition or cover. Rainfall, temperature, relative humidity, soil pH, soil chemistry, soil color/texture, and topography (aspect, slope) data will be collected.

Las Vegas bearpoppy occurs on gypsum substrate with a substantial cryptogamic crust component. This soil type and the biological crusts that occur on these soil types are considered sensitive and easily damaged. Monitoring in such delicate habitat poses a problem for resource managers in that investigator impact may cause a significant amount of damage, which may be detrimental to the habitat dynamics and the plants found within this habitat. Minimizing habitat disturbance is an integral part of the current monitoring protocol. Disturbance trails and drainage channels will be used as much as possible to move around within the habitat. Mapping the target species within this habitat is accomplished using paper grid maps instead of collecting a specific GPS coordinate for each plant. This manual mapping technique minimizes the impact to the habitat because the researcher can stay on disturbance trails to map the plants instead of walking across undisturbed gypsum soil to GPS every plant.

SPATIAL ALLOCATION OF SAMPLING UNITS

All sub-populations selected for monitoring were equally weighted by plot number and size. The transect was subjectively placed in an area of high density at each site. The target species plots were placed along the transect using a restricted random sampling manner with one plot placed randomly within each 33 or 34 meters. The community ecology plot was randomly placed along the transect. A separate transect will be placed so that it runs in and out of the habitat supporting the sub-population. The abiotic plots will be randomly spaced along this 2nd transect.

TEMPORAL SAMPLING OF SAMPLE UNITS

Las Vegas bearpoppy rare plant and community ecology plots will be sampled annually the first 3 years and then subsequently every 3 years or in years with above average rainfall. Abiotic data will be collected in the first year of monitoring and then as determined necessary based on changes in climate patterns or dramatic shifts in species composition or cover. Data collection will take place beginning the last week of April and continuing through the 3rd week of May when plants are in a flowering/fruiting stage and seedlings are visible.

SAMPLING METHODS

At each site, disturbance trails (burro trails, off road vehicle tracks, and small drainages), which are common in this habitat, will be utilized as much as possible to set up plots and collect data. Vegetation is sparse in this habitat, which makes using disturbance trails for gathering data possible in most cases. The transect start and end points will be permanently marked, as well as the corners of all plots (except 1 x 1m) with an 8 inch nail and washer plus a stamped, aluminum tag. Meter tapes will only be used to mark the length of the transect and set up the plots in the first year of the study. A range finder will be used in consecutive years to place flagging at every 10 meter mark within the target species and community ecology plots decreasing the need to drag tapes across the habitat, which increases disturbance of sensitive gypsum soil and biological crusts. Occasionally, meter tapes may be needed for the larger community ecology plots when the terrain is rough and range finders are less effective.

GPS coordinates were recorded at all plot corners to include: easting, northing, elevation, and level of accuracy. When a plant was collected within a plot for identification, the specimen would be identified soon after collection and then processed as a voucher specimen and subsequently stored in the Lake Mead Study Collection Herbarium or at the Wes E. Niles Herbarium on the campus of the University of Nevada Las Vegas.

Upon completion of monitoring each year, researchers entered data into the appropriate database and compile notes from all researchers involved in data collection.

Protocol Logistics

Personnel requirements and training

One lead field researcher will be responsible for completing monitoring each year including, scheduling and preparing for data collection, training assistants, gathering all necessary equipment needed for monitoring, transportation to each site, making sure data is collected properly and is input in to the database, and ensure that voucher specimens are processed. The lead researcher must meet the following requirements:

- Strong familiarity with local flora both native and invasive species
- Experience conducting plant surveys
- Familiarity with gypsum and biological crust habitats
- Rare plant knowledge
- Ability to hike for considerable distances and up and down uneven terrain
- Ability to tolerate high ambient temperatures during field work
- Experience driving on 4-wheel drive roads

Assistant researcher(s) will be responsible for helping lead researcher in above described duties plus have the ability to hike for considerable distances and up and down uneven terrain, tolerate high ambient temperatures, and quickly learn several plant species commonly found in study area.

