



Ecological Health Assessment in Southern Nevada

Final Report – FAA010017 (GBCESU)

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Executive Summary

The purpose of this project was to ascertain scientific opinion concerning research priorities for southern Nevada. The project consisted of two workshops and two periods of “homework”, and in both instances federal land management agency representatives and scientists found a lot of common ground, found it easy to talk to one another and each showed genuine respect for the other. In both workshops there was an atmosphere of willingness by the scientists to understand the agencies problems, constraints and needs, in order to offer useful suggestions about future research priorities.

Four of the southern Nevada federal land-management agencies - the Bureau of Land Management (BLM), the National Park Service (NPS) the U.S. Fish and Wildlife Service (USFWS) and the U.S. Forest Service (USFS) – worked with the Desert Research Institute (DRI) to organize the workshops. Questions, issues and concerns raised by these four agencies (the partner agencies) were the focus of the first workshop, held in May, 2006. The questions were provided to participating scientists as homework prior to the workshop; were the topics for discussion at the workshop between agency representatives and the scientists’ panel; and provided the context for the scientists’ first report concerning research needs for southern Nevada. This report was pre-circulated to most participants for the August workshop (all those who pre-registered, approximately 90%) and provided them with background and information on what was considered important by agencies, rather than what issues scientists would like to address (which therefore would become “important”). Thus informed, the participants in August were able to accomplish a large amount of work in a relatively short time (two days), and to stay focused, so that the end result met agency and managers’ needs.

The second workshop in the series, “Research Needs for the 21st Century” was held at the DRI in Las Vegas on August 15-16, 2006 and was attended by almost 90 scientists, and state, federal and local agency employees. Participants were generally satisfied with the workshop, which was divided between Breakout Group sessions and a group interactive polling exercise.

Environmental and societal context was provided by introductory presentations from the Southern Nevada Agency Partnership (SNAP) Board, and the partner agencies which had been actively involved in working with DRI to design and implement the workshop process. Results of the first workshop “Research Needs for Southern Nevada” were presented by two of the scientists who had been involved, and provided a summary of the agency questions, issues and concerns that were the driving forces for discussion of research priorities in Breakout Groups.

On the second morning of the workshop, Breakout Group leaders (the scientists who had been involved in this project since May) presented their group’s top three research topics. The SNAP Science and Research Team and DRI had requested that only scientist participants in Breakout Groups take part in the “voting” to determine the groups’ top three topics. One group (*Humans and desert ecosystems*) did not comply with this request because the Breakout Group leader was the only scientist in the group. The *Cultural resources* group conducted two voting sessions, one for scientists only – the results of which were presented

and carried forward into the polling process. In addition, the topics selected when everyone in that group voted are presented in the group's summary report, a part of this report.

The 30 topics presented by the Breakout Group leaders were ranked in importance by all workshop participants using an interactive keypad technology, and the following topics were selected as the three highest research priorities for southern Nevada:

- Integrated water-ecology model
- Alternative futures
- Ecological effect of invaders

The wording of the research topics' short titles, which was used for the polling, played a part in how the topic was ranked. Therefore, it may be that the overall priorities reflect the related issues and concepts behind the title, rather than specific elements of any suggested research. One strength of the Breakout Groups' selection process was that it tended to favor multi-disciplinary topics that integrate a large number of issues and concerns. As a result, some of the more specific lower ranked topics are also represented in those with higher ranking, although they are not explicitly stated in the topic description.

Each keypad used in the polling process was coded to reflect the professional activity of the participant, allowing identification of the desired scientific opinion. It is acknowledged that the voting audience contained a higher number of natural resource managers and scientists relative to those from cultural resource disciplines, which may have contributed to the low ranking for many of the social and archaeological topics. This was the subject of considerable discussion among participants following the polling. Realistically there is a considerable opportunity for collaborative work between "environmental," "social," and "cultural" scientists, with several examples outlined during the discussion. Such collaboration would add greatly to many projects. Many long held opinions on this subject were expressed during the workshop discussion sessions. Integrating the groups to maximize positive results from research topics is one of the challenges faced by both scientists and managers in southern Nevada.

Communication among agencies and between agencies and scientists is also a challenge, but will greatly facilitate the "out of the box" thinking and operating that will be required to effectively address the most urgent research needs in southern Nevada, and develop an interagency science and research strategy. The scientists who attended the August workshop were all enthusiastic about the prospect of helping the agencies with issues and problems, and most of them said that they would continue to help if called upon to do so. If scientists and agency personnel develop strong partnerships that transcend traditional boundaries of operation, we will increase our awareness of interfaces and connections (for example, between agency lands and the urban environment), which will ultimately lead to more effective land management.

CONTENTS

Executive Summary	iii
Background to the Two-workshop Process	1
Introduction.....	1
Final Report Components	2
The Breakout Groups.....	2
The Polling Process.....	10
Post-polling Discussions.....	12
Similarities and Overlap among the Top 30 Topics	13
Scientific Opinion	14
Issues Considered Important by Several Background Groups but not in the Top 30.....	22
APPENDIX 1. Combined and Ranked Questions from Partner Agencies.....	1-1
APPENDIX 2. Report of May Workshop.....	2-1
APPENDIX 3. Breakout Group Summaries from August Workshop.....	3-1
APPENDIX IV. Breakout Group Presentations from August Workshop	4-1
APPENDIX V. Polling Results from August Workshop.....	5-1

LIST OF TABLES

1. Additional stressors discussed during Breakout Groups.	5
2. Gaps in knowledge identified during Breakout Group discussions.....	6
3. Rank of top 30 topics presented for polling by occupation group.....	11
4. Summary of topics discussed in Breakout Groups.	16
5. Research priorities identified by scientists and experts during polling process.	22

Background to the Two-workshop Process

In late 2005, under Assistance Agreement number FAA010017 (GBCESU) “Ecological Health Assessment in Southern Nevada”, the Desert Research Institute was tasked with conducting “...workshops and meetings with stakeholders engaged in science and research activities benefiting resource management of public lands in southern Nevada. The objective of these workshops and meetings is to gain insights and opinions from the scientific community on the current status and needs for science research and monitoring in southern Nevada.” The results from these workshops and meetings were intended to “...provide information needed for a larger effort to develop a comprehensive interagency science and research strategy.”

Accordingly, and working with the four southern Nevada federal land-management agencies - the BLM, NPS, USFWS and USFS – (the partner agencies), DRI began a series of meetings with the Southern Nevada Agency Partnership (SNAP) Science and Research Team (S&RT) in early 2006, to design and implement a process for conducting workshops specifically to address agency needs, in the bigger picture context of the Mojave Desert ecosystem. Initially, the SR&T identified thirteen disciplines and themes under which issues and questions related to resource management could be addressed, and a number of scientists were selected and invited to participate in the workshop process throughout 2006, as a panel of experts. In consideration of the forthcoming science and research strategy, agency needs and concerns, and the Assistance Agreement, the S&RT and DRI developed a process which resulted in two workshops conducted by scientists (including the panel of experts), and attended by both scientists and agency resource specialists and managers.

Introduction

Although different in approach and style, the partner agencies raised a significant number of shared issues during the May workshop. A lack of information in the form of baseline data was consistently referred to, as was the need to operate at species-level scales. Perhaps the most forcefully stated issues concern the increase in human population in the region which causes pressure on the resources and concomitant increase in demands upon agency personnel; and the necessity of meeting federal mandates that to some extent fosters a “reactionary” approach to the exclusion of innovation and research. The level to which agency activity is focused and driven by threatened and endangered species caused comment and concern among the experts, and the change in effort on agency-specific biological research resulting from the formation of the BRD in 1996 was also noted.

During the first day of the May workshop, the panel of 13 scientists met with resource specialists from each of the four federal partner agencies in turn to discuss the questions and concerns, which had been summarized in a pre-circulated document – Appendix 1 of this document. The panel of scientists spent the second day of the workshop reviewing agency issues and concerns in the context of current knowledge and agency needs.

Results of this workshop (Appendix 2) were presented as a report under research themes, and included a synopsis of the agency questions and concerns, a summary of the most current research and knowledge and new pertinent research for each theme. It also included a list of suggested priority research areas for the agencies – a total of 57, and

bibliographies under theme headings. The individual sections of this report were written by the panel of scientists, and the document was compiled by DRI.

Taking the results of the May workshop as its starting point, and informed by the pre-circulated May report, the August workshop participants were charged with generating a prioritized list of research needs for southern Nevada, together with lists of stressors and gaps in knowledge. These objectives were agreed between the S&RT and DRI as part of the approach toward meeting overall goals.

The August workshop “Research Needs for the 21st Century” built on the May workshop (“Research Needs for Southern Nevada”), for which federal partner personnel were asked to supply lists of their research and monitoring questions, and the research-related issues that were of most concern to their staff. In this context, “research” was defined as “the collecting of information” with an aim of “discovery and interpretation of facts, revision of accepted theories, and/or practical application of such new or revised theories” (www.m-w.com). It also included inventory and long-term monitoring, and might relate to one, or multiple, species and communities. Questions related to policy and policy decisions were not included.

Final Report Components

This Final Report provides the best available consensus on what scientists believe to be appropriate for research priorities related to conditions in southern Nevada, and includes five Appendices:

- Federal partner agency questions, issues and concerns provided for the May workshop – Appendix 1.
- A report of the May workshop written by the panel of scientific experts – Appendix 2.
- The Breakout Group leaders’ summaries of the August workshop - Appendix 3.
- The Breakout Group Leader’s August Power Point presentations – Appendix 4.
- The report on the polling process conducted during the August workshop, prepared by Strategic Initiatives for The Mary Orton Company – Appendix 5.

Although attaining all the research goals discussed and prioritized at the August workshop is not immediately likely, they are agreed on by both agency representatives and scientists, and many could be uniquely structured to solve important real world problems that the agencies must face now, and increasingly as the 21st century progresses. This report represents opinions regarding research and research-related activities, and is not a list of action items for federal land managers to accomplish. It is recognized that decisions on implementation of future research projects do not rest with any of the personnel who made recommendations at either the May or August workshop.

The Breakout Groups

Although there were originally 13 disciplines and themes selected by the S&RT and DRI, ten topics were identified as important during discussions among agency representatives and the experts during the May workshop. Agencies requested the inclusion of Air Quality as a discipline for May, but it was not included in August as local agencies are

not involved and managers therefore decided to eliminate it. The ten topics were each addressed by a Breakout Group at the August workshop and were led by the scientists who participated in May, as follows:

- *Humans and desert ecosystems** – Mark Brunson, Utah State University
- *Inventory, monitoring and indicators* – Jeff Herrick, US Department of Agriculture – Agricultural Research Service
- *Fire* – Matt Brooks, US Geological Survey
- *Invasive species* – Stan Smith, University of Nevada - Las Vegas
- *Water* – Frank D’Agnese, Earth Knowledge Inc. and Don Sada, Desert Research Institute
- *Geomorphology, geology and soils* – Vic Baker, University of Arizona
- *Landscape dynamics* – Jim McMahon, Utah State University
- *Cultural resources* – Rick Ahlstrom, HRA Inc.
- *Restoration* – Kent Ostler, Bechtel Nevada and Dick Toth, Utah State University
- *Species conservation and biodiversity* - Brett Riddle, University of Nevada - Las Vegas

Summaries of the Breakout Groups’ discussions and conclusions are attached as Appendix 3. A total of 88 participants were somewhat evenly distributed among the Breakout Groups (BGs), although the *Cultural resources* group, at 13, was the largest. Participants self-selected the BG which they wanted to join, and the four partner agencies were encouraged to send as many staff as possible to the workshop. Each group leader was assisted by a facilitator, who had received training on taking notes and eliciting responses during discussion. The groups consisted of a mixture of scientists and agency personnel, and for all except *Species conservation and biodiversity* (which was a new theme added in July), research questions from the May workshop were the starting point for discussion of stressors and gaps in scientific knowledge.

A preliminary list of potential stressors on federal partner agency lands, identified by the Lake Mead NRA and the USFS, was supplied to the groups to initiate discussion – the following list is a condensed version of that:

- Burro and horse impacts
- Cattle grazing and impacts
- Invasion of exotic plants
- Impact of subsidized and parasitic species
- Pesticides and herbicides, poisoning and trapping
- Illegal off road vehicle use

* The designations for each Breakout Group (e.g., *Humans and desert ecosystems*, *Fire*, *Water*, etc.) are used throughout this report for clarity and emphasis.

- Wildfire
- Drought
- Water use and quantity associated with growth of region
- Water Quality; springs, surface water, lakes
- Change to riparian and spring habitats, impacts of decreases in flow
- Soil Disturbances (other than cattle, burro, vehicle, e.g. construction, visitor uses, past mining impacts)
- Non-native animals (other than cattle, burros; crayfish, bullfrogs, Africanized bees)
- Regional air quality – haze, nitrogen deposition, dust deposition
- Visitor Uses: trails, desert soils disturbances
- Habitat Fragmentation – Highways (e.g., US Hwy 93), park roads
- Urbanization adjacent to boundary
- Impact of development on habitat and wildlife
- Recreation – habitat loss and degradation, wildlife mortality
- Highways, roads and trails

In discussion, seven of the groups decided that climate and climate change were the most important stressors for southern Nevada (Table 1) followed by urbanization/development, invasive plants/exotic species and altered water regimes/budget. Most groups produced their own, topic-specific, list of stressors although the *Inventory, monitoring and indicators* group discussed the list provided by the NPS and USFS and decided they had nothing to add. Input from the other nine groups is shown in Table 1.

Gaps in knowledge were also discussed in most groups as a precursor to prioritizing research needs, and the results are shown in Table 2. The *Restoration* group did not discuss this subject, so the two group leads were each asked to supply some material for the table in this report. Similarly, the *Fire* and *Geology, geomorphology and soils* BG summaries did not include anything on gaps, but the BG leads in each case were able to supply notes from their groups' deliberations. The format of responses to this item vary slightly, the information from this table was taken directly from the BG summaries in Appendix 3 (or was provided by the leads as mentioned) and has not been edited.

Table 1. Additional stressors discussed during Breakout Groups.

Stressor	Breakout Group/Theme									
	Fire	Invasive Species	Water	Restoration	Species Conservation and Biodiversity	Humans and Desert Ecosystems	Geology Geomorphology and Soils	Landscape Dynamics	Cultural Resources	
Climate and climate change	✓	✓	✓	✓	✓		✓	✓		
Urbanization/development – wildland-urban interface				✓	✓	✓	✓	✓	✓	
Altered water regimes/budget		✓	✓	✓	✓		✓			
Invasive plant species - exotic species	✓		✓	✓	✓			✓		
Precipitation variability - cycles/trends	✓	✓		✓				✓		
Humans on the landscape (increase, use of natural resources)	✓	✓	✓						✓	
Landscape fragmentation				✓	✓		✓	✓		
Fire				✓			✓	✓	✓	
Land use, land use change, land ownership change			✓	✓					✓	
Habitat modification - change in dynamics					✓			✓		
Nitrogen despositon	✓	✓		✓						
Livestock, wild horses, burros (public perception, overgrazing)	✓	✓		✓						
Road proliferation		✓			✓		✓			
Recreation - increase and change					✓		✓		✓	
Social and demographic change, cultural attitudes						✓			✓	
Agency policies - lack of capacity for rapid response	✓					✓				
Illegal dumping - and collecting of cultural resources		✓							✓	
Contamination			✓				✓			
ORV use (especially illegal)		✓						✓		
Landscape, aquarium and pet industries		✓	✓							
Disease and parasite vectors		✓	✓							
Subsidence			✓				✓			
Decrease in soil quality/productivity				✓			✓			
Surface disturbance - loss of crusts				✓			✓			
Reservoir drawdowns		✓								
Lack of healthy ecosystems		✓								
Loss of pollinators					✓					
Lack of understanding of ecosystem processes						✓				
Difficulty of cooperation between agencies						✓				
Top-down decisions - political agendas						✓				
Land managers' lack of understanding of cultural resources									✓	
Increasing use fees						✓				

Table 2. Gaps in knowledge identified during Breakout Group discussions.

Item	Description
Fire Science Studies	The general lack of fire science studies in the Mojave Desert leads to the conclusion that virtually all potential fire research topics should be listed as information gaps, which is not particularly useful when deciding what the research priorities should be. What is more useful is the addition of the element of urgency to each of these information gap topics. This is basically what led us to the prioritized research topics listed in our report. The basic logic for the order that these topics were place in is as follows. Fire effects is the highest priority information gap that needs to be filled. An understanding of effects of fire, both negative and potentially positive, needs to be established before fire management plans can be developed. Although there is general consensus that fire has mostly negative effects at lower to middle elevations in the Mojave Desert (e.g. creosotebush through blackbrush), the details of these negative effects (especially the magnitude of impact on soil seedbanks) need to be known to develop effective management responses. Also, fire at higher elevations (e.g. PJ, interior chaparral, ponderosa pine forests) may have very different effects and dynamics, many of which may be considered positive in helping address land management goals. This information gap can most likely be addressed by research funded by the interagency Joint Fire Science Program, National Science Foundation, USDA, or local sources such as the Southern Nevada Public Lands Management Act. The design and evaluation of post-fire management treatments is the next information gap priority. Once fire effects are understood well, then management responses to mitigate known negative effects can be developed and evaluated. Current federal land management policy calls mostly for standard responses which are applied broadly across the western United States (e.g. seeding) with little understanding of the impact that the types of species and their application rates, methods, and timings will have on mitigating the negative effects of fire. This gap should be addressed by sufficient funding of the monitoring phases of emergency stabilization, rehabilitation, and restoration projects. Fire trends, past, current, and future are important to know for planning current and future management responses. As mentioned above, effects of fire may vary based on elevation, but these relationships may change with regional changes in climatic regimes. Also, the current spatial and temporal variation of fire across the landscape needs to be placed in a historical context to fully evaluate its implications for land management. This information would appropriately be funded by more traditional sources of research funding, and local sources, such as those listed above for fire effects. Fire suppression and fuels management treatments are basically designed to minimize the need for post-fire management intervention. I accordance with agency policies regarding effectiveness monitoring, the evaluation of these treatments should be supported by project funds directed at monitoring. Finally, the topic of human interactions with fire places fire management in the braoder context of land management and that that this implies. This research priority recognizes that no aspect of land management should be addressed individually without accounting for other influences that may be considered external to the traditional management approach (e.g. the interactions of recreation considerations with fire management).

Table 2. Gaps in knowledge identified during Breakout Group discussions (continued).

Item	Description
<i>Invasive Species</i> (posed as unanswered questions for Southern Nevada invasive species)	1. What biological attributes make good invaders? 2. Does the genetic structure of invading populations differ from native species? 3. What is the relationship between disturbance and invasion success? 4. What community/ecosystem attributes are resistant to invasion? 5. What key biotic interactions (e.g. competition, predator/parasite release, etc.) allow invasives to be successful? 6. What are the effects of species invasions on community structure? 7. What are the effects of species invasions on ecosystem function? 8. What are the effects of management on invaded systems? 9. How do we characterize “invasiveness” of ecosystems? 10. What are the tools and techniques available for invasive species management? 11. How do we create an early detection and risk management system?
<i>Water - Research Necessary to Address Gaps in Knowledge</i>	<u>Groundwater Systems</u> • Develop and test an ecological systems conceptual model that integrates groundwater modeling, spring ecology, and human dimensions to enable interdisciplinary assessments of groundwater use and value. • Improve understanding of the geologic framework of aquifers to better quantify water budgets (e.g., aquifer recharge and discharge rates), flow patterns, and geochemistry. • Improve methods to quantify parameter uncertainty and propagate this through models that are produced. • Develop methods to scale up from nested, local-scale groundwater models to regional-scale flow system models. • Improve methods to characterize aquifers and construct groundwater models that more accurately predict their response to human use. <u>Springs and Riparian</u> • Improve knowledge of spring ecology by quantifying biotic and abiotic factors affecting the abundance and distribution of species and the structure of aquatic and riparian communities. • Use ecological information to assess the response of spring-fed aquatic and riparian systems to incremental changes in use (ergo decreased spring discharge, non-native ungulate use, recreation, etc.). • Develop integrated models that incorporate ecology, groundwater hydrology, and human factors to enhance decision making capabilities for sustainable groundwater use. • Inventory the biotic and abiotic characteristics of springs. • Determine and evaluate indicator species and conduct ecological studies to define spring system biological integrity. • Conduct studies to understand of groundwater/surface water interactions and relationships between biological and hydrological characteristics of springs. • Determine ‘reference conditions’ for springs in relation to factors such as topographic setting and hydrology. • Determine effective restoration techniques and identify characteristics of seral stages of biological change expected after restoration is initiated. • Conduct studies to understand the anthropogenic history of human interactions with springs.

Table 2. Gaps in knowledge identified during Breakout Group discussions (continued).

Item	Description
Restoration	1. Spatial history of urbanization: 5-year increments 2. Demographic changes in human populations. 3. Major land use drivers (residential, recreation, grazing, etc.) 4. Inventory and scale of ecosystems degraded- local to regional. 5. Research in cause/effect relationships in the degradation of ecosystems. 6. There is no general synthesis of successful restoration techniques for the Mojave Desert Ecosystem 7. There is tremendous variability among sites to be reclaimed and thus common reclamation techniques are often not successful; need to identify key components for successful restoration 8. Greater need to understand seed-soil-climate interfaces to understand germination requirements and successful establishment. 9. Need to understand competition of exotics with natives during restoration effort. 10. Need to understand thresholds where plant communities can't recover naturally or with assistance
Species conservation and biodiversity - (listed in no particular order)	1. Life histories 2. Habitat requirements 3. Species associations (e.g., plants/pollinators) 4. Metapopulation structure 5. Population genetics 6. Population dynamics 7. Current vs. historical distributions 8. Current vs. historical population connectivity
Humans and desert ecosystems	Discussions took their starting point from the original list of knowledge gaps that had been recommended for research after the May workshop, consisting of five topical areas: • Comprehensive study of recreation use patterns and visitor characteristics that would identify likely locations of visitor use impacts; valuable, non-substitutable recreation experiences; and visitor attributes useful for guiding visitor education campaigns. "Recreation" was defined broadly to include a wide range of visitor activities that typically occur during non-obligated time, including harvest of plant materials for cultural, medicinal, or food purposes. • Analysis of existing options for educational programs to identify those most useful for reaching specific target audiences (e.g., rock climbers, OHV riders). • Research on costs and benefits of visitor use limits, particularly in comparison to costs/benefits of management that concentrates rather than restricts use. • Examination of the underlying environmental values held by Clark County residents with respect to southern Nevada desert ecosystems. • Evaluation of alternate approaches to cross-boundary monitoring and planning that could be effectively integrated across agencies and ownerships.
Geology, geomorphology and soils	<i>Primarily:</i> Consistent region-wide mapping at varying scales (from local high-resolution to regional, lower resolution) of soils and associate geomorphic units. <i>Additionally, but not discussed in depth:</i> Lack of knowledge of regional variations in soil/ecological factors as they specifically affect soil variability on the landscape. Lack of detailed knowledge of how soil function is impacted by both disturbance and recovery processes.

Table 2. Gaps in knowledge identified during Breakout Group discussions (continued).

Item	Description
<i>Landscape dynamics</i>	We generally do not know much about any reciprocal effects “A” on “B” in nature. Researchers usually study one-way effects of almost anything, ignoring reciprocal effects. We tend to consider trends or changes in ecological processes as being represented by straight lines or smooth curves on a graph. In fact, thresholds (conditions where rapid changes in a response variable over small changes in the value of a driver variable) are likely common and important for management purposes. We do not know how to predict these. For many of the agencies involved in these discussions, there are good studies of the natural history of species of concern, but little information at the community and ecosystem level. This is caused by the need to spend time and energy, differentially, on individual species of concern. This focus obviates some the important studies necessary to meet larger land management goals. One must be mindful of the limitations of alternative futures analyses. These analyses are meant to provide a variety of different scenarios that can occur in response to some sort of change in a system. The studies should also include the various potential consequences of these scenarios. Ecologists and managers alike often forget that there are considerations other than the ones based on good research and data collection that guide final choices. This is where politics and human priorities, regardless of natural system consequences, trump data. Plans for mitigation and/or restoration should be developed for the consequences of various scenarios as a way to lessen the effects of “bad” decisions. While there are lots of data for the impacts of conspicuous landscape changes such as building roads, fragmentation of natural communities, etc., there are few data on the effect of the more subtle changes in landscape architecture. For urbanization we have a good idea of the effects on the growing cities, e.g., heat islands, but much less understanding of the influence of urbanization on surrounding areas, e.g., urban areas as epicenters for the colonization of wildlands by non-native or noxious species.
<i>Cultural resources</i>	• Information on the presence, nature, and condition of cultural-resource sites over large areas of public land • Detailed reconstructions of environmental conditions experienced by human groups over the past 10,000 years • Better tools for the time placement of the majority of archaeological sites that are known from surface evidence alone • Information on the effectiveness of procedures and tools for determining the location and nature of buried archaeological deposits • Conceptual and data-driven frameworks or models for describing and interpreting spatial and temporal variability in human use of landscapes and landscape elements • Information on the effectiveness of steps taken to preserve and protect cultural resources—education, signage, directing and restricting access, etc. • A better understanding of the current land-use practices and concerns of American Indian communities and of other “ethnically” defined groups; better information on Traditional Cultural Properties important to these groups

Table 2. Gaps in knowledge identified during Breakout Group discussions (continued).

Item	Description
<i>Inventory, monitoring and indicators</i>	• <i>Indicators</i>: there is inadequate information on relationships between indicators and ecological processes/functions they are intended to represent, and how these relationships vary across the landscape in southern Nevada. • <i>Inventory</i>: biophysical and socioeconomic inventories are incomplete. These inventories are required to design monitoring programs, and to interpret and apply assessment and monitoring data to management. • <i>Implementation</i>: there is insufficient knowledge of how to plan and implement monitoring to support agency objectives. While much relevant <i>information</i> exists, it has not been organized and interpreted so that it can be effectively applied. Where science-based implementation guidance does exist, it is agency-specific, making landscape-scale interpretations of the resulting data difficult or impossible.

Discussions on stressors and gaps in knowledge led to the development of a list of research topics, and/or related issues (such as databases and GIS) which usually included a revision of and expansion upon topics from the May workshop (which arose directly from agency questions) as well as new topics (for specific information see individual BG summaries included as part of this report as Appendix 3).

Using a mixture of discussion and self-adhesive dots (as a voting tool), each group selected their three highest priority research, or related issues, topics. In the interest of acquiring outside opinions by scientists on these issues, it was agreed among the S&RT members and DRI that agency participants would not “vote” in the prioritization process during the BGs. However, the only non-agency person in the *Humans and desert ecosystems* group was the BG lead, so all participants in this group voted – with the caveat that they consider science rather than policy and management. The *Cultural resources* group conducted two voting sessions – results from the first of these (in which the scientists only voted) became the group’s top three priorities and were carried forward into the polling process. Results of their other session (in which everyone voted) are written up in their report – see Appendix 3.

The selection of three priorities for each group resulted in an overall total of 30 topics, which were the subject of PowerPoint presentations on the second morning of the workshop (see Appendix 4), and were then ranked by all participants using a facilitated Decision Support Technology (DST) polling system (see Appendix 5).

The Polling Process

All participants participated equally in this process. By agreement among the S&RT and DRI, everyone was pre-assigned to a polling group based on their professional occupation and involvement in the overall workshop process. This resulted in a group of 12 “experts” which was the panel of scientists who had participated since May, met face to face with agency representatives to hear their concerns, led the BGs, and had considerable background understanding of the project. A second group consisted of “scientists” whose title reflected their professional activities, and a third group comprised participants from the state and federal agencies – “participants”. It was felt that this division would ensure that the scientific opinion sought by the S&RT was obtained from the exercise.

A very preliminary assessment of the DST graphics (“Polling Results” prepared by Strategic Initiatives for The Mary Orton Company, Appendix 5) shows that in fact there was a relatively close correspondence in polling between “expert”, “scientist” and “participant” groups (Table 3). Topics for prioritization were generally quite broad, with the six issues most highly ranked by all participants as follows – in order of priority:

- Integrated water-ecology model
- Alternative futures
- Ecological effects of invaders
- Restoration potential
- Fire effects
- Spring system biotic integrity

Table 3. Rank of top 30 topics presented for polling by occupation group.

Shortened topic title	Experts	Scientists	Agency participants	Groups combined
Integrated water-ecology model	2	1	8	1
Alternative futures	1	3	5	1
Ecological effects of invaders	4	2	5	1
Restoration potential	6	6	1	4
Fire effects	7	5	2	4
Spring system biotic integrity	3	15	3	6
Mechanisms of invasion	7	4	5	6
Prioritize for conservation by filling information gaps	9	15	9	8
Biophysical and socioeconomic indicators	5	14	12	8
Visitor use patterns and characteristics	11	24	3	10
Urbanization effects	12	7	19	10
Threshold level of natural or artificial habitat	21	7	15	12
Fire trends, past current and future	24	9	9	12
Characterize/model groundwater systems	25	12	12	14
Management methods and effects	20	9	19	14
Soil-edaphic relationships	9	13	22	16
Landscape and climate change	12	9	24	16
Post-fire management	14	15	17	18
Fulfill information gaps necessary for conservation of conservation of critical species of concern	14	21	15	18
Geologic, geomorphic and pedologic patterns	16	22	12	18
Treatment effectiveness	19	22	11	21
Complete inventories (terrestrial and aquatic)	16	20	22	22
Loss of soil function, recovery and indicators of soil health	16	15	26	22
Plan and implement monitoring to support agency objectives	26	19	19	24
Cultural resources historic context	22	26	17	25
Plant establishment techniques	22	25	28	26
Cultural resource inventory	29	27	25	27
Outreach programs analysis	27	28	29	28
Agency resource needs	28	29	29	29
Research methods	30	30	27	30

It is important to note that the top three in this list of priorities identified by all workshop participants (i.e., both scientists and managers) are identical to those selected by scientists (see Table 3) and that Fire effects and Restoration potential are also both high on everyone's list.

Spring system biotic integrity was ranked considerably lower by the scientists group than by the experts, and, conversely, threshold level of natural or artificial habitat was placed lower by the experts. However, these are small differences in the overall process, and all topics are potentially important.

Post-polling Discussions

The professional background of the participants resulted in an ecological/environmental bias, in which social science issues featured as less of a concern, with all three of the cultural resources group's issues being placed low in the poll. The group discussion following polling addressed participants' inherent tendency to "vote" for issues with which they were familiar. In general, the higher ranking issues were interdisciplinary and the lower ones were theme-specific or with a narrower focus. A perceived lack of cooperation and understanding between cultural resource specialists who generally had a strong regulatory focus, and the broader environmental community was commented upon, which generated discussion of potential collaborative studies, such as past human adaptation to climate change, and the role of humans in the northward migration of mesquite.

The wording of the brief topic titles (which were used for polling) undoubtedly played some role in how the topics "scored" – for example, the second of the *Cultural resources* topics appeared as "cultural resources inventory" which sounds as though it would probably be strongly theme/discipline-oriented. However, the topic is broader than it appears, and relates to the history of human occupation and land use – which has multidisciplinary components and shows potential for collaborative research involving archaeologists together with other disciplines. Similarly, the second *Water* topic "spring system biotic integrity" calls for current, historic and prehistoric condition assessments – which would utilize archaeological research, and potentially involve archaeologists. Visitor use patterns and characteristics was ranked low by scientists but third overall by agency participants. This topic was one selected by the *Humans and desert ecosystems* group, which only included one scientist and underscores the fact that the make up of the group affected the prioritization process. It also serves as an example of the differences in perception of "importance" between scientists and agency personnel – what scientists consider important isn't necessarily what the agencies actually need information about.

Additional discussion, following polling, involved the group's comfort level with "small scale" as scientists and managers. This tends to inhibit our thinking at the expense of landscape related issues and contexts, and therefore also our collaborative and multidisciplinary strategies. Similar inhibitions may relate to the concept of time, but are less strongly expressed. However, there was discussion as to whether we should have approached the workshop exercises from discrete short-term and long-term perspectives. Discussion also addressed how we overcome our inertia – breaking traditions of collecting data the same way and working with the same people. Perhaps we need to develop new teams and change the way we ask questions. Interfaces and connections – between agency lands and the urban environment, between archaeologists and ecologists, between events such as fire and the

cause of these events - are important issues and concerns for our changing society. If scientists and agency personnel develop strong partnerships that transcend traditional boundaries of operation, we will increase our awareness of interfaces and connections, which will ultimately lead to more effective land management.

Similarities and Overlap among the Top 30 Topics

The 30 research topics and related issues discussed in this section consist of the most critical three from each of the 10 BGs. All topics suggested by the BGs were evaluated, by their group, on the following two questions as well as any additional theme-specific criteria developed by the individual groups (see Appendix 3):

- Does the topic address more than one agency, region, discipline, topic, or issue; or cross landscape boundary scales (ecotones, political boundaries, agency jurisdictions)?
- Would addressing the topic have significance for long-term effective land management?

A “yes” answer to these questions was considered to be greater justification for selection of that topic as a BG priority than a “no” answer. The selection process was a method for narrowing down the field and focusing scientists and agency participants’ thinking, in order to assist the scientists in making recommendations.

There are nine common threads that appear in topics/research issues put forward by more than one BG, as follows:

- Processes (*Invasive species, Species conservation and biodiversity, Geomorphology, geology and soils, Landscape dynamics, Inventory, monitoring and indicators*)
- Modeling (*Water, Humans and desert ecosystems*)
- Genetics (*Invasive species, Species conservation and biodiversity*)
- Retrospective analysis, long temporal frameworks (*Fire, Water, Restoration, Cultural resources*)
- Alternative futures (*Landscape dynamics, Inventory, monitoring and indicators*)
- Indicator and rare species (*Water, Restoration, Species conservation and biodiversity, Cultural resources, Inventory, monitoring and indicators*)
- System function (*Invasive species, Restoration, Species conservation and biodiversity*)
- Effects of management (*Fire, Invasive species, Restoration, Inventory, monitoring and indicators*)
- Education (*Humans and desert ecosystems, Cultural resources*)

One of the common threads, alternative futures, was unexpected. An alternative futures analysis (scenario-based planning) uses both modeling and design techniques that involve local stakeholder groups in decision-making. The spatially explicit futures models address human-environment interactions through empirical representation of human-induced

change across time. Past patterns and correlates of change are then used spatially to “project” alternative future scenarios. Especially important to the future scenario modeling effort is consideration of stakeholder priorities to indicate viable alternative land-use options, which leads to the sharing of differing perceptions and views. Alternative futures analyses are typically facilitated by outsiders, or persons not immediately involved in the region being studied. They operate at local, landscape or regional scales, over a typical period of 20 to 50 years, involve both environmental and demographic data and are designed to specifically address local issues and concerns - such as urban growth and development.

The term “retrospective analysis” is used by the editors of this report to describe a group of strategies discussed, or proposed, by BGs and includes studies of fire histories, the anthropogenic history of human interactions with springs, a synthesis of historical data for restoration projects, and paleoenvironmental reconstructions. The research involved in paleoenvironmental reconstructions, to use an example, may include climate, plant associations and community boundaries, hydrology of springs and washes and alluvial geology from the “environmental sciences” as well as packrat midden studies, tree-ring analysis and anthropological research from the “cultural resources sciences”. The cultural resource contribution to retrospective analysis for fire history, and for any project requiring a long-term perspective on vegetation could therefore be considerable. Similarly, *Cultural resource* inventory would provide indicator and rare species information of value to researchers in other topic areas – for example, subsurface testing of archaeological sites for section 106 or 110 compliance could provide charred seeds or other datable organic remains, helping ecologists with paleoclimatic reconstruction. Buried archaeological sites with preserved organic remains can provide one of the most accessible records of past vegetation and animal communities. Prehistoric plant and animal remains provide important clues about abundance and distribution of plant and animal communities, and even the charcoal recovered from prehistoric fire hearths can give solid information about tree and woody shrub species thousands of years ago.

Landscape scales and change were also perceived as critically important by *Fire, Water, Species conservation and biodiversity, Geomorphology, geology and soils, and Landscape dynamics*. During the May meeting, as well as the brief agency presentations in August, there was a persistent acknowledgement by each of the agencies that a lack of “approach” or “decision-making process” accounted for a great deal of frustration and fragmented research and analysis in the area of land management. The two most common problems appeared to be a failure to put the issue being studied in a larger context of both the bio-physical and political realms as well as a failure to integrate the various processes across landscape scales (e.g. change in ground water levels, change in vegetation cover, change in habitat, change in species, etc.). The *Inventory, monitoring and indicators* BG was the most vociferous in its recommendations to coordinate and standardize agency requirements and interactions, although this topic was also discussed by the *Humans and desert ecosystems* group (see Table 4).

Scientific Opinion

Polling results from the experts (Breakout Group leaders) and scientists groups were combined, in an effort to meet the goal of the workshop, which was to “...gain insights and opinions from the scientific community on the current status and needs for science research

and monitoring in southern Nevada.” Using the data presented in the graphs in Appendix 5 (Appendix C of that report) the number of scientists and experts (BG leaders) who ranked each topic as highest priority was added to the number of scientists who ranked it second highest priority. For example, four of these participants ranked “soil-edaphic relationships” as the highest research priority and three as the second highest – for a total of seven. By comparison, the “integrated water-ecology model” received 19 votes – and 21 votes if the scientists and experts (BG leaders) who ranked it as the third highest priority are included. Table 5 shows the scores for all topics. The full wording for all topic short titles is given in the right hand column in Table 4, and the numbers in the central column in this table indicate which ones were the top 10 priority topics identified by scientist participants.

The top three research topics identified by this group of scientists and BG leaders are identical to those selected by all the workshop participants using the DST, but then scientific opinion diverges. Urbanization effects was ranked 11th by all participants (Table 3) and Threshold level of natural or artificial habitat was 12th. Prioritization for conservation by filling information gaps and Visitor use patterns and characteristics were #s 8 and 10 respectively when all three groups of participants were combined, but the scientists ranked them 15th and 24th respectively – although the BG leaders who met with representatives from the four partner agencies in May to discuss their questions, issues and concerns ranked them somewhat higher (Table 3).

<u>Top 10 topics selected by scientists</u>		<u>Top 10 topics selected by all participants</u>	
1	Integrated water-ecology model	1	Integrated water-ecology model
2	Alternative futures	2	Alternative futures
3	Ecological effects of invaders	3	Ecological effects of invaders
4	Urbanization effects	4	Restoration potential
5	Mechanisms of invasion	5	Fire effects
6	Fire effects	6	Spring system biotic integrity
7	Restoration potential	7	Mechanisms of invasion
8	Biophysical and socioeconomic indicators	8	Prioritization for conservation by filling information gaps
9	Spring system biotic integrity	9	Biophysical and socioeconomic indicators
10	Threshold level of natural or artificial habitat	10	Visitor use patterns and characteristics

In general, all these topics are broad and comprise several elements which might be the subject of discrete studies, or for which some information is likely to exist already. Many require operating at a landscape level scale, and most are multidisciplinary in nature. They will be effectively addressed by broad subject solicitations, and selection of projects which contribute to more than one topic will maximize returns for investment.

Table 4. Summary of topics discussed in Breakout Groups (numbers in center column are scientist's ranking of priority for topic).

All topics discussed in Breakout Groups		Topics presented for polling exercise
Fire		
Fire effects - is a grass fire regime developing in the Mojave? What are additive effects to habitat of fire plus other stressors? Is fire worse than, say, road proliferation?	#6	Fire effects - includes multiscale effects and the grass fire cycle
Post-fire management effects - for example, is seeding effective without invasive removal? Is seeding more effective than planting? Which communities recover without assistance? What are natural recovery pathways?		Post-fire management effects
Fire trends - past, current and future - includes analysis of distant and recent past burning patterns, how these patterns are shifting, and predictions for the future		Fire trends - past, current and future
Fire suppression effects		
Fuels management effects, including post-fire seeding, land use restrictions and other management actions after fires		
Human interactions with fire - past and current use of fire as a management tool and effect on fire regimes arising from human activity - e.g. livestock grazing		
Predictive fire modeling, and modeling effect of predicted climate change on fire behavior		
Invasive Species		
What are the community/ecosystem/watershed characteristics that are resistant to invasion?	#5	Mechanisms of invasion - incorporates ecophysiology, genetics, population biology and invasiveness
What are key biotic interactions that allow invasive species to be successful?	#3	Ecological effects of invaders - incorporates biotic interactions, community structure and ecosystem function
What biological attributes, including genetics, make good invaders?		Management methods and effects - incorporates methods development, early detection, risk management and effects of removals
What are the relationships between disturbance and invasion success, including alteration of natural disturbance regimes?		
What are the effects of invasions on community structure and ecosystems?		
What are the effects of species invasion on ecosystem function, including productivity, nutrient cycling, watersheds and the atmosphere?		
What are the effects of management on native systems (treatment and non-treatment)		
How to characterize invasiveness of systems and how can this information be used?		

Table 4. Summary of topics discussed in Breakout Groups (numbers in center column are scientist's ranking of priority for topic) (continued).

All topics discussed in Breakout Groups		Topics presented for polling exercise
What are the tools and techniques for invasive management and their effects on native systems, including inventory, monitoring, outreach, early detection and risk management?		
Water		
Conceptual model development and testing. Include ecological models - coupling, feedback processes. Multiple factor/interactions systems models (not predictive). Models need to be developed in context of management decisions.	#1	Integrated water-ecology model - includes water-ecosystem-human dynamics for prioritizing characterization and inventory programs, directing research and management and directing decision making
Determine factors affecting the abundance, distribution and biotic integrity of riparian and aquatic communities associated with springs	#9	Spring system biotic integrity - including current, historic and prehistoric condition in hydrologic and landscape association contexts. Address habitat modification, indicator and rare species
What time lags are there between pumping and effects? If there is a change in management in response to impacts due to groundwater withdrawal, will system rebound and how long will it take?		Characterize/model groundwater system components at multiple scales including sensitivity and uncertainty analysis and responses to stressors (e.g., pumping)
Need studies to understand components of water budget (ET, recharge etc.) = sensitivity testing of conceptual model		
Need to identify appropriate indicator species ("canary") for stress to sensitive habitats/species = evaluation of indicator species		
Need to understand anthropogenic history of human interaction at springs		
Need to inventory springs - include temporary ones, hydrologic and ecological components, reference conditions		
Improve understanding of geologic framework of aquifer water budgets, recharge and discharge, groundwater flow and geochemistry		
How to quantify parameter uncertainty and propagate it through models that are produced?		
Characterize aquifers and construct groundwater flow models to predict the responses to groundwater pumping		
How do you translate scale from nested groundwater models to regional flow system models?		
Need research into potential water conservation techniques		

Table 4. Summary of topics discussed in Breakout Groups (numbers in center column are scientist's ranking of priority for topic) (continued).

All topics discussed in Breakout Groups		Topics presented for polling exercise
Restoration		
What are the biotic and abiotic thresholds that determine the recovery potential of the dominant ecosystems within the region and what are the key variables that define those thresholds?	#7	Restoration potential - includes retrospective analysis, identification of priority ecosystems and collaborative experiments
What is the effectiveness of standard restoration treatments for key ecosystems and different disturbance regimes?		Treatment effectiveness - includes retrospective analyses, collaborative projects and rigorous monitoring
What are the plant establishment (seeds and transplants) requirements for promising revegetation species, what are the best treatments to promote establishment, and which species should be placed into seed increase or propagation programs?		Plant establishment techniques
What information on restoration approaches can be obtained from a synthesis of historic and current information? Includes development of databases and decision support systems		
Key indicators of site recovery potential		
Species Conservation and Biodiversity		
Prioritize species (including migratory) for conservation by filling information gaps using one or more of the following approaches: molecular phylogeny, phylogeography and population genetics; range and distribution in Southern Nevada in relation to overall species distribution and range; functional importance to ecosystem or associated species assemblages; species vulnerability; species irreplaceability.		Prioritizing species (including migratory) for conservation by filling information gaps. Include phylogenetic and biogeographic context, geographic range, functional importance of species, and species' vulnerability and irreplaceability.
Importance of fragmentation on small populations		Fill information gaps necessary for conservation of critical species of concern including life histories, habitat requirements and ecosystem processes, species associations, metapopulation structure, population genetics and dynamics, current vs historical distributions, vulnerability, current vs historical population connectivity.
Identify cumulative effects of stressors and synergistic interactions	#10	Determine threshold levels of natural or artificial habitat disturbance/degradation/fragmentation before compromising species viability or loss of system function. Include influence of exotic species.
Identify species guilds/assemblages that are indicators of ecosystem health		
Threshold levels of natural and artificial habitat disturbance/degradation/fragmentation before compromising species viability (including exotic species) or loss of system function		

Table 4. Summary of topics discussed in Breakout Groups (numbers in center column are scientist's ranking of priority for topic) (continued).

All topics discussed in Breakout Groups	Topics presented for polling exercise
Fill information gaps necessary for conservation of critical species of concern	
Assemble research teams around targeted species and biodiversity hotspots	
<i>Humans and Desert Ecosystems</i>	
Visitor use patterns and characteristics - including recreation and non-recreation with emphasis on data gaps	Visitor use patterns and characteristics - data gaps should include cultural differences and hard-to-observe activities such as gathering
Outreach program analysis - what works? Includes inventory of existing programs and study of audience perceptions	Agency resource needs - modeling affects of change including staffing, infrastructure, budgets and local knowledge
Use limits - identify high and low capacity areas. Impacts of use limits on visitor experience	Outreach programs analysis - what programs exists, how effective are they and how is information received?
Ecosystem values for residents and visitors	
Multiple-agency management and partnership formation - including cross-jurisdictional, local government, NGO and private sector	
Urban sprawl/local land use planning - effect on wildlife migration, how to incorporate open space	
Agency resource needs - applying predictive models to suggest ecosystem responses to variations in federal agency staffing levels	
Law enforcement and compliance - what causes vandalism on federal lands? What methods are most likely to be effective against undesirable behavior?	
<i>Geomorphology, Geology and Soils</i>	
Geology, geomorphic and soil patterns	Geologic, geomorphic and pedologic patterns - spatial and temporal relationships between landscape components, soil types and plant communities.
Loss of soil function, soil recovery and the indicators of sustainable soil health	Soil-edaphic relationships - includes ecological factors (e.g., plant physiology) and micro environmental factors
Soil and its edaphic relationships	Loss of soil function, recovery and indicators of soil health - testing, calibrating and developing indicators of soil health. Includes evaluation of existing indicators, and "early warning" components.
Pedogenic history as a baseline	
Soil climate change vs climate change	
Fire regimes and impacts on soil climates - especially temperature and moisture	
Function of the soil ecosystem health measured with/by micro and macro biotic function	

Table 4. Summary of topics discussed in Breakout Groups (numbers in center column are scientist's ranking of priority for topic) (continued).

All topics discussed in Breakout Groups		Topics presented for polling exercise
Restoration viability and sustainability		
Wind and water erosion		
Measurement of soil indicators - including degradation and recovery		
Soils and spring ecosystems		
<i>Landscape Dynamics</i>		
Alternative futures	#2	Alternative futures - what development options maximize natural values and minimize environmental damage?
Landscape change	#4	Landscapes and climate change - using landscape gradients to predict response of landscape mosaics to climate changes
Urbanization effects and boundaries		Urbanization effects - proximal and distant impacts of urbanization on critical features and attributes of landscapes and conservation areas
Road effects, both direct and indirect		
Corridor size		
Roads as routes for invasives		
Role of landscape architecture in communities and ecosystems		
How do various attributes of conservation areas influence them?		
How do local processes influence regional landscapes?		
Effects of global change		
Reciprocal effects of landscape features and ecosystem processes		
Identify important gradients (e.g., temperature, moisture) that enable species to adjust their distributions		
Model the impacts of climate change		
<i>Cultural Resources</i>		
Importance of historical period cultural resources and places important to living people as well as the prehistoric		Cultural resource historic context - organized in terms of place, time and theme. Compile existing knowledge and identify data gaps. Use for future research and setting priorities.
Concepts of the "natural" environment need to acknowledge presence and influence of humans		History of human presence on the southern Nevada landscape - cultural resource inventory - include prehistoric and historic - identification, evaluation, reporting and archiving.
Paleoenvironmental reconstructions are important for identifying appropriate and realistic goals for efforts to maintain southern Nevada's "ecological health"		Effective strategies for long-term preservation of cultural resources - research methods for site recognition, data collection, interpretation and education
Sampling strategies		

Table 4. Summary of topics discussed in Breakout Groups (numbers in center column are scientist's ranking of priority for topic) (continued).

All topics discussed in Breakout Groups		Topics presented for polling exercise
Basic tools to evaluate encountered cultural resources Methods and chronologies as a basis for understanding human interaction over time with the environment Testing current methods and developing new ones, including GIS Collecting data appropriate to answer questions Preservation thresholds Private vs public resource preservation Education (outreach) - best methods and strategies Connection with other sciences Land use through time Effectiveness of current management policies/laws Fire use by humans, water use by humans - impacts of water use to spiritual uses		
<i>Inventory, Monitoring and Indicators</i>		
Combine monitoring (e.g., water/wells) and compile protocols. Identify key areas	#8	Develop, select, calibrate and provide information necessary to interpret biophysical and socioeconomic indicators - including development and use of alternative future scenarios to help identify future stressors and help guide biophysical monitoring plan
Coordinate federal agencies' relationships to county and local governments		Complete biophysical and socioeconomic inventories necessary to design monitoring programs, and to interpret and apply assessment and monitoring data to management
Establish long term monitoring sites on landscape scales - first determine qualifying attributes of sites - regional scale for water, soil and a broad range of human impacts		Develop guidance necessary for agencies to plan and implement monitoring in support of their collective objectives. Clearly define objectives, standardize and coordinate across federal, state and local agencies
Why is multiple indicator species monitoring important?		
Determine functional elements of systems		
So what? Effectiveness monitoring + process monitoring for general long-term trend		
Keep compatible procedures throughout long term monitoring (100 yrs+)		

Table 5. Research priorities identified by scientists and experts during polling process.

Topic name	Ranked highest priority by this number of scientists	Ranked 2nd highest priority by this number of scientists	Total "votes" for highest and second highest priority	Ranked 3rd highest priority by this number of scientists	Total "votes" for highest three priority levels
Integrated water-ecology model	14	5	19	2	21
Alternative futures	10	9	19	3	22
Ecological effects of invaders	8	9	17	4	21
Urbanization effects	5	7	12	4	16
Mechanisms of invasion	5	6	11	4	15
Fire effects	4	5	9	8	17
Restoration potential	4	5	9	6	15
Biophysical and socioeconomic indicators	7	2	9	6	15
Spring system biotic integrity	3	6	9	2	11
Threshold level of natural or artificial habitat	4	4	8	5	13
Landscape and climate change	5	3	8	4	12
Management methods and effects	1	7	8	2	10
Soil-edaphic relationships	4	3	7	8	15
Post-fire management	1	6	7	3	10
Geologic, geomorphic and pedologic patterns	1	4	5	5	10
Loss of soil function, recovery and indicators of soil health	0	5	5	5	10
Fulfill Information gaps necessary for conservation of critical species of concern	4	1	5	3	8
Characterize/model groundwater systems	1	4	5	2	7
Plant establishment techniques	1	4	5	0	5
Plan and implement monitoring to support agency objectives	5	0	5	3	8
Prioritize for conservation by filling information gaps	3	1	4	6	10
Complete inventories (terrestrial and aquatic)	2	2	4	3	7
Cultural resources historic context	4	0	4	2	6
Fire trends, past current and future	1	2	3	8	11
Visitor use patterns and characteristics	1	2	3	5	8
Treatment effectiveness	2	1	3	1	4
Outreach program analysis	1	2	3	1	4
Cultural resources inventory	2	1	3	1	4
Research methods	2	1	3	0	3
Agency resource needs	0	1	1	2	3

Issues Considered Important by Several Background Groups but not in the Top 30

Table 4 is a compilation of the topics discussed by the individual BGs (left column) as well as those that were presented for the polling exercise (right column). The data for this table were extracted from the BG leaders' reports (Appendix 3), the flip charts used during BG discussions, and the BG leaders' PowerPoint presentations (Appendix 4).

In the process of refining their top three research topics and/or related issues, many of the groups made them broad and inclusive to try and capture some aspects of the other topics discussed (see Appendix 3 for details, as well as Table 4). The other topics discussed are also of critical importance, particularly if they cross cut several BGs. Those which do so are listed below:

- Human interactions with the landscape (e.g., springs) and ecosystem processes such as fire, over time
- Fire regimes – impacts on soils, fire suppression effects, fuel management effects
- Climate change – impacts on landscapes, as part of soil change, influence on fire behavior
- Roads as routes for invaders, and in context of system stressors
- Agency partnerships to combine monitoring and protocols and address sociological issues
- Fragmentation effect on small populations and species viability

Many of these cross-cutting issues/topics present opportunities for, and would be more effectively accomplished with, collaborative activity not only between agencies but also between environmental and social scientists. In fact, teams of agency personnel, agency scientists and academic scientists in a variety of social and environmental fields are needed to address many of the questions successfully.

Summary

The Ecosystem Health Assessment workshop process was designed by the SNAP S&RT and implemented by DRI with assistance from the four federal partner agencies, the S&RT and the University of Nevada, Las Vegas, Public Land Institute. This has resulted in a prioritized list of research topics for southern Nevada, based on scientists' knowledge and experience.

The top 10 of these are:

- Integrated water-ecology model
- Alternative futures
- Ecological effect of invaders
- Urbanization effects
- Mechanisms of invasion
- Fire effects
- Restoration potential
- Biophysical and socioeconomic indicators
- Spring system biotic integrity
- Threshold level of natural or artificial habitat

These topics are broad, multidisciplinary, and are connected by variables such as spatial scale and human and urban interactions with the natural environment. Changing environments, whether from human action or climatic factors, present a “moving target” for managers and scientists and this underscores the value of long term monitoring, and the need for collaboration and sharing of information and data.

The opinions presented provide the best available scientific advice on what research is needed for southern Nevada. Policy recommendations are outside the scope of this project. The need for continued efforts to integrate and standardize agency activity – at all levels – is clear, and will become more urgent as we develop real multidisciplinary studies and increase and activate our collaborative networks.

APPENDIX 1. Combined and Ranked Questions from Partner Agencies - into disciplines and issues categories

These will form the basis for discussion on May 3. Agencies will meet with the Panel of Experts in two-hour time blocks (see Agenda) and will pose questions and raise discussion topics of their own choice – based upon the material in this document.

The role of the Panel in this is largely as listeners, soliciting information when needed to assist them in completing their task for this first workshop – which is a synthetic state-of-the-science document (directly related to the subjects discussed with Agencies) with an accompanying bibliography. This document will contain not only new, relevant and appropriate research results, technologies and techniques – but will also provide Expert feedback on the overall “importance” of issues and questions raised by Agencies in the context of Ecosystem Health in Southern Nevada.

Color codes indicate the origin of questions:

NO COLOR: F&WS Ecological Services and National Wildlife Refuge System

GREEN: USFS

YELLOW: BLM

BLUE: NPS

GRAY: Cultural Resources Team

Upper case letters at the end of each (most) questions indicate the urgency or priority for addressing that question, or comment:

H : high priority

M : medium priority

L: low priority

Notes on the ranking procedure from BLM

In general, if questions were supported by funding from other sources they were allocated a low priority/urgency (L), and regional research questions were ranked high (H). For example: there are a lot of desert tortoise questions, which were ranked low urgency as there is considerable work being done on tortoise-related issues and Clark County has invested substantially in this already.

The Ash Meadows is unique and should be provided with whatever is necessary for it to be a functional system. The Sociology questions include some which are educational and may overlap with the SNPLMA (Southern Nevada Public Lands Management Act) Public Information and Education program, or in a Clark County program.

Notes from F&WS:

Overall, F&WS needs a better understanding of the entire Death Valley Regional Flow as well as site specific current conditions. There is a need to understand the relationship of water/current conditions with biological resources, so that the impacts on wildlife refuges of increased water usage from development in the Las Vegas, Pahrump, and Amargosa Valleys can be predicted. Long-term spring discharge monitoring is critical. H

Need research that addresses the interactions between human activities and its affects on ecosystems, plant and wildlife populations. For example, what is the effect of OHV road creation on plant and animal populations? What is effect of fragmenting wildlife and plant populations by development in southern Nevada? What is the affect of introduced exotic species? What is the affect of pollutants on wildlife species?

“Big picture” questions from NPS

What abiotic processes “drive” ecosystem function and plant, animal, community viability? H

What are the key indicators of resource condition? Is it possible to develop indicators? H

What is the “health assessment”/condition of resources? H

What are the trends in resource condition? H

What are the ecosystem functions/key resource dynamics?

What key conservation measures maintain resources? H

What are the key resource drivers? (climate, fire regime, e.g.) M

What impacts (stressors) are occurring within agency management control; what are the long term impacts to resources of concern? M

What activities propose impacts to resources or threats to resource integrity? M

How are resources distributed across the landscape in relationship to activities that may impact resources or threaten resource integrity? M

What areas/resources are outside of the normal range of variation? M

Animal biology

Understand cumulative effects analysis for growth induced impacts to wildlife (including bighorn sheep) populations in Clark County including increased recreation uses (appropriate day use levels for minimizing effects to species), highway widening and increased traffic levels, and urban development in basins. Corollary: Is there a critical width for effective wildlife corridors? L

- Assess the biological resources associated with the habitat in and around Corn Creek. What kind of habitat exists there now and how valuable is it and to which species?
- To what extent are free-ranging dogs impacting the desert tortoise and other vulnerable wildlife; what are effective control methods? L
- What is the status of the relict Pahranaagat (*Microtus montanus fucosus*) and Ash Meadows (*M. m. nevadensis*) montane voles? M
- How do desert tortoises respond to wildfires? L
- What is the rangewide and southern Nevada environmental baseline for the Mojave Desert tortoise? L
- What is the current distribution and density of the desert tortoise, inside and outside of critical habitat? Trends? L
- Do local desert tortoise populations interact through a metapopulation dynamic? At what temporal scale? L
- How does desert tortoise distribution, density, and demography vary with habitat, human use or other threats, and management? L
- How do the following management actions affect desert tortoise populations: highway fencing, fire restoration, invasive plant species abatement/restoration, raven control?
- Are there adverse population-level effects of commercial collection of reptiles; what species are at most risk? L
- What beneficial and negative factors are affecting the bighorn sheep population on the Desert National Wildlife Range? Are mountain lion numbers out of balance with the bighorn population? L

Which springs and other water sources are heavily utilized by introduced game species? Which spring sites and guzzlers have been developed for wildlife and where are they located? H
What is the distribution and present management of native big game (i.e., mule deer and bighorn sheep) and introduced species (horses, burros, elk) on the NRA? What effects do they have on species of concern? H
What is the known and potential distribution of species of concern? H
What is the range of variability in population dynamics for each TES species in the present time? H
What is the status and trend of species of concern? H
What role do the SMNRA populations play in species rarity and viability? What is the SMNRA current wildlife distribution pattern on the landscape? H

What is the distribution of non-native exotic species of interest (and which ones should be of interest)? H

What is the distribution of native animal species of interest? M

Plant ecology

Determine the long-term effects of using cultivated native grasses to restore springs across the Mojave Desert. M

Determine the impact of bighorn sheep guzzlers on surrounding vegetation.

- How does soil moisture affect riparian and semi-riparian plants?
- What is the relationship between vegetation on spring mounds and the water table?
- What competitive grasses can be used in a restoration program to out-compete invasive non-native vegetation? Can we increase seed production of salt grass (*Distichlis spicata*) or can it be grown and transplanted from a “sod farm?” L
- What is the best method to control native plants that have reached “pest” status, i.e., cattails and Phragmites?
- How does fire retardant affect the growth of native and non-native plant species? M

What is the known and potential distribution of species of concern? L/M

What is the range of variability in population dynamics for each TES species in the present time? L/M

What is the status and trend of species of concern? L/M

What role do the SMNRA populations play in species rarity and viability? L/M

What tree ring data is being gathered by the University of Arizona? L/M

What ecological or vegetative community classification system shall be used or created for the SMNRA? L/M

What is the distribution of native plant species of interest (MSHCP covered or watch list, NV listed, FWS listed, agency interest, public interest)? H

What are the population trends of native plants of interests? H

What is the distribution of vegetation communities of interest? (e.g. catclaw/acacia, ponderosa pine, spring-riparian communities) H

What is the distribution of non-native exotic species of interest (and which ones should be of interest)? H

What are appropriate “condition assessment” indicators or native plants and vegetation communities? M

Landscape ecology and ecosystem processes

- What are the seasonal dynamics of moist soil seeps, soil chemistry, and vegetation? M/L
- What are the trophic dynamics and interactions among major ecosystems on the refuges; in particular, the trophic role of springs in relation to the surrounding uplands? M/L
- What are the ramifications of supplementing water for horses and burros; *i.e.*, what are the effects on springs (*e.g.*, effects on nutrient dynamics, effects on riparian vegetation) and other species? M/L
- What are the effects of water development (wells, guzzlers, etc.) and livestock distribution on vegetation, including sensitive plants and soil properties? M/L
- What are the effects of various weed control methods (*e.g.*, goat grazing, prescribed fire, chemicals, etc.) on refuge ecosystems? M/L
- What are the relative sensitivities of animal and plant communities to ecosystems stresses, *i.e.*, what species and ecosystems functions are likely to change or be lost first? H
- What are the key species whose presence or absence can critically alter the composition of local communities? M/L

What are areas of high species diversity and habitat? M/L

What are past biophysical factors/variables that affect population dynamics for each TES species? M/L

Where are prime areas/critical habitats for TES species? M/L

What habitat components are important for the life cycles of species of concern (*i.e.*, soils, water, fire, associated species, niches, pollinators, etc.)? M/L

What ecological processes are important to species of concern? M/L

What are the risks and threats associated with each species of concern and their habitat, habitats of concern, and ecological systems? M/L

What is the relationship between climate, vegetation and soils? M/L

How can we define biodiversity hotspots on the landscape so they are associated with concrete features? M/L

What ecological processes are important to communities at risk (fire, flood, insects, soils, etc.)? H

What natural resources are associated with spring communities? H

Riparian habitat and springs

Determine the impacts of protective fencing on sensitive aquatic fauna. (*i.e.*, is some disturbance required for spring snails and other species?). M

- What are the effects of hydrocarbons (or other chemicals) from motorized vehicles in runoff into spring or riparian habitats? M
- What are the unique or specific habitat requirements of native springsnail populations in important springs or streams in southern Nevada? M

- How do we maintain genetic flow of native fish species (*e.g.*, Ash Meadows pupfish, *Cyprinodon nevadensis mionectes*) within a spring system while preventing the spread of non-native species (*e.g.*, large-mouth bass)? M
- What role did the now extinct species, Ash Meadows poolfish (*Empetrichthys merriami*), play in the Ash Meadows ecosystem? Does the closely related Pahrump poolfish (*E. latos*), which has been extirpated from its native habitat, fill the same niche and can it be safely and successfully relocated in the Ash Meadows system? M
- Why is the Devils Hole pupfish (*Cyprinodon diabolis*) population declining? M
- How do we increase the number of Devils Hole pupfish? M
- Can native fish such as the Devils Hole pupfish be successfully propagated in artificial refugia? M
- What can be done to prevent excessive predation of razorback sucker egg and larvae? L
- What is the best way to stock razorback sucker in Lake Mead? L
- What are the effects of environmental contaminants on razorback sucker recovery in Lake Mead? L

Where are spring sites? L

What is the flow rates/regimes? H

Air quality

Determine the impacts of dust palliatives on sensitive flora and fauna and their communities (desert tortoise, Las Vegas bearpoppy, others) M

Geomorphology/geology

- Prior to restoration of spring/stream systems within the refuges, an improved understanding of stream channel morphology and natural change thresholds (*e.g.*, the geomorphic dynamics of multiple parallel channel formation) is needed. M

Issues of erosion rates and the covering or exposure of cultural resource site locations. M

Soils

Better understand dynamic soil properties to determine if any such properties can be effectively used as an indicator of ecosystem change. H

Identify soil/vegetation characteristics that can be predictive of Las Vegas bearpoppy habitat across its range. H

- What are the relationships between soil and vegetation specific to sensitive plants (*e.g.*, component analysis, *i.e.*, minerals, etc.) H
- What are the effects of public use on soil properties?
- What are the effects of dust on desert landscapes, primarily plants and cryptobiotic crust? H

Archaeology

Where is the physical evidence of past human behavior focused as it interrelates to the ecological zones? M

How has human land use on the Spring Mountains changed over time and affected the physical and natural resources? M

What effects are social and/or natural factors having on cultural resources? M

What are the tribal cultural/social links to resources on the Spring Mountains? M

How are traditional cultures, e.g., Southern Paiute, being affected by current and proposed land use on the SMNRA? M

What is the relationship between the “biodiversity hotspots” and the location of sites? M

Did American Indians use, manipulate, or affect the plants at these habitats? M

Do “hotspots” need some element of human disturbance to flourish or do they survive independently of man? M

Did local American Indians use fire as a tool on their “Holy Land” or let nature take its course only? M

Were species of large mammals hunted to extinction or low numbers on the mountains by American Indians or Anglo inhabitants or did they ever exist there, e.g. bear, bighorn sheep, and antelope? M

Cultural resource is both hard science as well as soft or social science. What we sometimes define as natural process are actually cultural processes or manipulations of human behavior (impacts and mitigations). Environmental factors influencing cultural manipulation, influencing ecosystems, influencing culture, and the regeneration of the cycle over time.

1. How do we adequately recognized and evaluate this interconnected process?
2. How do we portray this integrated cultural/natural science?

In southern Nevada we have a unique landscape that includes high snow-bearing peaks and plateaus draining into major water systems of rivers, springs, and wetlands.

1. How has resource utilization of various environmental zones influenced settlement patterns?
2. What was the environment from late Pleistocene to present? How have these changing environments influenced human occupation? Manipulation of the landscape? (Need for paleoenvironmental reconstruction studies - Paleonidology studies. Pollen studies. Ostracod studies.)

The Las Vegas area seems to be a hub of cultures flowing in and out of the area, following these waterways, creating trails and routes, influencing the populations they encounter and establishing cultural identity.

1. Who are the “Virgin Anasazi?” Are they true Anasazi or existing populations influenced by Anasazi?
2. What was the Numic spread?

3. How do you identify ethnicity/culture from the archeological record?
4. What are the trails and routes? What were their main purposes? Ceremonial? Trade? Who used them?
5. How does the movement and influence of populations relate to ceremonial and sacred sites (traditional cultural properties/places [TCP])?
6. What and where are these TCPs?

Structures are the manifestations of social engineering. They are the remnants of human manipulation of the environment and survival within the environment, a satisfaction of socioeconomic (industry, recreation, education, transportation, etc.) needs.

1. What are these structures?
2. What are the influences to building these structures? Utilitarian? Engineering? Aesthetics?
3. What is their significance and how do we evaluate them?

Data is the archive and administrative record of all research. Artifacts and specimens are the tangible evidence of research.

1. How do we synthesize and evaluate the data and collections that are generated by these projects into a system that can be shared/accessed for research and education?
2. Have standardizations been developed and implemented among agencies? Are we looking at quality control of the data?
3. Everybody seems to be collecting voucher specimens which are dispersed in repositories throughout the US. Should we be looking at systems where projects can share voucher specimens so that we eliminate duplication of efforts?
4. Should we be looking at an interagency centralized repository for the handling of archives, artifacts, and specimens?
5. How will the information be accessed?

Sociology

Model sociodemographic structure of urban areas and its impact on adjacent natural areas. H
Determine what methods increase public commitment to protecting public lands. H

- Determine carrying capacity at sensitive areas within the refuges. M
- What forms of recreation are compatible with the sensitive species/habitats in the refuges?
- What is the best way to measure and track the cumulative effects to listed and sensitive species from multiple use activities on public lands? H
- What is the visitor carrying capacity for recreation activities on the Spring Mountains NRA in relation to the sensitive, endemic species? Could also be applied to other public lands with sensitive resources such as Lake Mead NRA, Red Rock NCA, Sloan Canyon NCA, etc. M
- How do we prevent dumping of aquarium fish into native waters? How do we become effective at getting the message out?
- How are budget cuts (both within school systems and federal agencies) impacting the teaching of natural sciences and outdoor education? How do we overcome these impacts?

- Create curriculum to educate and instill benevolence in students (and adults) regarding natural resources, sensitive species, and the desert environment.
- Finance videos and other educational material for distribution to schools.
- Develop liaison with school district to endorse outdoor education and include natural resources in science programs.
- Develop promotional materials to increase public awareness and benevolence towards sensitive species.
- Develop promotional materials to increase ecotourism in southern Nevada.
- Develop and implement methodologies to reduce damage by public to sensitive resources.
- Develop partnerships with user groups to conserve natural resources.

What is visitor satisfaction on the NRA, including transportation, quality of experience, recreation opportunities etc.?

What is the projected increase in visitation over time?

What human activities occur on the NRA and how do they impact the resource and other visitors?

What types of use will increase over time?

What do local and non-local visitors, tribes, adjacent property owners value about the NRA and what are their “special places”?

What values are commonly held and what values may conflict?

What is the history of land management on the NRA?

What activities at what locations pose a higher safety risk on the NRA?

How can the FS improve environmental education both for visitors and the community at large?

What signage improvements are needed on the NRA?

What is the public’s perception of fire use, wildfires and fuel reduction? How can the FS better educate them on these issues?

What additional services, privately or publicly provided, would visitors like to see on the NRA?

Invasive plants and animals

Determine the effect of herbicides, specifically those targeting weeds common to Mojave Desert scrub communities, on the desert tortoise. H

Quantify the effectiveness of goats for exotic species control. Corollary: Determine transmission potential of Johnn's Disease and other communicable diseases between goats and desert bighorn sheep in the Mojave Desert environment. L

- What factors control the dynamics of colonization and invasion by populations that are recovering.
- What impacts are invasive aquatic species (*e.g.*, crayfish, *Procambus clarkii*, and *Melanoides tuberculata*) having on native spring and stream systems and habitats in southern Nevada, particularly native endemic species such as fishes and invertebrates (*e.g.*, endemic springsnails)? What are the competitive interactions between *Melanoides* and native endemic snails under predation pressure by introduced crayfish? M
- What are the best methods for controlling crayfish, *Melanoides*, and non-native fish without harming the spring/stream system and its native endemic species? M
- How do we prevent the invasion of new species such as the zebra mussel, milfoil, mudsnail, etc.? M

- Is the application of a pre-emergent herbicide (*e.g.*, Oust) along roads an effective method to control the spread of invasive weeds, particularly Sahara mustard? H
- How do we control red brome in the Mojave Desert? M
- How serious is the invasion of five-hook bassia? How is it controlled? (Little research has been done on this species.)
- What are the effects of herbicides on endemic aquatic invertebrates and fish? M
- What roles can fire and flooding play in the control of invasive plant species on Refuge lands?

Where are the exotic plant and animal species located in the NRA?

What adverse impacts to habitats/species of concern have occurred from non-native species?

What are the rates of spread/invasion of non-native plants? H

Groundwater hydrology

Accurately quantify water-budget terms (*e.g.*, recharge, natural discharge, evapotranspiration, spring discharge, stream baseflow, withdrawals by pumping, interbasin flows). Corn Creek and Pahranaagat specifically mentioned by F&WS. M/H

Define the hydrogeologic framework and reducing uncertainty associated with corresponding hydraulic properties. M/H

- How is groundwater pumping affecting the water temperatures, habitat, distribution, and physiology of the Moapa dace? M/H
- What are the effects of springflows on surface soil moisture? M/H
- What are the effects of rainfall, or the lack thereof (*i.e.*, drought) on springs and soil moisture. M/H

How do human impacts and natural environmental factors influence and affect hydrologic function of groundwater resources? M/H

Land degradation and habitat fragmentation

Identify critical threshold for road/trail density where habitat quality is significantly reduced. Develop models to assess the cumulative impacts of urban expansion on adjacent natural systems, using a select number of disturbance front indicators. H

- Can native springsnails and their habitat requirements be used as indicators of ecosystem health of important springs or stream systems? H
- What are the direct and indirect effects of dirt roads on sensitive species and springs, including weed dynamics, prevention of genetic flow, dust, etc? H
- How do we redesign roads crossing large wetlands (such as the Carson Slough at Ash Meadows NWR) that will not impede the flow of water and wildlife? M
- How are desert tortoise and small mammal populations responding to highway exclusionary fencing? L

- What are the effects to desert tortoise populations that result from major utility corridors; is there a threshold width at which desert tortoise habitat becomes functionally fragmented? L
- How does development and human induced environmental stresses, *e.g.*, non-native species and pollutants etc, affect the ability of plant and wildlife species to disperse and colonize new habitat? H

What are important corridors between habitats? H

What habitats are fragmented and how are they impacting species of concern? H

How can we describe fragmentation in a practical way to guide NRA management activities? H

What TES species do we know are affected, or might be affected by fragmentation? H

What are “special habitats” (or “niche habitats”) in the Spring Mountains NRA of conservation concern?

What are the ecological systems and where are they located?

Restoration

- What process should be undertaken or monitoring parameters implemented to determine the success/effectiveness of spring and riparian restoration activities on refuges in the Desert NWR complex?
- How do we monitor the success of desert spring and stream restoration? What are the key indicator species that should be monitored?

How do human impacts and natural environmental factors influence and affect watershed health, restoration activities and urban development?

What is the effectiveness of current restoration activities? H

What mitigation activities/conservation measures are necessary? What is the effectiveness of current mitigation activities? M

What restoration activities are needed? M

Fire

Understand post-fire effects on desert seed bank (both native and exotic) and restoration treatments that can be most effectively used. H

- An assessment of the fire history for all refuges within the Desert NWR complex is needed. What role did fire play in maintaining spring/riparian/wetland vegetation? H
- What role should fire play today in areas with invasive plant species?
- Is seeding of native plants an effective post-fire rehabilitation tool; what techniques are most effective with limited resources? H
- Are fire breaks an effective wildfire management tool for Mojave desert scrub communities; can fire breaks be established without increasing desert tortoise habitat fragmentation or public access into desert tortoise habitat? M

How much biomass should we leave for natural resources, soils, after fuels treatment projects?

What is the history of wildfire starts and spread of on the SMNRA? L

What effect does fire have on natural and cultural resources, recreation, and the Urban Interface? L

What effects have fires had on the conditions of Bio-Hotspots and Spring Areas? L

How do today's fire patterns compare to historic fire patterns (pre-settlement)? L

What are the current and predicted fire conditions? L

Should the SMNRA consider a permanent closure of camp fires outside of developed areas? L

Monitoring/sampling issues

Develop a consolidated geospatial database of soils and corresponding ecological site information for Clark, and relevant portions of Nye and Lincoln Counties. H

- Monitor groundwater levels in and around the entire Corn Creek area. M/L
- A comprehensive water quality sampling effort of all the springs and wells at Ash Meadows NWR (including some upgradient wells outside of Ash Meadows) is needed to help identify sources of water and flow paths. (Sampling effort should include physical parameters, anions, cations, metals, and isotopes.) H
- An updated analysis of trends in spring discharge and well levels on Ash Meadow NWR is needed. The FWS has 15 years of data for some monitoring sites, but what does it all mean? H
- Can water monitoring activities throughout southern Nevada be coordinated between the various land-management agencies to be consistent in methods and to avoid duplication of efforts? Is it feasible to give responsibility for water monitoring to one agency or is duplication necessary to ensure reliability of data? M/L
- Survey/mapping of non-native vegetation is needed for all refuges within the Desert NWR Complex. M/L
- Baseline information (inventory and monitoring) is needed on small terrestrial vertebrates and terrestrial invertebrates. M/L

Can the NRA identify umbrella (or surrogate) species to manage and monitor that would benefit TES species of small populations and/or at larger scale habitats such as biodiversity hotspots? What is the past and present status and scope of monitoring efforts on the Spring Mountains NRA? M/L

What management activities are impacting species of concern and communities at risk (human factors such as fire suppression, water diversions, fuel treatments, recreation activities, mining, lumbering, grazing, etc.) that are affecting ecosystems? M/L

In order to address the current demands of visitors for recreational activities, more cultural resource inventory addressing Section 110 of the NHPA needs to be conducted in order to know what sites should be protected for future research or if data recovery needs to occur now. This needs to occur with tribal involvement. M/L

Identified Research Needs

- A better understanding is needed of the unique soil at Ash Meadows NWR that is associated with some of the last pristine alkaline wet meadows in the world. Initiate an

ecosystem research program in alkali meadow habitats to clarify climate and groundwater impacts on soil carbon dynamics and trophic dynamics.

- Need research that begins to address the affects of climate change (temperature change, increased nitrogen deposition, shifts in rainfall patterns etc.) on plant and wildlife species in southern Nevada.
- An assessment of vegetative community change through time is needed for all refuges within the Desert NWR Complex (e.g., dendrochronology studies, aerial and satellite imagery – past, present and future).
- Basic life history information is needed for all of the endemic species in Ash Meadows NWR.
- Need research and long term studies to better understand differences between annual variability and long term trends in species and ecosystems in southern Nevada, *i.e.*, we need to be able to distinguish between a bad year due to drought and a bad year because the population is declining due to current management.
- Need research on the long-term viability of plant, animal and ecosystems in Clark and Lincoln counties.
- Need research into habitat restoration technology with better follow-up on projects to determine on what is working and what is not. Better data sharing of restoration information.
- Need research to better understand parasite, disease and pathogen transmission in southern Nevada plant and wildlife species.
- Research into the factors (biotic and abiotic) that affect and define the distribution of rare and endemic species. This information will be needed if we want to expand current populations of endemic species or create new populations elsewhere.
- Research that identifies the separate and combined effects of physical and biotic factors in limiting the establishment and growth of recovering species in degraded systems. (e.g. how do we get species like desert tortoise to recover in ecosystem that is being invaded by exotic grasses or hammered by OHV activity; how do we restore sensitive aquatic species in degraded aquatic habitat?
- Research that identifies and addresses how to manage the long term threats to ecosystem sustainability in southern Nevada.
- Research and inventories into the patterns of species distributions, habitat, genetic diversity in southern Nevada. This information will be critical to managing species.
- Research into the biology of rare and endemic species and develop the scientific information needed to sustain and manage populations of concern.

APPENDIX 2. Report of May Workshop, May 3-4, 2006

Editors: Judith Lancaster, David Mouat and Paul Buck, Desert Research Institute.

Executive Summary

Overall the first workshop was considered by both the experts and the federal agency personnel as quite successful, with a high level of listening, questioning and exchanging of information among the participants. The panel of experts commended the agencies involved for the diversity and nature of their questions, for their honesty in discussions and for their seeking outside advice in addressing concerns.

Although different in approach and style, the four agency groups raised a significant number of shared issues. A lack of information in the form of baseline data was consistently referred to, as was the need to operate at species-level scales. Perhaps the most forcefully stated issues concern the increase in human population in the region which causes pressure on the resources and concomitant increase in demands upon agency personnel; and the necessity of meeting Federal mandates that to some extent fosters a “reactionary” approach to the exclusion of innovation and research. The level to which agency activity is focused and driven by threatened and endangered species caused comment and concern among the experts, and the change in effort on agency-specific biological research resulting from the formation of the BRD in 1996 was also noted.

Agencies requested the inclusion of Air Quality as a workshop topic, however, there was no discussion of air quality-related questions - perhaps because local agency personnel have not been involved with these concerns. It is included as a section in this report partially as a recommendation for local involvement as part of the “big picture” – although we realize that time and personnel are constraints upon adding activities to currently overloaded schedules.

In organizing the second workshop (August 15-16, 2006) we face challenges of relevance and timeliness. How can the experts and other workshop participants make recommendations for sound science and research that fit the needs of agencies, and that they have time and personnel to implement? Continued “buy in” to the workshop process will provide a reality check and help ensure that the first criterion is met; increased cross-agency communication and collaboration may help the latter. Communication at all levels is critical – as well as agencies talking to and working with each other, involvement of the public, educational institutions and NGOs will, in the long term, facilitate some agency activities.

In the interim, it is hoped that suggestions in the “Research Needs/Needed Research/Recommendations/Proposed Science” sections of this report will provide both sufficient guidance to enable agencies to respond to SNPLMA Round 7 proposals, and topics for discussion at management and resource specialist levels within agencies.

The editors of this Report attempted to provide consistency in organization and clarity. It was not our intention to ensure grammatical correctness.

Introduction

In the context of this project, ecosystem health is defined as “a state in which ecological processes are properly functioning, so that the structure, organization and activity of the system is sustained, producing resources and satisfying values”. Assessing this condition is done

through the measurement of suites of indicators and indexes, and comparison of these measurements with past metrics in order to determine trend.

The Desert Research Institute (DRI) is partnering with BLM, NPS, F&WS and USFS to identify and prioritize research needs for Southern Nevada, to enhance management capability and to enable agencies to direct SNPLMA funding where it is most needed. DRI has been meeting with the Interagency Science and Research Team to develop the strategy for this one-year (2006) task. DRI has assembled a Panel of Experts to review management issues, and is organizing two workshops to acquire both agency input and expertise from the scientific community.

The overall project deliverables, provisionally scheduled for October, include a report summarizing prioritized research needs for Southern Nevada, which will provide guidance for agency and interagency response to research proposals, and provide a framework for future agency management strategies.

To ensure that this final report focuses on issues that are relevant to the four agencies, and to structure the organization of the workshops, DRI requested lists of questions and concerns from the agencies, which were supplied by the Science and Research Team members. These agency questions and concerns, broadly grouped by resource area and/or management issue, were discussed at the first workshop (May 3-4) when the Panel met with agency personnel, in two-hour time blocks (one for each of four agencies).

This report is organized into topics that were identified as important during discussions among agency representatives and the Panel, and provides both a summary of state-of-the-science knowledge and pertinent research gaps or needs relating to agency questions, issues and concerns. The topics covered are:

Humans and desert ecosystems	Geomorphology/geology and soils
Inventory, monitoring and indicators	Landscape dynamics
Fire	Cultural resources
Invasive species	Restoration
Water	Air quality

Each topic report concludes with a section on recommendations, research needs or proposed science to address research needs of specific issues stated by the agency representatives. Some suggestions for research priorities for the second workshop (August 15-16) have also been made. A list of references/bibliography has been compiled as a separate document.

Humans and Desert Ecosystems in Southern Nevada

Mark Brunson, Department of Environment and Society, Utah State University, Logan.

This section covers a wide range of issues pertaining to the relationships between desert ecosystems and the people who live near, use, and/or manage natural environments in southern Nevada. To fully address the issues identified by the agencies would require drawing on ideas from psychology, sociology, economics, cultural geography and history, making it infeasible to assess the state of relevant science in this document. However, it is possible to organize them into three broad questions, and then to focus on gaps in social science knowledge about those topics as it has been applied to public land management in arid and semi-arid ecosystems.

The questions raised in the pre-workshop documents and during the workshop itself fall into three broad categories of human/environment interactions. The question categories are:

- *Who is using public lands in southern Nevada, which locations are most sought after for which uses, and what benefits do they obtain from those lands?* This category includes questions about the locations and types of public land uses taking place, demographic characteristics of users, and the features of preferred experiences in nature including recreation, scenic viewing, non-commercial harvest of plant materials, etc.
- *How can tools for visitor management and education be used to reduce or contain impacts of recreation use on southern Nevada ecosystems?* This category represents the largest number of questions, including those pertaining to public awareness-building, enforcement of laws and agency regulations, and recreation user capacities.
- *How are broad demographic and socioeconomic trends in Clark associated with changes in desert ecosystems?* This category includes “big-picture” questions that are most useful in planning and prediction of future impacts and use trends.

In our subsequent discussions, the scientist panel identified a fourth category of social science question worthy of research: *How can strategies be designed for cross-boundary management that account for inter-agency differences in policies, resources, and organizational cultures?*

Uses, locations and benefits

Research on recreation users, locations, and preferred experiences is useful for predicting where activities and associated impacts are most likely to occur, and also for identifying situations where it may be more difficult to restrict use for ecosystem protection (e.g., experiences for which no equivalent substitute exists, such as rock climbing in Red Rock Canyon NCA). Profiles of participants in specific activities are useful for designing and targeting educational messages. Many studies exist of recreation visitor attributes, including demographic variability in activity choices, recreation experience benefits, and attachment to “special places” or regionally and nationally known destinations. Typically such research is site- and activity-specific, undertaken in response to specific management concerns. A literature search found no recreation use studies for southern Nevada, but within specific activities Clark County recreationists should be similar to those elsewhere in the West. Cordell (2004) offers the best comprehensive study of outdoor recreation use on public lands. Also the Forest Service, through its National Visitor Use Monitoring (NVUM) process, collects data periodically on use of the Spring Mountains. While use patterns vary across agencies – e.g., water activities concentrated at Lake Mead, winter

sports at Spring Mountains – NVUM data may offer some insights into recreation visitation on other agencies' lands as well as on Forest Service land.

Other than recreation, ecosystem services and land uses of deserts and rangelands have received almost no research attention. Few studies exist of scenic beauty judgments for desert landscapes, nor has there been research on non-commercial harvesting of piñon nuts or other products except in the context of traditional Native American uses.

Tools for reducing or containing impacts

Various tools have been used to reduce impacts of human uses. Those drawing the most interest from southern Nevada agency representatives were public education and visitor (or “carrying”) capacities. Both have been a focus of much research, but again not in southern Nevada. Studies abound of influences on environmentally responsible behavior. Outdoor recreation participation is positively associated with pro-environmental behaviors, and research suggests that it matters little whether those activities are appreciative (e.g., hiking) or involve more intense resource use (e.g., hunting, OHV riding). However, few studies have linked education campaigns designed to improve ecological awareness with changes in specific behaviors during recreation experiences. Also, it is difficult for pro-environmental messages to compete in the “information marketplace” with other messages that are more relevant to everyday concerns. Programs aimed at motorized recreationists such as Tread Lightly! appear to influence behaviors positively, but systematic research on such efforts is lacking. Nor do studies yet exist of how changes in educational systems (e.g., No Child Left Behind) affect children’s ability to gain environmental awareness.

Many researchers have explored the potential for visitor capacities to improve recreation experiences and maintain environmental quality. While use limits have been shown to enhance the quality of recreation experiences in crowded settings, the weight of evidence suggests that use limits are counter-productive for protecting ecosystem characteristics because displaced users disperse to multiple alternative destinations, and the relationship between use levels and environmental impacts is non-linear with most impacts occurring even at low levels of use (Hammitt and Cole 1998). Increasingly scientists urge managers to find ways to concentrate visitors as much as is feasible in environments that are more resistant to use impacts. However, little research has evaluated the effectiveness of such strategies, nor of their effects on visitor experience quality.

Demographic and socioeconomic trends

Phenomenal population growth in Clark County is a primary driver of ecosystem change. Managers expressed interest in gaining a better understanding of socio-demographic change in the region and its effects on desert ecosystems. Studies of population growth elsewhere in the Intermountain West have found that natural amenities are primary reasons for in-migration, but this may not apply to Las Vegas. While much has been written on the growth of Las Vegas and the “boomburbs” of Henderson and North Las Vegas, very little has examined how that growth is influenced by the natural environment or on how the nature of that growth affects residents’ attitudes toward the southern Nevada desert. A chapter in Rothman’s (2003) *Neon Metropolis* probably comes closest.

Cross-agency management

Ecosystem processes, wildlife, and recreationists all cross agency boundaries at will. Therefore it can be helpful to develop planning, management, and monitoring strategies that are shared among agencies. Many researchers have examined the “cultures” of land management agencies and barriers to cooperation; more recently much has been written about the potential for cross-boundary stewardship in the context of ecosystem management (e.g., Knight and Landres 1998). But almost all of this literature is theoretical or conceptual; few case studies exist of how cross-agency cooperation can be used to assess and sustain ecosystem health and none have been conducted in southern Nevada.

Recommended research areas

- A comprehensive study of recreation use patterns and visitor characteristics across public lands managed by the four federal agencies would be useful in identifying:
 - where recreation use impacts on ecosystems are most likely to occur and increase
 - which locations or ecological community types are especially valued for recreation and therefore may be poor candidates for strategies to limit or contain use
 - what visitors characteristics may be useful for targeting information/education campaigns to specific user populations.

Such a study could also consider leisure uses such as harvest of medicinal, food, and other plant materials.

- Although it may be unreasonable to expect public education campaigns to affect recreation behaviors on a region-wide scale, analysis of existing educational programs (e.g., Tread Lightly!) would be useful for identifying approaches that can reach specific populations such as rock climbers or OHV riders.
- As visitation increases and pressure increases to implement recreation use limits at popular settings, research is needed which compares the social and ecological impacts of capacity-based approaches to those of management strategies that seek to concentrate use.
- On a more fundamental level, it would be helpful for managers and outreach coordinators to learn which components of desert ecosystems (if any) are most valued by Clark County residents and therefore might be used in developing ecosystem protection and education strategies.
- Finally, research is needed that evaluates pilot projects for monitoring or planning involving multiple land management agencies.

Inventory, Monitoring and Indicators in Southern Nevada

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All four agencies identified needs for tools that would increase their ability to (1) identify and monitor key socioeconomic and biophysical DRIVERS of ecosystem change, (2) cost-effectively monitor the single and cumulative impacts of these drivers on TRENDS in ecosystem condition and on the status of individual species, and (3) monitor the EFFECTS and EFFECTIVENESS of specific management actions, including restoration.

(1) DRIVERS. At least two agencies expressed a need to better understand current and potential future socioeconomic and biophysical *drivers*. This information should improve the ability to create *land use management plans*; to predict what types of *prevention*, *mitigation* and *restoration* activities will be required in the future; and to identify *where* they most need to be applied. This requires high-quality inventories of the spatial variability in ecosystem response as a function of underlying *soils* and *geomorphology*. These factors control water and nutrient availability, which determine both the type of plant and animal communities that can exist in this arid environment (e.g. springs vs. low-elevation rocky slopes vs. gypsum-dominated soils), and their capacity to resist and recover from different combinations of stressors (drivers).

2) TRENDS. All of the agencies cited the need for improved tools for monitoring resource *trends* as high priorities. More *cost-effective* tools are needed to track changes in both resource condition, or health, and individual species (especially invasive, and MSHCP- and FWS-listed). There are not sufficient resources available to monitor all species of concern throughout the landscape. Indicators are needed that address *multiple issues*. The agencies also need improved systems for deciding *where* and *what* to monitor so that they can focus their limited resources on those parts of the landscape that are most susceptible to change, and where apply the monitoring data can be applied to support management actions that affect the direction or rate of change.

(3) EFFECTS and EFFECTIVENESS. A third priority identified by all of the agencies is the need to *cost-effectively* monitor the *effects* of specific events (e.g. fire, off-road vehicle traffic, road construction, increased ground water pumping), and the *effectiveness* of management actions designed to *mitigate* adverse impacts, including activities. The requirements for these monitoring systems are similar to those for trends (above), but they tend to be more intensive and site-specific.

Currently available tools: General/terrestrial

A number of tools are available to address at least partially the needs listed above. The key *drivers* of change are widely recognized and have been discussed in the literature. However, our ability to predict the specific effects of these drivers on different soils and biotic communities is limited. The Forest Service and Natural Resources Conservation Service are in the process of completing soil surveys and ecological site descriptions that describe the predicted responses of different parts of the landscape to some drivers (e.g. fire and grazing). These documents need to be expanded to address stressors associated with the urban fringe (e.g. off-road vehicle traffic).