Operational requirements

Data collection at each monitoring site should be complete within 2 days unless unexpected problems occur (bad weather, damaged equipment, illness, access issues, etc.).

Equipment

Equipment needed to successfully complete monitoring for Las Vegas bearpoppy include: one four wheel drive vehicle, one or two GPS units, NPS park radio, binoculars, camera, compass, one 100m long meter tape, pin flags, pins with pre-measured string, cardboard cutouts, PVC pipe frame (1 x 1m), implements for abiotic sampling, data sheets, pen and pencil, sharpie, field notebook, plant press, and pruners. In the first year of monitoring additional equipment will be necessary to delineate plots including: eight inch nails, washers, and small aluminum tags.

DATA ACCURACY, REPEATABILITY AND MANAGEMENT

Guidance for data accuracy and quality comes from the report from the Data Management Plan (National Park Service 2007) and from Palmer and Landis (2002).

Spatial Data

Spatial data to be collected during this project will include locations of grids, plots, and transects for covered plant monitoring and research. GPS coordinates will be recorded at each corner of plots or at end points of each transect including: easting, northing, elevation, and accuracy. Where applicable, all major disturbance trails within populations chosen for monitoring will be identified using GPS units set to collect point locations every 6 seconds. Where GPS data collection isn't possible (i.e. canyons), coordinates will be determined from GIS data layers. Spatial data will be collected with a Thales MobileMapper CE (or equivalent mapping-grade GPS) using standardized data dictionaries in the GPS. In some cases when only general locations are required (e.g., for planning purposes on proposed vegetation manipulations), a Garmin GPSMAP 76Cx may be used. All data requiring accurate locations will be collected with a maximum Probability Dilution of Precision (PDOP) of 6.0 and will be WAAS differentially corrected. Point locations will be recorded using the average of at least 20 points taken at 1 second intervals. All data will be collected using the UTM 11 NAD 83 projection and datum.

All spatial data will be stored as ESRI shapefiles/geodatabases. Linked tables (if any) will be documented in the data including the field used to link between tables. Data dictionaries will be developed for all spatial data. Data dictionaries will be incorporated into the attribute section of the metadata. All data will be provided with accompanying metadata. The metadata for spatial data will be in a standard ESRI metadata format.

Tabular Data

Tabular data collected during this project will include information related to surveys, population estimation, and community ecology data. In general, these data include: site name; plot, transect, and quadrat number; date; survey personnel; survey start and stop times; and general comments. These data will be collected in the field on standardized datasheets. To assure quality of vegetation data collected in the field, a team of two biologists will consist of at least one individual trained in local plant identification and ecology. The individual making observations and measurement of foliar cover and height will seek confirmation from their team member on difficult estimates. Personnel will be rotated through the teams with the intent of equalizing estimates across personnel. In the event that only one researcher is available, he/she must be experienced with the flora of the Mojave Desert, the target species and its habitat, and the monitoring protocols. Cardboard cutouts representing 2.5%, 5%, 10%, and 25% of quadrat areas will also be used as visual aids to more accurately estimate percent cover. Species identification questions will be submitted to individuals trained in plant identification or forwarded to the individual functioning as the LMNRA botanist. Data sheets will be evaluated at the end of each site visit to confirm recordings. Scientific notebooks will be maintained as specified in SOP(s) and will contain or reference, as appropriate, the following technical information:

* a description of the work performed;
* names and dates of individual(s) performing the work and/or making the entries;
* any changes to the methods used;
* equipment and software used;
* identification of associated data files;
* preliminary observations and conclusions

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USING MONITORING DATA TO IMPROVE DECISION MAKING

Monitoring data can be valuable to land management agencies in that they can help determine the appropriate action or no action alternative concerning the management of rare plant habitat. Additionally, a long term monitoring data set will benefit future researchers or land managers by providing them with the necessary tools to make decisions about a particular species, its habitat, or threats status. Without such data, future managers would have to begin at square one in evaluating the health or status of a rare plant species and its habitat without the benfit of knowing how the populations have changed through time.