Many lists of indicators exist that can be used to develop strategies for monitoring *trends*, including specific *effects* of particular events or mitigation activities. Some of these indicators are directly related to the issue of interest (e.g. listed species population size estimates). However, these are frequently expensive and unreliable. There are many more general sets of indicators of ecosystem health. The *Sustainable Rangelands Roundtable* developed a large list of indicators for upland, non-forested ecosystems. While the list is designed for use at a national scale, an accompanying report discusses whether and how the indicators might be adapted for use at local or regional scales. The NRCS *National Resources Inventory* and the USFS *Forest Inventory and Analysis* (FIA) also are applying protocols at the national level, while the National Park Service is developing lists of indicators for each geographic region, including the Mojave Desert, through its Vital Signs process. The BLM has several agency and interagency documents that describe a number of assessment and monitoring protocols, including *Interpreting Indicators of Rangeland Health*, a qualitative assessment protocol with a set of complementary quantitative indicators which is nationally applied by both NRCS and BLM.

All of these protocols can serve as sources of potentially useful indicators. Their application to management in southern Nevada, as in much of the rest of the country (Herrick et al. 2006), is currently limited by three factors. The first is that the indicators have not been tested and calibrated to determine how closely they are correlated with critical changes in different parts of the landscape in southern Nevada, and how many measurements are required. The second is that little guidance is available to managers to help them decide which indicators should be applied in what parts of the landscape to address specific monitoring objectives. Indicators are required that cost-effectively address multiple monitoring objectives in order to reduce duplication in monitoring efforts. The third is that relatively few indicators are available for monitoring cumulative effects at the landscape scale. Indicator species are often touted but their utility is limited, except in some aquatic systems, due to high cost and frequently low reliability.

Most of the above sources focus on biophysical indicators. The Sustainable Rangelands Roundtable is unusual in that it also offers a comprehensive list of indicators that may be useful in monitoring socioeconomic trends as well as anthropogenic stressors on arid and semi-arid ecosystems. Social and economic conditions and trends already are intensively monitored, and data are publicly available from U.S. government sources (e.g., Census Bureau) at scales from city neighborhoods to the entire nation. However, research is generally lacking about which of these are most useful for identifying trends that can be linked to stresses on ecosystems.

Currently available tools: Aquatic

A number of programs have inventoried aquatic systems in southern Nevada. Most of these programs have dealt with rare and endangered fishes, but others have examined springs in Clark County, and inventoried springs below 2300 m elevation for springsnails. Inventories over past decades have documented native and introduced fish populations, and the location of rare aquatic macroinvertebrates. Amphibian inventories have been conducted through most of Clark County. Spring inventories are currently being conducted on all National Park Service lands, and they have been completed for Death Valley National Park. Inventory protocols have been prepared to assess management issues at springs on National Park Service lands in southern Nevada and California.

The monitoring of aquatic systems has been limited to discharge measurements by U.S. Geological Survey (at a limited number of sites) and population estimates for rare fishes. Monitoring programs have not integrated quantified descriptions of target habitats with abundance estimates of the monitored species. Thus, information describing temporal variations in the abundance of a species cannot be linked to characteristics of the aquatic environment. As a result, it is difficult to identify which changes in the environment may be causing populations to decline. Absence of this information makes it difficult to correctly modify management practices and increase the status of the species being monitored. Long-term monitoring protocols have been prepared for Colorado River fishes and aquatic and riparian components of spring ecosystems (on National Park Service lands). Protocols for other aquatic systems have been prepared by the U.S. Forest Service and U.S. Bureau of Land Management.

Indicator species have not been identified in southern Nevada, where they may indicate whether aquatic systems are impaired or healthy and if they are persistent or ephemeral. Indicator species have been determined for most of the United States, but appropriate indicators for the relatively harsh conditions that characterize aquatic systems in the desert southwest are poorly understood. Endangered fishes have been used as indicator species in many southern Nevada waters, and declines in their abundance have changed management and typically improved the quality of their environments. Crenobiontic species are believed to be indicators of springs with stable environments and persistent discharge over long geologic periods.

Recommended research areas

- In general, research is needed that address the limitations to application of indicators in southern Nevada:
 - existing indicators must be tested, calibrated and potentially modified to ensure that they accurately reflect critical changes in ecosystem condition, and to identify which are sensitive to early changes associated with cumulative impacts of multiple stressors
 - in some cases, new indicators will need to be developed, but in most cases, indicators that have already been nationally adopted can be applied or adapted
- For socio-economic indicators, research can help identify whether demographic and economic measures collected by other agencies are useful indicators of changes in land use or ecosystem condition, as well as which indicators are effective for on-site monitoring
- New indicators should be developed for landscape-scale analyses.
- In aquatic systems, inventory programs should be developed that address specific management needs for individual aquatic habitat types (e.g., spring, stream, lake, river) and high priority management species.
- Research also can determine the intended ecological role of indicator species in southern Nevada, identify suitable species for use as biological indicators, and assess how they can be used to inform management.

- Guidance documents must be developed that help managers design monitoring plans that address multiple objectives. These documents should be based on region-specific research on the appropriate number, location and timing of measurements.

Wildland Fire Management in Southern Nevada

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The purpose of this document is to provide a brief summary of current scientific knowledge to support our recommendations for future research and monitoring. Research priorities expressed by representatives from four Federal land management agencies in southern Nevada (BLM, FWS, NPS, USFS) at Workshop #1 of the Ecosystem Health Assessment of Southern Nevada Project on 3-4 May 2006 are also summarized, and a revised list for consideration by a wider range of participants at Workshop #2 on 14-16 August 2006 is suggested.

Summary of Current Knowledge and Information Needs

Vegetation in southern Nevada is thought to be poorly adapted for recovery following fire due to the perception that seedbanks experience high mortality rates and perennial plants experience low survival rates. These ideas stem from a few seminal publications on the effect of fire in the deserts of southwestern North America (Humphrey 1974, Wright and Bailey 1982). Although heating during Mojave Desert fires can immediately reduce seedbank densities, these effects appear to be highly variable and remain mostly unstudied (Brooks 2002, Brooks unpublished data). Immediate mortality of established vegetation can also be high, but varies significantly among species and with conditions during burning (Brooks and Minnich 2006). The long term effects of fires can also vary. Burned areas often remain noticeably different from adjacent unburned areas for 50 to 75 years, although in some cases landscapes can exhibit relatively little evidence of previous burning after as few as 5 to 10 years (M. Brooks personal observation). Seedbank density and composition can also remain affected 15 to 20 years after burning (M. Brooks unpublished data), but these results from a few sites in one vegetation type are currently the only data available. Land managers need more precise guidance than is currently available to help identify situations where seedbank and vegetation mortality may be especially high, and where they may take a particularly long time to recover to pre-burn conditions.

The primary concerns associated with seedbank and vegetation responses to fire are that slowly recovering native vegetation will increase the chances of non-native plant invasion, soil erosion, and habitat degradation for wildlife, especially for the federally Threatened desert tortoise (*Gopherus agassizii*) (Brooks and Pyke 2001, Brooks and Esque 2002, Brooks and Minnich 2006) and other sensitive species. However, the specific relationships between vegetation changes following fire and these key natural resource factors remain relatively unstudied.

Years of high winter and spring rainfall can increase continuity of fine fuels by stimulating the growth of non-native annual grasses that fill interspaces between shrubs and allow fires to spread (Brown and Minnich 1986, Brooks 1999, Brooks and Minnich 2006). A similar relationship has

been documented in the Sonoran desert as well (Rogers and Vint 1987, Schmid and Rogers 1988). Species such as red brome (*Bromus rubens*) and Mediterranean grass (*Schismus arabicus* and *S. barbatus*) provide more persistent and less patchy fine fuelbeds than do native annual plants, breaking down more slowly and persisting longer into the summer and subsequent years (Brooks 1999). These species often dominate postfire landscapes (Brooks and Berry accepted), and the fuel conditions they produce have the potential to increase the size, decrease the spatial complexity, and shorten the time interval between desert fires (Brooks and Pyke 2001, Brooks and Esque 2002, Brooks et al. 2004). However, in some cases these non-native annuals do not dominate post-fire landscapes and recently burned areas are not particularly susceptible to subsequent burning (M. Brooks personal observation). The conditions that promote the establishment of an invasive plant/fire regime cycle (Brooks et al. 2004) need to be better understood to effectively manage postfire landscapes in the Mojave Desert.

The effects of fire is a growing concern in southern Nevada, due to increasing trends in the size of fires across the Mojave Desert during the past 25 years (Brooks and Matchett in review). This trend was punctuated during the summer of 2005 when >1 million acres burned in the Mojave Desert, mostly in southern Nevada. Land managers are concerned that this trend is spiraling upwards and beyond the natural range of fire regime variation, and that the positive relationship between non-native annual grasses and fire is creating an invasive plant/fire regime cycle that will fundamentally alter the Mojave Desert ecosystem. The mechanism of type-conversion from high diversity native shrublands to low diversity non-native annual grasslands is well-known farther north in the Great Basin, if it is occurring in southern Nevada, the time to stop it is now.

The primary method currently used to manage post-fire landscapes in southern Nevada is aerial seeding. There is much controversy over this management response, largely because there is very little information available on its effectiveness. Similarly, efforts to manage fuelbeds using herbicides or mechanical treatments are hindered by limited information.

Recommended research areas

There are five general thematic areas where we believe information is needed to evaluate the current threats that fires in southern Nevada pose, and to develop strategies to mitigate these threats. These general themes are discussed in the following paragraphs.

- **Fire histories** provide an important frame of reference for making fire management decisions. Pre-settlement (anglo-american) conditions are often the reference point for current fire management objectives. This information is typically inferred from physical evidence such as fire scars on trees or charcoal deposits in sediments. Unfortunately, most of southern Nevada is not amenable to either of these approaches. As an alternative, historical documents can be used to determine how humans may have altered fire regimes during the early years of settlement. Aerial photographs are generally available from the mid-1900s, which can provide records of past fires. Recent fire records from land management agencies, and satellite imagery, provide the most reliable sources of information, but these data only extend back a few decades. An assessment of past fire conditions is needed to determine if current conditions are anomalous, and cause for concern. Specific assessments for southern Nevada have not yet been done.

- **Fire effects** on soils, vegetation, and wildlife are also critical to understand. This information is needed to evaluate how changing fire regimes ultimately affect these high-value resources. Even if current fire regimes are found to be within the natural range of variation, the effects of fire on southern Nevada ecosystems still may be different today than in the past. These differing effects may be caused by interactions of fire with shifting rainfall patterns and with the multiple land uses and anthropogenic disturbances that are pervasive in southern Nevada, such as livestock grazing, roads, off-road recreation, atmospheric nitrogen deposition, and wildlife diseases, just to name a few.
- **Fire suppression tactics** can also vary in their ecological effects from physical hand-lines or dozer lines, to the chemical effects of fire retardants and foams. Limited fire suppression options in wilderness or desert tortoise critical habitat areas may result in larger fires. Although the direct ecological effects of various fire suppression tactics may be undesirable, they must be weighed against the effects of not using them, which may result in fires growing larger.
- **Fuels management** is typically implemented at local scales to protect human infrastructure (e.g. homes, recreation areas), but its use also extends to managing fire over large landscapes (e.g. large fuelbreaks). Whether mechanical thinning or herbicides are used, their implementation is often hindered by legal restrictions and a general lack of solid scientific justification. Like fire suppression tactics, the effects of fuels management treatments must be weighed against the potential effects of doing nothing.
- **Post-fire seeding** is the most practical emergency stabilization, rehabilitation, or restoration approach across broad landscapes such as those encompassed by large fires. However, the establishment rate of these treatments is difficult to predict, and their ultimate ecological effects are largely unknown. There are also significant questions associated with the species that should be used, and the rate, timing, and method by which they should be applied.

Research and Monitoring Priorities Expressed by Land Managers at Workshop #1

- Fire effects on vegetation and seedbanks
 - Natives vs. non-natives
 - Desert tortoise forage and habitat species
 - Biodiversity hotspots (e.g. Spring Mountains)
- Postfire seeding strategies
 - What techniques are most effective with limited resources?
- Fire history
 - Past conditions
 - Current and predicted future conditions
- Fuels management
 - How much biomass should be left after fuels treatments?
 - Are firebreaks an effective fire management tool that will not significantly impact the desert tortoise?

Invasive Species in Southern Nevada

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Summary of Current Knowledge and Information Needs

Invasive Species – General Attributes

Biotic invaders are species that establish a new range in which they proliferate, spread, and persist to the detriment of the environment (Mack et al. 2000). In most cases, these invasive species are non-native, or “exotic” species. Exotic species have become increasingly significant management problems in parks and reserves, frequently complicating restoration projects. This is especially the case when exotic species reach such high densities that they become community dominants, and it is in this role that exotics pose the greatest threat to native ecosystems and biological reserves. From an economic perspective, the “cost” of exotic species can also be high – nonindigenous species in the United States cause major environmental damage and losses totaling approximately \$137 billion per year, primarily through habitat degradation and increased restoration costs for disturbed sites.

The number of exotic plant species reported in local and regional floras of the desert areas of California and Nevada is approximately 13% of the total flora. Although the percentage of exotic species in the flora is relatively low compared to other bioregions, exotics often dominate plant community cover and productivity (Brooks 2006a).

Three primary factors attributed to the differential success of invasive species are (1) propagule pressure, (2) availability of limiting nutrients, especially in disturbed sites, and (3) release from enemies (predators, parasites, etc.). Research and management of exotic species in southern Nevada can be classified into one of these three topical areas.

Terrestrial/Riparian Habitats

The primary invasive plant species that appear to be of greatest concern in southern Nevada are red brome (*Bromus madritensis* ssp. *rubens*) and Sahara mustard (*Brassica tournefortii*) from upland areas, and saltcedar (*Tamarix ramosissima*) from riparian areas. A great deal of basic and applied research has been conducted on saltcedar, a more moderate amount on red brome, and very little basic research has been undertaken on Sahara mustard.

Red brome is an invasive annual grass that has invaded most of the Mojave Desert region, and is closely related to cheatgrass of the Great Basin region. Alien annual grasses (*Bromus* and *Schismus*) have been shown to directly compete with native annual plants in the Mojave Desert. They also can stimulate fire in wet years due to dry fuel build-up; fire in turn can promote the dominance of invaders, thus creating an invasive plant-fire regime cycle. *Bromus* invasion can also decrease soil nitrogen availability through the production of lower-quality litter that slows down nutrient cycling.

Saltcedar is currently the dominant species of most riparian areas of the southwestern U.S. Reduced flood disturbance has most often been associated with the invasion of non-native saltcedar, which displaces native flood-dependent trees such as cottonwood, willow, and

mesquite. Saltcedar reaches deeper for groundwater farther from waterways, and it builds up banks and islands, which it then colonizes through sediment capture. Saltcedar invasion therefore represents not only a replacement of less water consumptive vegetation by a species that consumes more water, but it also increases the extent of heavily vegetated areas near waterways and thus further increases water loss on a landscape-area basis. Saltcedars are deciduous shrubby species, whereas *T. aphylla* (athel) is an evergreen tree that is not considered as invasive as saltcedar, although it is posing significant problems at LMNRA. Disturbingly, hybridization between saltcedar and athel has been observed in this region. The implications of this hybridization for the relative invasiveness of these species is unknown, but needs to be investigated.

Aquatic Habitats

A number of invasive vertebrates and invertebrates occur in rivers, large springs, and larger spring-fed streams in southern Nevada. They include non-native amphibians, fish, and invertebrates. Sport fish and bullfrogs are the most common vertebrate invasive species in the Colorado River (Minckley et al. 2003), while mosquito fish and aquarium fish are most common in springs. Where these fish occur, they are usually more abundant than native fishes, with over 50% of the species of the current fish fauna in Nevada being introduced, the highest number in the U.S. Asian clams, crayfish, and the red-rimmed melania are the most common invasive aquatic invertebrates. Invasive aquatic species are currently unknown from small springs. The abundance and distribution of native aquatics is reduced by predation, competition for food and space, and diseases carried by invasive species. These interactions frequently reduce native vertebrate and invertebrate populations, and often cause the endangerment of rare native species. Ecological information about many invasive aquatic species is known from studies in other regions, but there is little information quantifying their interactions with southern Nevada's aquatic fauna. The distribution of invasive aquatic species is relatively well documented, but new species are often introduced and the distribution of established species is increased by passive (ergo human) and active dispersal.

Management Issues

Research and management approaches are often inadequate to tackle the invasive species problem. The current focus is mostly on the characteristics and control of individual invading species. However, early detection and treatment of invasions at a landscape scale, before explosive spread occurs, will prevent many future problems. Comprehensive reviews have shown that control of biotic invasions is most effective when it employs long-term, ecosystem-wide strategies rather than a tactical approach focused on battling individual invaders (Mack et al. 2000).

An emerging consensus within conservation biology is that complete extirpation of invasive species may not be economically feasible or even desirable from a restoration perspective (D'Antonio et al. 2004). Recent research has shown that species removal in isolation can result in unexpected, potentially negative, changes to other ecosystem components. These secondary effects will become more likely as numbers of interacting invaders increase in ecosystems, and as exotics in late stages of invasion eliminate native species and replace their functional roles.

Recommended research areas

- At present, we have an incomplete understanding of the factors that are important in controlling the establishment and spread of exotics in desert habitats. We have even less understanding about the potential impacts of these exotic species upon native plants and communities. More basic research is needed to document changes in distributions of exotics in the desert, how various extrinsic and intrinsic factors influence their growth and distribution, and how the abundance of exotic species affects ecosystem structure and function. This basic research must be conducted at multiple scales, from genetics and population processes to the role of species in ecosystems.
- Detailed research on populations of invasive species will contribute to an overall understanding of the invasion process that may aid in the formulation of policy and help to focus attention on invasions that are especially prone to becoming problematic. In this regard, long-term monitoring of populations before and during invasion as well as before, during and after any control attempts can provide valuable ecological information. Integrally tied to population biology is the genetic structure of populations. The genetics of invasive species has been relatively unexplored, but could offer insights into mechanisms of invasion. Recent studies suggest that the invasion success of many species depends more on their ability to respond to natural selection than on broad physiological tolerance or plasticity. Thus, these studies stress the importance of genetic architecture, and the utility of genomic approaches for determining invasion mechanisms.
- From a landscape perspective, we need to know what types of communities and ecosystems are vulnerable or resistant to invasive species. The diversity resistance hypothesis argues that diverse communities are highly competitive and readily resist invasion, but it needs to be determined if such a generalization applies to desert, riparian and aquatic ecosystems in the region.
- The greatest deficiency in knowledge of aquatic invasive species in southern Nevada is weak quantification of ecological relationships between native and non-native species, how to minimize deleterious interactions between native and non-native species, and identifying and controlling diseases spread by invasive species. Primary research topics are to (1) determine physicochemical factors affecting the abundance of invasive species, (2) determine interspecific interactions between native and invasive aquatic species, (3) utilize ecological information to control deleterious interactions between native and invasive aquatic species, and (4) determine diseases that are associated with invasive species and determine their effect on the abundance of native species.
- From an applied perspective, roads are believed to be a major contributing factor to the ongoing spread of exotic plants. Plant communities that are physically invasible (*e.g.* characterized by deep or fertile soils), disturbed, and near roads appear most vulnerable to invasion (Gelbard & Belnap 2003). Thus, the role of road systems in exotic species dispersal, including comparative surveys of developed *versus* roadless areas, are critical in understanding this phenomenon and how best to manage road building and/or road closure programs.

- Finally, species invasions are occurring in a landscape of global change. Recent evidence suggests that many invasive species share traits that will allow them to capitalize on the various elements of global change, particularly elevated CO₂ and increased nitrogen (via dust deposition or increased disturbance). Indeed, we have already observed cheatgrass and red brome to show a much stronger growth response to elevated CO₂ and increased soil nitrogen than do native species. As global change increasingly impacts ecosystems, we will need to obtain more detailed information as to how these factors may affect the ecology of invasive species in this region.

Research and Monitoring Priorities Expressed by Land Managers at Workshop #1

- What are the rates of spread/invasion of non-native plants?
- What is the distribution of non-native exotic species of interest, and which ones should be of interest?
- What adverse impacts to habitats/species of concern have occurred from non-native species?
- How do we control red brome in the Mojave Desert?
- What impacts are invasive aquatic species (*e.g.* crayfish, *Procambarus clarkia*, and *Melanoides tuberculata*) having on native spring and stream systems and habitats in southern Nevada, particularly native endemic species such as fishes and invertebrates (*e.g.* endemic springsnails). What are the competitive interactions between *Melanoides* and native endemic snails under predation pressure by introduced crayfish?
- How do we prevent the invasion of new aquatic species such as zebra mussel, milfoil, mudsnail, etc.?
- What are the best methods for controlling crayfish, *Melanoides*, and non-native fish without harming the spring/stream system and its native endemic species?
- What are the effects of herbicides on endemic aquatic invertebrates and fish?
- What are the effects of herbicides, specifically targeting weeds common to Mojave Desert scrub communities (*e.g.* red brome, Sahara mustard), on the desert tortoise?
- Is the application of pre-emergent herbicides (*e.g.* Oust) along roads an effective method to control the spread of invasive weeds, particularly Sahara mustard?

Water Resources in Southern Nevada

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Background

Water management issues in southern Nevada are focused on groundwater hydrology, spring ecology (including a number of endangered and rare aquatic and riparian species), and Colorado River management.

Water resources in southern Nevada include springs, spring-fed streams, and the Colorado River. Flow in the river is actively managed to for hydroelectric power, flood control, and municipal and agricultural supplies. Dams creating Lake Mead and Lake Mojave impound the river, and reaches of flowing water are short and supplied by hypolimnetic dam release. Impoundments

and flow alteration have altered functional characteristics of the river and justified listing several fish and birds as endangered. The Colorado River water is managed by implementing court decrees that guide all public and private water use activities. Fish and wildlife are managed by State and Federal agencies and endangered species management is funded through the U.S. Bureau of Reclamation and the Lower Colorado River Multiple Species Habitat Conservation Plan. Resource agencies that attended the first meeting did not indicate that additional funds are needed to address Colorado River management issues.

Groundwater Hydrology

Much of the previous technical effort in the region is important, innovative science being conducted by world-class researchers. Clearly, the new findings and methods being developed in southern Nevada will have significant implications not only within the region but also in other arid ecosystems worldwide.

Scientific analyses of groundwater resources in the region have focused primarily on hydrologic and geologic research including the following:

- Identifying waters from different aquifers
- Delineating flow paths
- Evaluating sources and distribution of ground-water recharge
- Ground-water pumping
- Climate conditions and their impacts

The major ground-water modeling activities in the region include the large, regional model of the Death Valley ground-water flow system (USGS), modeling efforts of the Nevada Test Site and vicinity (DOE), and the ground-water modeling efforts of the southern part of the White River ground-water flow system (SNWA).

Spring Ecology

Springs provide most of the surface water across the southern Nevada landscape. They occur from high (~3300 m) to low (450 m) elevations and vary in size from temporary seeps to large (flowing ~ 0.28 m³/sec, or 10 ft³/sec), geologically persistent springs. They occur singly or in provinces, and the only permanent streams in the region are supported by springs. Springs in this region are supported by three types of aquifers. High elevation springs on mountain blocks are typically small, cold and supported by perched aquifers. Springs on bajadas and along the base of mountains are cool, larger, and usually supplied by shallow, valley fill aquifers. Many valley floor springs are warm and supplied by a deep regional aquifer that flows from east central Nevada and west central Utah through carbonate rocks. Regional aquifer springs and many valley fill springs are occupied by endemic aquatic animals, and their associated soils and wetlands support endemic plants. Excessive use of groundwater, invasive species, surface water diversions, and trampling and feeding by non-native ungulates have altered most springs in the region, caused aquatic extinctions, and justified the listing of many plants and animals as endangered. Due to the importance of springs and these rare species to Federal land management agencies in the region, a number of research and management programs have been implemented. Conservation programs involving springs in southern Nevada include recent

establishment of National Wildlife Refuges in Ash Meadows and the upper Muddy River. Many studies have examined the life history, physiology, and biogeography of endemic fish, and several ecological studies have examined benthic macroinvertebrate and riparian communities, springsnails, and amphibians in springs. The distribution of described, endemic aquatic animals and plants associated with springs is reasonably well known. Research in the Spring Mountains provides insight into ecological effects of natural and anthropogenic disturbances on macroinvertebrate and riparian communities. Ecological information shows that there are distinctive habitat requirements for each endemic species and that aquatic communities vary widely among springs.

Federal Agency Management Concerns and Questions

Understanding the region's water resources and the ecosystems that depend on it, naturally dominates the questions posed by, and the uncertainty facing, the DOI agencies. These questions may be summarized as the following:

- Why are pupfish populations declining and how are ground-water levels related?
- How does the lower carbonate aquifer and geologic structures impact ground-water flow and spring discharges?
- What are the expected impacts from ground-water pumping and when will these impacts occur?
- How do we protect sensitive species and ecosystems from growth and human encroachment?
- Where should urban growth be focused, how much, and what are acceptable land uses?
- Are there adequate water supplies to meet competing needs?
- How do we use limited funds to help us make sound management decisions?
- What are uncertainties attributed to scale, and how does this limit the accuracy and resolution of analyses and models?
- There is not enough data in critical areas, such as new, appropriate well locations to monitor groundwater, and access to extensive and comprehensive data at existing monitoring wells is limited.
- Predictions and simulations provide non-unique solutions – there are many equally likely outcomes.

How can uncertainty be decreased by incorporating appropriate information into region and basic scale groundwater flow models.

Research perspectives

Groundwater Hydrology

The dominant physical feature of the Death Valley ground-water flow system and the adjacent ground-water flow systems is the Great Basin carbonate aquifer. The importance of the carbonate aquifer in relation to regional ground-water flow can not be understated. Most water resource management questions are impacted by the uncertainty related to this aquifer and its interaction with the rest of the ground-water flow systems.

Science teams in the region continue to investigate the carbonate aquifer and its related biologic and hydrogeologic systems to address uncertainties in:

- Ground-water flow paths and travel times
- Radionuclide transport
- Ground-water pumping and its impact
- Climate variability
- Vertical-flow directions
- Role of hydrogeologic framework, faults, and other geologic structures on ground-water flow
- Biotic and habitat consequences of system changes
- Distribution and rates of recharge & discharge
- Impacts of analytical and simulation simplifications on results and predictions
- Importance of natural processes on the overall system

During the workshop discussion both scientists and managers voiced their concern over what is still not known about the natural systems of the region; however, their attention was clearly on different issues.

While the scientists felt that there still is a great deal of scientific work to do, the managers expressed the need to put all of the pieces of science together to gain a more comprehensive understanding that would assist in making decisions. The answer is most likely that both of these views are valid.

Recommended research areas

Groundwater

- More formally pose the water resource management decisions facing the region so that managers would be better able to frame the questions that scientists are required to answer
- More aggressively integrate the existing knowledge base that has already been amassed over the years.

Until these two steps are completed, the community will be unable to determine what additional knowledge must be acquired in the region.

Spring Ecology

The greatest deficiency in existing information is weak quantification of ecological relationships between aquatic life and physicochemical elements of the aquatic environment. Primary research topics are:

- Determining spatial and temporal variation in naturally functioning populations and communities.
- Determining proximate and ultimate factors affecting the abundance of rare and endangered species.
- Quantifying microhabitat preferences for physicochemical elements of spring environments for these species.
- Determining how groundwater-surface water interactions affect spring-fed aquatic and riparian communities at springs.

- Determining levels and types of habitat modification (e.g., surface diversions and groundwater use, recreation, ungulate trampling, etc.) that can occur without affecting the biotic integrity of spring ecosystems.
- Developing captive breeding programs for rare species as needed.
- Identifying reference springs (ergo undisturbed by human activities), quantify their riparian and aquatic communities, quantify spatial and temporal variability in their aquatic and riparian communities, and determining relationships between aquifer characteristics and biotic communities.

Geomorphology, Geology and Soils in Southern Nevada

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Background

Soil knowledge and information needs were identified by all four agencies. Three general types of needs were identified: soil-vegetation relationships, land degradation and recovery processes, and soil indicators. All of these rely on an understanding of underlying geology and geomorphic patterns, and the spatial relationships between landscape elements, soils, and plant communities.

(1) GEOLOGY AND GEOMORPHOLOGY. Many of the questions asked by the agencies, while not explicitly addressing geology and geomorphology, ultimately depend on an understanding of geology and geomorphic patterns and processes. Geology and geomorphology figure prominently in the BLM's concern with the regional hydrogeological framework in regard to quantifying the water budget, and they are specifically mentioned in regard to stream/spring systems: there is a need for improved understanding of channel morphologies and the thresholds involved in channel changes (more in the "Water Resources" section of this report). Geomorphology also figures prominently in archaeological concerns with the location of cultural resources, and specifically in the erosion of and deposition over cultural resource sites.

(2) SOIL-VEGETATION RELATIONSHIPS. Most of the agencies placed a high priority on the maintenance and/or recovery of particular plant and animal species. More information is needed on which soils are most likely to support viable populations of listed plant and animal species, and of invasive species. This will also require more information on which dynamic soil properties (e.g. spatial and temporal distribution of water and nutrients) limit plant establishment and survival.

(3) LAND DEGRADATION AND RECOVERY PROCESSES. All four agencies are very concerned about land degradation. The BLM, NPS and FWS gave a high ranking to these issues and the USFS put them at the top of their list of questions. The NPS is particularly interested in carrying capacity issues relative to OHV's, and how to jump-start recovery following land degradation. Vegetation recovery plans require information on the range of plant communities that can be established. These plans are currently based on expert knowledge and often do not take into account inherent differences among soils and geomorphic units. Clearly disturbance is an issue for the physical land surface, as well as for associated ecological and hydrological

concerns. Information is needed on the recoverability and vulnerability of different soils (extending the work of the USGS project) and the extent to which soil structure (e.g. compaction) and fertility must be addressed as part of the restoration process. This information should also help to generate carrying capacity estimates.

(4) SOIL INDICATORS. Due to the long lifespans and infrequent regeneration of many of the dominant ecosystems in Mojave Desert plant communities, soil degradation can occur before changes in perennial plant cover. Both the NPS and BLM identified a need for soil indicators based on an improved understanding of the relationships between soil properties and ecosystem processes, including plant establishment, runoff and erosion. There was a particular interest in the use of dynamic soil properties as indicators of ecosystem change (e.g. BLM: bearpoppy habitat).

Current State of the Science

The reference list at the end of this brief report provides a flavor of the existing geomorphological and soil science for the region. Most of these focus on the interrelationships of soils with geomorphic surfaces and landscape elements. Excellent studies in this regard have also been accomplished in nearby regions, notably in the southern California Mojave and near Yucca Mountain. There is also literature on land disturbance and recovery in the Mojave, e.g., Webb et al. (1988), including the effects of off-road vehicles on some soils and geomorphic surfaces and the recovery of severely compacted soils (Webb, 2002) and there are several relevant studies which address soil vegetation relationships and dynamics, including the classic work of Beatley (1975) and Webb's more recent studies (Webb et al., 1987). However, our understanding of the relative resistance of different parts of the landscape to different types of degradation is quite limited, and there are few reliable, inexpensive indicators available that have been tested in the region.

The NRCS ecological site descriptions and the USFS and NRCS soil surveys include information about soil-vegetation relationships. Information on soil and vegetation dynamics, however, is relatively limited, especially at lower elevations. This is due to the extremely slow growth rates and infrequent establishment events associated with low precipitation, and the limited number of truly long-term (> 50 years) studies. There are also several studies and a significant amount of local (unpublished) knowledge about the habitat requirements of some of the listed species. However, much of this information is anecdotal. Furthermore, little of it takes into account landscape position. Soil indicators have been identified for other ecosystems, but few have been tested or calibrated for southern Nevada (see "Inventory, Monitoring and Indicators" report).

Recommended research areas

- Geology and geomorphic patterns. There is a clear need for a regional framework of landscape understanding, such as would be provided by the regional mapping of surficial deposits and associated terrains. The landscape elements, including alluvial fan surfaces, channelways, terraces, mountain slopes, etc., can all be related spatially and associated with soil types and plant communities. This kind of mapping, initially done at coarser scales for the whole region, will provide a framework for

- understanding the natural landscape as it transcends the artificial boundaries of administrative units
- Soil-vegetation relationships. Research in this area should focus on soils where better information is needed to establish more realistic management and restoration objectives.
 - Soil degradation and recovery. Research in this area should focus particularly on emerging and increasing threats, including road construction, off-road vehicle traffic, and nitrogen deposition
 - Soil indicators. The emphasis should be on testing and calibrating existing indicators that have the potential to be sensitive to early stages of degradation and recovery, and to be repeatable and cost-effective. Development of new indicators should be a secondary priority.

Landscape Ecology/Landscape Planning in Southern Nevada

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Landscape Ecology

Landscape ecology is a term coined by a German geographer, Carl Troll, in 1939. It became a self-conscious subdiscipline of ecology around 1980 when the International Association for Landscape Ecology was formed. Books and a journal, *Landscape Ecology* started in 1987, quickly followed. Since these early beginnings, landscape ecology has become an integral part of the curriculum in the life sciences.

Landscape ecology deals with the documentation of spatial heterogeneity of landscape elements, including organisms and the substrates and objects in their environments. Of special interest are the influences of this heterogeneity on biotic and abiotic processes. Special attention has been paid to the application of landscape concepts to problems of natural resource management and conservation. Early examples of such applications were the attempt to use the island biogeography theory developed by MacArthur and Wilson to determine the characteristics of nature reserves, which more recently became the framework for metapopulation theory.

Important aspects of landscape ecology include the consideration of the spatial and temporal scales at which processes occur, the importance of the characteristics of patches in a landscape mosaic and the study of ecotones and ecoclines, among others. A phenomenon related and important to these considerations is the fragmentation of landscapes by a variety of forces, including human use.

It should be clear from this brief overview that because a landscape perspective integrates biotic and abiotic processes across scales, all government agencies should be using a landscape ecology perspective for many of their management decisions and plans. More specifically, in southern Nevada where the size of the urban footprint is growing at an astounding rate, a priority of resource managers should be to expedite research and planning initiatives within a landscape

perspective – the rate and magnitude of transformation of natural into urban landscapes will, in many cases, overwhelm the efficacy of individual, population, species or local ecosystem scale conservation and management strategies.

It is interesting to note that in the first meeting with agency representatives, much of the concern was directed to the species level and to a few ecosystem processes. A landscape perspective when making decisions, regardless of specific research projects, may be an important addition to the managers' toolbox.

Landscape Planning

The following comments represent a distillation of the four presentations made by Agency representatives on 3 May with respect to the subject area of land degradation and habitat fragmentation. There was a consistent reference by all four groups to issues of “scale”. Their presentations often emphasized the need to understand the big picture in contrast to the necessity of addressing smaller units of research or management e.g. landscape-level research in contrast to site-specific issues. Several major subject areas were referred to in this context. The need for major research on ground water hydrology, fire, and invasive plants and animals head the list of concerns. All four groups also referenced the need for common baseline data (soils and vegetation) with respect to these concerns as well as the need for long-term monitoring of these resources.

Although each of the four groups presented various wish lists of research, none of the four presented or indicated the manner in which their agency approaches the analysis, planning and management of their respective areas of responsibility. The question of scale was a good indicator of this lack of systematic approach to understanding their respective landscapes. It was not clear how each of the issues they were addressing were somehow imbedded in the setting or context of their landscapes. Most of the discussion in their presentations emphasized traditional science approaches to management problems e.g. a conventional ad hoc “reductionist” approach without addressing the issue of context.

Lastly, with respect to the questions of “scale” and “context”, there was little indication as to how each of the four units assess their management strategies before implementation in the field. It was not clear whether future monitoring of their actions was being carried out over space and time. What are the consequences of their management practices?

Recommendations for the Agencies

It appears clear that each of the agencies need to step aside from traditional approaches in their planning and management programs. There needs to be full collaboration between the various disciplines (and agencies) in addressing the three major concerns of ground water hydrology, fire and invasive species. Given the enormous projected growth for the region, the resolution of these concerns should be examined within the context of the urban/wildlife interface. Parallel to this internal interagency collaboration is the necessity to reach out and participate with city, county, and state planning organizations. In some cases, this should include NGOs such as The Nature Conservancy, Audubon Society, etc. An immediate concern is the preparation of common baseline data needed by each agency to facilitate their planning and management

activities. Priority data sets should be identified immediately as well as their spatial scale of resolution.

A broad framework or approach should also be developed which takes into account large scale landscape issues as well as more detailed scale studies. The approach should take into account both the biophysical components of the landscape as well as those which deal with culture and settlement. There is a need to describe the evolution of both the natural and built environment of this region in order to provide an appropriate context for future decision making. The various “drivers” inherent in these two systems (biophysical-cultural) should also be identified and elaborated upon in order to determine their role in future management strategies.

Recommended research areas

- Evaluate the fragmentation effects of road and trail building. Do you know how such fragmentation of continuous habitat influences species of special interest to your agency?
- In fragmented habitats, what is the optimum size of corridors that connect the fragments? This is often a species-specific assessment.
- How do roads and trails act as routes of invasion for alien species?
- What role does the architecture of the landscape play in the persistence of species or communities of concern? Often we spend so much time on biological needs of communities we overlook the fact that some structural attributes may be important, e.g., snags and holes for birds or outcrops for certain plants and animals.
- Do changing landscape structures increase the incidence and intensity of disturbances such as fire, invasion by alien species, the spread of disease?
- How do the sizes and shapes of conservation areas influence the persistence of species and habitats of interest? Is there a minimum viable area? Is there an optimum shape for conservation of particular species?
- How do features of your landscapes of local interest contribute to biotic and abiotic processes within a larger regional landscape (e.g., critical resources along migratory routes)?
- Can you predict how critical features and conservation areas in your landscape mosaic will respond to models of global climate change?
- Can you predict how critical features and conservation areas in your landscape mosaic will respond to consequences of urbanization such as changing hydrogeological dynamics through ground-water pumping?

Cultural Resources in Southern Nevada

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Agency Viewpoints

In advance of the Ecological Health Assessment in Southern Nevada Workshop, the SNAP (Southern Nevada Agency Partnership) Cultural Resource Team met to discuss inter-agency cultural-resource (i.e., “archaeological”) research issues. The team produced a list of primary needs for all lands in southern Nevada (revised slightly here to include other concerns raised by the agencies both during and prior to the workshop):

- Basic inventory to determine the location, nature, and status of cultural resources
- Development of a new Historic Context for Southern Nevada to provide a framework for investigating and evaluating cultural-resource sites
- Study of land-use through time, identifying temporal and spatial variability, as well as continuity, in Southern Nevada’s settlement history
- Study of interactions among cultural groups living within and adjacent to the Southern Nevada region
- Ethnological studies to aid in the identification and evaluation of archaeological sites and Traditional Cultural Properties (TCPs)
- Assessment and improvement of archaeological methods and development of better cultural chronologies
- Interdisciplinary study of past environments (including the hydrology of springs and streams), of fire history (including the possible use of fire by Indian people as a land-management tool), and of rates and processes of erosion and deposition (affecting site condition and visibility)
- Assessment of the status and additional analysis of existing collections of archaeological artifacts and samples
- Development of GIS databases
- Development of heritage tourism and efforts to make research on cultural resources relevant to the public
- Assuring the preservation and sustainability of the region’s cultural sites.

Discussion

A number of the research needs identified by the members of the Cultural Resource Team stand apart from those expressed by spokespersons for the other, natural-history based disciplines included in the Ecological Health Assessment Workshop. It seems appropriate, therefore, to begin a discussion of cultural resource issues by considering some links between those resources and the other subject areas included in the workshop:

- Previous research in southern Nevada has demonstrated a strong relationship between the distribution of archaeological sites and specific characteristics of the “natural” environment, involving in particular topography, geomorphic processes, surface hydrology, and plant communities.
- Research has also shown that the occupants of those sites experienced environmental conditions that differed to a greater or lesser degree from those that exist today or even that existed during the historical period. Archaeologists are therefore interested in, and

often sponsor through their projects, studies that seek to “reconstruct” environmental conditions of the Terminal Pleistocene and Holocene epochs. Such studies are inherently inter-disciplinary.

- Archaeologists make use of these reconstructions, but also produce data that can contribute to their development
- Paleoenvironmental reconstructions are an important component in identifying appropriate and realistic goals for efforts to maintain Southern Nevada’s “ecological health”
- In the context of the last 10,000 years, any broad-scale concept of the “natural” environment needs to acknowledge the presence and influence of human groups living on the landscape
- Cultural-resource sites are a primary source of data for understanding that human presence in the environment
- The concept of “cultural landscapes” provides a context for understanding the nature and trajectory of “man-land” relationships in the Southern Nevada Region

The concept of cultural landscapes is also relevant to several of the other cultural-resource concerns expressed by the government agencies. They include the development of a new regional Historic Context and the development of GIS databases that can contribute to regional-scale research of man-land relationships through time. GIS can, in particular, contribute to the delineation and characterization of environmental zones that, as previously noted, had a significant impact on settlement patterns within the region.

The landscape perspective is also important for the stated goal of conducting basic inventories of cultural resources—specifically inventories that are not occasioned by development projects (i.e., in conformity with Section 110 of the National Historic Preservation Act). “Complete” inventory of the region’s public lands is an elusive goal, because of the expense involved but also because the standards for recording cultural-resource sites, as well as the sites themselves, have changed and will continue to change over time. A realistic goal for site inventory on a regional scale is to continually expand and improve the *sample* of lands that have been searched and of sites that have been identified and recorded. Landscapes provide a context for apportioning the available survey effort, which should be based in part on measuring the redundancy in information collected on the cultural resources that occur in particular environmental zones. The new regional Historic Context should address this and other sampling issues.

Along with cultural landscape, another idea that can serve to unify the list of agency research needs concerns the fact that cultural sites represent a finite, nonrenewable resource that needs to be protected for the future. It follows that one important goal of inventory is to provide a baseline for measuring change in the condition of populations of sites over time. It is also important to maintain and make use of existing collections of archaeological objects and data, because in many cases these “records” are all that remains of sites that have been “removed” from the site inventory. Furthermore, the methods and procedures for discovering and investigating cultural-resource sites (including research guidelines presented in Historic Contexts, site-inventory goals, means of locating and characterizing subsurface remains, standards for data-recovery, accuracy and pertinence of GIS layers, and so on) should be continually scrutinized to assure that the

maximum information is obtained from a “stock” of prehistoric and historic sites that, preservation efforts notwithstanding, will continue to decrease over time.

A third idea that unifies the agencies’ list of primary needs concerns the participation of various interest groups in the preservation and study of the region’s cultural resources. These groups include Native American communities, associations of avocational and professional archaeologists, participants in Nevada’s site-steward program, and members of the general public who have some degree of interest in learning about, and preserving the vestiges of, Southern Nevada’s cultural history. There are two ways in which these and other interest groups are related to the list of “research needs.” First, better, more effective means should be found for communicating the results of research to the various “publics” that share an interest in cultural resources. Second, the effectiveness of these means of communication should itself be considered an important research objective.

Recommended research areas

- One valuable, near-term research goal for cultural resources in Southern Nevada is the preparation of a new Historic Context for the region. This is important for three reasons. First, the need for this document was stressed by the agency representatives who participated in the workshop, as well as by other members of the Cultural Resource Team. Second, a new context is long overdue. And third, a well-crafted Historic Context could structure and promote the kinds of research that the agencies have identified as important to them.
- A second important goal is to continue and expand efforts to compile region-wide data sets, involving in particular survey data but also excavation data. This should include the development, verification, and dissemination (as appropriate) of data bases and data layers, suitable for GIS manipulation, relating to cultural-resource sites, plants and plant communities, springs, surface geology and soils, and so on.
- A third, related goal is the development of one or more “finder’s guides” for existing collections of objects, records, and reports relating to the region’s cultural resources—what collections are held by what institutions, located both within and outside the region? What is the condition and accessibility of these collections?
- A fourth near-term project is to explore means for fostering interdisciplinary studies of past environments and for encouraging interaction among interested parties, including archaeologists, paleoenvironmentalists, specialists who analyze biological specimens from archaeological contexts, geomorphologists, biologists, and so on.

Restoration in Southern Nevada

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Research and Monitoring Priorities Expressed by Land Managers at Workshop #1

How do we prioritize restoration projects?

How do we efficiently evaluate the effectiveness of restoration treatments?

There are several books and publications on arid land restoration that outline general factors that should be considered for these harsh environments (Allen, 1988; Crosswhite and Crosswhite, 1982; Goudie, 1990; Wallace, et al. 1980). These are helpful and address the unique problems associated with revegetation in arid lands. There are only a few publications that would be considered users manuals for revegetation of southwestern deserts (Bainbridge et al., 1998, Bainbridge et al., 1995; Cox et al., 1982; Institute for Land Rehabilitation, 1979; Newton and Claasen, 2003; and Ostler et al., 2002). These publications provide general guidance for revegetation but there are many issues and questions that remain unanswered particularly for burned areas that are becoming a serious issue in the Mojave Desert.

Recommended research areas

Answering these questions will require much more research particularly in the following areas:

- seed dormancy, germination, and establishment;
- viable seedbanks following fire
- interactions of seedlings with soils;
- precipitation patterns and water requirements for establishment;
- interactions of seeds and seedlings with animal predators and
- cost effective revegetation practices for large burned area i.e. seed rates, seed mixes, seed burial.

It has been stated that revegetation in areas where precipitation is less than 230 mm per year is a difficult if not impossible task (Plummer et al., 1968). Wallace et al. (1980) claim that only two years in six have suitable precipitation for revegetation to be successful in the northern regions of the Mojave Desert. Research sponsored by DoD, USGS, DOE and other federal agencies over the past 10 years has focused on developing effective revegetation strategies for arid lands of the desert southwest (Anderson and Ostler, 2002; Bainbridge et al., 1998; Roundy et al., 1995; Winkel et al., 1999). Improvements in technology, species selection, and planning have increased the likelihood of success and yet there is much we do not understand.