DATA ANALYSIS, AND REPORTING AND ARCHIVING

Consultations with a statistician have begun and will result in a description of statistical analyses that will be performed on the monitoring data. Consultations with LMNRA data managers resulted in a database in which to store and access all monitoring data

Data Interpretation

Data interpretation may be provided by some or all of the following, UNLV staff statistician, BLM botanist, NPS botanist, Clark County staff.

Data Communication

The communication of monitoring data is the essential link to improving decision making and conservation. The appropriate decision makers that need to know the results of monitoring are the Chief of Resource Management at LMNRA and the Assistant Field Manager for Renewable Resources, Las Vegas office, BLM. The data will be presented through power points or findings reports. Reports and scientific publications will be developed after 2 years to communicate results to improve the work of others and to facilitate peer review and the improvement of this work.

Data Archiving

Data will be archived in the LMNRA. Distribution of data outside the NPS may meet specific conditions set by the NPS and the receiving agency. Outside repositories will include, Clark County Central Repository, BLM, and the Nevada Natural Heritage Program database.

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Poppy - Density Datasheet

Site: _____ Plot: _______ Date: _____ Recorder: ________________

Quadrat:			
Plant ID	SC	Cond	Flwr/Fr
	Y/N		Notes
Tracks:			
Scat:			

Quadrat:			
Plant ID	SC	Cond	Flwr/Fr
	Y/N		Notes
Tracks:			
Scat:			

Quadrat:			
Plant ID	SC	Cond	Flwr/Fr
	Y/N		Notes
Tracks:			
Scat:			

Quadrat:			
Plant ID	SC	Cond	Flwr/Fr
	Y/N		Notes
Tracks:			
Scat:			

Size Class: **1**) 0-5 cm-seedling; **2**) 6-12 cm- juvenile plant 2nd yr; **3**) 13-19 cm- juvenile 3rd yr; **4**) 20-26 cm - adult plant 3rd yr; **5**) 27-32 cm - adult plant 4th yr; **6**) >32 cm - large adult plant

Condition: 1 = Excellent (No dead material, looking very vigorous) 2= Good (little dead material and live material looking healthy) 3= Fair (a lot of dead material and live material with low vigor) 4= Poor (mostly dead or dying)

Flower/Fruit: **Y/N**; Mark **Y** if plant flowered or fruiting this year, mark **N** if it did not

Community Ecology Plot Datasheet

Site ____ Species: ________ Date ____ Recorder ____________

Quadrat:			
Species	Cover	# Rare	Notes
	Y/N	Notes	
Trails:			
Scat:			

Quadrat:			
Species	Cover	# Rare	Notes
	Y/N	Notes	
Trails:			
Scat:			

Quadrat:			
Species	Cover	# Rare	Notes
	Y/N	Notes	
Trails:			
Scat:			

Quadrat:			
Species	Cover	# Rare	Notes
	Y/N	Notes	
Trails:			
Scat:			

NOTE: 0.25 m2 = 0.25%; 0.50 m2 = 0.50%; 1 m2 = 1%;

VEG. COVER:
1 = 0-1%, 2 = 1-2%, 3 = 2-5%, 4 = 5-10%
5 = 10-25%, 6 = 25-50%, 7 = 50-75%, 8 = 75-95%, 9 = >95%

Quad Map

Site ________ Plot ________ Quadrat ________ Date ________ Researcher ________

Species: ________

NW NE

SW SE

Monitoring Protocol for *Astragalus geyeri* (threecorner milkvetch)