Any long-term strategy to achieve success in arid land revegetation must work within the ecological constraints of the area. This means attempting to restore a vegetation association that is successional within the existing ecosystem. Although the soil may be severely disturbed and native vegetation lost or replaced by nonnative weeds, the general climatic conditions, including precipitation patterns, remain constant. Because of limited funds, revegetation of disturbed areas, particularly large burned areas, must be sustainable after the first season with no additional inputs. To reach this goal, not only do species need to be adapted to site conditions, but erosion must be under control and natural nutrient cycles reinitiated. Each site and vegetation type

present different challenges and, thus, different revegetation strategies must be employed if success is to be attained.

Air Quality in Southern Nevada

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Although air quality was not explicitly stated as an issue of concern by agency representatives, and did not feature in questions posed by the agencies, the following three examples of legislative language referring to protection of scenic resources on Federal Lands in southern Nevada indicate that it is an important topic.

Red Rock NCA

In order to **conserve, protect, and enhance** for the benefit and enjoyment of present and future generations the area in southern Nevada containing and surrounding the Red Rock Canyon and the unique and nationally important geologic, archeological, ecological, cultural, **scenic**, scientific, wildlife, riparian, wilderness, endangered species, and recreation resources of the public lands therein contained, there is established the Red Rock Canyon National Conservation Area.

Lake Mead NRA

Lake Mead National Recreation Area shall be administered by the Secretary of the Interior for general purposes of public recreation, benefit, and use, and in a manner that will preserve, develop, and enhance, so far as practicable, the recreation potential, and in a manner that will **preserve the scenic**, historic, scientific, and other important features of the area, consistently with applicable reservations and limitations relating to such area and with other authorized uses of the lands and properties within such area.

Spring Mountains NRA

The Secretary, acting through the Chief of the Forest Service, shall manage the Recreation Area in accordance with the laws, rules, and regulations pertaining to the National Forest System and this subchapter to provide for -

(1) the **conservation of scenic**, scientific, historic, cultural, and other values contributing to public enjoyment;

Discussion

The majority of Clark County, Nevada has been designated as non-attainment with the National Ambient Air Quality Standards (NAAQS) for particulate matter less than 10 microns in diameter (PM10) and for 8-hour averaged ozone. While measurements of PM10 and ozone are sparse on Federal Lands in Clark County, all four land management agencies (USFS, BLM, NPS, and USF&WS) manage lands within the non-attainment areas for PM10 and ozone (see ozone non-attainment area map at http://www.co.clark.nv.us/Air_Quality/Studies/FinalAttainmentBoundary.pdf).

PM10 concentrations typically decrease rapidly with distance from sources (Chow *et al.*, 1999). As most federal Lands in Clark County are not in close proximity to significant PM10 sources

(e.g. within 1 km), concentrations in excess of the NAAQS are probably not widespread. High concentrations of PM₁₀ over significant FLM areas are most likely to occur in conjunction with transport from source areas (e.g. Las Vegas Valley) during high wind conditions.

Ozone air pollution is more regional in nature. Peak ozone concentrations usually occur downwind from cities due to the time needed for the photochemical reactions to occur. In Clark County the highest ozone concentrations are typically in the northwestern areas of the Las Vegas Valley (T&B Systems 2006). During the summer of 2005, the highest concentrations were recorded at the Las Vegas Paiute Reservation near US-95 between the Lee Canyon and Kyle Canyon roads. This area is surrounded by BLM administered land and is very close to the Spring Mountains National Recreation Area administered by the US Forest Service and the Desert National Wildlife Refuge administered by the US Fish & Wildlife Service. Though not monitored at these areas, it is likely that the portions of the Spring Mountain NRA and the Desert National Wildlife Refuge experience ozone concentrations in excess of the 8 hour NAAQS. Limited monitoring data by the National Park Service at Lake Mead indicate ozone values approaching the NAAQS.

While it is the responsibility of Clark County to control air pollution sources to the extent that the NAAQS are complied with, the Federal Land Management agencies have in their governing legislation requirements to protect resources on the land they manage. FLMs can and should take an active role to ensure that the air resource over their land is protected. This includes participation in air quality studies, reviewing and commenting on: proposed State Implementation Plan (SIP) sections prepared by Clark County; proposed air quality regulations and monitoring programs; new sources proposed to be built in Clark county; etc.). The Bureau of Land Management in particular has a potentially direct effect on air quality through its land sales by making additional land available for urban development.

Federal Land managers should be concerned about the effects of these levels of ozone on employees, visitors, flora, and fauna. There has been little research on the effects of ozone on desert plants; however adverse effects on Ponderosa pine (which occur on USFS and USF&WS administered lands in Clark County) have been well documented (e.g. James *et al.*, 1980).

Visibility is an air quality related value that is of concern to Federal Land Managers in Clark County. All four FLMs have scenic vistas important to the visitor experience. These vistas are often hazy due to pollution from local sources (e.g. Las Vegas) and regional haze (a mix of many source areas in the southwestern US, Mexico, offshore shipping and even, occasionally, Asian dust). Presently visibility protection is mandated only for Federal Class I air quality areas (mostly national parks and wilderness areas established by 1977). The closest Class I visibility protected areas are Zion National Park and Grand Canyon National Park. States must submit SIPs by 2007 indicating how they intend to protect and improve visibility at these areas. This program will, by default, afford some visibility protection for federally managed lands in Clark County. Even though there are no Class I areas in Clark County, legislation and policy developed for areas with scenic values such as Red Rocks NCA, Spring Mountains NRA, etc. typically require the FLM to protect scenic resources.

Another air quality issue of concern to Federal Land managers is deposition of atmospheric nitrogen to the ecosystem. Nitrogen deposition occurs due to emissions of nitrogen oxides (NO_x) and ammonia. NO_x is produced during high-temperature combustion processes such as in motor vehicles and power plants. Nitrogen deposition alters vegetation due to its fertilizing affects. It may encourage the growth of alien species at the expense of native plants in the Mojave Desert (Brooks, 2003).

Recommended research areas

- Studies to evaluate the effects of high ozone concentrations on flora and fauna native to Clark County should be considered, starting with a monitoring program to characterize ozone levels on Federal Lands in Clark County.
- For FLMs in Clark County take an active role by monitoring haze levels and aerosols that contribute to haze. Data analysis methods should then be used to better understand the sources of visibility impairment on Federal Lands in Clark County.
- Monitoring deposition of atmospheric nitrogen.

Recommendations for Workshop #2 – August 15-16, 2006

Fire

Revised List of Research and Monitoring Priorities for Consideration at Workshop #2

- Fire effects on vegetation and seedbanks
 - Temporal issues
 - Immediate effects (first postfire year, Emergency Stabilization funding phase)
 - Short-term effects (second and third postfire year, Rehabilitation funding phase)
 - Long-term effects (fourth year+, management unit funding)
 - Taxa issues
 - Natives vs. non-natives
 - Desert tortoise forage and habitat species
 - Sensitive species
 - Other issues
 - Conditions that lead to an invasive plant / fire regime cycle
 - Interaction of fire with subsequent rainfall patterns
 - Interactions of fire with post-fire land use regimes (e.g. livestock grazing, OHV use)
- Fire effects on wildlife
 - Temporal issues
 - Immediate mortality
 - Long-term effects on habitat characteristics
 - Taxa issues
 - Sensitive species (e.g. desert tortoise)
- Postfire seeding strategies
 - What techniques are most effective with limited resources?

- Species mixes (life forms, natives vs. non-natives)
 - Seeding rates
 - Seeding timings
 - Application methods
- How do results vary among contrasting vegetation types, rainfall years, and post-treatment land use regimes
- Fire history/Fire regimes
 - Historical conditions (pre- and post-settlement)
 - Current conditions
 - Predicted future conditions
- Fuels management
 - Effects of different techniques (herbicides, mechanical, prescribed fire)
 - Fuels and potential fire behavior
 - Sensitive species (e.g. desert tortoise)
 - Plant community structure
- Ecological effects of fire suppression tactics
 - Dozer lines, retardant drops

Invasive Species

Additional Research Priorities to be Considered at Workshop #2

- What are the primary invasive species of concern in southern Nevada, and is each early or late in its invasive sequence?
- What is the population ecology of primary invasive species of concern?
- What is the genetic structure of primary invasive species of concern?
- Given the genetic and population structure of primary invasive species of concern, are there any functional attributes of these species that can be used as a target of control?
- Are the primary species of concern competitively superior to the important native species in habitats of concern, and if so, why?
- What role do roads play in the dispersal of invasive species into more remote areas?
- Are there disturbance regimes or community types that are more or less susceptible to invasion?

Restoration

Revised List of Research and Monitoring Priorities for Consideration at Workshop #2

How do we develop realistic and meaningful restoration goals and objectives?

How do we prioritize restoration projects?

How do we identify the best restoration approach to meet our stated goals?

How do we efficiently evaluate the effectiveness of restoration treatments?

References

Introduction

This list of references is organized into topics that were identified as important during discussions among agency representatives and the Panel of Experts, the topics covered are:

Humans and desert ecosystems
Inventory, monitoring and indicators
Fire
Invasive species
Water
Geomorphology/geology
Soils
Landscape dynamics
Cultural resources
Restoration
Air quality

The Panel was asked to provide a list of references for each of the topics, some of which are subdivided into “key” and “additional reading” sections. The list is by no means exhaustive, but is designed to provide an introduction to the topic in the context of ecosystem health and management.

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APPENDIX 3. Breakout Group Summaries from August Workshop

Ecosystem Health Assessment Workshop Research Needs for the 21st Century

The following sections summarize the discussions, results, and conclusions that stem from the Breakout Groups at Workshop #2 of the Ecosystem Health Assessment and Resource Management in Southern Nevada Project on 15-16 August 2006. The individual summaries were written by the Breakout Group Leaders (whose names are under the title line of each summary), and their content has not been changed in any way. They are in the order in which they were presented to all participants on the second morning of the workshop, and are preceded by an aggregated list of the 30 top priority research topics for southern Nevada, as identified during the Breakout Group sessions.

Top 30 Research priorities for southern Nevada, by Breakout Group

*Fire**

- Fire effects
- Fire trends, past, current, and future
- Post-fire management

Invasive species

- Mechanisms of invasion
- Ecological effects of invaders
- Management methods and effects

Water

- Integrated water-ecology model
- Spring system biotic integrity
- Characterize/model groundwater systems

Restoration

- Restoration potential
- Treatment effectiveness
- Plant establishment techniques

Species conservation and biodiversity

- Prioritize for conservation by filling information gaps
- Fill information gaps necessary for conservation of critical species of concern
- Threshold level of natural or artificial habitat

Humans and desert ecosystems

- Visitor use patterns and characteristics
- Agency resource needs
- Outreach programs analysis

Geomorphology, geology and soils

- Geologic, geomorphic and pedologic patterns
- Soil-edaphic relationships
- Loss of soil function, recovery and indicators of soil health

Landscape dynamics

* The designations for each Breakout Group (e.g., *Humans and desert ecosystems*, *Fire*, *Water*, etc.) are used throughout this report for clarity and emphasis.

- Alternative futures
- Landscape and climate change
- Urbanization effects

Cultural resources

- Cultural resource historic context
- Cultural resource inventory
- Research methods

Inventory, monitoring and indicators

- Biophysical and socioeconomic indicators
- Complete inventories (terrestrial and aquatic)
- Plan and implement monitoring to support agency objectives

Fire Breakout Group

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Stressors

- Livestock, wild horses, burros
- Climate change
- Invasive plant species
- Humans on the landscape
- Rainfall cycles/ trends
- Nitrogen deposition
- Agency policies

Decision Criteria for Prioritization (the last 3 were added by this group)

- Does the topic address more than one agency, region, discipline, topic or issue; or cross landscape boundary scales?
- Would addressing the topic have significance for long-term effective land management?
- Does the topic address multiple ecosystem components?
- Is the topic timely, both in terms of immediacy of need and other reasons to start a project now rather than later?
- Is there currently little or no information available on the topic?

Prioritized Research Topics (the first 3 were nominated for the whole-group prioritization exercise)

1. Fire effects
2. Post-fire management effects
3. Fire trends past, current, and future
4. Fire suppression effects
5. Fuels management effects
6. Human interactions with fire

Summary of the Prioritization Process

We first acknowledged that the ultimate ecosystem component we were focusing on was fire regime, which includes frequency, intensity (heat release), seasonality, spatial pattern (size and complexity), and type (crown vs. surface) of fire. Fire regimes are affected by the spatial and temporal distribution of fuels and ignition sources, and how these forces interact with topography. Since the topography

typically changes over geologic time, whereas the first two can change over years to decades, our determination of stressors focused on those that affect fuels and ignition sources.

Stressors included those that are local in scale and potentially under the control of land managers (livestock, wild horses, burros, invasive plant species, humans on the landscape, agency policies) plus those that broad in scale and largely out of their direct control (climate change, rainfall cycles/ trends, nitrogen deposition). It can be tempting to prioritize research topics in the latter category lower than those that fall in the former. However, we believe that one must understand the effects of broad-scale ecosystem changes on local processes to accurately evaluate the effects of local-scale stressors. Therefore, our list of stressors was not prioritized, and was only used to provide context for our determination of research needs.

We revisited the research topics recommended by Matt Brooks and Stan Smith as a product of Workshop #1 of the Ecosystem Health Assessment of Southern Nevada Project, 3-4 May 2006 (Table 1). The breakout group revised some of these topics, and added one topic. *Fire trends, past, current, and future* was a revised topic created to emphasize the need for information on burning patterns and fire regimes that occurred in the distant past and during recent decades (i.e. fire histories), analyses on how these regimes may be shifting, and predictions on what may occur in the future. *Post-fire management* was a revised topic that was more inclusive than the workshop #1 title, and included sub-topics such as post-fire seeding, land use restrictions (e.g. livestock grazing, OHV use), and other management actions that typically occur after fires. *Human interactions with fire* was the one topic identified in Workshop #2 that did not have any analogue from Workshop #1. It represents past and current use of fire as a management tool by humans, in addition to other effects on fire regimes that may arise for various human activities (e.g. effects on fuels or ignition frequency).

<i>Table 1. Research topics recommended from workshop #1 and their modifications and additions from workshop #2. *modified or added topics</i>	
Topics from Workshop #1	Topics Modified in Workshop #2
Fire histories	Fire trends, past, current, and future*
Fire effects	Fire effects
Fire suppression tactics	Fire suppression tactics
Fuels management	Fuels management
Post-fire seeding	Post-fire management*
	Human interactions with fire*

The prioritization process for the research topics listed on the right side of Table 1 proceeded through multiple voting stages. The first cut by dot voting led us to eliminate *human interactions with fire*. We then began ranking the remaining 5 topics on an interval scale. This proceeded through 2 votes, each time one topic clearly received the highest ranking, but the remaining topics were either tied or differed by a single point (considered a tie), and were pushed to a subsequent vote. The first ranking produced *fire effects* as the clear first priority and *fuels management effects* as the next topic to eliminate. The second ranking produced *post-fire management* as the second priority, but did not eliminate the remaining two topics. We decided by consensus that *fire trends, past, current, and future* slightly edged out *fire suppression tactics*. Although, this process produced a ranking of fire research

needs, we feel all topics are important to improve the effectiveness of fire management in southern Nevada.

Other Recommendations

We had extensive discussions about how to provide more guidance on prioritizing fire research needs. We noted that fire management issues vary widely across southern Nevada, especially among ecological zones. Two recent publications were summarized by the Breakout Group Leader that the group thought would provide helpful guidance for reviewing research proposals. (Brooks and Minnich, 2006; Brooks and Matchett, *accepted*). The basic message from these publications is that the major changes in Mojave Desert fire regimes are occurring in the middle elevation ecological zone bounded at the lower end by the upper elevations of creosotebush scrub and Joshua Tree woodlands, and at the upper end by sagebrush, interior chaparral, and the upper elevations of blackbrush shrublands. Changes in this zone appear to be driven by an invasive plant / fire regime cycle (*sensu* Brooks *et al.*, 2004) whereby invasive annual grasses are altering fire regimes. Currently, changes in the middle elevation zone are focused at broad scales in the northeastern and eastern Mojave, but foci of activity at smaller scales have appeared elsewhere as well (e.g. Joshua Tree National Park). Thus, we recommend that fire research which focuses on the middle elevation vegetation types should be top priorities for funding in southern Nevada.

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Additional Stressors (specific to Invasive Species):

- Pulse rainfall responses (high rainfall anomalies) and climate change
- Altered riparian flow regimes and water diversion by development and agriculture
- Reservoir drawdowns, creating new habitats (specific to Lake Mead National Recreation Area)
- Lack of robust, healthy ecosystems (incl. diversity maintenance)
- Nitrogen augmentation – air, groundwater, agriculture
- Ornamentals and the landscape industry; aquarium and pet industries
- Disease and parasite vectors
- Illegal dumping of landscape materials and dredge spoils
- Road proliferation
- Humans as vectors
- ORVs in general
- Public perception (*e.g.* wild horses and burros)

Decision Criteria for Prioritization:

We identified no additional criteria for prioritization.

Gaps in Knowledge (posed as unanswered questions for Southern Nevada invasive species):

1. What biological attributes make good invaders?
2. Does the genetic structure of invading populations differ from native species?
3. What is the relationship between disturbance and invasion success?
4. What community/ecosystem attributes are resistant to invasion?
5. What key biotic interactions (*e.g.* competition, predator/parasite release, etc.) allow invasives to be successful?
6. What are the effects of species invasions on community structure?
7. What are the effects of species invasions on ecosystem function?
8. What are the effects of management on invaded systems?
9. How do we characterize “invasiveness” of ecosystems?
10. What are the tools and techniques available for invasive species management?
11. How do we create an early detection and risk management system?

Summary of the Prioritization Process:

Stan Smith started the breakout group by quickly summarizing Workshop #1, noting that all the agencies listed invasive species as one of their top priority issues for research and management focus. The *Invasive species* Breakout Group then commenced our discussions by examining the recommended research areas from the May report (Workshop #1), which were authored by Stan Smith, Matt Brooks, and Don Sada. These were, as follows:

1. Basic research on invasive species
2. Population ecology of invasive species (including genetics)
3. Vulnerability of native communities and ecosystems to invasion
4. Aquatic invasives
5. Roads and invasive species
6. Global change and invasive species

The group quickly felt that we needed a slight different approach than this set of six priorities, for several reasons. First, basic research of invasive species can be considered the centerpiece of most invasive species science programs, and so we felt that more focused objectives needed to be formulated within this broad category. Research Area #1 also overlaps broadly with Research Areas 2 and 3. Second, after some discussion, we felt that it would not be the preferred strategy to separate aquatic invasive species from terrestrial invasive species, even though the species involved are completely different. However, the *processes* involved (vectors, biotic interactions, genetics, etc.) may not be. From a practical view, we also felt that it would be inappropriate to separate aquatic and terrestrial invasions for the whole-group prioritization process, since both are equally important to agency biologists and managers. And finally, in southern Nevada we can probably actually separate out three ecological systems that have a unique set of invasive species – upland desert, riparian, and aquatic. Because riparian ecosystems are a transitional ecosystem between terrestrial and aquatic systems, it would be problematic to arbitrarily assign riparian systems as either terrestrial or aquatic for research prioritization purposes.

After this assessment of the May priorities, we next formulated more specific research questions for which we feel there is an inadequate level of understanding in southern Nevada. These are listed as our “Gaps in Knowledge” (see list above). Using this series of questions, we then asked “Are there broad areas in which research could focus to address these questions?” in order to develop a research prioritization process. We arrived at five broad areas:

1. Attributes of invaders (questions #1, 2 and 5 from Gaps in Knowledge above)
2. Elements that determine “invasibility” (questions 3, 4 and 9)
3. Biotic interactions between invasive and native species (question 5)
4. Effects of invasive species on communities and ecosystems (questions 6 and 7)
5. Management methods and effects (questions 8, 10 and 11)

Using these potential research areas, our group then conducted a vote to see if we could rank them by research priority. All five received support, but the results, in order of priority, were: (1) attributes of invaders; (2) elements that determine invasibility; (3) management methods and effects; (4) community/ecosystem effects; and (5) biotic interactions. While this was a useful exercise, it left us with a dilemma in that coming forward with only the first three research criteria would leave us with the recommendation that no research should be conducted on the effects of invasive species on natural

ecosystems, or on the biotic interactions of invasive species with native species. *Both of these areas of research are absolutely fundamental in any integrated invasive species research/management program.*

Given this potential dilemma, we chose to incorporate these five research areas into three even broader areas for prioritization by the whole group because we simply could not put forth a research program that omitted fundamentally important areas that we need information on in order to manage for invasive species. The results of those final deliberations are provided in Table 1 below, and represent our Final Priority Research Areas. Consistent with our past vote, Research Area #1 was our highest ranked priority, Research Area #3 was our second-ranked priority, and Research Area #2 was our third-ranked priority.

Table 1. Final Priority Research Areas

<i>Research Area</i>	<i>Incorporates</i>
1. Mechanisms of Invasion	Ecophysiology Genetics Population Biology Invasiveness
2. Ecological Effects of Invaders	Biotic Interactions Community Structure Ecosystem Function
3. Management Methods and Effects	Methods Development Early Detection Risk Management Effects of Removals

Concluding Comments:

1. The effects of invasive species on our native ecosystems is one of the most important management issues that we have to address in southern Nevada. This was highlighted by the fact that each agency had invasive species as one of the high priority issues in Workshop #1.
2. The three Priority Research Areas (Table 1) identified by the *Invasive species* Breakout Group are all essential in formulating an integrated invasive species research and management program in southern Nevada.

Relevant Literature

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Water Breakout Group

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Background

Water resources in southern Nevada addressed by the *Water* group focused on ground waters and the springs, spring-fed streams, and associated riparian systems that they support. Our analysis was conducted by integrating the broad disciplines of hydrology and ecology to set directions for the future. Issues regarding the Colorado River were not considered by this group because they will be addressed during future planning exercises that focus on the river.

A number of studies and modeling activities have examined groundwater resources in southern Nevada. They have produced a regional model of the Death Valley ground-water flow system, modeled groundwater resources of Nevada Test Site and vicinity, and the southern part of the White River groundwater flow system. This work has focused on identifying waters from different aquifers, delineating flow paths, evaluating sources and distribution of groundwater recharge, evaluating potential effects of groundwater pumping, and relationships between climate and groundwater. Existing information provides a foundation to evaluate the response of groundwater to increased use, but additional work is needed to accommodate issues involving scale, integrating nested and regional flow models, and characterize uncertainty to more accurately characterize aquifers and predict their response to pumping.

Springs have been a focus of most groundwater hydrology and rare fish natural history studies in southern Nevada. In contrast, few studies have examined spring ecology, and most of this information for southern Nevada springs is limited to studies in the Spring Mountains. Existing information shows there is a wide diversity of springs in southern Nevada, that physicochemical and biotic characteristics are influenced by natural and human caused disturbances, that most springs have been adversely affected by habitat modification, that predicting biological characteristics of springs is difficult, and that large and small springs may be inhabited by highly endemic vertebrates and invertebrates. Springs in southern Nevada are noteworthy because of the large number of extinctions and extirpated populations recorded from them in this region.

Early discussions by the *Water* group were segregated into 'Groundwater' and 'Spring and Riparian' issues. Stressors and Gaps in Knowledge are segregated into these categories below:

Stressors

Groundwater Systems

- Extraction due to increased human use (including effects on water chemistry, aquifer size and recharge,
- Contamination from point and non-point sources
- Land subsidence due to excessive extraction
- Effects of climate change on recharge
- Effects of land use and land change on recharge and aquifer production (e.g., increase of impervious surfaces, wildfire, etc.).

Springs and Riparian

- Habitat modification (including affects of ungulate grazing, recreation, mining, diversion of surface water and use of groundwater, channelization, impoundments, altered water quality, and increased incidence of fire due to high fuel loading, air quality).
- Invasive plant (e.g., tamarisk, arundo,) and animal (aquarium fish and mollusks, crayfish, parasites, etc.) species.

Research Necessary to Address Gaps in Knowledge

Groundwater Systems

- Develop and test an ecological systems conceptual model that integrates groundwater modeling, spring ecology, and human dimensions to enable interdisciplinary assessments of groundwater use and value.
- Improve understanding of the geologic framework of aquifers to better quantify water budgets (e.g., aquifer recharge and discharge rates), flow patterns, and geochemistry.
- Improve methods to quantify parameter uncertainty and propagate this through models that are produced.
- Develop methods to scale up from nested, local-scale groundwater models to regional-scale flow system models.
- Improve methods to characterize aquifers and construct groundwater models that more accurately predict their response to human use.

Springs and Riparian

- Improve knowledge of spring ecology by quantifying biotic and abiotic factors affecting the abundance and distribution of species and the structure of aquatic and riparian communities.
- Use ecological information to assess the response of spring-fed aquatic and riparian systems to incremental changes in use (ergo decreased spring discharge, non-native ungulate use, recreation, etc.).
- Develop integrated models that incorporate ecology, groundwater hydrology, and human factors to enhance decision making capabilities for sustainable groundwater use.
- Inventory the biotic and abiotic characteristics of springs.
- Determine and evaluate indicator species and conduct ecological studies to define spring system biological integrity.
- Conduct studies to understand of groundwater/surface water interactions and relationships between biological and hydrological characteristics of springs.
- Determine ‘reference conditions’ for springs in relation to factors such as topographic setting and hydrology.

- Determine effective restoration techniques and identify characteristics of seral stages of biological change expected after restoration is initiated.
- Conduct studies to understand the anthropogenic history of human interactions with springs.

Evaluation Criteria

- Does the topic address more than one agency, region, discipline, species, or issue; address multiple ecosystem components or cross landscape boundary scales (ecotones, political boundaries, agency jurisdictions)?
- Significance for long term management: Would addressing it increase long-term effectiveness of management? Would not addressing it reduce the long-term effectiveness of land management?
- Is the information urgently needed to implement effective land management?

Issues/Questions Discussed

The group was initially hesitant to prepare a short list of research topics that combined groundwater hydrology and spring ecology. During discussion, the importance of linkages between the two disciplines led the group to agree they should be considered under common and separate research umbrellas, as appropriate. Lists of stressors and potential research areas were prepared to create a foundation for discussion. Comparing research topics between the disciplines revealed that future groundwater research would build on a substantial amount of previous work and that work in spring ecology was rudimentary and that basic studies are needed before managers can quantitatively integrate ecology into the decision making process. After discussion, the group decided upon three priority research topics; one is strictly groundwater, one focuses on spring ecology, and another integrates these disciplines by developing an ecological systems model to assist with design of future ecological and groundwater research, and the decision making process.

Top Three Topics

Priority 1—Integrated Water-Ecology Model

Groundwater studies provide insight into the natural dynamics of aquifer systems and the effects of groundwater development on these systems. This information has not been examined in the broader context that is necessary to understand a number of relevant relationships such as those between groundwater resources, rural economies, and the integrity of phreatophytic vegetation and spring-dependent riparian and aquatic life. The integrated water-ecology model is envisioned as a conceptual model that is needed to guide ecological, social, and groundwater research to more effectively provide decision makers with information based on a broad foundation of resource issues. The focus of this work would be to develop and test the important components of integrated hydrological, ecological, and human system conceptual models.

Priority 2—Spring Ecology

Springs are the only source of water over vast regions of southern Nevada, and most have been disturbed by human activities such as surface diversion, groundwater pumping, livestock grazing, and recreation. Past studies indicate that their ecology is affected by factors including water chemistry and topographic features, as well as natural and human disturbances. Ecological studies are needed to guide spring management and restoration programs by determining relationships between aquifer

characteristics and their biota, and their response to incremental increases in human disturbances from diversion (surface and groundwater), livestock, and recreation. This information is also needed to prevent declines in a number of endemic species and to reduce the influence of non-native plants and animals on natural communities. Ecological studies should also be designed to identify potential indicator species, determine spring reference conditions, and to provide decision makers with information to determine levels of groundwater use that are compatible with maintaining spring integrity.

Priority 3—Groundwater Hydrology

Impacts and stresses to groundwater systems occur at multiple scales. For this reason, hydrogeologic characterization and numerical modeling of groundwater systems must also be conducted at various scales. Characterization and numerical modeling improves our understanding of aquifer systems and allows us to better understand and predict the potential effects of ground-water development. The hydrogeologic framework of an aquifer system defines the physical geometry and composition of the surface and subsurface materials and structures through which ground-water flows. Unfortunately, our knowledge of the surface and subsurface characteristics of these hydrogeologic frameworks is often limited. Also, data describing the amount of water that exists in, and moves through, these systems are poorly understood. These baseline data must be gathered continuously so that changes to these systems may be monitored. Numerical groundwater models should be used to better understand which components of these groundwater systems are most important to understand for different groundwater development scenarios. Sensitivity and uncertainty analyses are important tools to aid in our understanding of these groundwater systems components and features.

Relevant Literature

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Restoration Breakout Group

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Three of the members of this group were agency personnel so they did not participate in the priority ranking. The group started off with having to go back to a basic definition of Restoration that was acceptable to all the members. Restoration was defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration). The key attributes that would be important to establish in a restored ecosystem would include resistance, resilience, and sustainability.

Stressors:

The list of stressors developed by the group included:

- Urbanization
- Invasive species
- Intensive land use
- Fire
- Climate/weather
- Highly variable precipitation
- Decrease in soil quality/productivity
- Surface disturbance
- Landscape fragmentation
- Overgrazing
- Nitrogen deposition
- Decrease in water tables and spring flows

Gaps in Knowledge

1. Spatial history of urbanization: 5-year increments
2. Demographic changes in human populations.
3. Major land use drivers (residential, recreation, grazing, etc.)
4. Inventory and scale of ecosystems degraded- local to regional.
5. Research in cause/effect relationships in the degradation of ecosystems.
6. There is no general synthesis of successful restoration techniques for the Mojave Desert Ecosystem
7. There is tremendous variability among sites to be reclaimed and thus common reclamation techniques are often not successful; need to identify key components for successful restoration

8. Greater need to understand seed-soil-climate interfaces to understand germination requirements and successful establishment.
9. Need to understand competition of exotics with natives during restoration effort.
10. Need to understand thresholds where plant communities can't recover naturally or with assistance

Decision Criteria

The criteria that we utilized were those four areas that were presented in the original “Question” provided by DRI as an attachment in an earlier e-mail. Those criteria were:

- Broad or multi-scalar
- Related issues
- Effective long-term land management
- Research

Issues/Questions Discussed

The group started with the original research questions that were presented from the May Workshop and subsequent report. Several in the group felt those research areas were too narrowly focused on active revegetation and did not include the larger scope of restoration. Also the original questions did not include the possibility of passive restoration. We agreed that those research ideas presented in May were too narrow, particularly when viewed within the context of our decision criteria. Thus the six research areas from the May report were synthesized into two basic areas, restoration treatment effectiveness and plant establishment techniques. We were told by the organizers that one of the original research areas, cost effectiveness of revegetation practices, should not be considered so it was dropped. The group did add two additional research areas - restoration potential of disturbed sites and a synthesis of the historical data available. The latter included the development of databases from existing literature and ongoing studies and using this to develop a decision support system such as Veg Spec developed by the Natural Resources Conservation Service.

We had four research areas that were prioritized using the criteria presented above. Only four people participated in that prioritization. Only two of those people had any real hands-on experience in restoration. In my opinion (that of one of the authors, Kent Ostler) this was not an adequate number of knowledgeable people to accomplish this task.

The top three research areas in order of priority were:

1. Restoration Potential
2. Treatment Effectiveness
3. Plant Establishment Techniques

Restoration Potential

A significant part of our discussion focused on the importance of defining the restoration potential of disturbed ecosystems. To establish viable management and restoration goals, it is necessary to understand the current ecosystem or restoration potential. In the past, a frequent goal of both management and restoration has been to re-create and manage for predisturbance conditions. There are several problems with this approach. It assumes stable or equilibrium conditions, and ignores changes in climate and land uses. It also assumes that site conditions or primary processes have not been irreversibly altered due to the perturbation or disturbance. A more realistic approach is to base management and restoration goals on the current potential of an ecosystem to support a given set of

conditions. This approach requires an understanding of the types and magnitudes of abiotic and biotic thresholds that may have been crossed as a result of disturbance, and of the alternative states that currently exist for these ecosystems.

Alternative state and threshold concepts are being used increasingly by land managers to describe the vegetation communities/ecosystem types that exist on the landscape. For example, the USDA Natural Resources Conservation Service is now using alternative state and transition models to describe the ecological sites that exist on rangelands in the United States (USDA, 1997). Basically, the alternative states for a given vegetation or ecosystem type are cataloged, and the relationships between them are described (see Fig. 1 for a generalized example). The alternative states include the "high condition, potential community" that is typically the management or restoration goal. They also include any other states that exist such as those that may have been degraded as a result of overgrazing by livestock, altered fire regimes or weedy species invasions. The progression of one state to another is illustrated with a series of connecting arrows, and the type of disturbance or management action influencing the different states is indicated. This type of cataloging provides a convenient means of describing the various alternative states, the relationships among them, and the disturbances and management actions affecting the transitions between states.

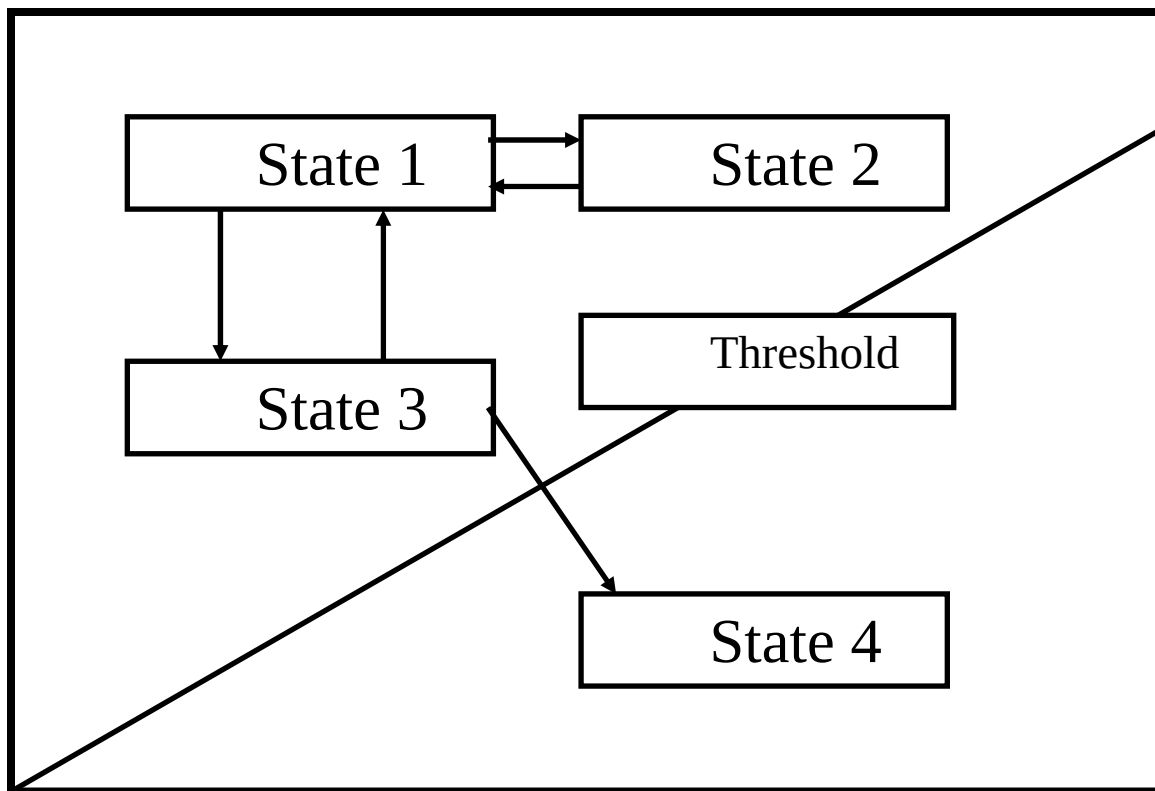


Figure 1. A generalized state and transition diagram.

To use alternative state and threshold concepts in a restoration context, it is necessary to both identify the alternative states that exist for the disturbed or degraded ecosystem and to define the thresholds between the possible states in terms of quantifiable ecosystem characteristics. Defining the thresholds that exist between states is necessary because the recovery potential of a given ecosystem depends on the characteristics of the threshold that exists between the states (see Figure 2). If a threshold has not been crossed, then the system should be able to recover to the original state with minimal intervention. In this case, passive restoration may result in the return of the system to a less degraded state. This could include simply eliminating the perturbation, such as over grazing, or reinstating natural processes, such as fire. If a threshold has been crossed, a new state exists that has a unique set of possible successional trajectories. If a biotic threshold has been crossed, in most cases the primary processes are still functional, and it may be possible to return the system to the original state through some type of restoration activity. This could involve using herbicides to eliminate exotic species, reseeding with the appropriate species, and deferring land uses until the ecosystem has reestablished. If an abiotic threshold has been crossed such as can result from changes in soil or hydrologic properties, the primary ecosystem process are often altered or nonfunctional. Once an abiotic threshold has been crossed, restoration to the predisturbance state is seldom ecologically or economically feasible. It is often necessary to treat the system as an entirely new state or a new site type, and to develop the appropriate restoration or management methods for the new state or site type.

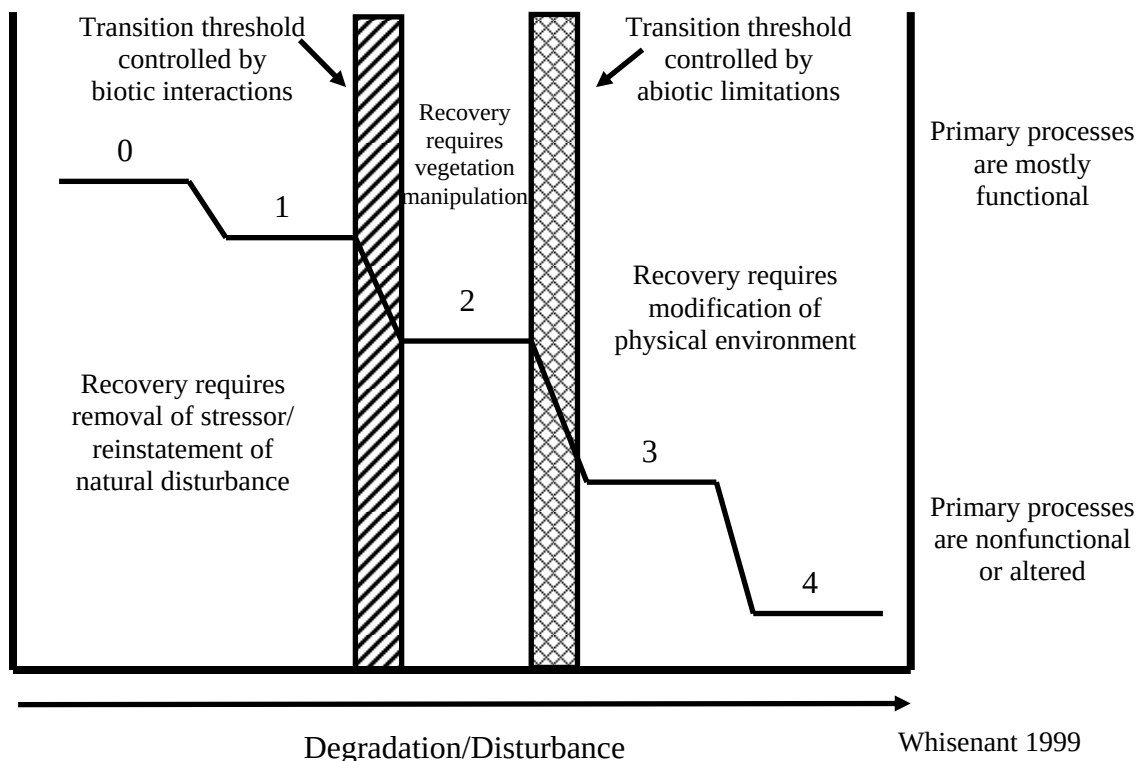


Figure 2. Stepwise degradation of a hypothetical ecosystem type illustrating two common and frequently incremental transition thresholds - abiotic and biotic. Adapted from Whisenant (1999).

One method of identifying alternative states and defining thresholds is to use restoration experiments or adaptive management approaches that examine the abiotic and biotic responses of sites representing an appropriate range of abiotic and biotic conditions to specific treatments or management actions. This approach has been used successfully in the Great Basin to define the alternative states and transitions and, thus, restoration potentials for riparian ecosystems affected by stream incision (Wright and Chambers, 2002). It also is being used to examine the recovery potentials of sagebrush ecosystems following invasion by cheatgrass (*Bromus tectorum*) and expansion of pinyon and juniper as part of a multi-institutional project funded by the Joint Fire Sciences Program.

The principal question for this research area is: What are the biotic and abiotic thresholds that determine the recovery potential of the dominant ecosystems within the Mojave Desert region, and what are the key variables that define those thresholds?

The approach outlined by the group to address this question included the following: (1) Conduct retrospective analyses and syntheses of the existing literature to develop an understanding of ecosystem responses to both disturbance and past restoration treatments. (2) Identify priority ecosystems and ecosystems that are particularly sensitive to disturbance or that do not recover easily. (3) Use collaborative research and management restoration experiments that take advantage of ongoing or planned efforts to assist in identifying the alternative states and defining the thresholds that exist for Mojave ecosystems. The benefits from this area of research are that it allows managers to:

- Assess the response of Mojave ecosystems to past disturbance and restoration treatments
- Identify sensitive ecosystems
- Prioritize ecosystems and sites for restoration
- Identify types of restoration needed (active vs. passive)
- Establish realistic restoration objectives
- Develop management decision criteria.

Treatment Effectiveness

The key question is: What is the effectiveness of standard restoration treatments for key ecosystems and different disturbance regimes? Although we couldn't include cost as a component of this question, it certainly should be central to the question. There are many variables that would contribute to the success or failure of techniques particularly when one considers the various levels/types of disturbance that are possible. The dominant factor is that of precipitation during establishment which is highly variable under natural conditions of the Mojave Desert. This factor has to be considered when evaluating past project performance and future risks. Reducing this risk through irrigation is generally possible on only a limited basis but it has been shown to be very successful. Research could focus on a retrospective analysis although few restoration efforts have been successful. Detailed analysis of these projects would be needed to identify key variables for success or failure. Collaborative research and management projects should be conducted in an adaptive management framework. Rigorous and consistent monitoring and documentation would be needed to compare multiple projects over multiple years.

Plant Establishment Techniques

The key question (really several questions) is: What are the plant establishment (seeds and transplants) requirements for promising revegetation species, what are the best treatments to promote establishment, and which species should be placed into seed increase or propagation programs? This is a critical area in the Mojave Desert. Unless we get promising species into seed increase programs

there will never be adequate supplies of seeds or plants to meet restoration needs. Money was available for emergency stabilization after the 2005 fires that devastated the Mojave Desert; however, there was not an available supply of seed so many areas received no seed or dramatically reduced amounts. Seed costs also limited how much seed was applied and hence the success of the seeding efforts. Hand collected seed is expensive and supplies are generally unreliable. This research area was rated very low by the combined groups but I (Kent Ostler) believe that was simply a product of the limited time for the breakout group leader's presentation not its true importance or its role for successful restoration. You can't restore any ecosystem without the appropriate plant/seed materials. If they are not available then you fail. That was not presented with the appropriate depth or passion due to time constraints.

Relevant Literature

- Berger, John J (Editor)(1990). Environmental Restoration: Science and Strategies for Restoring the Earth. Island Press, Washington D.C.
- Harker, Donald, Evans, Sheri, Evans, Mark, and Harker Kay (1993). Landscape Restoration Handbook. Lewis Publishers, Boca Raton, FL.
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- Wright, J. M. and J. C. Chambers. 2002. Restoring sagebrush dominated riparian corridors using alternative state and threshold concepts: biomass and species response. *Applied Vegetation Science* 5:237-246.

Species conservation and biodiversity Breakout Group

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Additional stressors (special significance for Species Conservation/Biodiversity)

- Exotic species—three categories of stressor:
 - “macro” interactors (e.g., predation, competition)
 - “micro” interactors (e.g., pathogens)
 - ecosystem conversions
- Habitat fragmentation / loss / modification
- Fire—modification of habitat dynamics
- Global warming
- Loss of pollinators
- Recreation
- Changes in hydrology
- Roads/trails
- Urban ecotone

Gaps in knowledge (listed in no particular order)

1. Life histories
2. Habitat requirements
3. Species associations (e.g., plants/pollinators)
4. Metapopulation structure
5. Population genetics
6. Population dynamics
7. Current vs. historical distributions
8. Current vs. historical population connectivity

Criteria for prioritizing issues/questions

Only those identified generally (more than one agency, region, etc; long-term effective management; effectiveness and efficiency; affect more than one species)

The top three issues/questions

[the first two were ranked equally]

1. Prioritizing species (including migratory species) for conservation by filling information gaps using one or more of the following approaches:
 - a. Utilize molecular phylogeny, phylogeography, and population genetics to place population/species of concern in southern Nevada within a broader evolutionary (phylogenetic and biogeographic) context
 - b. Place geographic range and distribution in southern Nevada within context of total range of population, species, or species-group
 - c. Determine functional importance of population/species to ecosystem function or associated species assemblages
 - d. Determine population/species vulnerability
 - e. Determine population/species irreplaceability
2. Fulfill information gaps necessary for conservation of critical species of concern (e.g., information needed to develop conservation assessments and strategies) including:
 - a. Life histories
 - b. Habitat requirements and critical ecosystem processes
 - c. Critical species associations
 - d. Metapopulation structure
 - e. Population genetics
 - f. Population dynamics
 - g. Current vs. historical distributions
 - h. Vulnerability
 - i. Current vs. historical population connectivity
3. Determine a threshold level of natural or artificial habitat disturbance / degradation / fragmentation (including influence of exotic species) before compromising population / species viability or loss of system function.