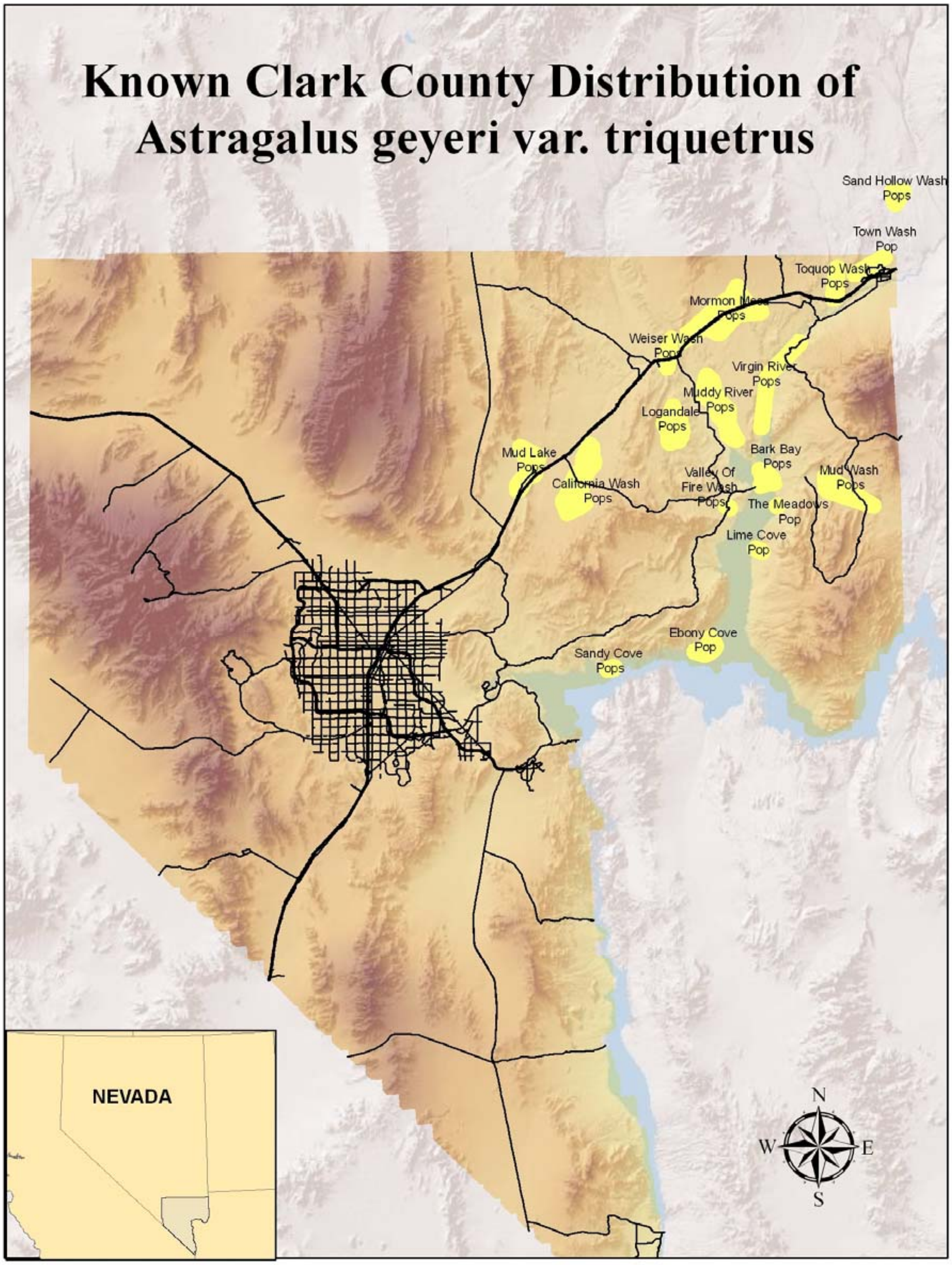
SPECIES BACKGROUND

Astragalus geyeri var. *triquetrus* (threecorner milkvetch) is a rare, sand loving, annual plant endemic to Clark and Lincoln Counties in southern Nevada and Mojave County in northwestern Arizona. This species is on the Nevada Natural Heritage Programs Sensitive List (ranks G2 S2-defined as imperiled), is listed as a covered species under the (MSHCP), and has status as a critically endangered species in the state of Nevada. The northern and eastern most distributions of this species are at Sand Hollow Wash in Lincoln County and at Coon Creek in Mojave County. Threecorner milkvetch in Clark County reaches a southern extension at Sandy Cove on the north shore of the Boulder Basin (LMNRA) and a western extension at Dry Lake Valley in Clark County. The highest concentration of populations is found in the Mormon Mesa area of Clark County on Bureau of Land Management (BLM) land (Niles et al. 1995).

Threecorner milkvetch has a geographic distribution associated with a sedimentary deposit called the Muddy Creek Formation (Niles et al 1995). This formation is widely exposed in the hills along the Overton Arm, Virgin Basin, and Boulder Basin sections of LMNRA and extends northward along the Virgin River valley and westward along the Muddy River and Meadow Valley Wash. Weathered sediments from this formation, re-deposited as aeolian or fluvial sand, provide the substrate upon which threecorner milkvetch is found (Niles et al.1995).

In the mid-1990s, Niles et al. (1995) conducted surveys of all known and potential locations of threecorner milkvetch within LMNRA and adjacent regions of Nevada and Arizona. Niles et al. identified 19 threecorner milkvetch sites. Since then, surveys have been geographically limited and no systematic assessment of population status has occurred in the last ten years. Other partial surveys done since that time have found some new populations, but no new complete assessment has been completed.

An assessment of threats by The Nature Conservancy (2007) resulted in 9 threats being ranked as High or Very High. These include: urban development and sprawl, OHV use and trail development, increased fire frequency and intensity, energy development, surface water development, invasive plant species, utility corridor construction and maintenance, urban development, Lake Mead inundation and shoreline fluctuation, and


Known Clark County Distribution of
Astragalus geyeri var. triquetrus
Sand Hollow Wash Pops
Town Wash Pop
Toquop Wash Pops
Mormon Mesa Pops
Weiser Wash Pops
Virgin River Pops
Muddy River Pops
Logandale Pops
Mud Lake Pops
California Wash Pops
Valley Of Fire Wash Pops
Bark Bay Pops
Mud Wash Pops
The Meadows Pop
Lime Cove Pop
Ebony Cove Pop
Sandy Cove Pops
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inappropriate agricultural practices. Several of these threats are site specific (energy development, Federal land disposal, legal OHV use), while others are more widespread. Specifically on the lands that this monitoring protocol is designed for, the primary threats are urban development and sprawl, competition from invasive species, OHV use, inundation and shoreline fluctuation, and trampling and grazing (cattle, burros, horses).

The impacts to the habitat caused from scientific field studies can be similar to impacts caused by the general public or trespass animals, but in most cases to a lesser degree. The amount of disturbance from investigators varies depending on the habitat. Individual field oriented research projects and monitoring studies should include an evaluation of investigator impact to the particular habitat upon which the research will be conducted especially if it includes long term monitoring.

INDICATORS

Species Indicators

- Population density of plants in average to above average rainfall years

Habitat Indicators

- Cover of native and non-native plant species
- Species richness
- Soil erosion (potential, if needed)

MONITORING AND SAMPLING OBJECTIVES:

The objective of the monitoring is to assess the status of selected populations of threecorner milkvetch and to gain a greater understanding of the important abiotic and biotic factors that influence population condition. The monitoring objectives for the three monitored populations occurring on BLM and NPS lands within Clark County are:

4. Maintain the current density (within 30% of the baseline measurement calculated from a year of average to above average rainfall) over the next 10 years. Sampling Objective is to be 80% sure of detecting a 30% change in density of threecorner milkvetch in average or above average rainfall years.

5. Correlate the abiotic factors of rainfall, temperature, relative humidity, and soil chemistry, with the density (measured in average to above average rainfall years) of threecorner milkvetch over the next 10 years.

6. Detect changes in species richness and cover of native and non-native plant species over the next 10 years. For species richness and for species cover within 30% of the first measurement taken in average to above average rainfall years. Sampling Objective is to be 80% sure of detecting a 30% change in species richness and cover of native and non-native plant species in average or above average rainfall years.

Management Response

If change is > 30% of target species population density (in average to above average rainfall years), native species richness or cover of native and non-native plant species monitoring will shift from status monitoring to assessing the effectiveness of one or more threat abatement actions such as, invasive species control, limiting OHV access, and limiting trespass cattle/burros/horses.