Brief synopsis of the issues/questions discussed

Discussion centered around the relevance and tractability of traditional gaps in knowledge that often drive research and management issues, include the perception that a disconnect often exists between the goals of legal mandates (e.g., assure persistence of target species of concern) vs. the task of turning data on population/species attributes (see list under “gaps” above) into productive management strategies and assessments. Riddle directed discussion in the direction of trying to think about more efficient, scientifically-based approaches to prioritizing and organizing the decision process on, e.g. which populations/species could be ranked most immediately threatened and of highest priority in terms of level of rarity, genetic/phylogenetic uniqueness/value, ecological importance, distributional complementarity and irreplaceability, etc.. This discussion provided the basis for developing the top three questions. However, even though there was generally good consensus between scientists and agency representatives on the important research topics, it should be said that some of the agency representatives were probably frustrated by the inability to provide a more definitive protocol for implementing approaches to more specifically address the list of knowledge gaps (see above) more directly. Again, it is important to emphasize that we still have the disconnect between what on the one

hand might be a scientifically justifiable way of encapsulating and prioritizing components of southern Nevada biodiversity for conservation and management, and on the other hand comprise the still-existing legal mandate that agencies are charged to “protect everything” on long lists of species of concern. Much work needs to still be done to move toward better reconciliation of these goals and requirements in biodiversity science and management.

Relevant Literature

Convention on Biological Diversity <http://www.biodiv.org/default.shtml>

Faith, D.P., C.A.M. Reid, and J. Hunter. 2004. Integrating phylogenetic diversity, complementarity, and endemism for conservation assessment, *Conservation Biology* 18:255-261.

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Peterson, A.T., and D.A. Kluza. 2003. New distributional modeling approaches for gap analysis, *Animal Conservation* 6:47-54.

Whittaker, R.J., M.B. Araujo, J. Paul, R.J. Ladle, J.E.M. Watson, and K.J. Willis. 2005. Conservation Biogeography: assessment and prospect, *Diversity and Distributions* 11:3-23.

Humans and desert ecosystems Breakout Group

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Skip Canfield, Nevada Division of State Lands

Scott Lamoreux, US Forest Service

Connie Moen, US Forest Service

Rosie Pepito, National Park Service

The *Humans and desert ecosystems* group addressed topics in which the focus of knowledge-gathering is on the characteristics, behaviors, knowledge, attitudes, and needs of the people who use and manage public lands in southern Nevada.

Stressors

The rapid pace of population growth in Clark County is almost surely the primary driver of ecosystem change and instability, producing stressors such as recreation, housing and infrastructure development adjacent to public lands, and air/water/noise pollution. These are all human activities.

For that reason our task with respect to stressors differed from that of most other groups. Not only did we identify factors that impose stress upon a particular ecosystem component (in this case, humans), but we also had to identify attributes of our component of interest that create or exacerbate stress on ecosystems. As a result, we identified 28 additional stressors beyond those developed earlier in the assessment process. Of these, the ones that most influenced our subsequent discussions about research included: factors associated with under-represented groups, such as the need to provide outreach materials to visitors with limited English speaking ability; lack of citizen awareness about ecosystem processes and impacts and means of mitigating impacts; and impediments to agencies' ability to manage the ecosystems such as political pressures, aging facilities, inter-agency differences, resource availability.

The complete list of stressors discussed is as follows:

- Population growth at the urban/wildland interface
 - Managing larger numbers of people
 - Increasing traffic
 - Dust pollution (largely a result of increased traffic)
- Social and demographic change in Clark County
 - Harvesting by cultural groups
 - Depreciating behaviors by visitors
 - Citizen perception that desert is wasteland (so no need for careful behavior)
 - Lack of ecosystem awareness among the public
 - Lack of bilingual education
 - Reduced mental and physical health due to loss of connection to nature

- Lack of capacity for rapid agency response (to increasing number of people)
 - Lack of interpretive staff – volunteer coordination needed
 - Aging facilities not up to current demands
 - Inadequate law enforcement capacity
 - Increasing regulations that dictate how managers must respond
 - Outsourcing of agency tasks results in loss of local knowledge
- Cooperation between agencies affected by differing regulations
 - Lack of mechanisms for cooperation between local and federal agencies
 - No advanced preservation of open space and trail corridors prior to BLM land sales (planning is reactive, not proactive)
 - Disconnect between local values for land use versus those of agency personnel
 - Tension between private landowners and government
- Top-down decisions often driven by political agendas rather than local circumstances
 - Congressional land-use designations change use patterns
 - Pending congressional land bill
 - Bureaucratic paralysis (due to threat of lawsuits by stakeholder groups)
- Lack of understanding of ecosystem stressors and carrying capacities
- Increasing fees

Gaps in Knowledge

Our discussions took their starting point from the original list of knowledge gaps that had been recommended for research after the May workshop, consisting of five topical areas:

- Comprehensive study of **recreation use patterns and visitor characteristics** that would identify likely locations of visitor use impacts; valuable, non-substitutable recreation experiences; and visitor attributes useful for guiding visitor education campaigns. “Recreation” was defined broadly to include a wide range of visitor activities that typically occur during non-obligated time, including harvest of plant materials for cultural, medicinal, or food purposes.
- Analysis of existing options for **educational programs** to identify those most useful for reaching specific target audiences (e.g., rock climbers, OHV riders).
- Research on costs and benefits of **visitor use limits**, particularly in comparison to costs/benefits of management that concentrates rather than restricts use.
- Examination of the underlying **environmental values** held by Clark County residents with respect to southern Nevada desert ecosystems.
- Evaluation of alternate approaches to **cross-boundary monitoring and planning** that could be effectively integrated across agencies and ownerships.

Issues/Questions Discussed

As we set about identifying additional research questions not presented in the report from the May workshop, we first spent time adjusting and clarifying the topics that already had been presented as gaps in knowledge. After these were reorganized several new topics were added. The revised list included:

- **Visitor Use Patterns and Characteristics:** We recommend a comprehensive study of visitor use, including but not limited to recreation. Studies would identify use patterns, locations and visitor attributes, with emphasis on “data gaps” that might be missed using standard visitor monitoring techniques. Examples might include: ethnic and cultural influences on use patterns; characteristics of non-recreation uses and users (e.g., gathering plant materials); use of public

lands by casino visitors; and activities that are hard to observe due to the remoteness of appropriate sites, off-peak timing of optimal use, or other factors.

- **Outreach Program Analysis:** Included in this topic are inventory of existing programs for citizen education, analysis of their effectiveness in influencing human behavior, and information on how audiences perceive and use information.
- **Use Limits:** Research would identify locations in southern Nevada that are more sensitive or more resilient to use (thereby helping with prioritization of carrying capacity studies) and would analyze impacts of use limits on visitor experiences.
- **Ecosystem Values:** Identification of aspects of southern Nevada ecosystems are most valued by Clark County residents and visitors.
- **Multiple-Agency Management and Partnership Formation:** This topic encompassed the previously identified need for finding ways to help agencies work more effectively across jurisdictional boundaries, as well as analysis of potential means to engage local governments, non-government organizations and the private sector in partnerships to further ecosystem management goals.
- **Urban Sprawl/Local Land Use Planning:** Because urban sprawl was identified as the most significant stressor on southern Nevada ecosystems, this research would analyze ways for land sale decisions under SNPLMA to best incorporate open space and biophysical concerns (e.g., corridors).
- **Agency Resource Needs:** Since members of the group had already identified lack of resources (e.g., staffing, infrastructure, budgets, local knowledge) as stressors affecting the ability of agencies to manage southern Nevada ecosystems, we saw a need to model and forecast agencies' resource needs for meeting ecosystem health objectives into the future. (For example, a researcher might gather information from other locations to build a model of the relationships between agency staffing and key ecosystem parameters such as changes in species diversity or vegetation loss, then use that model to predict ecosystem outcomes at different levels of federal agency staffing in Clark County.)
- **Law Enforcement & Compliance:** Research would assess why people engage in undesirable behaviors such as vandalism and refuse dumping, and identify the law enforcement methods that are likely to be most effective in obtaining compliance.

Criteria for Prioritizing Issues/Questions

In addition to the original criteria we were asked to use for prioritization (capacity to improve integration across agencies, issues or scales; and significance to effective long-term land management), we identified an additional criterion of urgency, or immediacy of need for knowledge. We also spent considerable time discussing whether research topics should (1) lead directly to an action strategy, and (2) be given lower priority if SNPLMA-funded studies on that topic already are ongoing. Ultimately we did not use the latter two criteria. We agreed that the first is really a function of managers' ability and resources rather than of scientific value. We did not reach consensus on the second criterion, but were advised by meeting organizers not to use it.

Top Three Issues/Questions

1. Visitor Use Patterns and Characteristics
2. Agency Resource Needs
3. Outreach Programs Analysis

Key Factors in Discussions

An important theme in our discussions was the need to focus on concerns and activities of under-represented groups, e.g., Native Americans or Hispanic immigrants. While not specifically required within topics, we believe ethnographic research might be helpful in understanding visitor use and user characteristics among people whose needs are often ignored in traditional recreation management strategies.

Although the results of the prioritization reflect the directive to choose *three* questions, there was almost no difference in ranking between Outreach Programs Analysis, Use Limits, and Law Enforcement & Compliance. One way to address the almost arbitrary exclusion of the latter two topics would be to find ways to incorporate them into research on Visitor Use Patterns and Characteristics. For example, studies of visitor uses that are difficult to observe could include both legal activities (e.g., caving) with illegal or undesirable ones (e.g., tagging). Similarly, sampling could be stratified to exert added effort toward studying visitors to the most ecologically sensitive sites, or activities for which experiences are least able to be found at other locations in the region.

The design of the workshop process called for priorities to be set only by scientists from outside the region or the four land management agencies, but we did not follow this rule. This is because everyone in the group except the leader works as an agency professional. Our group consisted of planners, cultural resource specialists, recreation managers and restoration specialists. When we voted, we took care to use science as the guiding principle. Nonetheless, our discussions and priorities reflected the frustrations felt by agency professionals as they strive to protect fragile ecosystems and serve citizens' needs under increasingly difficult circumstances.

This can be seen most easily in the selection of research topics, more than half of which focused on the needs of agencies themselves rather than on the land. We discussed how administrative or political concerns (e.g., pressures from Washington or Carson City; minute details of the NEPA process) can divert effort away from activities that directly benefit ecosystems. Another key concern was the loss of intimate landscape knowledge when agency staff are transferred to new locations. Because these do not directly affect the land, they may be less obvious topics for research. But they do affect long-term effective management of that land. This same concern drove our discussions about evaluation criteria, as some were concerned that the prioritization process tended to put added weight behind the most obvious or charismatic research needs, while other important issues continue to be ignored.

Relevant Literature

Note: While much has been written on the topics addressed by the *Humans and desert ecosystems* breakout group, the vast majority of it consists of internal documents by public land agency personnel that are not cataloged in libraries nor readily available to persons outside the specific office where it was produced, or else critical analyses by stakeholder groups that do not provide broad treatments of the subjects. Topics such as interagency cooperation and education of recreation visitors are not highly studied by academic writers. The best source of scientific information is the recreation research literature, as reflected in the sources listed below:

Haas, G. 2001. Visitor capacity in the National Park System. *Social Science Research Review* (Volume 2, Number 1). US National Park Service, Social Science Program, Washington. DC. 2K pp.

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- Manning, R., and J. Vaske. 2006. Analysis of multiple data sets in outdoor recreation research. *Leisure Sciences* 28(5):493-494.
- Shinew, K., M. Stodolska, M. Floyd, D. Hibbler, M. Allison, C. Johnson and C. Santos. 2006. Race and ethnicity in leisure behavior: Where have we been and where do we need to go? *Leisure Sciences* 28(4):403-408.

Geology, geomorphology and soils Breakout Group

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Breakout Group Members

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Stressors

- Fire
- Recreation/population increase
- Development
- Climate change
- Changes in geologic parent materials
- Roads
- Landscape fragmentation
- Subsidence
- Loss of microbiotic crusts
- Micro/macro biological changes as soil health indicators
- Contaminants
- Water budget

Decision Criteria for Prioritization

1. Subsume specialized research topics under broad topics that directly address “The Question”
2. Emphasize what is most fundamental to achieving the necessary scientific understanding of the BG Theme

Prioritized Research Topics

1. Geologic, Geomorphic and Pedologic Patterns
2. Soil-Organism Relationships
3. Loss of Soil Function, Recovery, and Indicators of Soil Health

Summary of the Prioritization Process

The group very quickly agreed that there is a clear need for an effective regional framework of landscape understanding, which has been provided by the newly released regional mapping of the Clark County Soil Survey and the associated geomorphic surfaces. The landscape components, for example, fan piedmonts, channel ways, river and stream terraces, mountain slopes, etc., can all be related spatially and temporally as soil types and their associated plant communities. This kind of mapping, initially done at an order 3 scale for the whole region, will provide a multi-scalar framework for understanding the natural landscape as it transcends the artificial boundaries of administrative units. Because the essential framework provided by such mapping, it has been a high priority with all of the units of government.

Everyone in our small group then agreed that the next priority should focus on soils and their chemical, physical and other relationships to soil, especially as it affects living organisms. This should include investigations of relevant ecological factors (e.g., plant physiology, soil climatology, and degree of pedogenic development) which reflect the spatial and temporal heterogeneity of the pedosphere as defined by local energy and water balance; and micro environmental factors, such as air and soil temperature regimes, soil moisture, evapotranspiration, snow melt patterns, and light available for photosynthesis.

Finally, it was concluded that work was needed in a variety of areas focused on loss of soil function, recovery, and indicators of soil health. Research in this area should focus on testing, calibrating and developing indicators of soil health as methods for recognizing loss of soil function, and as a scorecard on the rate and success of recovery efforts. This should include evaluations of existing indicators that are (1) repeatable and cost-effective, utilizing dynamic soil factors, which affect macro and micro biologic community structure or maturity index; and (2) can serve to indicate a problem long before the natural vegetation is lost or a degraded soil function occurs.

Relevant Literature

- Amundson, R., Chadwick, O.A., Sowers, J.M., Doner, H.E., 1989, Soil evolution along an altitudinal transect in the eastern Mojave Desert of Nevada, U.S.A.; *Geoderma*, v. 43, p. 349- 371.
- Page, W.R., Lundstrom, S.C., Harris, A.G., Langenheim, V.E., Workman, J.B., Mahan, S.A., Paces, J. B., Dixon, G.L., Rowley, P.D., Burchfiel, B.C., Bell, J.W., and Smith, E. I., 2005, Geologic and Geophysical Maps of the Las Vegas 30_ _ 60_ Quadrangle, Clark and Nye Counties, Nevada, and Inyo County, California; USGS Science Investigations Map 2814.
- Peterson, F.F., 1981, Landforms of the Basin and Range Province: Defined for Soil Survey; United States Department of Agriculture Technical Bulletin No. 28, 52 p.
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Landscape dynamics Breakout Group

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Stressors

- Invasion of exotic plants
- Illegal off-road vehicles
- Wildfire, including those related to exotic plants
- Climate change/drought
- Habitat fragmentation
- Urbanization at wildland boundaries
- Habitat degradation caused by many factors

Gaps in Knowledge

We generally do not know much about any reciprocal effects “A” on “B” in nature. Researchers usually study one-way effects of almost anything, ignoring reciprocal effects.

We tend to consider trends or changes in ecological processes as being represented by straight lines or smooth curves on a graph. In fact, thresholds (conditions where rapid changes in a response variable over small changes in the value of a driver variable) are likely common and important for management purposes. We do not know how to predict these.

For many of the agencies involved in these discussions, there are good studies of the natural history of species of concern, but little information at the community and ecosystem level. This is caused by the need to spend time and energy, differentially, on individual species of concern. This focus obviates some the important studies necessary to meet larger land management goals.

One must be mindful of the limitations of alternative futures analyses. These analyses are meant to provide a variety of different scenarios that can occur in response to some sort of change in a system. The studies should also include the various potential consequences of these scenarios. Ecologists and managers alike often forget that there are considerations other than the ones based on good research and data collection that guide final choices. This is where politics and human priorities, regardless of natural system consequences, trump data. Plans for mitigation and/or restoration should be developed for the consequences of various scenarios as a way to lessen the effects of “bad” decisions.

While there are lots of data for the impacts of conspicuous landscape changes such as building roads, fragmentation of natural communities, etc., there are few data on the effect of the more subtle changes in landscape architecture.

For urbanization we have a good idea of the effects on the growing cities, e.g., heat islands, but much less understanding of the influence of urbanization on surrounding areas, e.g., urban areas as epicenters for the colonization of wildlands by non-native or noxious species.

Criteria for Prioritizing Issues/Questions

The *Landscape ecology* group considered the nine questions posed in the “Recommended Research Areas, May Workshop Report” as well as several others that emanated from the group. These were variously reworked, combined, and some were dropped. This led to a group of six questions that were ranked. The scores of the ranking process are provided (Table 1). The scores obviously fall into three groups: a clear winner with 42 points, two losers with 15 points and a third group that included Reciprocal Effects (25 points), Landscape Change (27 points) and Urbanization Effects (23 points). Since this point span does not indicate a clear winner, extensive discussion occurred, several different types of votes were taken (choose the one best, choose the one worst etc.) and unanimity was reached. Even though Urban Effects had only 23 points compared to the 25 points garnered by Reciprocal Effects in the first voting process the subsequent voting clearly chose Urbanization Effects. The compelling reasons for this, especially for southern Nevada, are the significant population increase that will continue into the future with its attendant building boom that will impinge on natural resources and water supplies. This does not negate the importance of Reciprocal Effects, but we had to make our best judgment.

Table 1. Scores for six questions considered. Top three questions are bolded and underlined

								SUM
<u>ALTERNATIVE FUTURES</u>	<u>6</u>	<u>6</u>	<u>6</u>	<u>6</u>	<u>6</u>	<u>6</u>	<u>6</u>	<u>42</u>
RECIPROCAL EFFECTS	1	4	4	3	5	3	5	25
<u>LANDSCAPE CHANGE</u>	<u>5</u>	<u>3</u>	<u>5</u>	<u>5</u>	<u>4</u>	<u>4</u>	<u>1</u>	<u>27</u>
<u>URBANIZATION EFFECTS</u>	<u>4</u>	<u>5</u>	<u>2</u>	<u>4</u>	<u>3</u>	<u>2</u>	<u>3</u>	<u>23</u>
ROAD EFFECTS	2	2	3	2	1	1	4	15
PROCESSES	3	1	1	1	2	5	2	15

Issues/Questions Discussed

The following topics were discussed:

- Alternative futures
- Landscape change
- Urbanization effects
- Road effects, both direct and indirect
- Corridor Size
- Roads as routes for invasives
- Role of landscape architecture in communities and ecosystems
- How do various attribute of conservation areas influence them?
- How do local processes influence regional landscapes?
- Effects of global change
- Reciprocal effects of landscape features and ecosystem processes

Top Three Issues/Questions

Alternative Futures

What development options maximize natural values and minimize environmental damage?

(NB: This goal is best achieved by a combination of retrospective analyses, future development projections, and comparative analyses of development alternatives).

Landscapes and Climate Change

Using landscape gradients, can you predict how critical features and attributes in your landscapes and conservation areas in your landscape mosaics will respond to the climate changes suggested by current models of global climate change?

Urbanization Effects

Can you predict how critical features and attributes in your landscapes and conservation areas in your landscape mosaics that are proximate, as well as those that are more distant from natural area boundaries, are impacted by urbanization?

Discussions

The *Landscape ecology* group had wide ranging discussions about how to arrive at the most important questions to pose. As listed above, we considered a variety of topics and melded some. There was clear agreement that Alternative Futures was an important topic because it offers concrete bases for making decisions with clear statements of positive and negative consequences of various proposed actions. Changes in climate and landscape cover were also unanimously judged to be important foci. Clearly, landscape change and its attendant consequences are occurring more rapidly and with more clearly understood consequences than many other environmental changes, including climate change.

Finally, urbanization, while not receiving the highest number of votes was judged to be a contemporary problem of special importance to the Mojave Desert. Some of America's fastest growing communities are in the Mojave and they are expanding at an increasing rate. Planning is often directed to creating habitable conditions for humans, but even with laws in place, natural systems are often considered to be of very low priority in the planning process.

All in all it was an affable, intelligent group that kept on task and considered a wide variety of options. The final product is defensible and should aid agencies and urban planner alike as development of the Mojave Desert continues.

Relevant Literature

- Farina, A. 2006. Principles and Methods in Landscape Ecology: Towards a Science of Landscape 2nd ed. Springer-Verlag, NY
- Gutzwiller, K. (Ed.). 2002. Applying Landscape Ecology in Biological Conservation. Springer-Verlag, NY
- Hilty, J. A., W. Z. Lidicker, Jr, and A. M. Merenlender. 2006. Corridor Ecology. Island Press, Washington, DC
- Lovett, G. M., C. G. Jones, M. G. Turner and K. C. Weathers (Eds.) 2006. Ecosystem Function in Heterogeneous Landscapes. 2006. Springer Verlag, NY
- Wiens, J. A. and M. R. Moss, (Eds.). 2005. Issues and Perspectives in Landscape Ecology. Cambridge University Press, NY

Cultural resources Breakout Group

Richard V.N. Ahlstrom, HRA Conservation Archaeology, Tucson

Breakout Group Members

Scientists

Alice Baldrice, State Historic Preservation Office

Eva Jensen, Nevada Department of Cultural Affairs

Sali Underwood, State Historic Preservation Office

Elizabeth von Till Warren, HRA Conservation Archaeology

Agency Participants

Mark Boatwright, Bureau of Land Management

Steve Daron, National Park Service

Pat Hicks, US Bureau of Reclamation

Bryce Lloyd, US Forest Service (Facilitator)

Laurie Perry, US Bureau of Reclamation

Susanne Rowe, Bureau of Land Management

Mark Slaughter, US Bureau of Reclamation

Kathleen Sprowl, US Fish and Wildlife Service

Cultural resources include archaeological sites, buildings, and structures that date to the prehistoric and historical periods, as well as places that are important in perpetuating specific ethnic traditions.

Stressors

In assessing stressors of cultural resources, it is important to remember that cultural sites represent a nonrenewable resource—once they're gone, they're gone for good. Stressors include

- Urbanization, including leapfrog growth
- Increased human use of lands for recreation (from ecotourism to ATVs)
- Unauthorized human use of cultural resources (i.e., “pot-hunting” and “point-collecting”)
- Increased use of natural resources (water, minerals, etc.) and rights-of-way (for power lines, pipelines, roads, etc.), resulting in impacts to cultural resources
- Land managers' lack of understanding of cultural resources, as well as actions that the managers propose that impact those resources
- Fire, both “wild” and “prescribed”
- Cultural attitudes—lack of interest and concern among land-using “publics”
- The transfer from public to private ownership of lands containing cultural-resource sites

Gaps in Knowledge

- Information on the presence, nature, and condition of cultural-resource sites over large areas of public land
- Detailed reconstructions of environmental conditions experienced by human groups over the past 10,000 years
- Better tools for the time placement of the majority of archaeological sites that are known from surface evidence alone
- Information on the effectiveness of procedures and tools for determining the location and nature of buried archaeological deposits

- Conceptual and data-driven frameworks or models for describing and interpreting spatial and temporal variability in human use of landscapes and landscape elements
- Information on the effectiveness of steps taken to preserve and protect cultural resources—education, signage, directing and restricting access, etc.
- A better understanding of the current land-use practices and concerns of American Indian communities and of other “ethnically” defined groups; better information on Traditional Cultural Properties important to these groups

Criteria for Prioritizing Research Issues/Questions

- Does the topic address more than one agency, region, discipline, topic, or issue; or cross landscape boundary scales (ecotones, political boundaries, agency jurisdictions); or apply to multiple periods in the history of human land use?
- Would addressing the topic have significance for long-term effective land management?
- Is the research “doable”—can the research questions be successfully addressed with the means at hand?
- Will the research add significantly to current knowledge about cultural resources and about the past?

Issues/Questions Discussed

Most of the issues/questions discussed by the members of the *Cultural resources* group are identified in the accompanying lists of stressors, knowledge gaps, and top research issues/questions. Two topics, however, are not adequately reflected in those lists. One concerns the importance not just of prehistoric cultural resources, but of historical period ones as well. The other addresses the relationship between cultural-resource studies and “natural-history” perspectives on the region’s ecological health:

- In the context of the last 10,000 years, any broad-scale concept of the “natural” environment needs to acknowledge the presence and influence of human groups living on the landscape
- Cultural-resource sites are a primary source of data for understanding that human presence in the environment
- Previous research in southern Nevada has demonstrated a strong relationship between the distribution of archaeological sites and specific characteristics of the “natural” environment, involving in particular topography, geomorphic processes, surface hydrology, and plant communities.
- Research has also shown that the occupants of those sites experienced environmental conditions that differed to a greater or lesser degree from those that exist today or existed during the historical period. Archaeologists are therefore interested in, and often sponsor through their projects, studies that seek to “reconstruct” environmental conditions of the Terminal Pleistocene and Holocene epochs.
- Archaeologists make use of these reconstructions, but also produce data that can contribute to their development
- Paleoenvironmental reconstructions are an important component in identifying appropriate and realistic goals for efforts to maintain southern Nevada’s “ecological health”

Top Three Research Issues/Questions

In selecting the *Cultural resources* group’s “top three issues/questions” for presentation to the Workshop as a whole, we adhered to the specified procedure of relying only on the votes of the group’s “scientist” members. This was a mistake, for two reasons. First, it discounted the experience

and opinions of the group’s “agency” members, who made up the majority of the group and whose qualifications were comparable to those of the scientist members. Second, it eliminated from consideration the research issue/question that had the greatest chance of resonating with workshop participants whose backgrounds were in the natural sciences and who made up the great majority of the participants. That mistake is corrected here by including the three issues/questions that were of greatest concern to the *Cultural resources* group as a whole.

Updated Historic Context for the Southern Nevada Region

A historic context is a document that compiles existing knowledge concerning a region’s cultural resources and the lifeways that they represent, identifies gaps in that knowledge, and sets priorities and serves as a guide for future research. The goals of a historic context are therefore analogous to the goals of the Ecosystem Health Assessment Workshop. Historic contexts are also an essential underpinning for the federally mandated process of determining whether sites are “significant” and, on that basis, warrant further protection and research. The currently available context for the region is years out of date.

History of Human Presence on the Southern Nevada Landscape

The concept of “cultural landscapes” provides a context for understanding the nature and trajectory of “man-land” relationships in the southern Nevada region. That understanding must address stability and change in environments over time, stability and change in human adaptations to those environments; and the ways in which people affected, or changed, their environments. This broad topic includes a number of more specific research goals or needs, including

- Region-specific reconstructions, covering the last 10,000+ years and reflecting the highest degree of temporal resolution possible, of climatic conditions, plant association/community boundaries, hydrology of springs and washes, alluvial geology of major drainages; etc.
- Region-wide descriptions, for the recent and historic periods and in GIS-compatible formats, of southern Nevada’s natural environment (including plant communities, springs, etc.).
- Expanded and improved databases of previously recorded and excavated archaeological sites in the southern Nevada region—improved in particular through assessment of the quality of available records and, for critical sites, rerecording (if the site still exists) and reanalysis of archived records, artifacts, and samples.
- Collection of “new” data relevant to the research topic, through sample survey targeted to improving coverage of poorly understood landscape elements; site testing and excavation undertaken to mitigate impacts from construction and other projects and from land sales; and, if opportunities arise, excavation to satisfy specific research goals.
- Development of frameworks and models (conceptual, GIS, etc.) for integrating and interpreting the above-mentioned data sets; to support the writing of histories of “man-land” relationships in the southern Nevada region
- Exploration of institutional means for supporting and perpetuating the kind of interdisciplinary research outlined here.

Effective Strategies for the Long-Term Preservation of Cultural Resources

Because of the nonrenewable nature of cultural resources, preservation is an important goal for the region’s land managing agencies. Addressing this topic would, therefore, have significance for long-term effective land management (see the above list of criteria for prioritization). Preservation is not simply a management issue, but also has a critical research component, concerning the identification of

approaches to preservation, or combinations of approaches, that are most effective in specific situations. Such approaches include efforts to educate the general public about the value of cultural resources, interpretation of cultural-resource sites for the land-using public with trails and signage, restricting access to critical sites by blocking roads or installing fences, active monitoring of changes in the condition of selected sites, and strengthening laws and regulations intended to protect cultural resources. Which approaches actually work? The need here is to set realistic priorities for the allocation of resources.

Discussions

There was generally good agreement among the members of the *Cultural resource* group that the most important near-term goal for research on southern Nevada's cultural resources is the development of a new Historic Context for the region. This document can provide needed guidance for meeting other research goals, such as those enumerated above. There was also considerable agreement concerning the importance of the next set of three research issues/questions, which have been reorganized under the two categories of History of Human Presence on the Southern Nevada Landscape and Effective Strategies for the Long-Term Preservation of Cultural Resources.

Relevant Literature

- Ahlstrom, Richard V.N. (editor). 2005. *Desert Oasis. The Prehistory of Clark County Wetlands Park, Henderson, Nevada*. HRA Papers in Archaeology No. 4. Prepared for the Bureau of Reclamation, Lower Colorado Regional Office, Boulder City, Nev. HRA, Inc. Conservation Archaeology, Las Vegas.
(for a recent overview of Las Vegas Valley's prehistory)
- Betancourt, Julio L., Thomas R. Van Devender, and Paul S. Martin (editors). 1990. *Packrat Middens: The Last 40,000 Years of Biotic Change*. University of Arizona Press, Tucson.
(for one of the most robust approaches to the reconstruction of Terminal Pleistocene and Holocene environments in the Mojave Desert, Great Basin, and Southwest regions)
- Ezzo, Joseph A. 1996. *A Class I Cultural Resources Survey of the Moapa and Virgin Valleys, Clark County, Nevada*. Statistical Research Technical Series 58. Statistical Research, Inc., Tucson.
(for a fairly recent overview of cultural-resource data and issues from the eastern edge of the Southern Nevada region)
- Grayson, Donald K. 1993. *The Desert's Past: A Natural Prehistory of the Great Basin*. Smithsonian Institution Press, Washington.
(provides a broad, but also detailed perspective on relationships between human and natural history in the Great Basin)

Inventory, monitoring and indicators Breakout Group

Jeffrey Herrick, US Department of Agriculture –Agricultural Research Service, Jornada Experimental Range, Las Cruces

Breakout Group Members

Scientists

Susan Benjamin, US Geological Survey
Amrita de Soyza, University of Nevada, Reno
Tom Edwards, US Geological Survey

Agency Participants

Cristi Baldino, US Fish and Wildlife Service
Susan Barrow, US Forest Service (Facilitator)
Ross Haley, National Park Service
Bruce Lund, US Forest Service

Scientists and agency representatives participated as equal members of the group. All contributed to the scientific and technical discussions.

Stressors

The proposed list is quite comprehensive. We had no additional recommendations. However, it needs to be organized and condensed.

Gaps in knowledge

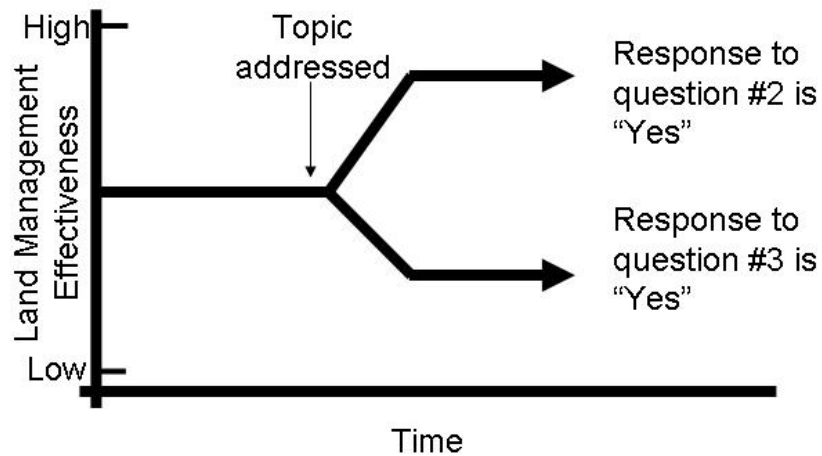
- *Indicators*: there is inadequate information on relationships between indicators and ecological processes/functions they are intended to represent, and how these relationships vary across the landscape in southern Nevada.
- *Inventory*: biophysical and socioeconomic inventories are incomplete. These inventories are required to design monitoring programs, and to interpret and apply assessment and monitoring data to management.
- *Implementation*: there is insufficient knowledge of how to plan and implement monitoring to support agency objectives. While much relevant *information* exists, it has not been organized and interpreted so that it can be effectively applied. Where science-based implementation guidance does exist, it is agency-specific, making landscape-scale interpretations of the resulting data difficult or impossible.

Criteria for prioritizing issues/questions

#2 and #3 are based on the original #2. We did not include the original #3 (“Can the topic be resolved effectively and efficiently?”).

1. Does the topic address more than one agency, region, discipline, topic or issue; or cross landscape boundary scales (ecotones, political boundaries, agency jurisdictions? (no change from original).

2. Would addressing the topic increase the long-term effectiveness of land management?
3. Would NOT addressing the topic reduce the long-term effectiveness of land management?



The issues/questions discussed

The participants concluded that the issues are effectively captured by the objectives listed in the following section.

The top three issues/questions

1. Develop, select, calibrate and provide information necessary to interpret biophysical and socioeconomic indicators.
2. Complete biophysical and socioeconomic inventories necessary to design monitoring programs, and to interpret and apply assessment and monitoring data to management.
3. Develop guidance necessary for agencies to plan and implement monitoring in support of their collective objectives.

Discussion

Inventory, assessment and monitoring data are required to address virtually all of the issues and questions identified by the other workshop groups. Many of the information needs overlap (e.g. most groups require some type of information on trends in vegetation cover and/or composition). Our group believes that a locally-adapted toolbox of indicators that could be flexibly adopted and applied would significantly increase the effectiveness and cost-effectiveness of land management in southern Nevada. It would reduce duplication of efforts and ensure that data could be more consistently interpreted across multiple spatial and temporal scales.

Please see Workshop #1 report for additional information which supports issues #1 and #3, and for relevant literature. Issues that were specifically discussed during by our group are summarized below.

Issue #1.

Develop, select, calibrate and provide information necessary to interpret biophysical and socioeconomic indicators.

The agencies already have several overlapping ‘toolboxes’ full of indicators. These indicators must be tested, calibrated and potentially modified to ensure that they accurately reflect critical changes in ecosystem condition, and to identify which are sensitive to early changes associated with cumulative impacts of multiple stressors. In some cases, new indicators will need to be developed, but in most

cases, indicators that have already been nationally adopted can be applied or adapted. This process should be multi-agency, and should address the following criteria:

- Related to ecological processes/functions
- Cost-effective
- Easy to interpret
- Easy to measure consistently
- High signal-to-noise ratio
- Link to spatial data structures, allowing for extrapolation to landscape *and* seek indicators of emergent landscape properties
- Amenable to sound sampling design in space and time
- Transferable (can be interpreted across multiple landscape units)
- Relevant to multiple issues

Indicators are required that provide early warning of impending changes (especially where changes are difficult to reverse), and that reflect long-term changes. In many cases, different indicators will be required to meet these two objectives. In particular, socioeconomic indicators that will help predict future human impacts on the landscape should be developed, selected and calibrated. We believe that alternative futures scenarios (including spatial decision support systems) can help identify future stressors and be used to guide development of biophysical monitoring plans.

Issue #2.

Complete biophysical and socioeconomic inventories necessary to design monitoring programs, and to interpret and apply assessment and monitoring data to management.

Inventories addressing the following types of information are relevant to this issue. The group had insufficient knowledge of the status of current inventories to determine which of the following require new or updated inventories.

- Physical characteristics (soils and geomorphology, hydrology (including spring number and production)), and extractable resources
- Biological characteristics (plant and animal species and communities)
- History of fire occurrence (spatial and temporal distribution)
- Socioeconomic characteristics (population (including demographics), infrastructure (including roads, trails and marinas), and resource extraction (including gravel, oil, gas and minerals).

Issue #3.

Develop guidance necessary for agencies to plan and implement monitoring in support of their collective objectives.

The guidance should include how to clearly define objectives to help ensure that the data will be used to guide management. It should provide a roadmap for helping managers select appropriate indicators that meet the criteria listed under Issue #1 above. If followed, this flexible roadmap should increase standardization and coordination across agencies (to the extent possible given unique legislative mandates).

Relevant Literature

There are numerous agency monitoring documents that should be consulted prior to initiating any monitoring research or development effort. The two documents listed below are extremely current specifically address many of the major issues listed in the report.

General

Carpenter, Stephen R., Ruth DeFries, Thomas Dietz, Harold A. Mooney, Stephen Polasky, Walter V. Reid, and Robert J. Scholes. 2006. Millennium Ecosystem Assessment: research needs. *Science* 314 (13 Oct):257-258.

Socioeconomic

Endter-Wada, Joanna, Dale Blahna, Richard Krannich and Mark Brunson. 1998. A framework for understanding social science contributions to ecosystem management. *Ecological Applications* 8(3):891-904.

Aquatic systems

Sada, D.W. and K.F. Pohlmann. 2006. U.S. National Park Service Mojave Inventory and Monitoring Network. Spring Survey Protocols: Level I and Level II. Unpublished report to U.S. National Park Service, Boulder City, NV.

Upland systems

Herrick, J. E., B. T. Bestelmeyer, S. Archer, A. Tugel, and J. R. Brown. 2006. An integrated framework for science-based arid land management. *Journal of Arid Environments* 65: 319-335.

APPENDIX IV. Breakout Group Presentations from August Workshop

Fire and Other Disturbing Events in Southern Nevada

Scientists

Matt Brooks (USGS)

Beih Newingham (UNLV)

Cris Tomlinson (NDOW)

Agency Participants

Carrie Ronning (BLM)

Amber Shanklin (Ash Meadows NWR)

Rob Mrowka (Clark County)

Stressors

- livestock, wild horses, burros
- climate change
- invasive plant species
- humans on the landscape
- rainfall cycles/ trends
- nitrogen deposition
- agency policies

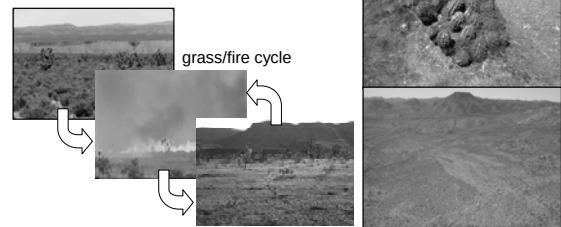


Decision Criteria

1. Does the topic address more than one agency, region, discipline, topic or issue; or cross landscape boundary scales?
2. Would addressing the topic have significance for long-term effective land management?
3. Does the topic address multiple ecosystem components?
4. Is the topic timely, both in terms of immediacy of need and other reasons to start a project now rather than later?
5. Is there currently little or no information available on the topic?

Top Research Priorities

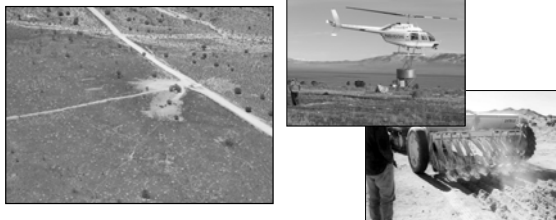
1. Fire effects



Listed in order of priority assigned. Titles from the May workshop are in parentheses.

Top Research Priorities

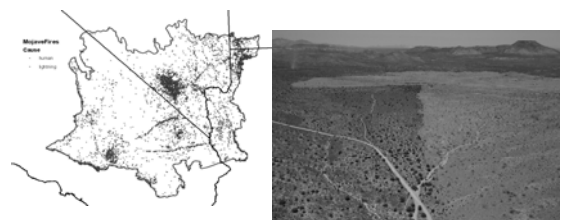
2. Post-fire management (previously called postfire seeding)



Listed in order of priority assigned. Titles from the May workshop are in parentheses.

Top Research Priorities

3. Fire trends, past, current, and future (previously called fire history)



Listed in order of priority assigned. Titles from the May workshop are in parentheses.

Other Research Priorities

4. Fire suppression tactics
5. Fuels management
6. Human interactions with fire (new topic not identified in the May workshop)

Listed in order of priority assigned. Titles from the May workshop are in parentheses.

Invasive Species

Group Leader: Stan Smith, UNLV

Facilitator: Alice Newton, NPS

Members: Scott Abella, UNLV
Curt Deuser, NPS
Tom Dudley, UCSB
Amy LaVoie, USFWS
Maria Ryan, UNR
Nita Tallent-Halsell, EPA/UNLV
Lewis Wallenmeyer, Clark Co.

Additional Stressors:

- Pulse rainfall responses (high rainfall anomalies)
- Altered flow regimes
- Reservoir drawdowns, creating new habitats
- Water diversion by development and agriculture
- Soil deposition as a result of water movement
- Lack of robust, healthy ecosystems
- Nitrogen augmentation – air, groundwater, agriculture
- Ornamentals and landscape industry
- Disease and parasite vectors
- Illegal dumping of landscape materials/dredge spoils
- Aquarium and pet industries
- Road proliferation
- Humans as vectors
- ORV's in general
- Public perception

Additional Criteria?

NO

Recommended Research Areas (from May report)

1. Basic Research on Invasives
2. Invasives Populations
3. Vulnerability to Invasions
4. Aquatic Invasives
5. Roads and Invasives
6. Global Change and Invasives

More Specific Research Questions:

Mechanisms of Invasion

- What biological attributes make good invaders? (1)
- What is the relationship between disturbance and invasion success? (2)
- What community/ecosystem attributes are resistant to invasion? (2)
- What key biotic interactions allow invasives to be successful? (3)

Ecological Effects of Invasions

- What are the effects of species invasions on community structure? (4)
- What are the effects of species invasions on ecosystem function? (4)

Management of Invasive Species

- What are the effects of management on invaded systems? (5)
- How do we characterize "invasiveness" of ecosystems? (2)
- What are the tools and techniques available for invasive species treatment? (5)
- How do we create an early detection and risk management system? (5)

First Try at a Research Prioritization Vote

<u>Research Area</u>	<u>Votes</u>	<u>Rank</u>
Attributes of Invaders	19	1
Elements that Determine Invasibility	17	2
Biotic Interactions	10	5
Community/Ecosystem Effects	14	4
Management Methods and Effects	15	3

Final Priority Research Areas

Research Area

Incorporates

1. Mechanisms of Invasion

Ecophysiology
Genetics
Population Biology
Invasiveness

2. Ecological Effects of Invaders

Biotic Interactions
Community Structure
Ecosystem Function

3. Management Methods & Effects

Methods Development
Early Detection
Risk Management
Effects of Removals





Water

Research Needs for the 21st Century

Frank D'Agnese
 Don Sada
 Laurie Averill-Murray
 Tom Culhane
 Craig Forster
 Debra Hughson
 Patrick Putnam
 Barry Moore
 Steve Mizell






Stressors

Groundwater	Springs & Riparian
• Extraction from increased human use • Surface discharge • Flow • Water quality • Temperature • Water levels • Climate variability & change • Contamination (point & non-point) • Consequence of land use change • Recharge • Discharge	• Habitat modification • Ungulates • Recreation • Mining • Diversion (gw & sw) • Channelization • Impoundment • Water quality • Fire • Restoration • Non-native species • Air quality • Climate variability & change



Prioritization Criteria

Recommended plus 'Urgency'



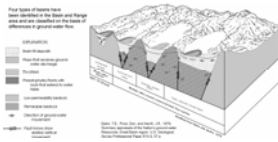



Water

Priority #1

Integrated water- ecology model

Develop and test conceptual models that integrate water-ecosystem-human dynamics in order to prioritize characterization and inventory programs, direct future research and management, and to better address decision-making needs






Water

Priority # 2

Spring system biotic integrity

Inventory and characterize current, historic, and prehistoric condition of springs. Quantify reference conditions in context of hydrologic and landscape associations. Develop methods to assess the ecological effects of habitat modification by understanding factors affecting habitat quality and the structure of riparian and aquatic communities, quantitatively identifying indicator species, and determining microhabitat preferences of rare species.





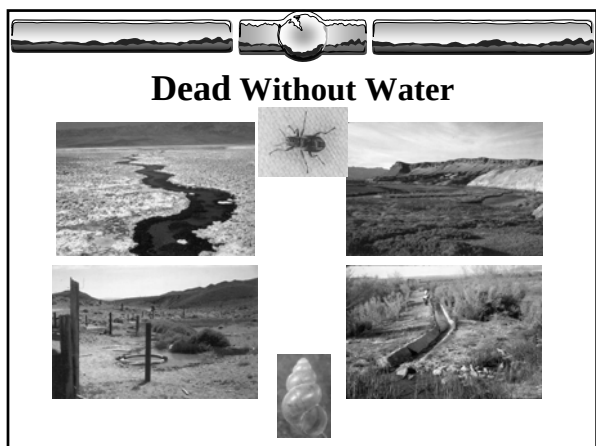

Water

Priority # 3

Characterize / model groundwater systems

Characterize groundwater systems at multiple scales and use models to evaluate the significance of specific system components and stressors (e.g. pumping) through sensitivity and uncertainty analysis.



Restoration Breakout Group

Jeanne Chambers, Josh Hoines, Zach Million, Craig Palmer, Sue Wainscott
Group Leaders: Kent Ostler, Dick Toth

Stressors

- Urbanization (Driver)
 - Desert dumping
 - ORV use
- Invasive species
- Intensive land use
- Fire
- Climate/weather
- Highly variable precipitation
- Decrease in soil quality/productivity
- Surface disturbance
- Landscape fragmentation
- Decrease in soil quality/productivity
- Surface disturbance
- Landscape fragmentation Over grazing
- Nitrogen deposition
- Decrease water tables and spring flow

Decision Criteria

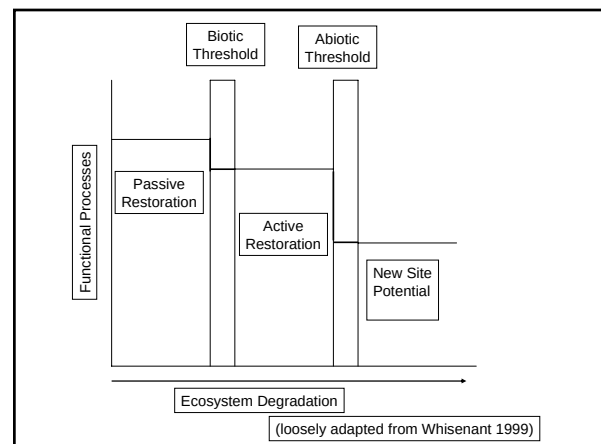
- Broad or multiscalar
- Related issues
- Effective long-term land management
- Research

Restoration Definition

- Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration)
- Key Attributes
 - Resistant
 - Resilient
 - ❖ Sustainable

Restoration Potential

- What are the biotic and abiotic thresholds that determine the recovery potential of the dominant ecosystems within the region, and what are the key variables that define those thresholds?
 - Use retrospective analyses and existing literature to determine context and knowledge of response to disturbance
 - Identify priority ecosystems
 - Use collaborative research and management restoration experiments that take advantage of ongoing or planned efforts



Restoration Potential USE

- Identify sensitive systems
- Identify types of restoration needed (active Vs. passive)
- Helps establish restoration objectives
- Prioritize sites that allow “biggest bang for the buck”
 - A management decision criteria

Treatment Effectiveness

- What is the effectiveness of standard restoration treatments for key ecosystems and different disturbance regimes?
 - Retrospective analysis
 - Collaborative research and management projects conducted in an adaptive management framework
 - Rigorous, documented monitoring that will inform both management and research

Plant Establishment Techniques

- What are the plant establishment (seeds and transplants) requirements for promising revegetation species, what are the best treatments to promote establishment, and which species should be placed into seed increase or propagation programs?

Historical Synthesis

- What information on restoration approaches can be obtained from a synthesis of historic and current information?
 - Develop databases of existing literature and ongoing studies on Mojave restoration
 - Use information on ecological sites and soils to develop decision support systems like Veg Spec

**Vote For Restoration
Thank You**

Species Conservation and Biodiversity

Brett Riddle lead
Marc Maynard facilitator

scientist

Dave Bradford
Jef Jaeger
David Syzdek

agency

Liz Bickmore
Karen Harvilk
Fred Edwards
Christina Lund
Teresa Prenden
Kent Turner

Species Conservation and Biodiversity

Stressors

Exotic species (macro/predation, competition)
Exotic species (micro/pathogens)
Exotic species (ecosystem conversion)
Habitat fragmentation/loss/modification
Fire / Modification of habitat dynamics
Global Warming

Species Conservation and Biodiversity

Stressors (cont.)

Loss of pollinators
Recreation
Changes in hydrology
Roads/trails
Urban ecotone

Species Conservation and Biodiversity

Decision Criteria

1. More than one agency, region, etc.
discussion about why this is important?
2. Long-term effective land management
3. Effectiveness and Efficiency
DRI took it out, but we argue that it is indeed a science-based issue
4. Does it affect more than one species?

Species Conservation and Biodiversity

Choosing Priority Topics

**Generally good consensus
between scientists and
agency representatives on
the important research
topics**

Species Conservation and Biodiversity

3 Top Priority Topics

Tie between the top two

Species Conservation and Biodiversity

1 of the 2 Top Priority Topics

Prioritizing species (including migratory species) for conservation by filling information gaps using one or more of the following approaches:

- *molecular phylogeny, phylogeography, and population genetics*
- *range and distribution in southern Nevada relative to total range of species*
- *functional importance to ecosystem or associated species assemblages*
- *vulnerability*
- *irreplaceability*

Species Conservation and Biodiversity

2 of the 2 Top Priority Topics

Fulfill information gaps necessary for conservation of critical species of concern including:

(information needed to develop conservation assessments and strategies)

- *life histories*
- *habitat requirements and critical ecosystem processes*
- *species associations (e.g. pollinators)*
- *metapopulation structure*
- *population genetics*
- *population dynamics*
- *current vs. historical distributions*
- *vulnerability*
- *current vs. historical population connectivity*

Species Conservation and Biodiversity

3rd of the Top Priority Topics

What is the threshold level of natural or artificial habitat disturbance/degradation/fragmentation (including exotic species) before compromising species viability or loss of system function?

Humans and Desert Ecosystems

Participants

- ◆ Mark Brunson – Group leader
- ◆ Lauren Brown – Assistant
- ◆ Rosie Pepito
- ◆ Connie Moen
- ◆ Scott Lamoreux
- ◆ Skip Canfield
- ◆ Mike Boyles
- ◆ Matt Burks

Additional stressors

- ◆ 28 additional stressors listed
 - Many fall into the “related issues” ... that are not necessarily “stressors” category
- ◆ In discussion, most influential on subsequent discussions included
 - Impediments to agencies’ ability to manage (political pressures, aging facilities, interagency relations, staffing)
 - Lack of citizen awareness
 - Under-represented groups

Decision criteria

- ◆ Considerable discussion about whether a topic is likely to lead directly to an action strategy (but is this a “scientific” criterion separate from long-term effective management?)
- ◆ Did add a criterion about urgency or immediacy of need

Research topics evaluated after reconsidering the original list

- ◆ Visitor Use Patterns/Characteristics:
 - ◆ Comprehensive study of visitor use (not just recreation) patterns and characteristics
 - ◆ Focus on “data gaps” – e.g., cultural differences, hard-to-observe activities, non-recreation uses (e.g., gathering)
- ◆ Outreach Program Analysis:
 - ◆ What programs exist, how effective are they in influencing behavior, and how is info received?

Research topics evaluated after reconsidering the original list

- ◆ Use Limits:
 - Including identification of locations that are more sensitive or more resilient to use, also including visitor experience impacts
- ◆ Ecosystem Values:
 - Which aspects of S. Nevada ecosystems are most valued by Clark County residents?

Research topics evaluated after reconsidering the original list

- ◆ Multiple Agency Mgmt. & Partnership:
 - How can we help agencies work more effectively across boundaries
 - What mechanisms exist to engage local govt., NGOs, private sector in partnerships?
- ◆ Urban Sprawl/Local Land Use Planning
 - How can land sales decisions incorporate biophysical concerns (e.g., corridors) and open space/recreation needs?

Research topics evaluated after reconsidering the original list

- ◆ Agency Resource Needs
 - What resources (staffing, infrastructure, budgets, local knowledge, etc.) will be needed to meet ecosystem health objectives into the future?
- ◆ Law Enforcement & Compliance
 - Why do people engage in undesired behaviors (vandalism, dumping, etc.) and what law enforcement methods are most effective in obtaining compliance?

Top Priorities

- ◆ Visitor Use Patterns and Characteristics
- ◆ Agency Resource Needs
- ◆ Outreach Programs Analysis

... But!!!

Caveats and considerations

- ◆ Two topics ranked very close in priority to Outreach Programs
 - Use Limits
 - Law Enforcement & Compliance
- ◆ We would like to see consideration in Visitor Use Patterns/Characteristics research to questions that would also illuminate other topics (e.g., focus on sensitive locations or illegal activities)

Caveats and considerations

- ◆ Concern about the process: We were torn between a desire to identify the most important topics, and to seize the opportunity to highlight areas of study that aren't already receiving attention
- ◆ We broke the rules: Only one scientist in group, so we all voted but took great care to try to use science as guiding principle

Geomorphology, Geology and Soils

Group Leader: Vic Baker, University of Arizona
Assistant: Ken Lucas, BLM
Participants: Roger Congdon, FWS
Jim Hurja, USFS
Douglas Merkler, USDA

Optimization will be
used to view the picture

Stressors

Fire	Landscape Fragmentation
Recreation/Population Increase	Dark Sky
Development	Subsidence
Climate Change	Loss of Microbial Crusts
Changes in Geologic Parent Material	Micro/macro Biological Changes
Roads	Contaminants
	Water Budget

Decision Criteria

1. Subsume specialized research topics under broad topics that directly address “The Question”
2. Emphasize what is most fundamental to achieving the necessary scientific understanding of the BOG Theme

Prioritized Research Topics

1. Geologic, Geomorphic and Pedologic Patterns
2. Soil-Edaphic Relationships
3. Loss of Soil Function, Recovery, and Indicators of Soil Health

Geologic, Geomorphic and Pedologic Patterns

There is a clear need for an effective regional framework of landscape understanding, such as would be provided by the regional mapping of soils and the associated geomorphic surfaces. The landscape components, for example, fan piedmonts, channel ways, river and stream terraces, mountain slopes, etc., can all be related spatially and temporally as soil types and their associated plant communities. This kind of mapping, initially done at coarser scales for the whole region, will provide a multi-scalar framework for understanding the natural landscape as it transcends the artificial boundaries of administrative units.

Soil-Edaphic Relationships

Research in this area should focus on soils and their chemical, physical and edaphic relationships (of or relating to soil, especially as it affects living organisms). This will include investigations of relevant ecological factors (e.g., plant physiology) which reflect the spatial and temporal heterogeneity of local energy and water balance; and micro environmental factors, such as air and soil temperature regimes, soil moisture, evapotranspiration, snow melt patterns, and light available for photosynthesis.

Loss of Soil Function, Recovery, and Indicators of Soil Health

Research in this area should focus on testing, calibrating and developing indicators of soil health as methods for recognizing loss of soil function, and as a scorecard on the rate and success of recovery efforts. This should include evaluations of existing indicators that are (1) repeatable and cost-effective, utilizing dynamic soil factors, which affect macro and micro biologic community structure or maturity index; and (2) can serve to indicate a problem long before the natural vegetation is lost or a degraded soil function occurs.

THE LANDSCAPE ECOLOGY TEAM

- Lee Brice, Clark Co.
- John Briggs, ASU
- Cameron Burrows, UCRiverside
- Nora Devoe, BLM
- Bill Kepner, EPA
- Jim MacMahon, USU, GL
- Gayle Marrs-Smith, BLM, Queen
- Henry Sun, DRI

VOTING RESULTS

								SUM
ALTERNATIVE FUTURES	6	6	6	6	6	6	6	42
RECIPROCAL EFFECTS	1	4	4	3	5	3	5	25
LANDSCAPE CHANGE	5	3	5	5	4	4	1	27
URBANIZATION EFFECTS	4	5	2	4	3	2	3	23**
ROAD EFFECTS	2	2	3	2	1	1	4	15
PROCESSES	3	1	1	1	2	5	2	15

ALTERNATIVE FUTURES: What development options maximize natural values and minimize environmental damage (best answered by retrospective analyses, future development projections, and comparative analyses of development alternatives)?

LANDSCAPE AND CLIMATE CHANGE: Using landscape gradients, can you predict how critical features and conservation areas in your landscape mosaics will respond to models of global climate change?

URBANIZATION EFFECTS: How does urbanization impact critical features and conservation areas in your landscape mosaic that are proximate and more distant from natural area boundaries?

STEP 1
COMPREHENSIVE RETROSPECTIVE ANALYSIS OF
LANDSCAPE CHANGE

STEP 2
DEVELOP PLAUSIBLE FUTURE PROJECTIONS
FOR DEVELOPMENT WITH OPTIONS

STEP 3
COMPARATIVE ANALYSIS OF VARIOUS
DEVELOPMENT OPTIONS RELATIVE TO
IMPORTANT ENDPOINTS (GOALS)

SUCCESS
ASSIST DECISION - MAKERS

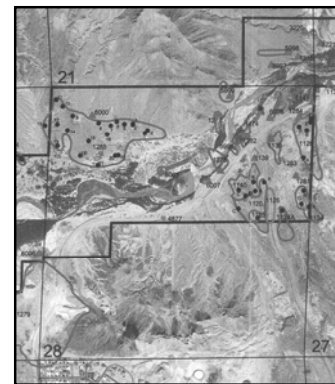
CULTURAL RESOURCES

Identifying Research Priorities



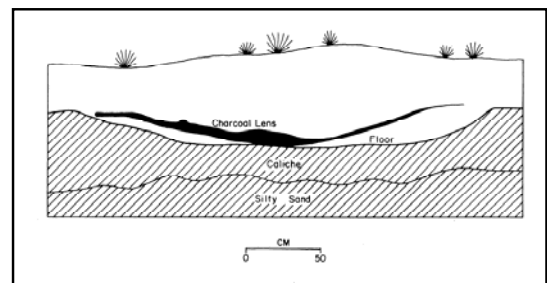
1. CULTURAL RESOURCE HISTORIC CONTEXT

- Compilation of Existing Knowledge
- Identification of Data Gaps
- Guide for Future Research
- Tool for Setting Priorities
- Organized in Terms of Place, Time, and Theme



2. CULTURAL RESOURCE INVENTORY

- Identification and Evaluation of Sites
- Prehistoric and Historic Sites, Historic Buildings, Places Important to Living People, and so on
- Documenting, Reporting, and Archiving
- Preserving Places and Knowledge



3. RESEARCH METHODS

- Evaluating and Improving Current Methods of Site Recognition, Data Collection, Interpretation, and Education
- Basis for Understanding the Place of Humans in the Environment Over Time
- Maximizing Knowledge Gained from a Finite Non-Renewable Resource

Inventory/Monitoring /Indicators



Bruce Lund
Amrita de Soyza
Cristi Baldino
Ross Haley
Tom Edwards
Susan Benjamin
Susan Barrow
Jeff Herrick
Dave "drop-in"
Mouat

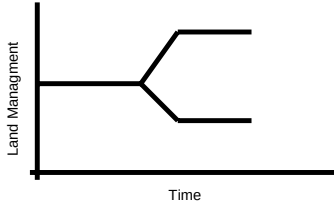


New Stressors

- None
- Need to organize existing into stressor types

Decision Criteria

1. (no change)
2. Would addressing the topic increase the long-term effectiveness of land management?
3. Would NOT addressing the topic reduce the long-term effectiveness of land management?



3 blind recommendations

- Biophysical and Socioeconomic Indicators: Develop, select, calibrate and provide information necessary to interpret indicators
- Complete Inventories (Terrestrial and Aquatic)
- Plan and Implement Monitoring to Support Agency Objectives

Biophysical and Socioeconomic Indicators

- Develop, select, calibrate and provide information necessary to interpret indicators with the following characteristics:
 - Related to ecological processes/functions
 - Cost-effective
 - Easy to interpret
 - Easy to measure consistently
 - High signal-to-noise ratio
 - Link to spatial data structures, allowing for extrapolation to landscape and seek indicators of emergent landscape properties
 - Amenable to sound sampling design in space and time
 - Transferable (can be interpreted across multiple landscape units)
 - Relevant to multiple issues

Biophysical and Socioeconomic Indicators (page 2)

- Socioeconomic:
 - Develop, select, calibrate indicators that will help predict future human impacts on the landscape
 - Provide information necessary to interpret the indicators
- Develop and use alternative futures scenarios (including spatial decision support systems) to help identify future stressors
 - This information can be used to help guide biophysical monitoring plan development

Inventories (Terrestrial and Aquatic)

- NOTE: *group has insufficient knowledge of status of current inventories to prioritize; this is a partial list*
- Physical characteristics
 - Soils and geomorphology
 - Hydrology (including spring number and production)
 - Extractable resources
- Biological characteristics
 - Plant species and communities
 - Animal species
- History of fire occurrence (spatial and temporal distribution)
- Socioeconomic
 - Population (including demographics)
 - Infrastructure
 - Roads
 - Trails
 - Marinas
 - Resource extraction (gravel, oil and gas, etc...)

Plan and Implement Monitoring to Support Agency Objectives with the following characteristics

- Clearly define objectives (monitoring is objective-driven)
- Program must pass the “so what” test
 - So what does it mean?
 - So whaddaya gonna do?
- Include indicators with the characteristics listed in research area #1
- Standardized across agencies (to the extent possible)
- Coordinate across federal, state and local agencies
 - Example: groundwater monitoring

Plan and Implement Monitoring (page 2)

- Socioeconomic (including demographic) including
 - Population
 - Infrastructure
 - Roads
 - Trails
 - Marinas
 - Resource extraction (gravel, oil and gas, etc...)
- Biophysical
 - Long-term trend (depends on process and organism; can often be >100 years)
 - Local
 - Regional (county-wide)
 - “Short-term” effectiveness monitoring (for management)
 - Restoration treatments
 - Mitigation
 - Enforcement (e.g. road closures)



APPENDIX V. Polling Results from August Workshop

Polling Results

Ecosystem Health Assessment and Resource Management in Southern Nevada

Research Needs for Management in the 21st Century

Desert Research Institute, Las Vegas, Nevada

August 15-16, 2006

Prepared by



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for

The
Mary Orton
Company LLC

Table of Contents

<i>Meeting Overview</i>	<i>1</i>
<i>Demographic Information.....</i>	<i>2</i>
<i>Research Evaluation Criteria</i>	<i>3</i>
<i>Relative Ranking of Research Areas</i>	<i>4</i>
<i>Meeting Evaluation</i>	<i>10</i>

Appendices

<i>Appendix A - Research Area Evaluation Matrix.....</i>	<i>A-1</i>
<i>Appendix B - Comparison of Subgroup Average Ratings by Research Area.....</i>	<i>B-1</i>
<i>Appendix C - Frequency Distribution of Research Area Ratings by Role</i>	<i>C-1</i>

Figures

<i>Figure 1 – Number of Participants by Role</i>	<i>2</i>
<i>Figure 2 – Relative Priority of Evaluation Criteria</i>	<i>3</i>
<i>Figure 3 – Relative Ranking of Research Areas by Subgroup</i>	<i>6</i>
<i>Figure 4 – Relative Ranking of Research Areas, Breakout Group Leaders</i>	<i>7</i>
<i>Figure 5 – Relative Ranking of Research Areas, Scientists</i>	<i>8</i>
<i>Figure 6 – Relative Ranking of Research Areas, Agency Participants.....</i>	<i>9</i>
<i>Figure 7 – Effectiveness of Meeting.....</i>	<i>10</i>
<i>Figure 8 – Usefulness of Interactive Technology.....</i>	<i>10</i>

Tables

<i>Table 1 –Rank of Research Areas by Subgroup</i>	<i>5</i>
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Meeting Overview

The Workshop was held at the Desert Research Institute (DRI) in Las Vegas, Nevada on August 15 and 16, 2006. More than 80 scientists and representatives from public land management agencies convened to identify and prioritize critical areas of research that could improve the management of public lands in Southern Nevada.

On the first day of the two-day meeting, participants organized themselves into ten breakout groups to identify and prioritize potential research areas in their area of expertise. They also discussed two decision criteria given them by the workshop organizers, and identified additional criteria that should be used to select the research projects to be funded. Each breakout group had a designated leader, a recognized expert in the field, who was supported by an agency staff person who had been trained as a facilitator for this workshop. Appendix A presents a matrix that lists the recommendations for research from each of the breakout groups, the changes to the first decision criteria, and the five additional decision criteria that were identified to be used in the overall prioritizing on the second day.

On the second day of the workshop, the participants discussed the added decision criteria, agreed to eliminate one (“Is it highly complex?”), and prioritized the remaining six decision criteria using interactive polling technology. Each participant was provided a remote FM radio input terminal with which to respond to questions generated by computer and projected on a large screen. The results were tabulated and immediately presented back to the group for discussion. Demographic information was collected to assess the different perspectives of participants based on their role at the meeting.



After discussing the decision criteria, each breakout group leader presented the top three research areas that were selected by his breakout group. All participants then individually rank-ordered the 30 proposed research areas using the matrix (see Appendix A) as a worksheet. The individual opinions were then collected using the interactive polling technology and immediately presented back to the group for discussion.

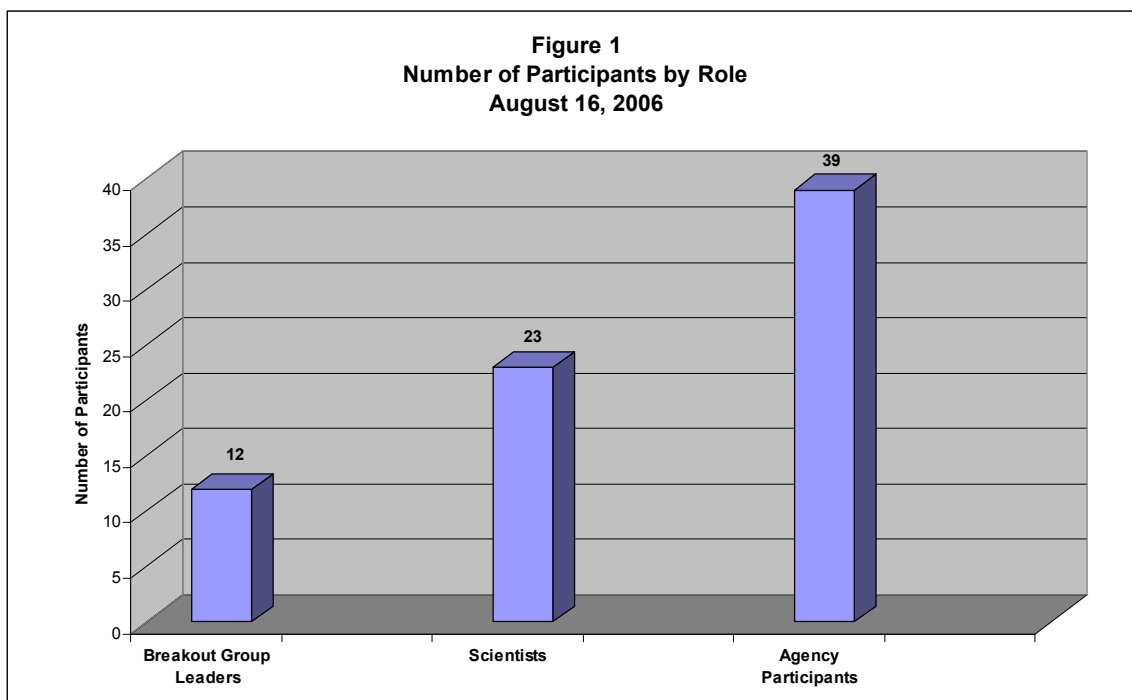
At the conclusion of the meeting, the participants were asked their opinion regarding the effectiveness of the meeting and the usefulness of the interactive polling technology.

This report presents the results of the interactive polling surveys. The DRI scientists who organized the workshop recorded the observations and conclusions from the discussion, and they will report them separately. This is the most important result of the day’s work, and the tables and charts in this document should be understood in light of those observations and conclusions.

It is important to note that the interactive polling process was designed to stimulate discussion and understanding of the perspectives of the various participants. It was not designed to be statistically representative of a broader group of participants. The number of participants may vary among polls since all participants may not have participated in every poll.

Demographic Information

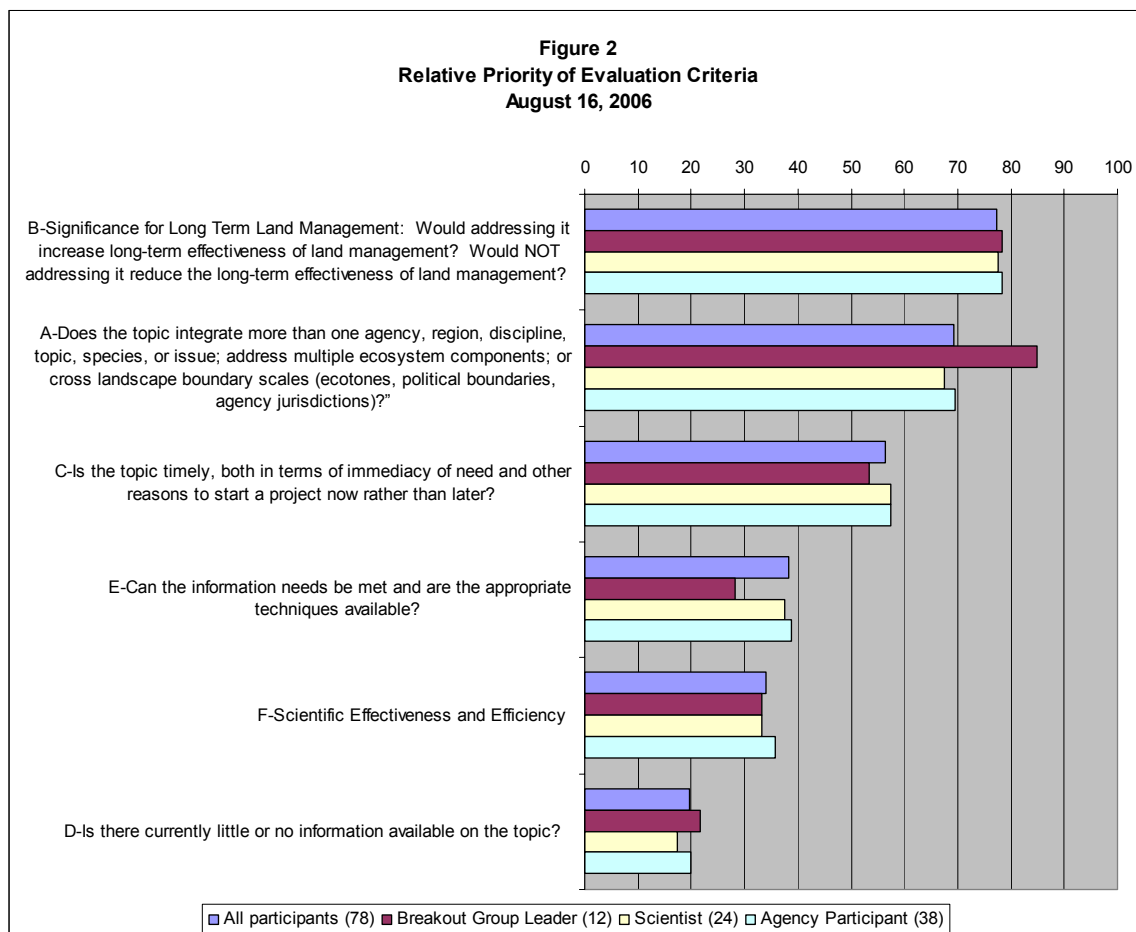
Information was collected regarding the role of the participants so that the results of the opinion surveys could be viewed and compared by the different groups. It was acknowledged that participants might fall into multiple categories since many of the agency participants and breakout group leaders were also scientists; therefore, the role of each participant was assigned prior to the meeting. Figure 1 presents the number of participants by role.



A total of eighty individuals participated in the opinion polling process. The sum of the subgroups is less than the total number of participants because not all participants arriving after the demographic information was collected were assigned to a subgroup.

Research Evaluation Criteria

The six decision criteria were prioritized using a paired-comparison technique where two of the criteria were presented to the group at a time and each participant individually selected which of the two criteria was most important. After evaluating all possible combinations, the results were calculated on a scale from 0 (lowest priority) to 100 (highest priority). The relative priority of the evaluation criteria is presented in Figure 2 for all the participants and each subgroup.



Relative Ranking of Research Areas

After the breakout group leaders presented the recommendations of each breakout group, the workshop participants ranked the 30 individual research areas on a scale from "10" (most important) to "1" (least important) using the worksheet matrix presented in Appendix A. Each participant assigned a "10" rating to their 3 most important research areas, a "9" rating to the 3 next most important research areas... and a "1" rating to the 3 least important research areas.

The individual ratings were collected using the interactive polling technology and the average rating of each research area for the group as a whole and for each subgroup was calculated and immediately presented back to the workshop participants for discussion. Table 1 compares the rank of each of the research areas for all participants and each of the subgroups. (Research areas ranking 1 – 5 are presented in red, research areas ranking 6-15 are presented in blue, research areas 16 – 25 are presented in green, and research areas ranking 26 -30 are presented in black.) Figure 3 presents a comparison of the average rating for all the participants and each of the three subgroups. Figures 4 – 6 present the results for each subgroup in priority order. Appendix B presents a graphic comparison of research area average ratings by role and Appendix C presents the frequency distribution of ratings for each research area by role.

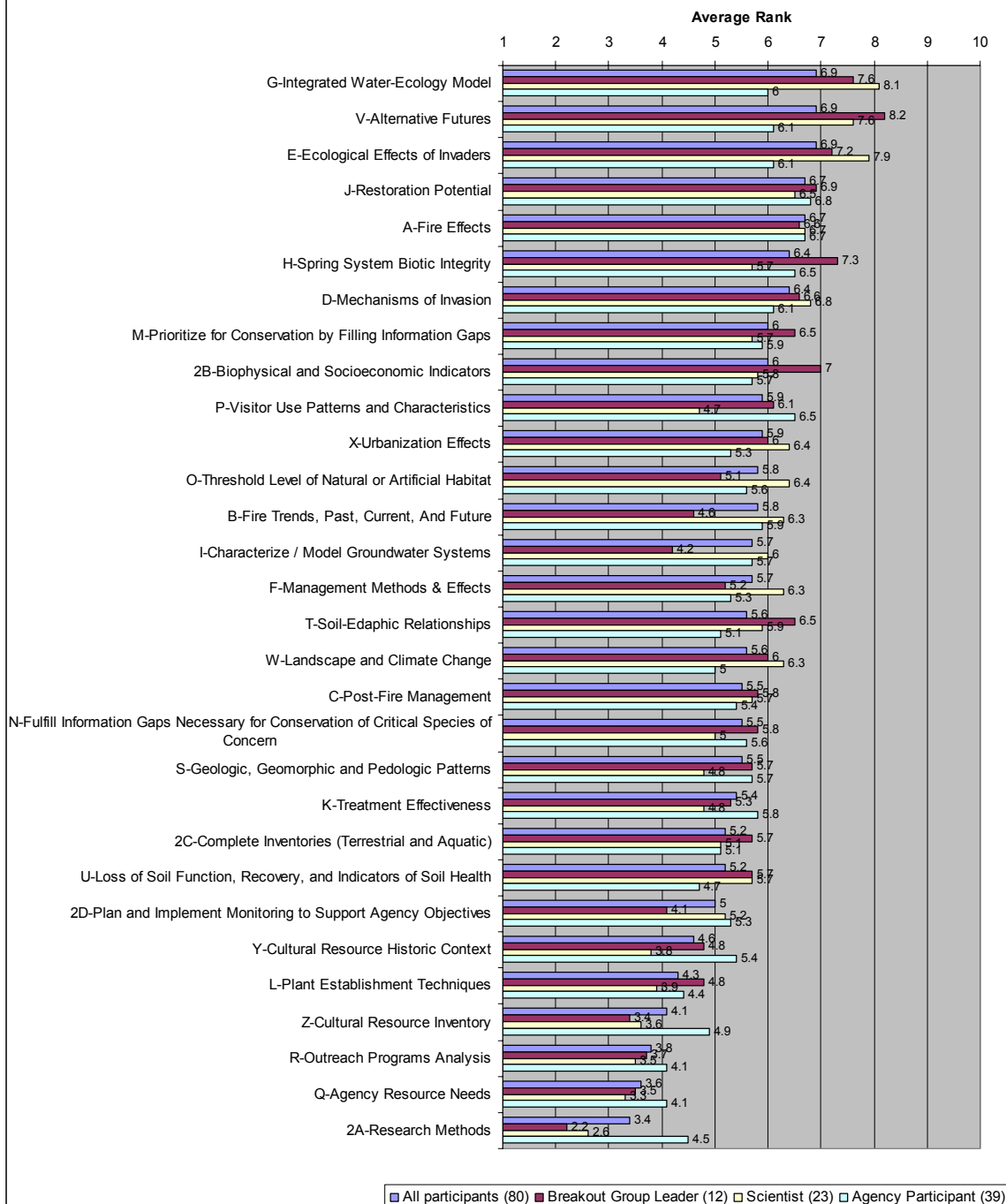
**Table 1
Rank of Research Areas by Subgroup
August 16, 2006**

Research Area	All Participants	Breakout Group Leader	Scientist	Agency Participant
Number in Group*	80	12	23	39
G-Integrated Water-Ecology Model	1	2	1	8
V-Alternative Futures	1	1	3	5
E-Ecological Effects of Invaders	1	4	2	5
J-Restoration Potential	4	6	6	1
A-Fire Effects	4	7	5	2
H-Spring System Biotic Integrity	6	3	15	3
D-Mechanisms of Invasion	6	7	4	5
M-Prioritize for Conservation by Filling Information Gaps	8	9	15	9
2B-Biophysical and Socioeconomic Indicators	8	5	14	12
P-Visitor Use Patterns and Characteristics	10	11	24	3
X-Urbanization Effects	10	12	7	19
O-Threshold Level of Natural or Artificial Habitat	12	21	7	15
B-Fire Trends, Past, Current, And Future	12	24	9	9
I-Characterize / Model Groundwater Systems	14	25	12	12
F-Management Methods & Effects	14	20	9	19
T-Soil-Edaphic Relationships	16	9	13	22
W-Landscape and Climate Change	16	12	9	24
C-Post-Fire Management	18	14	15	17
N-Fulfill Information Gaps Necessary for Conservation of Critical Species of Concern	18	14	21	15
S-Geologic, Geomorphic and Pedologic Patterns	18	16	22	12
K-Treatment Effectiveness	21	19	22	11
2C-Complete Inventories (Terrestrial and Aquatic)	22	16	20	22
U-Loss of Soil Function, Recovery, and Indicators of Soil Health	22	16	15	26
2D-Plan and Implement Monitoring to Support Agency Objectives	24	26	19	19
Y-Cultural Resource Historic Context	25	22	26	17
L-Plant Establishment Techniques	26	22	25	28
Z-Cultural Resource Inventory	27	29	27	25
R-Outreach Programs Analysis	28	27	28	29
Q-Agency Resource Needs	29	28	29	29
2A-Research Methods	30	30	30	27

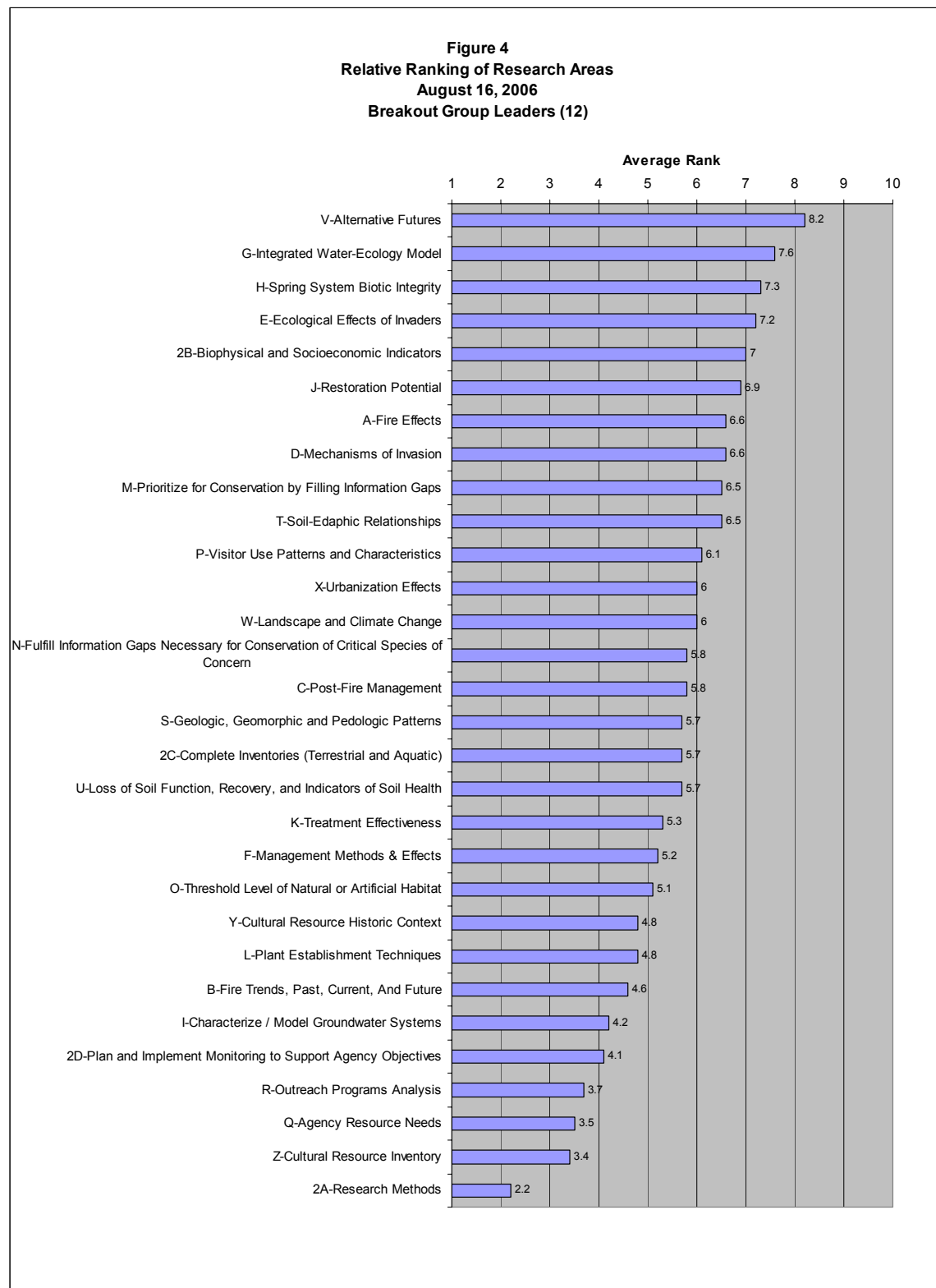
* The total number of participants is greater than the sum of the subgroups because not all participants arriving after the demographic information was collected were assigned to a subgroup.

**Ecosystem Health Assessment and Resource Management in Southern Nevada
Research Needs for Management in the 21st Century
Polling Results – August 16, 2006**

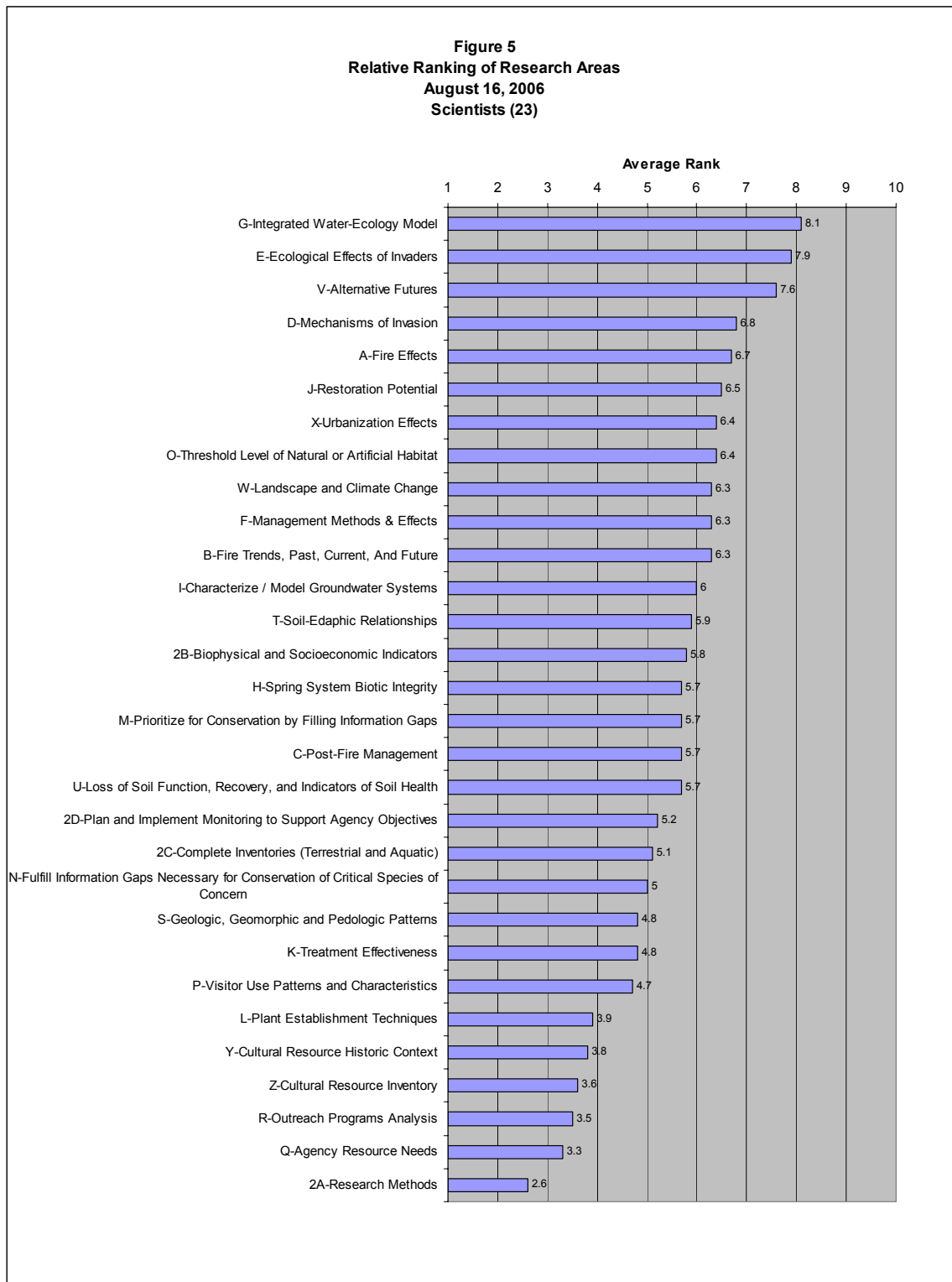
**Figure 3
Relative Ranking of Research Areas by Subgroup
August 16, 2006**

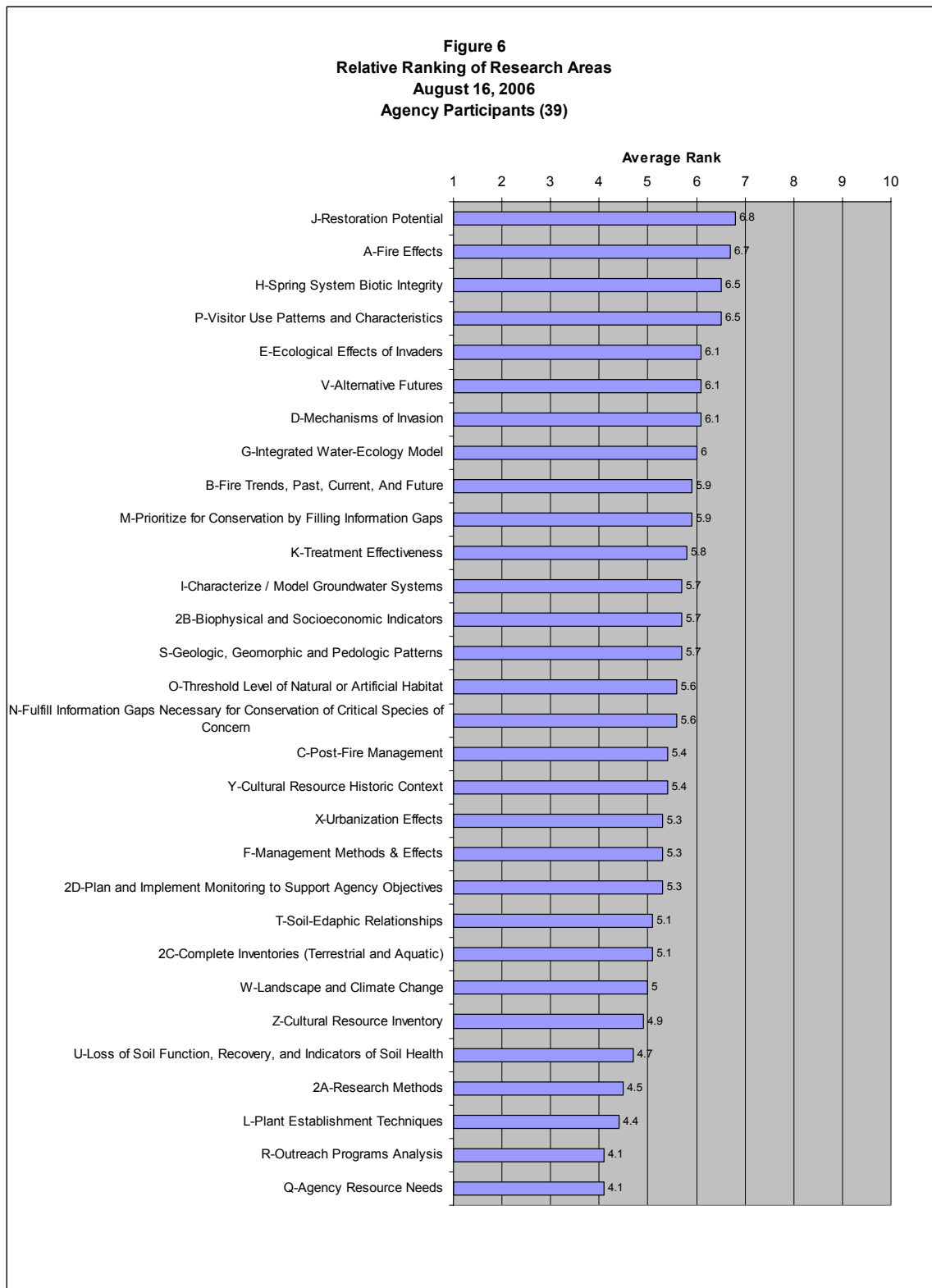


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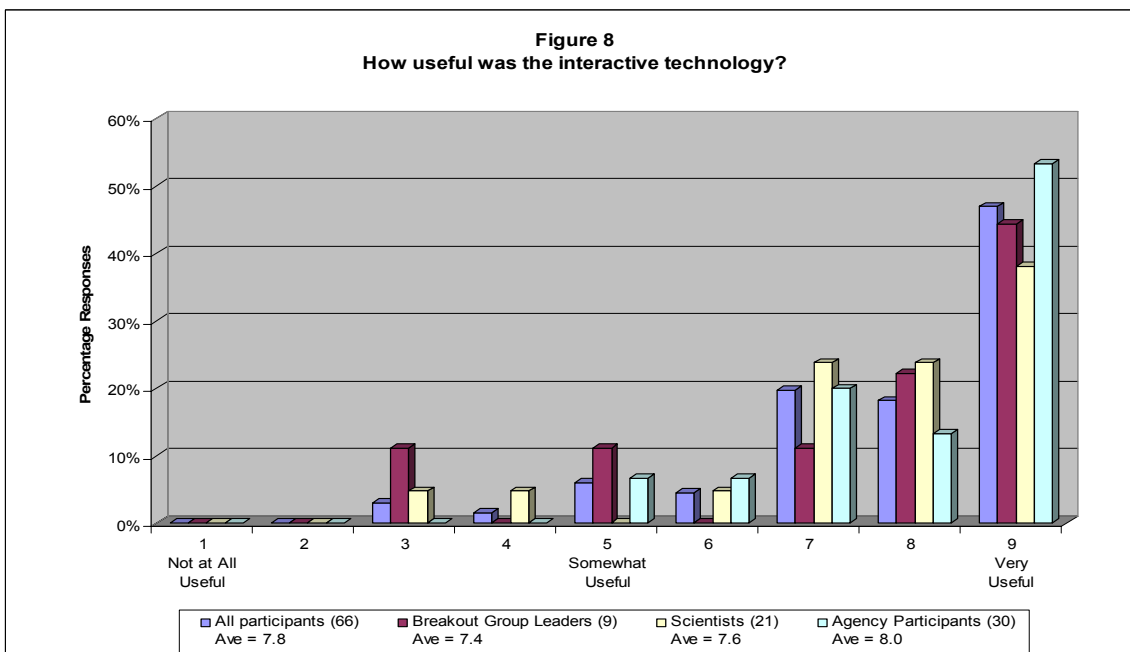
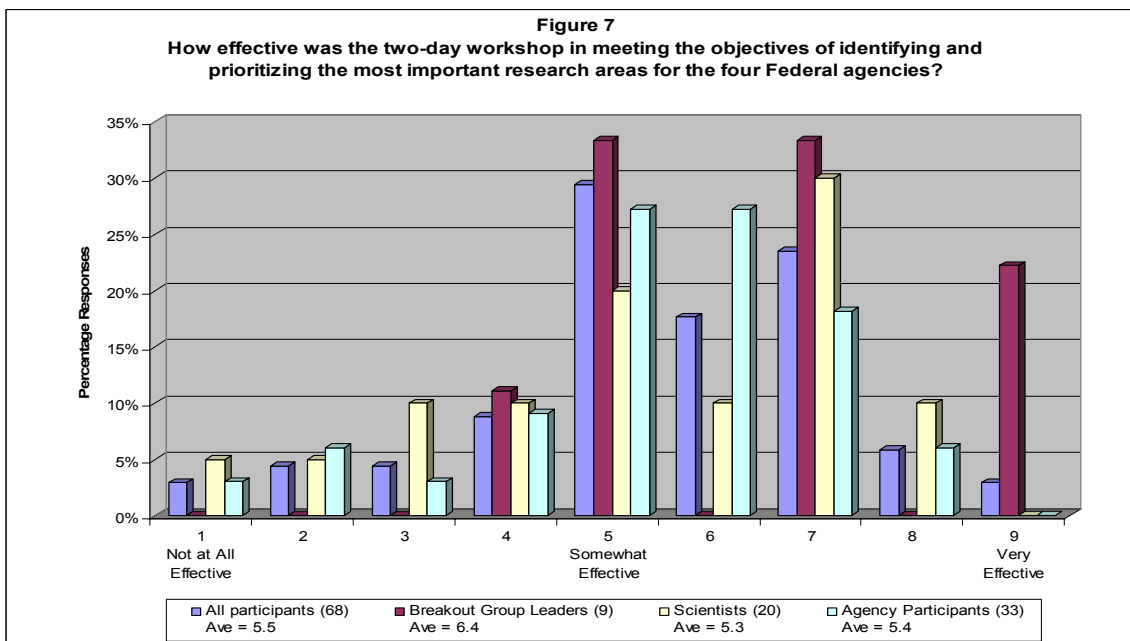
**Ecosystem Health Assessment and Resource Management in Southern Nevada
Research Needs for Management in the 21st Century
Polling Results – August 16, 2006**





Meeting Evaluation

At the conclusion of the meeting the participants rated the effectiveness of the meeting and the usefulness of the interactive polling technology. Figures 7 and 8 present the results of this poll.