Monitoring Plan

Pilot year study

Monitoring protocols were developed and plans implemented in 2006 to determine an appropriate experimental design for monitoring threecorner milkvetch. After evaluating the pilot year data (descriptive statistics, power analysis and sample size calculations), it was determined that a larger grid size was necessary to decrease variability among sampling units and increase power.

Sampling Design

Population of Interest

The population of interest to which we want to make inferences to are Ebony Cove, Sandy Cove, and Weiser Wash. The Bark Bay, Meadows, and Lime Cove populations historically supported few individuals and no modern surveys have relocated any threecorner milkvetch at those locations. Modern surveys at California Wash, Mormon Mesa, and Muddy River populations found little to no threecorner milkvetch plants and were not included in the selection process, The health and status of the Mud Lake, Toquop Wash, Town Wash, Logandale, Valley of Fire, and Virgin River populations was unknown at the beginning of this project and were not included in the random selection of populations for monitoring.

Populations were considered for monitoring based on size, time available to survey historical sites, and whether populations could be relocated at historical sites. Three populations met these criteria and were selected for monitoring. Inferences can only be made about the strata upon which plots occur.

SAMPLING UNIT AND SAMPLING METHOD

A grid-cell sampling approach to monitoring was employed. To address the trends in density of threecorner milkvetch we placed 36 x 36 meter temporary grids (corners recorded using a highly accurate GPS unit), which will be re-located each year at each monitoring site. The number of grids varies by site based on extent of the habitat and population of threecorner milkvetch. Quadrats (18- 6 x12m) were delineated within each grid.

Community ecology data will be collected within the same grids/quadrats every year for 3 years followed by data collection in years of average to above average rainfall.

Abiotic data will be collected in separate 1 x 1m temporary plots randomly along a transect placed so that it runs in and out of the habitat patch. Abiotic data will be collected in the first year of monitoring and then as determined necessary based on changes in climate patterns or dramatic shifts in species composition or cover. Rainfall, temperature, relative humidity, soil pH, soil chemistry, soil color/texture, and topography (aspect, slope) data will be collected.

FIELD METHODS

Measuring tapes will be used to lay out the grids and pin flags will be used for marking individual threecorner milkvetch plants for mapping. Individual GPS coordinates will not be recorded for each plant; instead, individual threecorner milkvetch locations will be recorded by marking plants on a field map of each grid showing spatial arrangement within each quadrat. The field maps will be digitized in the office after the field season is complete. Cardboard cutouts representing 1% and 2% of quadrat areas will also be used as visual aids to more accurately estimate percent cover.

Threecorner milkvetch occurs on loose, sandy soils and plants that occur on this habitat can be easily damaged by foot traffic. Monitoring in such delicate habitat poses a problem for resource managers in that investigator impact may cause a significant amount of damage, which may be detrimental to the habitat dynamics and the plants found within this habitat. Minimizing habitat disturbance is an integral part of the current monitoring protocol. Limiting the number of investigators helps minimize the amount of foot traffic a site will receive during the monitoring season.

SPATIAL ALLOCATION OF SAMPLING UNITS

Each grid location at the largest site Sandy Cove (1.45km^2) was selected randomly (using a stratified approach) by placing a "virtual grid" (in Arcmap) over known habitat after which random numbers were generated to select a coordinate (within the virtual grid). The randomly selected point translated to the southwest corner of each grid (8 grids at this site) and once on site a compass bearing for each direction was recorded. The remaining two sites supported smaller populations of threecorner milkvetch so we placed grids in areas where plants occurred (2 grids at each site).

TEMPORAL SAMPLING OF SAMPLE UNITS

Target species and community ecology data will be collected within the same grids/quadrats every year for 3 years followed by data collection in years of average to above average rainfall. Abiotic data will be collected in the first year of monitoring and then as determined necessary based on changes in climate patterns or dramatic shifts in species composition or cover.

SAMPLING METHODS

The corners of each temporary grid were recorded using a highly accurate GPS unit. GPS coordinates will be recorded at all grid corners to include: easting, northing, elevation, and level of accuracy. The grids will be relocated each monitoring year with the same or equivalent GPS unit.