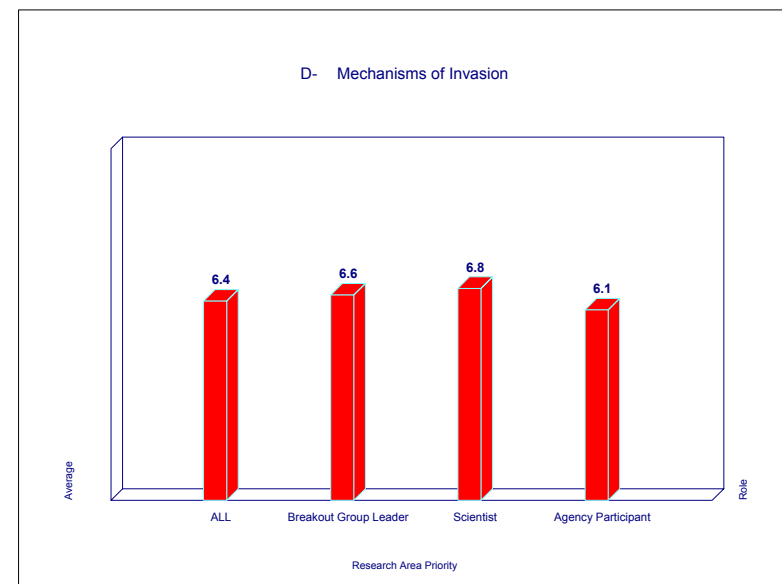
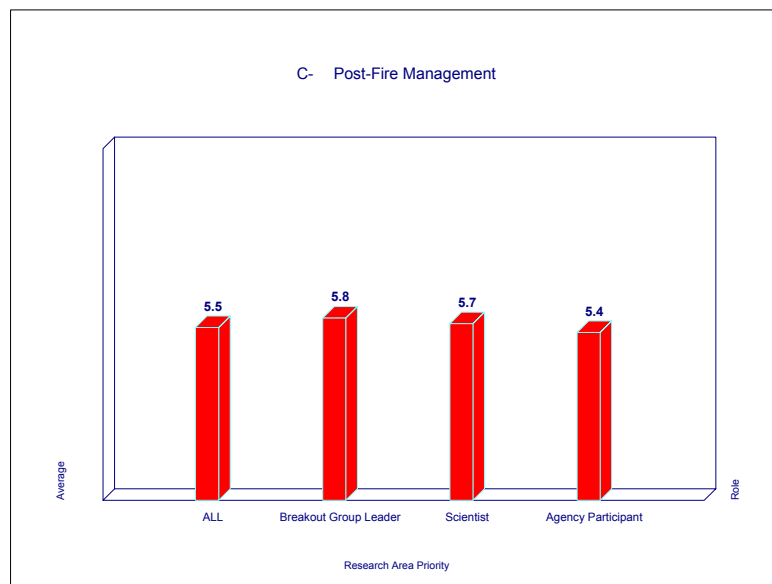
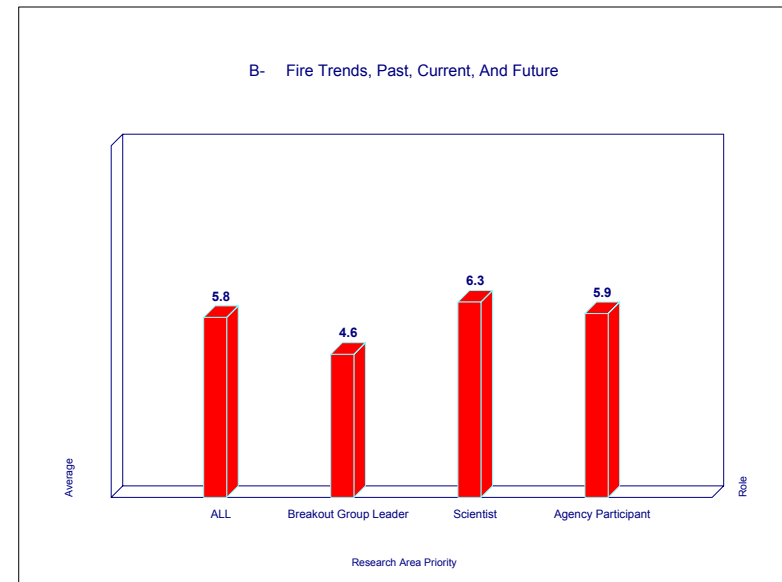
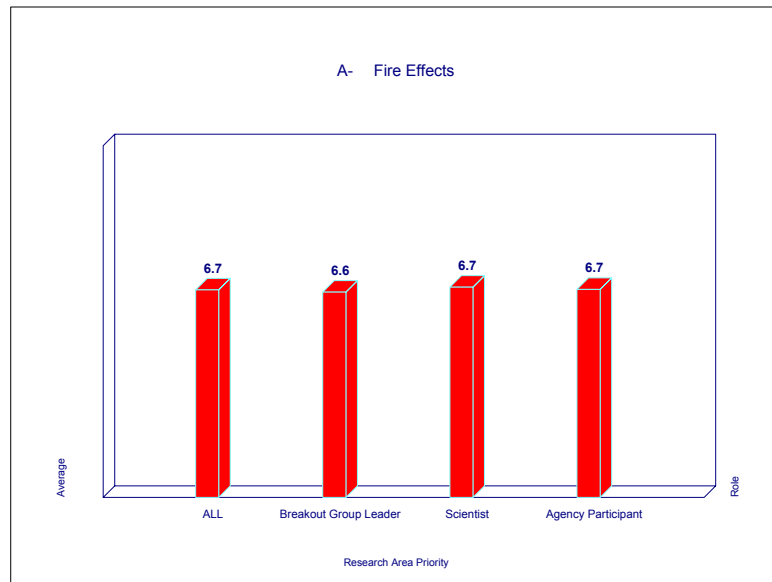


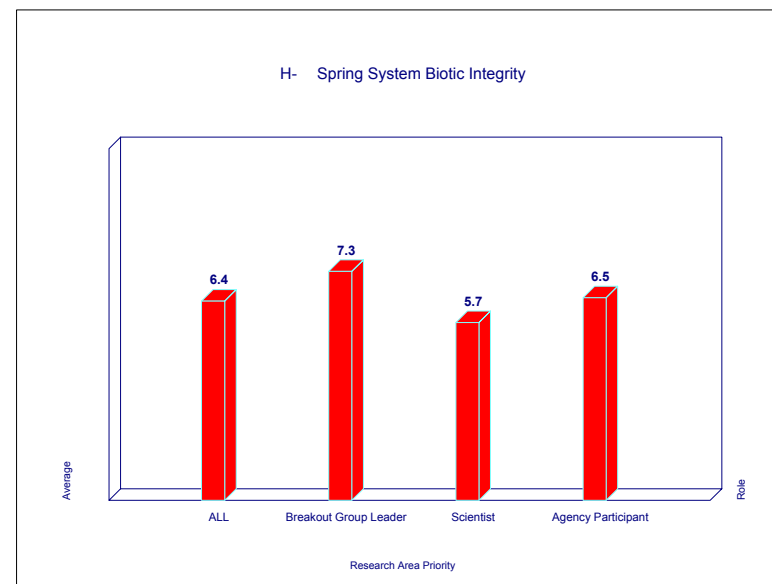
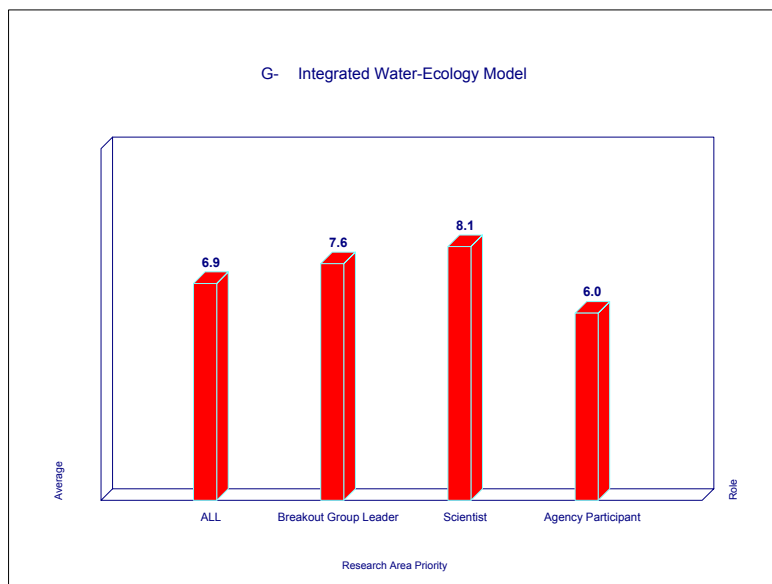
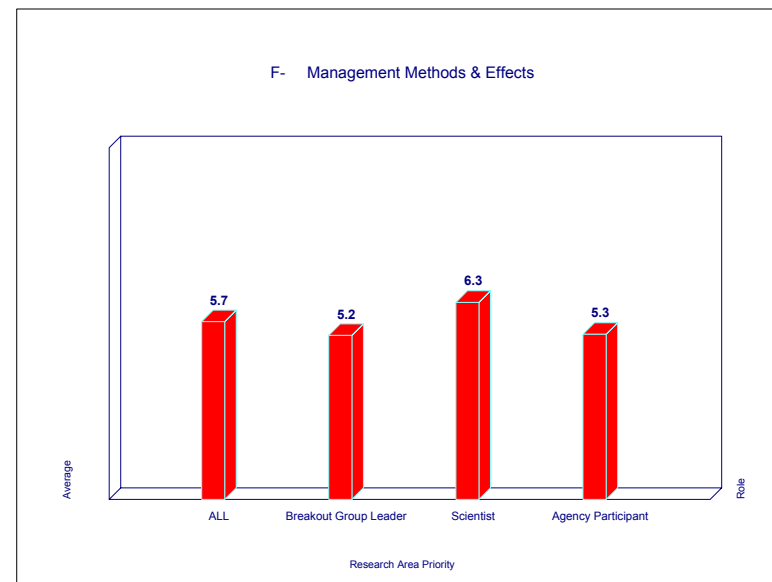
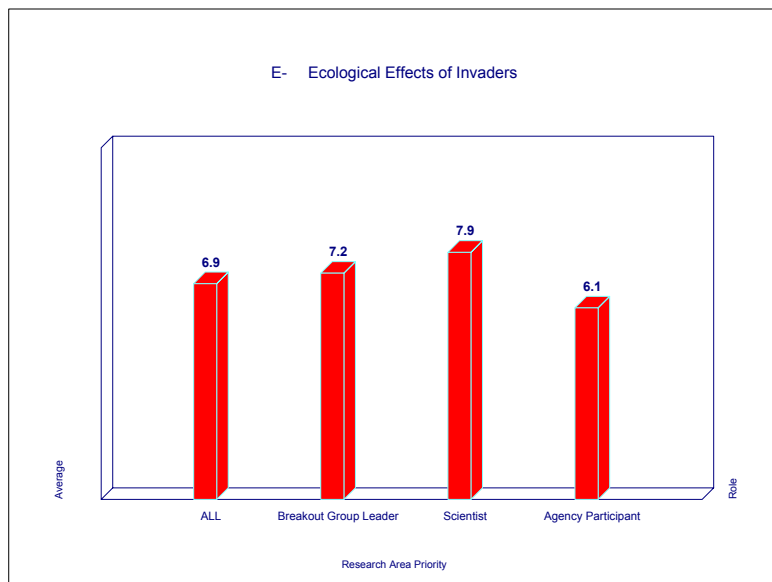
***Appendix A
Research Area Evaluation Matrix***

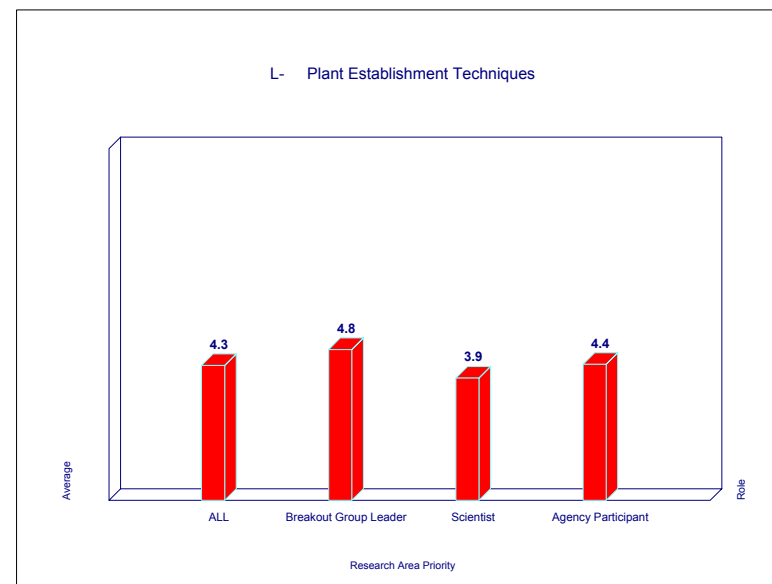
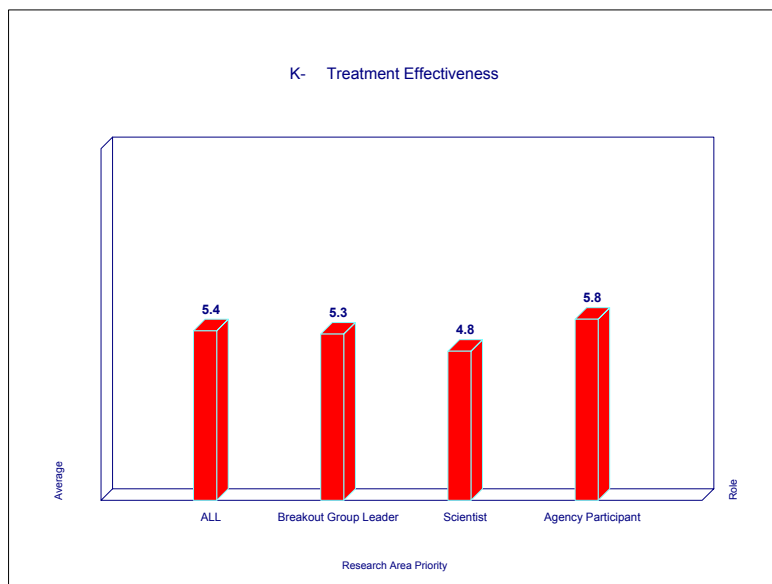
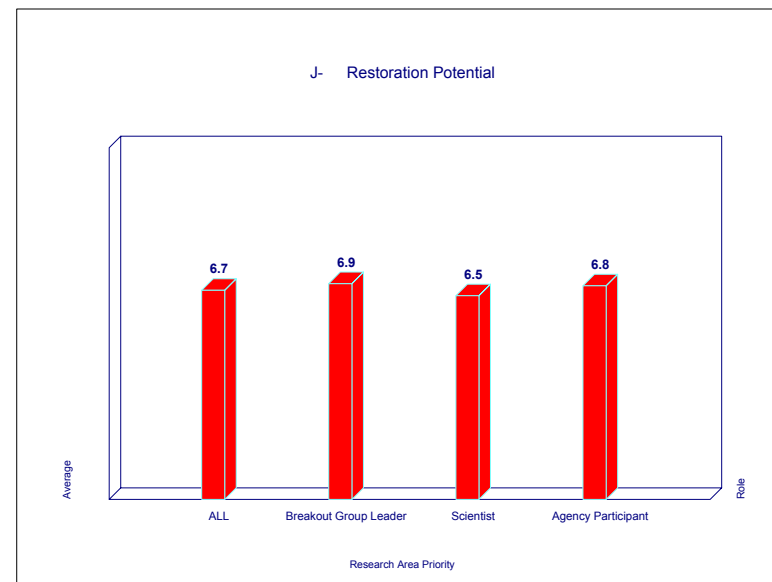
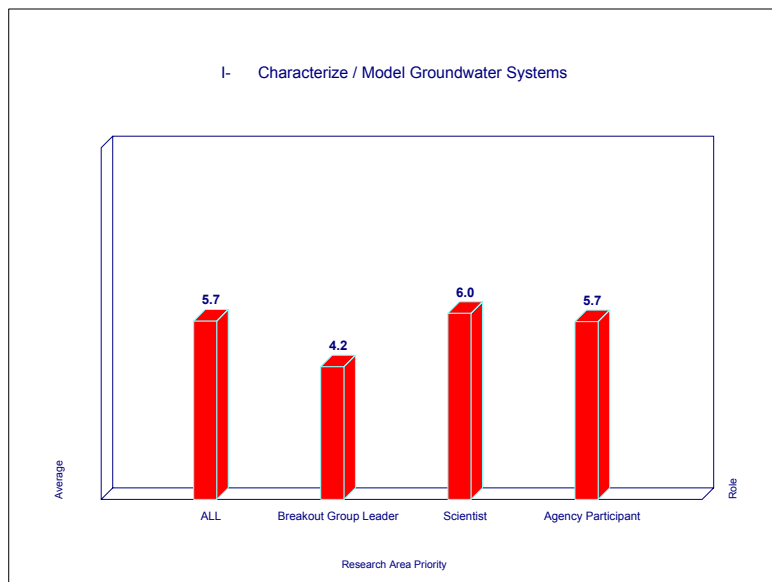
Y	Cultural Resources	Cultural Resource Historic Context								
Z		Cultural Resource Inventory								
AA		Research Methods								
AB	Inventory, Monitoring and Indicators	Biophysical And Socioeconomic Indicators								
AC		Complete Inventories (Terrestrial And Aquatic)								
AD		Plan And Implement Monitoring To Support Agency Objectives								

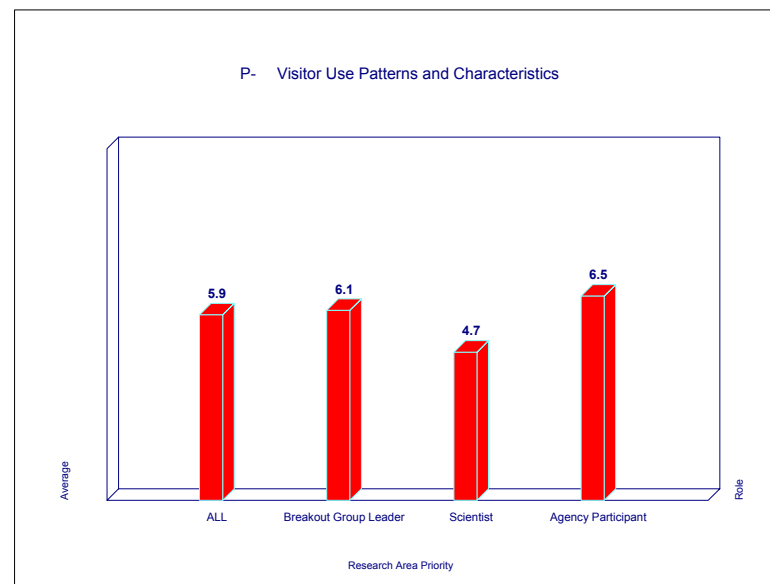
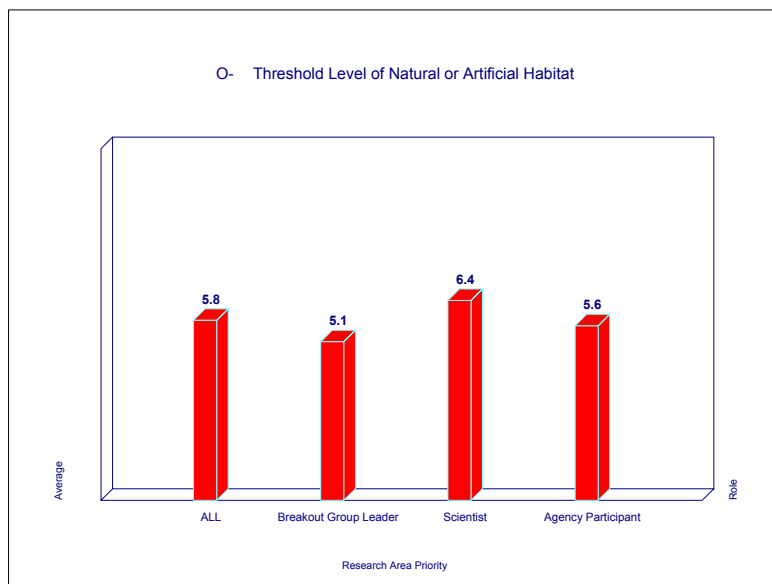
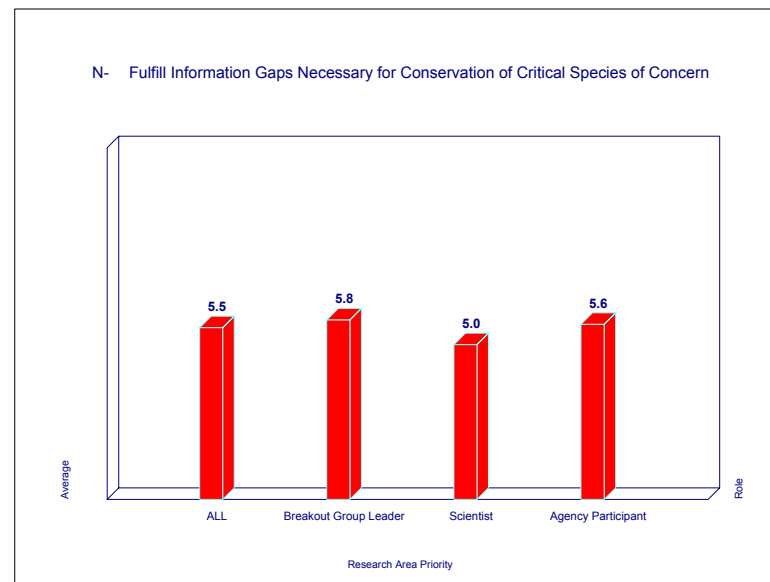
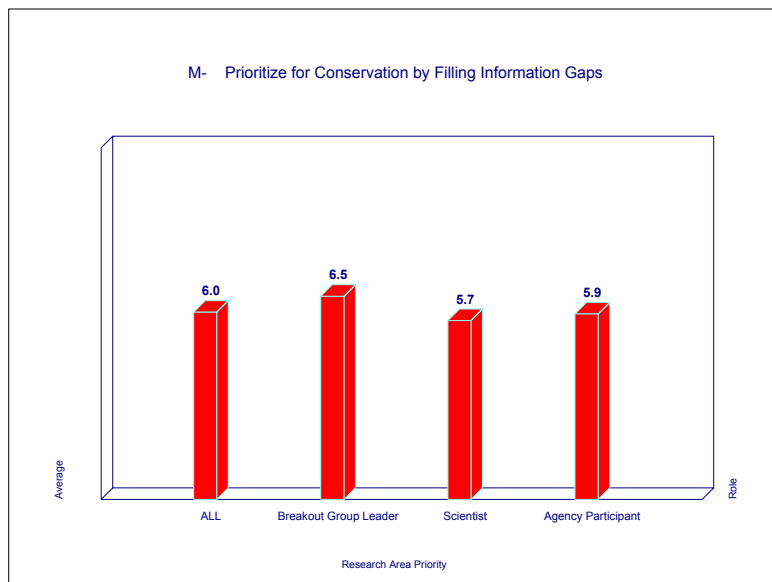
Appendix B
Comparison of Subgroup Average Ratings
by Research Area

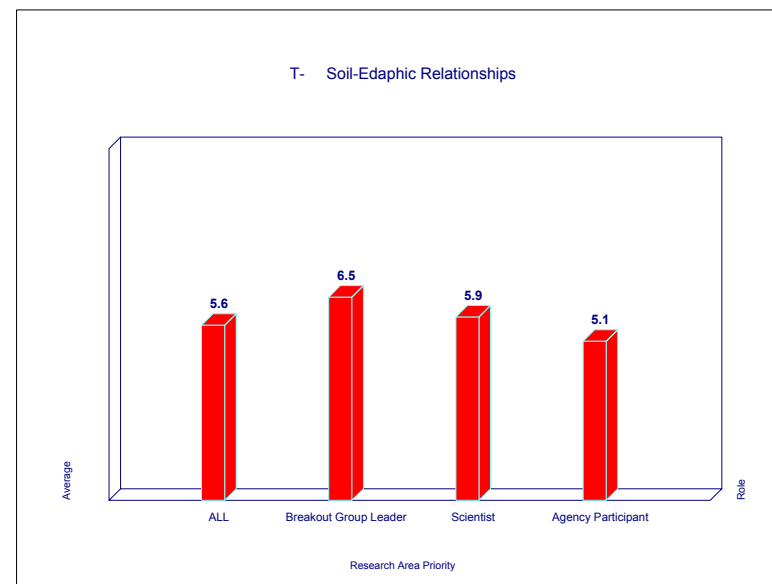
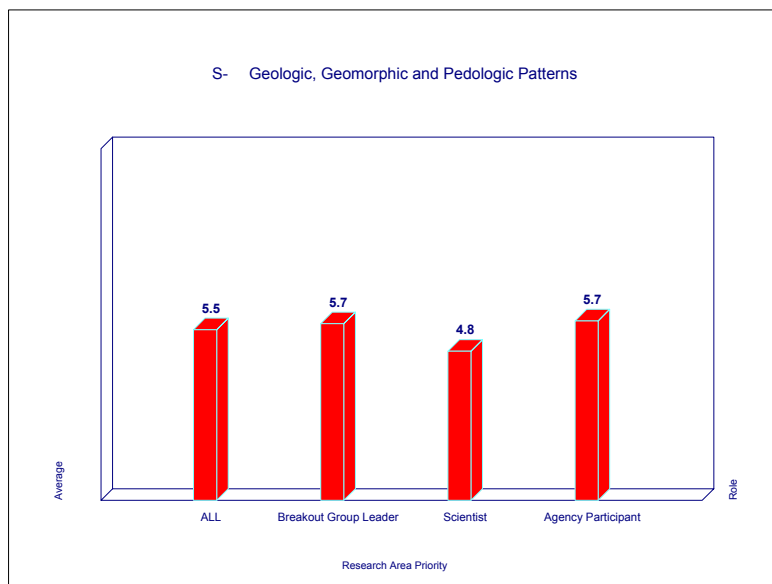
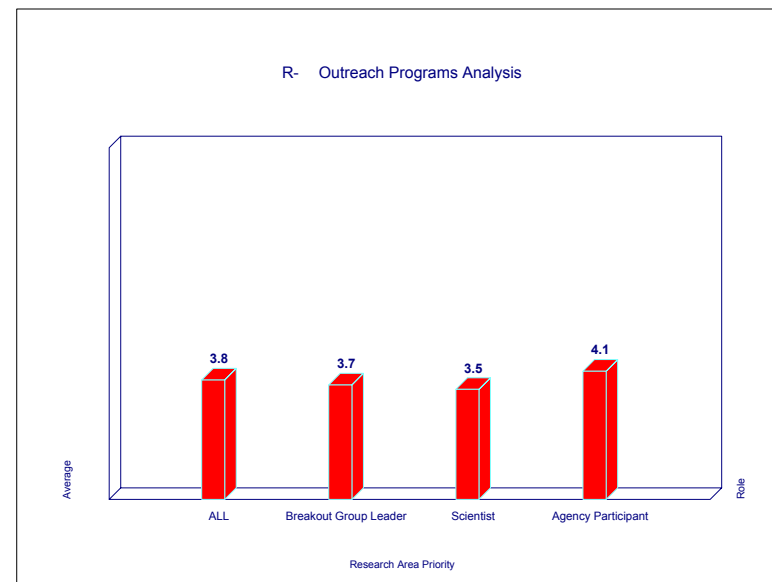
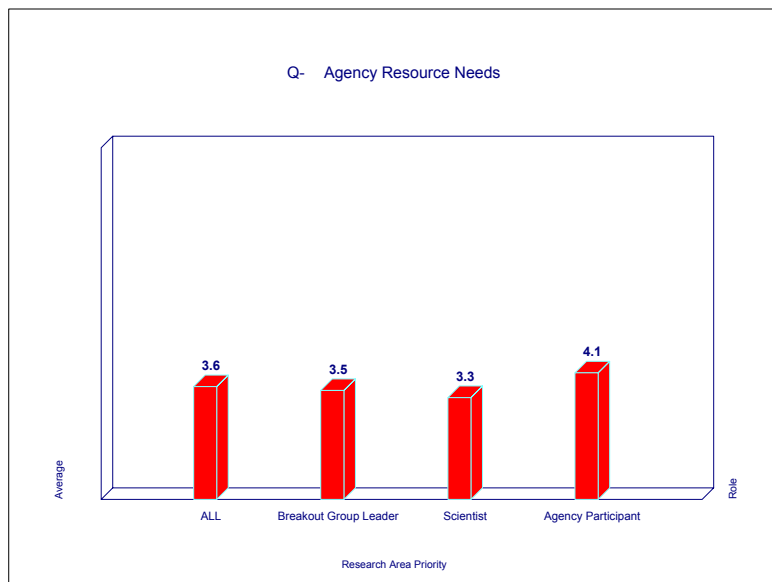
The Workshop participants ranked 30 individual research areas on a scale from "10" (most important) to "1" (least important). The following bar charts compare the average of the individual ratings of the participants in each subgroup for each of the 30 research areas. For example, if there were three people in a subgroup and they rated a research area "7", "8" and "9" respectively, the average of the subgroup would be "8".

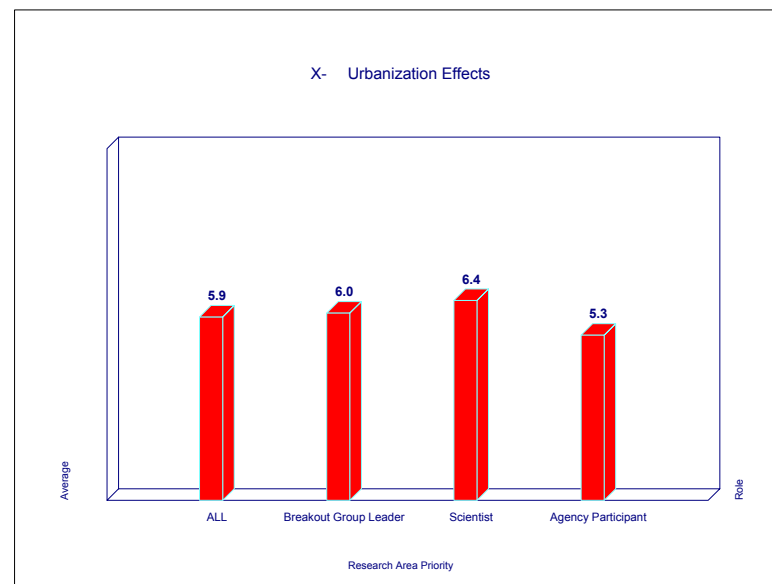
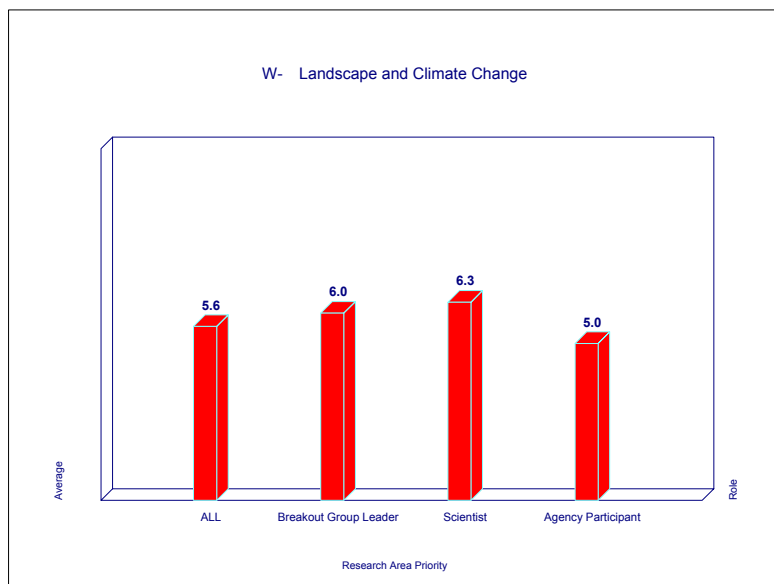
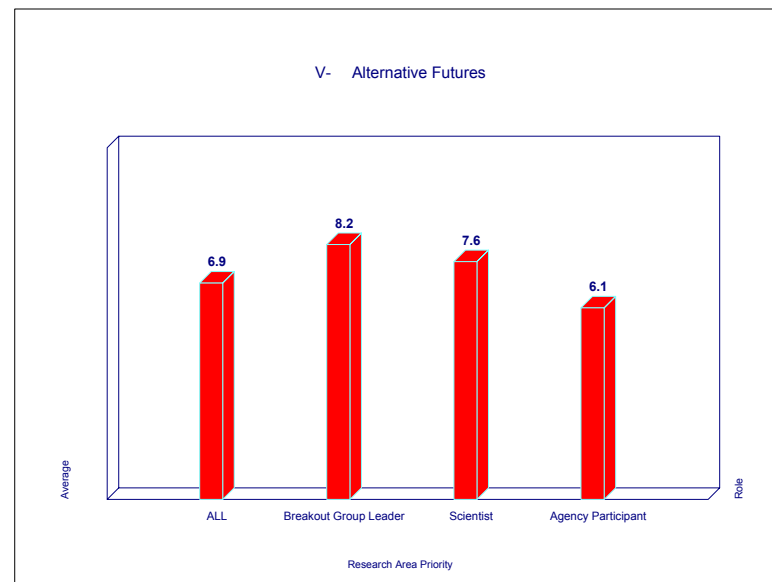
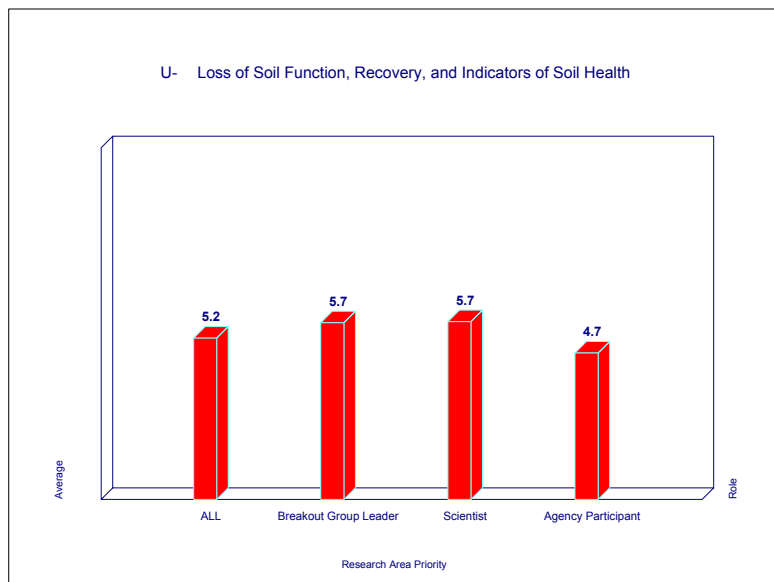


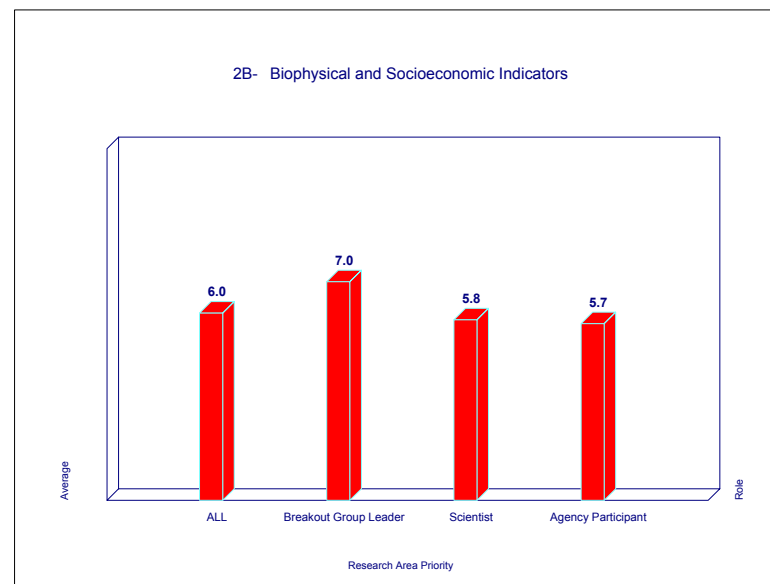
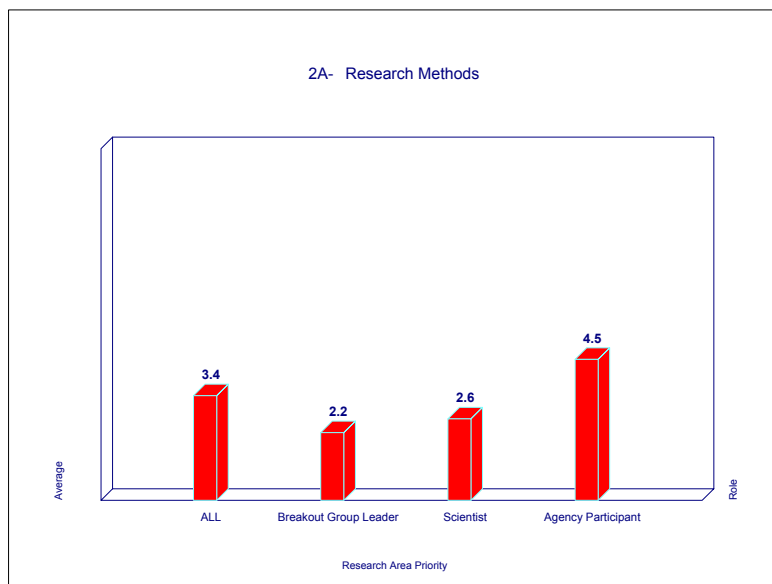
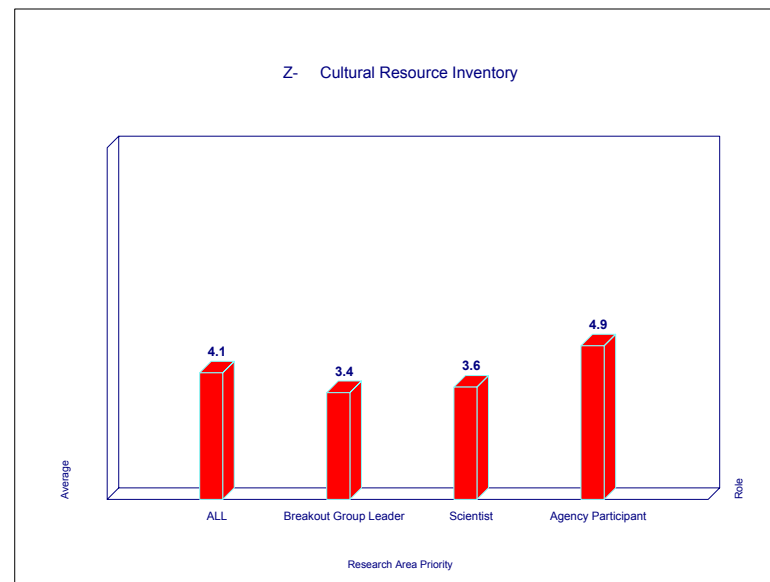
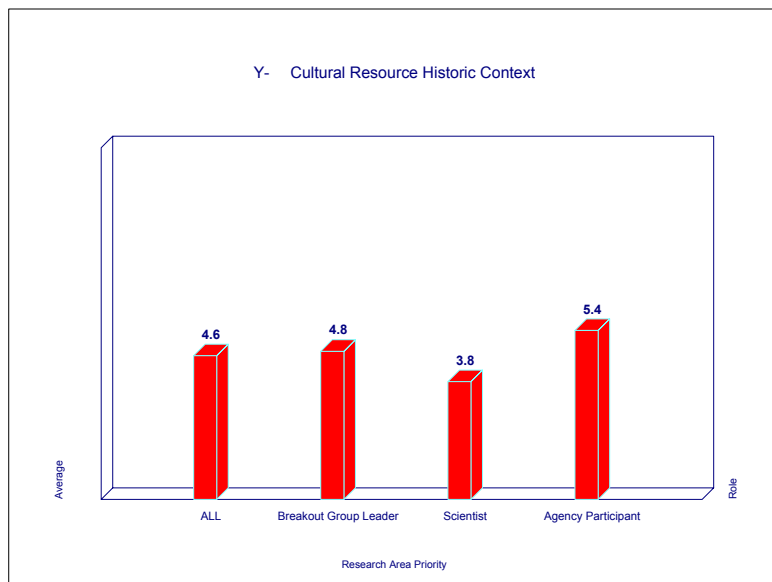