Occasionally, researchers may need to collect a plant within a plot for identification. The specimen would be identified soon after collection and then processed as a voucher specimen and subsequently stored in the Lake Mead Study Collection Herbarium or at the Wes E. Niles Herbarium on the campus of the University of Nevada Las Vegas.

Upon completion of monitoring each year, researchers will enter data into the appropriate database and compile notes from all researchers involved in data collection.

Protocol Logistics

Personnel requirements and training

One lead field researcher will be responsible for completing monitoring including, scheduling and preparing for data collection, training assistants, gathering all necessary equipment needed for monitoring, transportation to each site, making sure data is collected properly and is input in to the database, and ensure that voucher specimens are processed. The lead researcher must meet the following requirements:

- Strong familiarity with local flora both native and invasive species
- Experience conducting plant surveys
- Familiarity with sandy habitats
- Rare plant knowledge
- Ability to hike for considerable distances and up and down uneven terrain
- Ability to tolerate high ambient temperatures during field work
- Experience driving on 4-wheel drive roads

Assistant researcher(s) will be responsible for helping lead researcher in above described duties plus have the ability to hike for considerable distances and up and down uneven terrain, tolerate high ambient temperatures, and quickly learn several plant species commonly found in study area.

Operational requirements

Monitoring should be completed within 15 days unless unexpected problems occur (bad weather, damaged equipment, illness, boat availability, etc.).

Equipment

Equipment needed to successfully complete monitoring for threecorner milkvetch include: a vehicle, a boat, one or two GPS units, data sheets, compass, 1 x 1m frame, implements for abiotic sampling, several meter tapes, pen and pencil, sharpie, NPS park radio, camera, field notebook, plant press, and pruners.

DATA ACCURACY, REPEATABILITY AND MANAGEMENT

Guidance for data accuracy and quality comes from the report from the Data Management Plan (National Park Service 2007) and from Palmer and Landis (2002).

Spatial Data

Spatial data to be collected during this project will include locations of grids, plots, and transects for covered plant monitoring and research. GPS coordinates will be recorded at each corner of plots or at end points of each transect including: easting, northing, elevation, and accuracy. Where applicable, all major disturbance trails within populations chosen for monitoring will be identified using GPS units set to collect point locations every 6 seconds. Where GPS data collection isn't possible (i.e. canyons), coordinates will be determined from GIS data layers. Spatial data will be collected with a Thales MobileMapper CE (or equivalent mapping-grade GPS) using standardized data dictionaries in the GPS. In some cases when only general locations are required (e.g., for planning purposes on proposed vegetation manipulations), a Garmin GPSMAP 76Cx may be used. All data requiring accurate locations will be collected with a maximum Probability Dilution of Precision (PDOP) of 6.0 and will be WAAS differentially corrected. Point locations will be recorded using the average of at least 20 points taken at 1 second intervals. All data will be collected using the UTM 11 NAD 83 projection and datum.

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National Park Service 2007. Inventory, research and monitoring for covered plant species. Project number 2005-NPS-535-P. Lake Mead National Recreation Area. Boulder City, NV. 4 pages.

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The Nature Conservancy. 2007. A Conservation Management Strategy for Nine Low Elevation Rare Plants in Clark County, Nevada. TNC, Nevada Field Office Reno, Nevada. 390 pages.

Example of mapping data sheet for *Astragalus geyeri* var. *triquetrus* (6 x12m grid).

Site __________
Date __________ Grid __________ Quadrat __________ Recorder ____________________

NW | NE

6												
5												
4												
3												
2												
1												
	0	1	2	3	4	5	6	7	8	9	10	11

SW | SE

Data sheet for *Astragalus geyeri* var. *triquetrus*

Threecorner milkvetch Grid data

Grid _______ Date _______________ Recorder ______________________

Quad:			Quad:			Quad:			Quad:		
Species	Cover	Asge Location	Species	Cover	Asge Location	Species	Cover	Asge Location	Species	Cover	Asge Location

VEG. COVER:
1 = 0-1%, 2 = 1-2%, 3 = 2-5%, 4 = 5-10%
5 = 10-25%, 6 = 25-50%, 7 = 50-75%, 8 = 75-95%, 9 = >95%