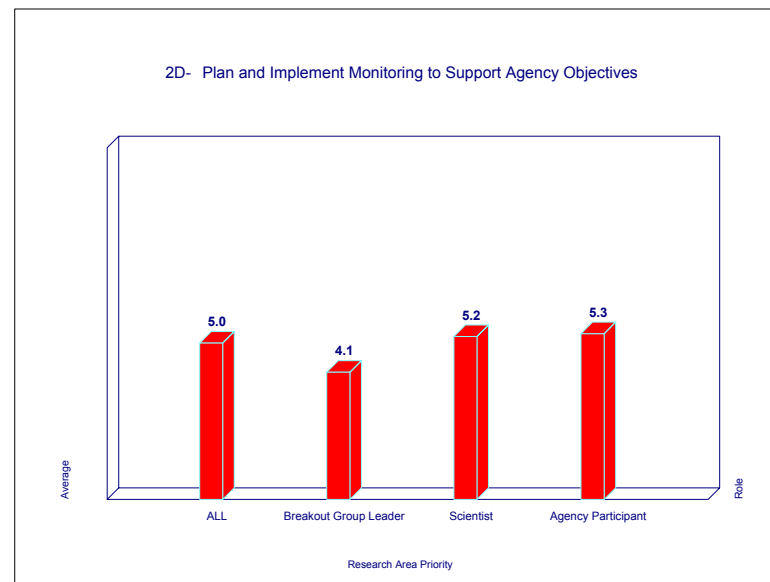
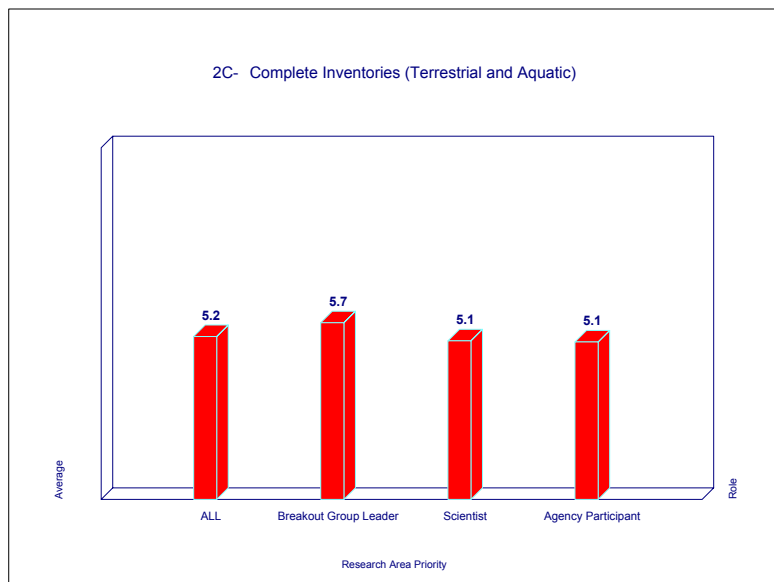






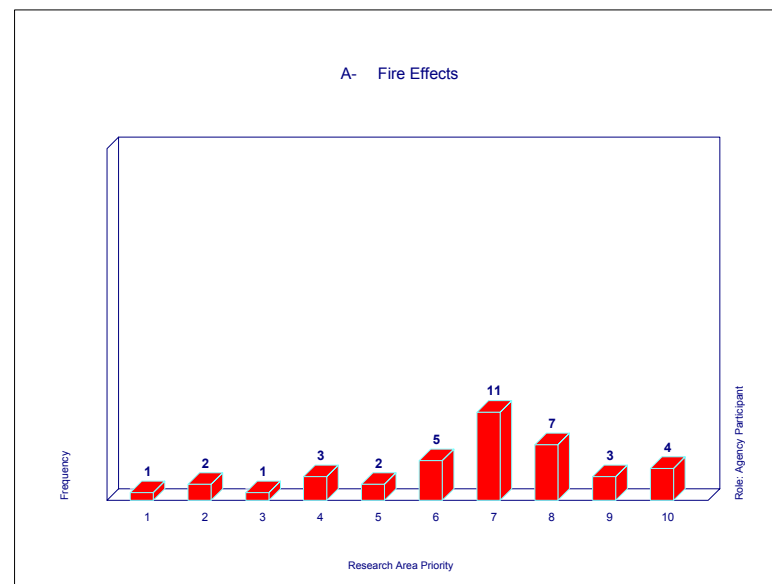
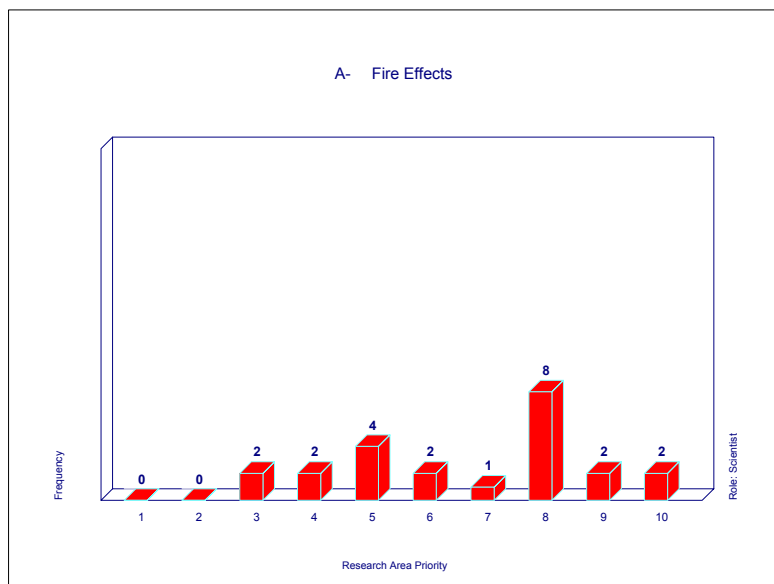
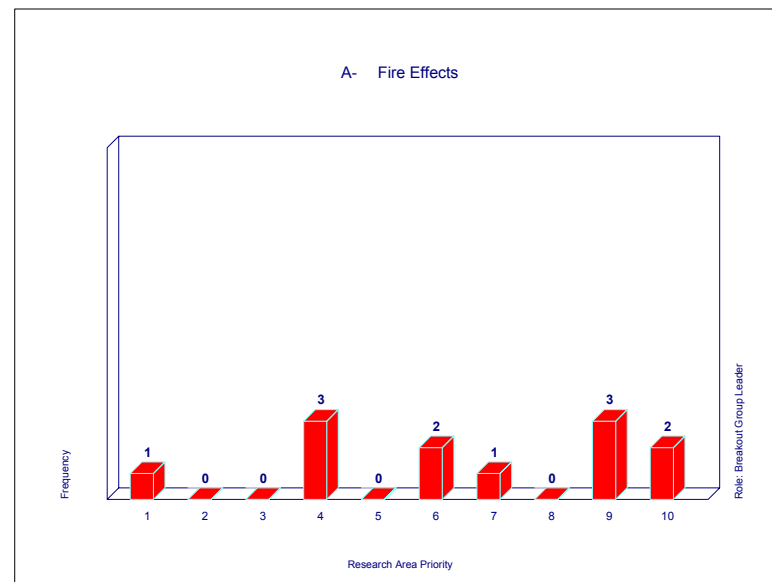
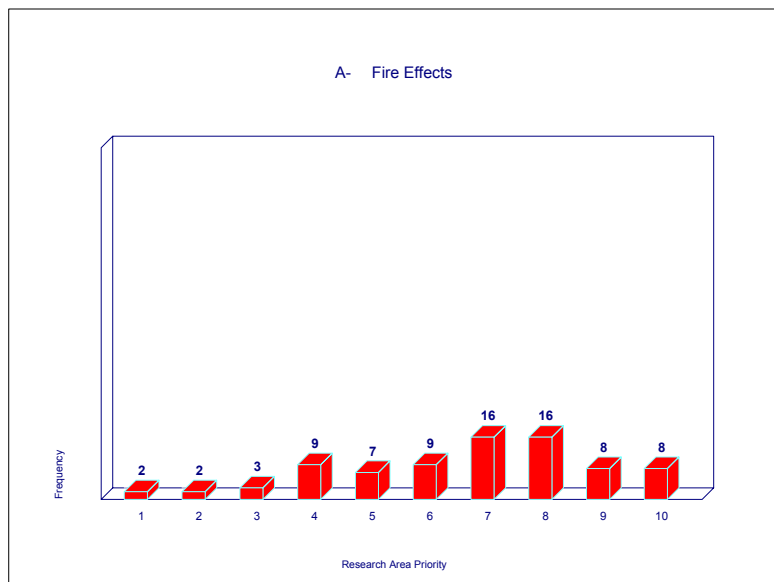




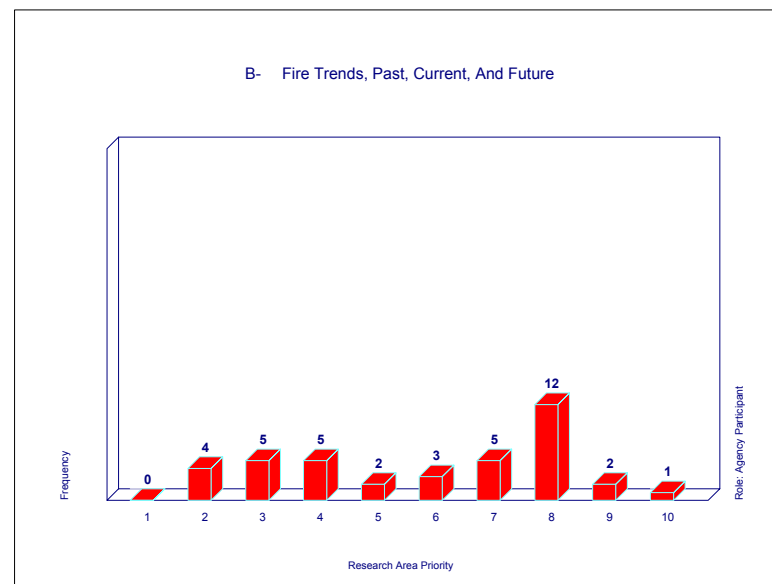
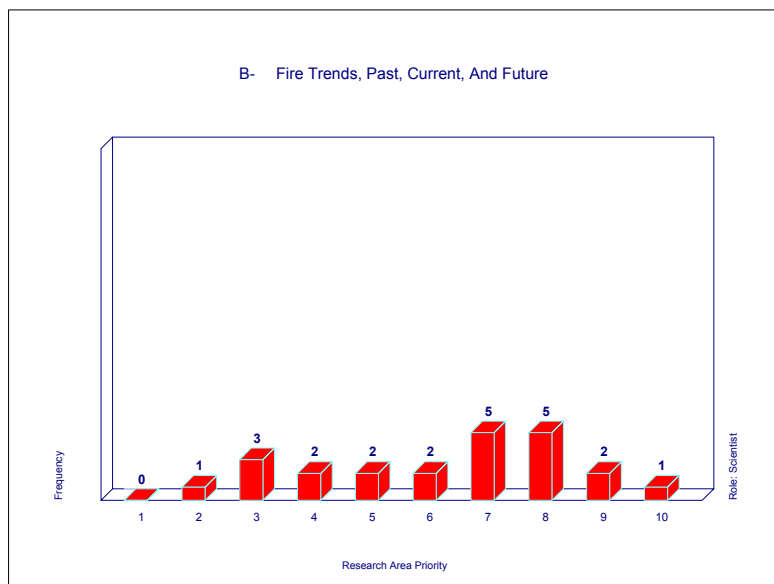
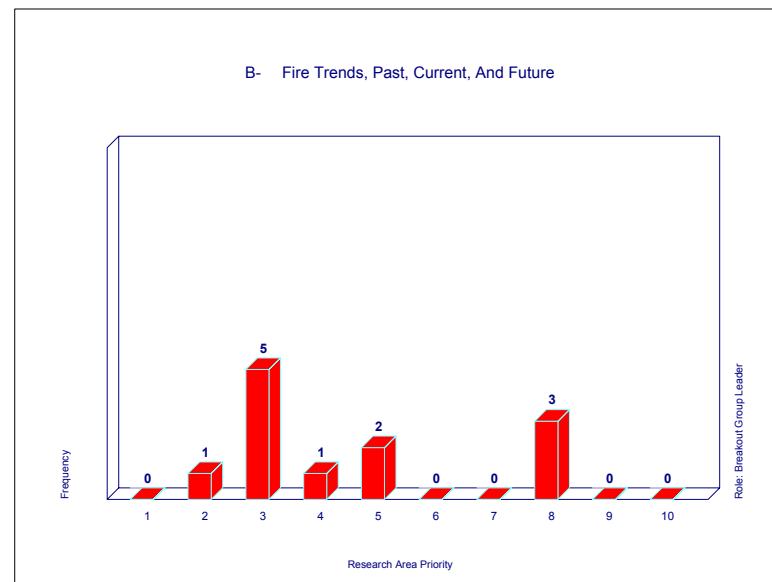
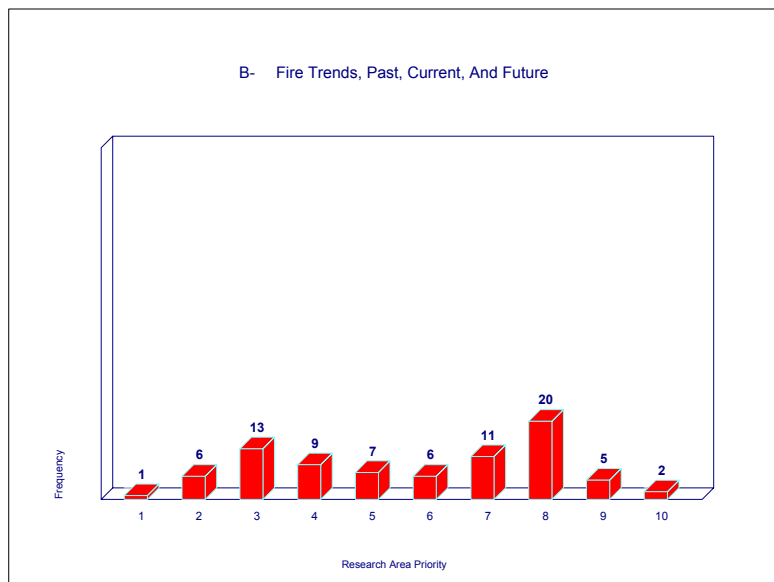


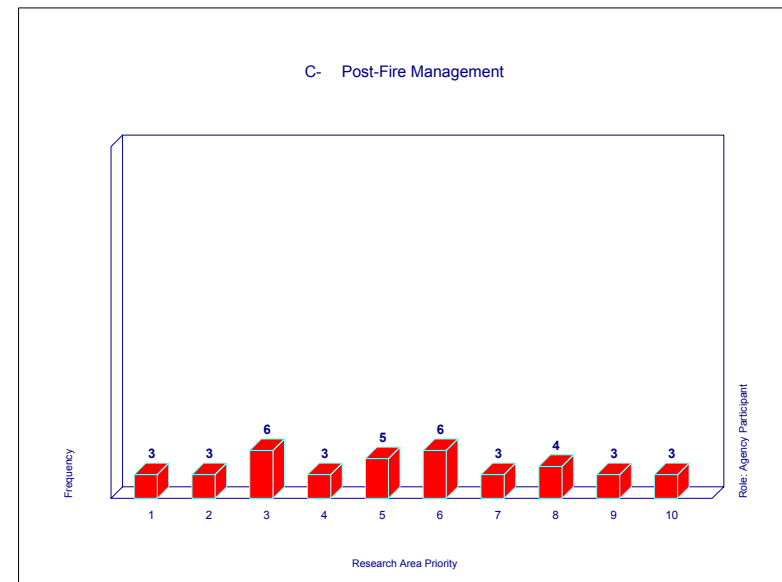
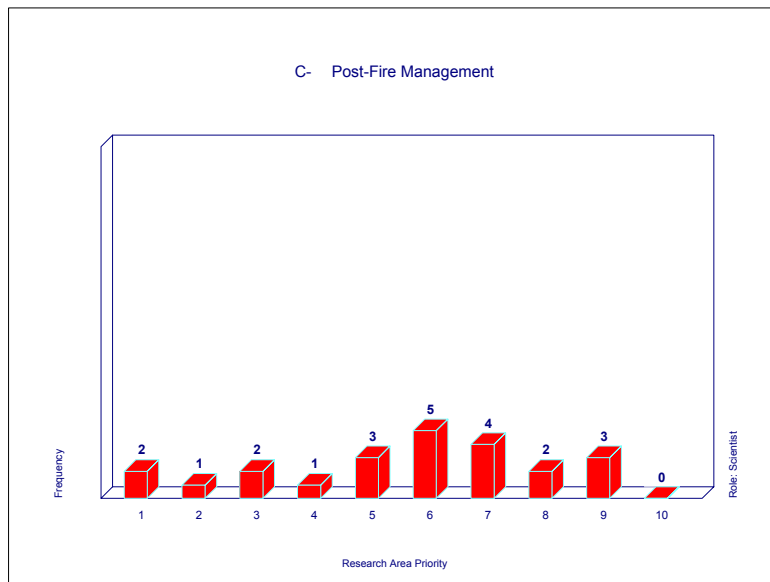
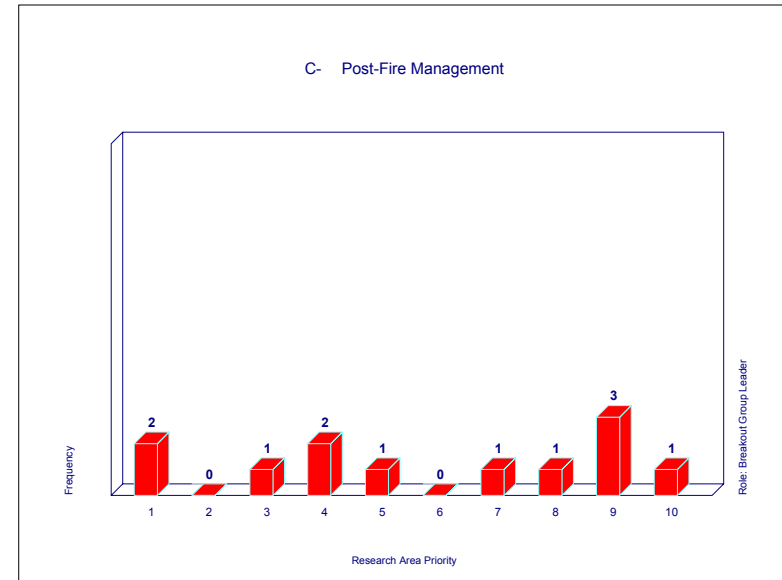
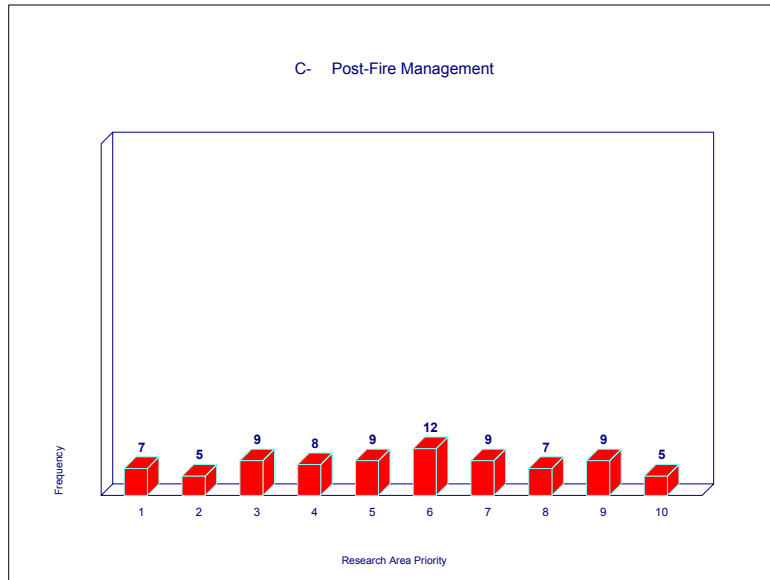
Appendix C
Frequency Distribution of Research Area Ratings
by Role

The Workshop participants ranked 30 individual research areas on a scale from "10" (most important) to "1" (least important). The following bar charts present the frequency distribution (scatter) of the ratings for all participants and the participants within each subgroup.



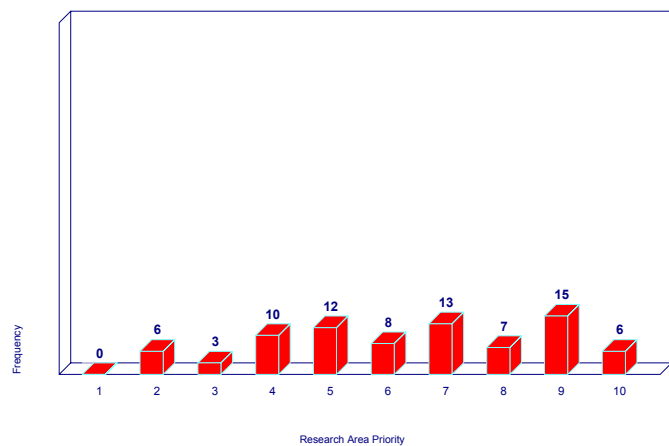
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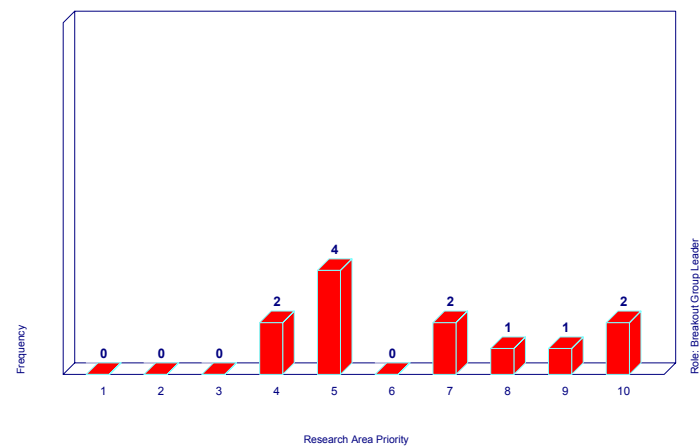


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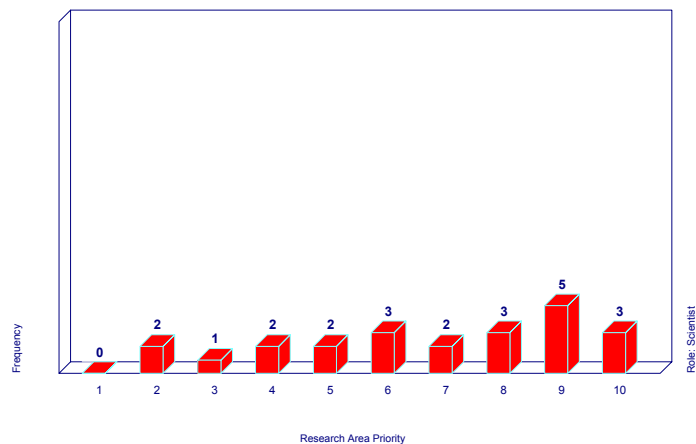
D- Mechanisms of Invasion



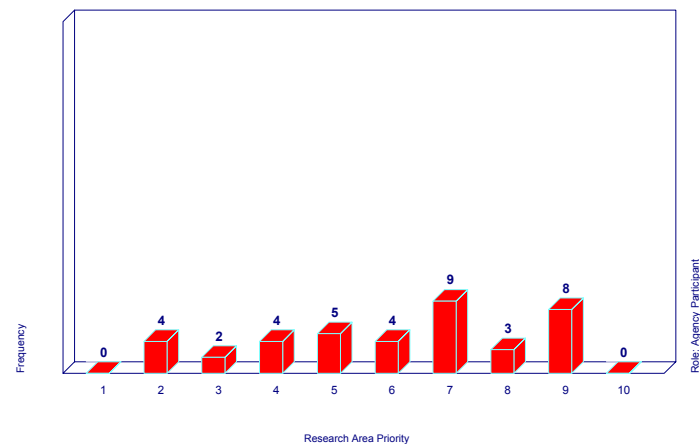
D- Mechanisms of Invasion



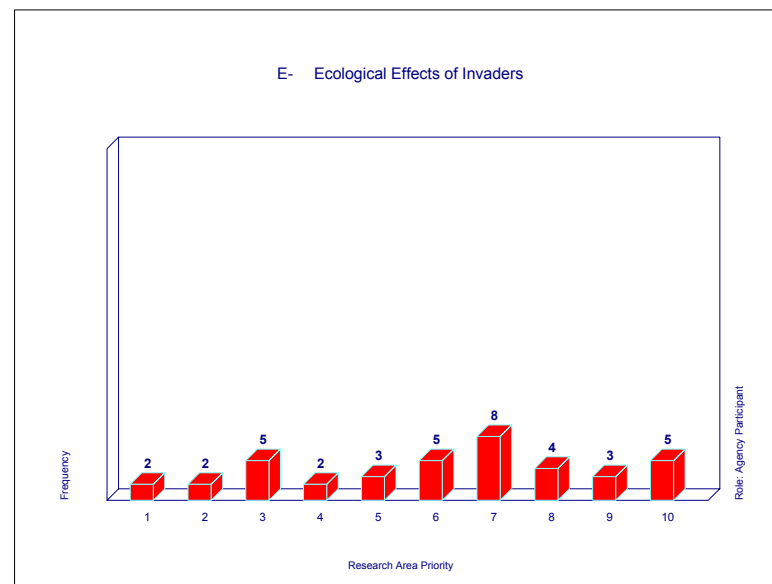
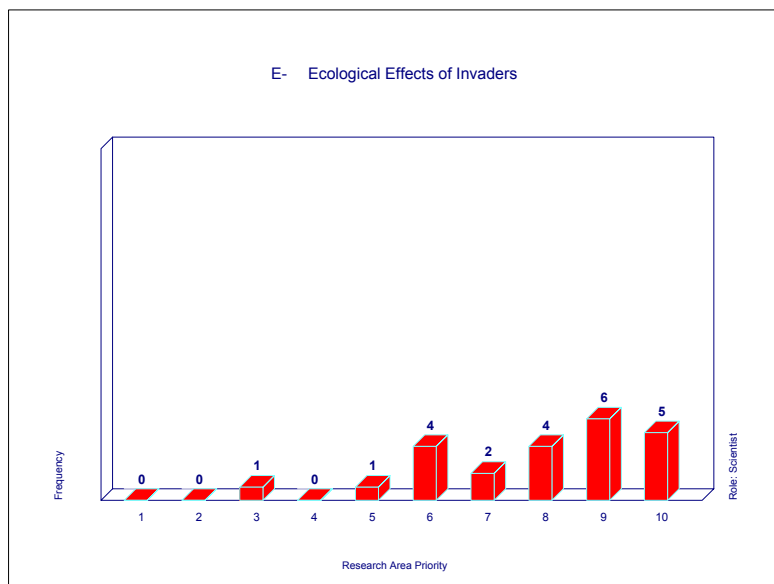
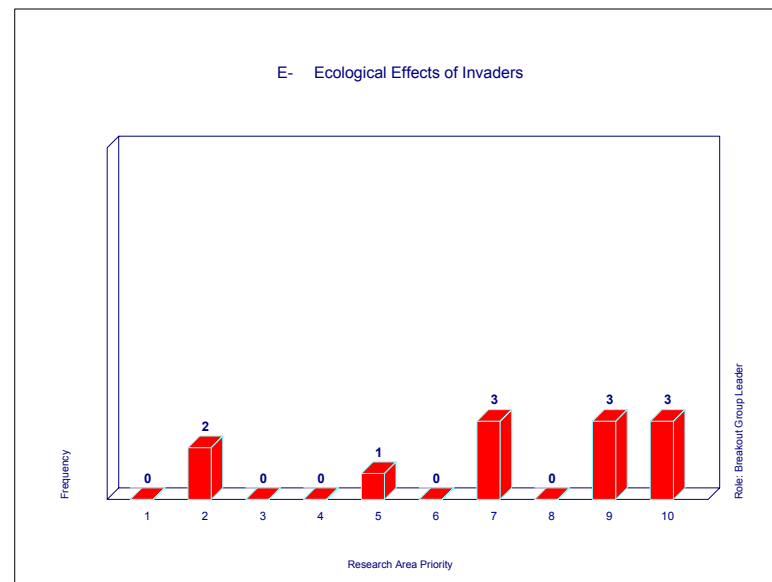
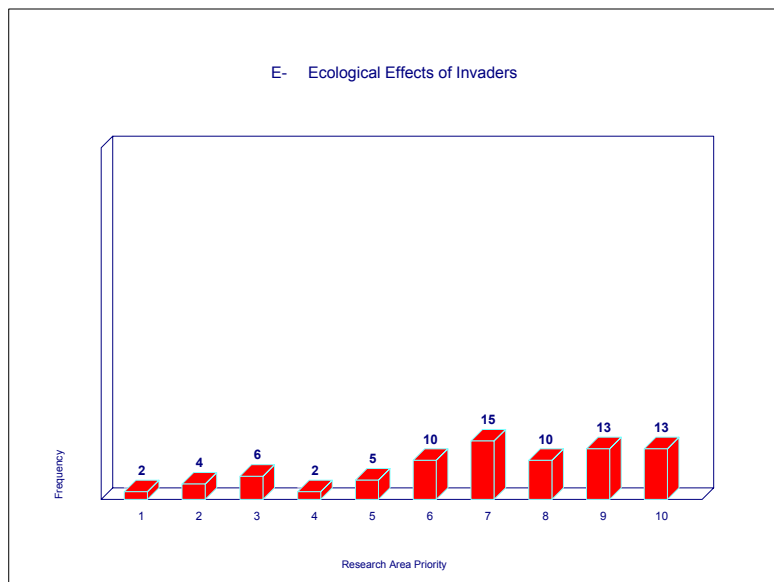
D- Mechanisms of Invasion



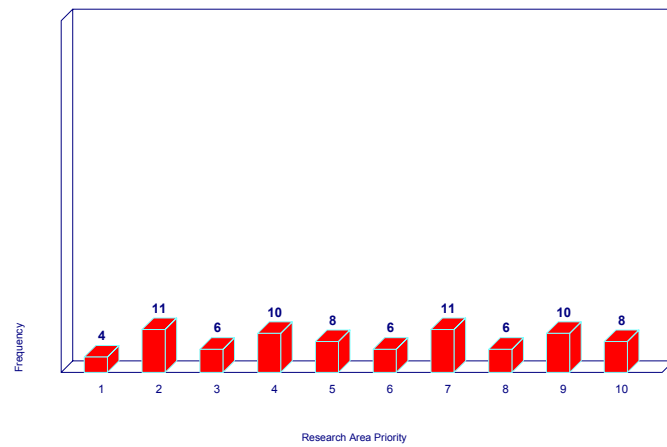
D- Mechanisms of Invasion



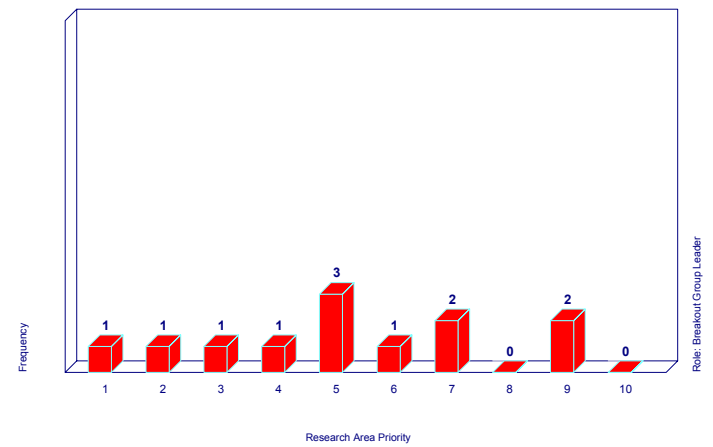
Strategic Initiatives



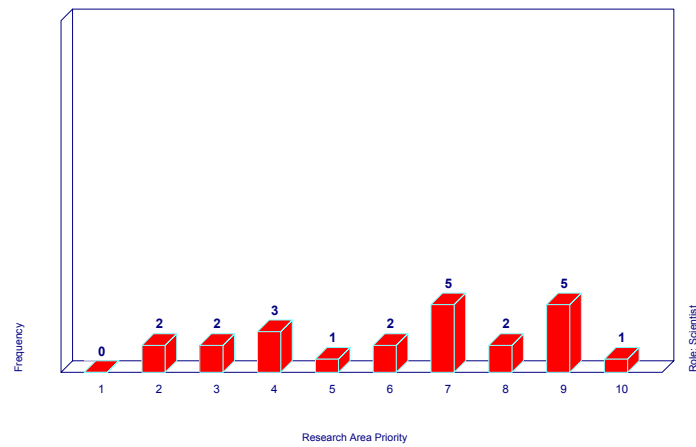
F- Management Methods & Effects



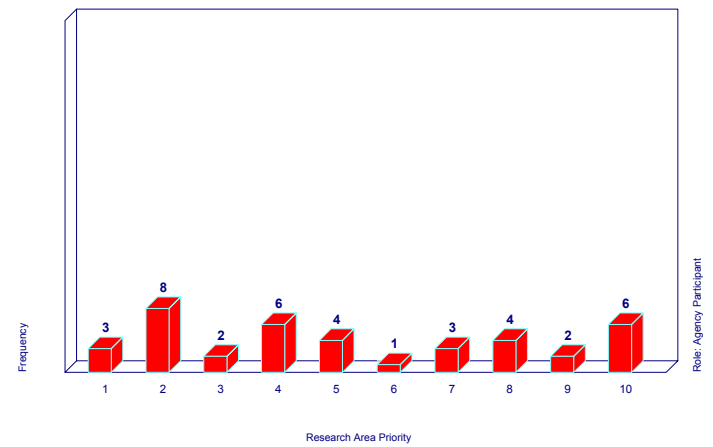
F- Management Methods & Effects

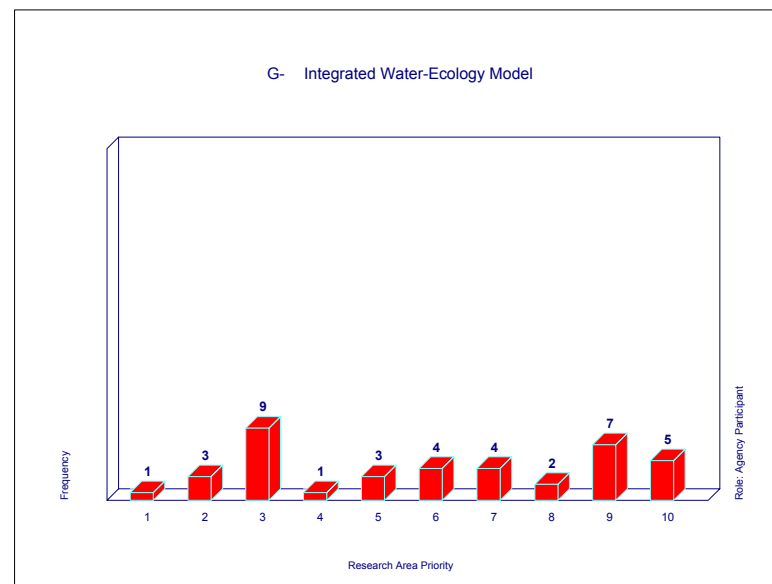
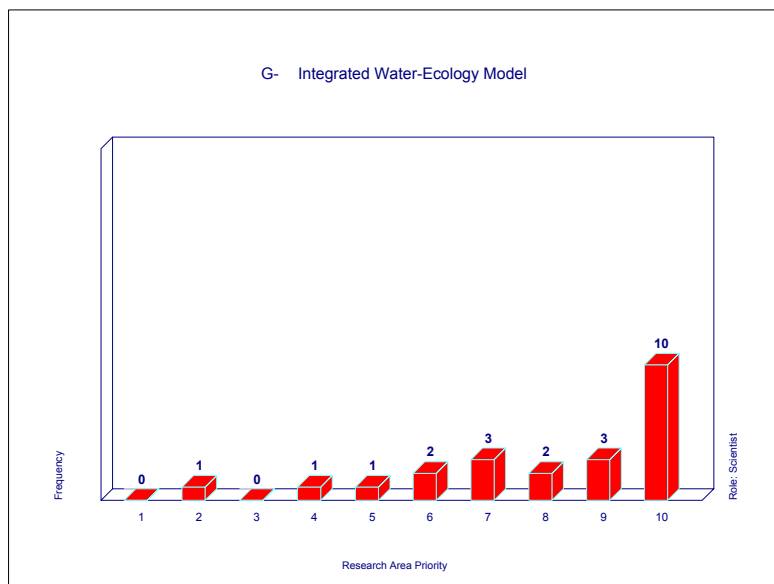
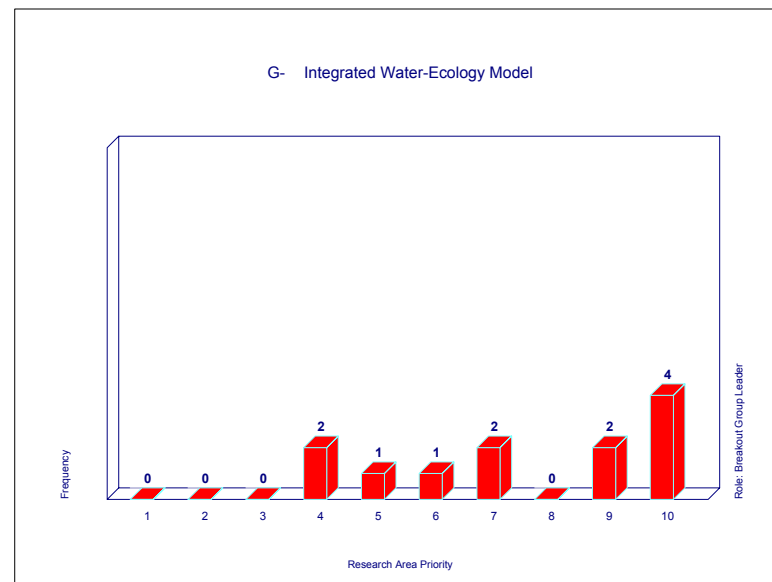
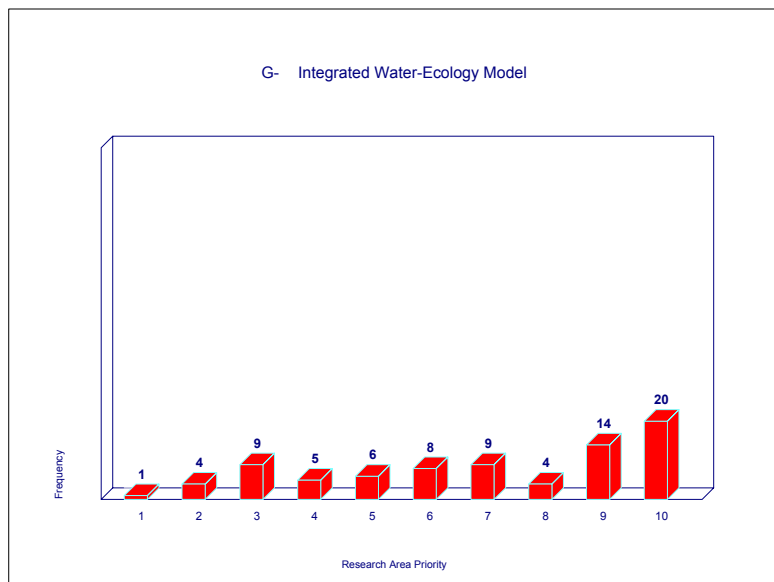


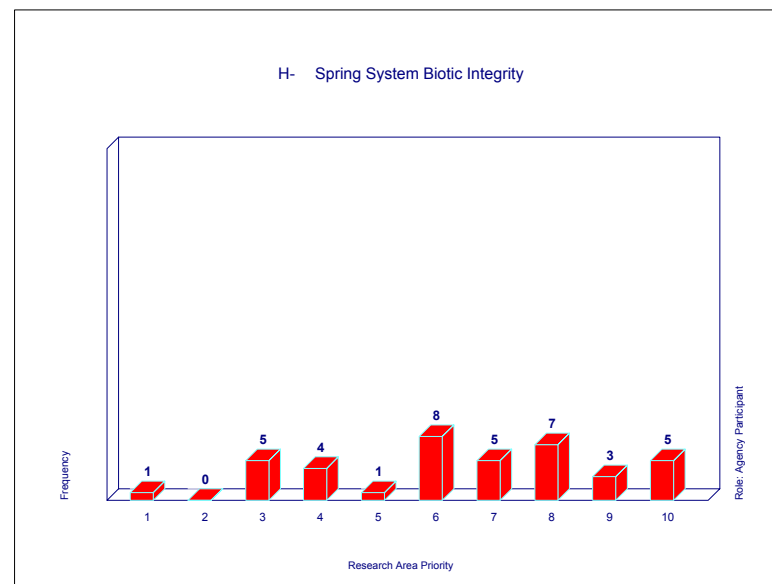
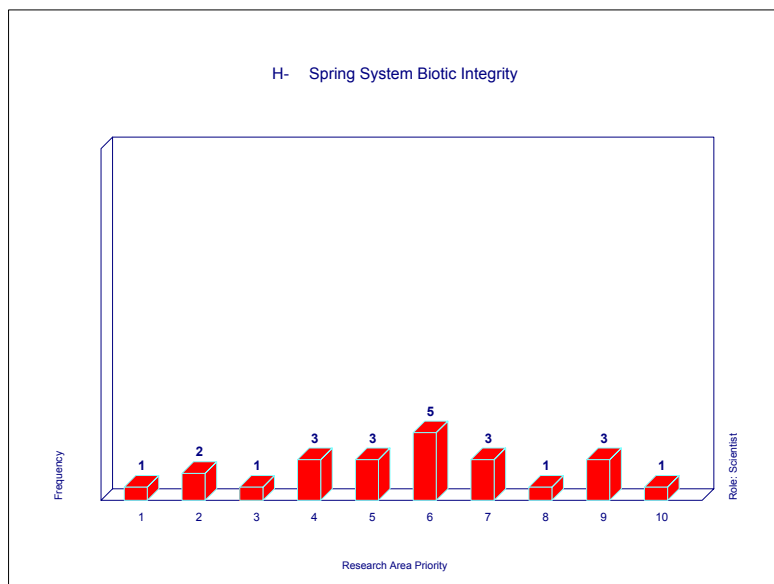
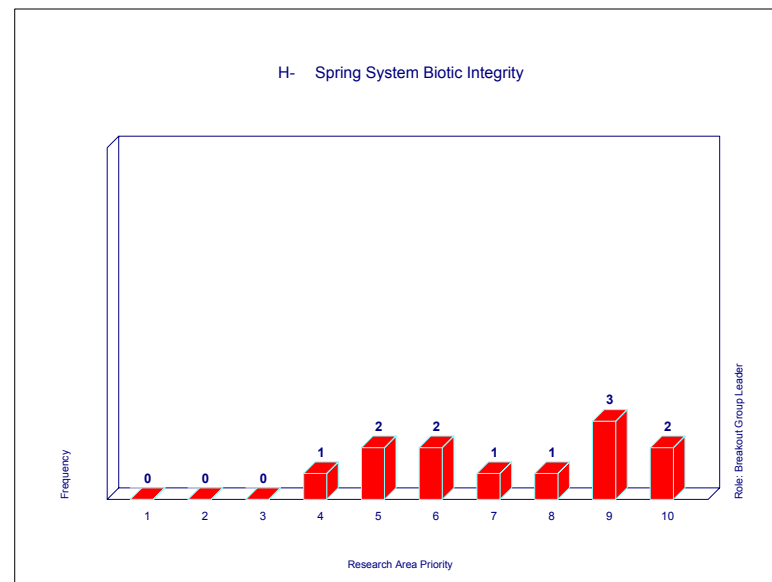
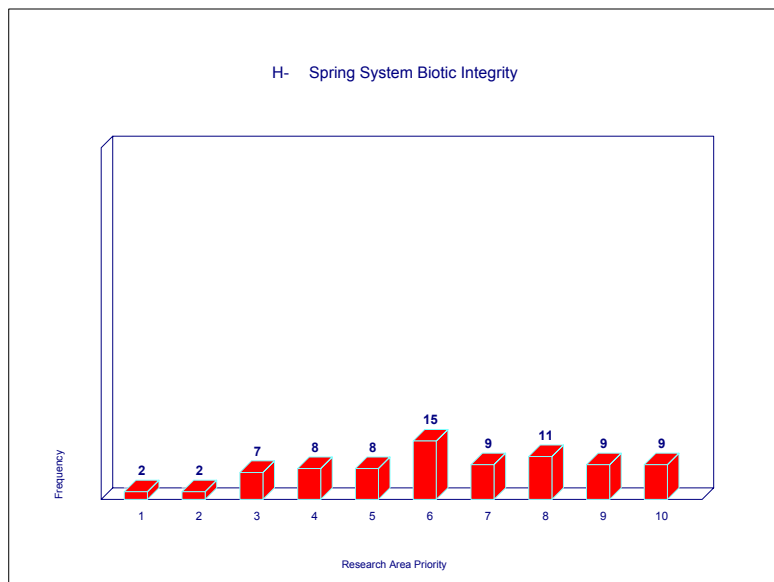
F- Management Methods & Effects



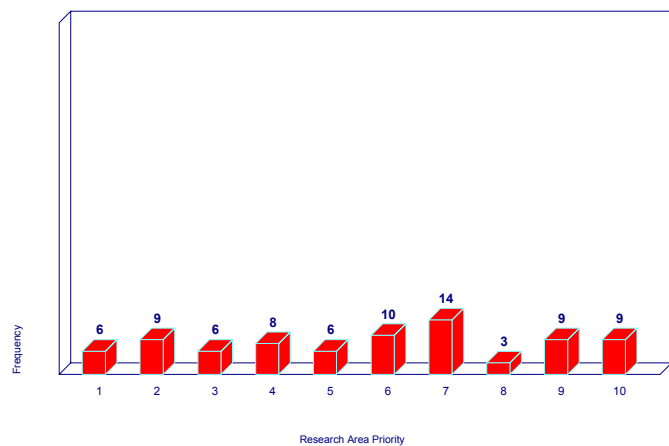
F- Management Methods & Effects



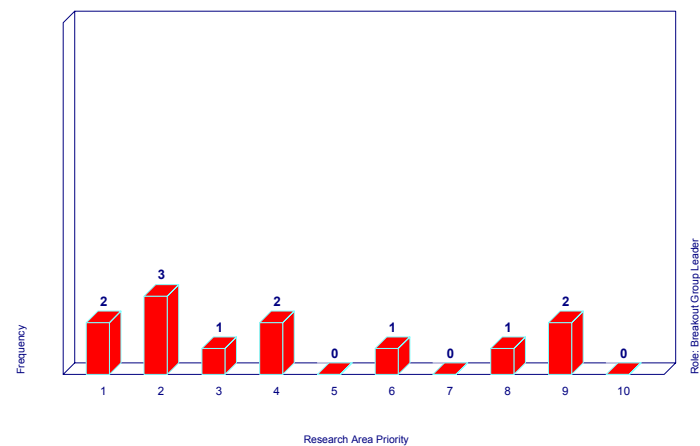




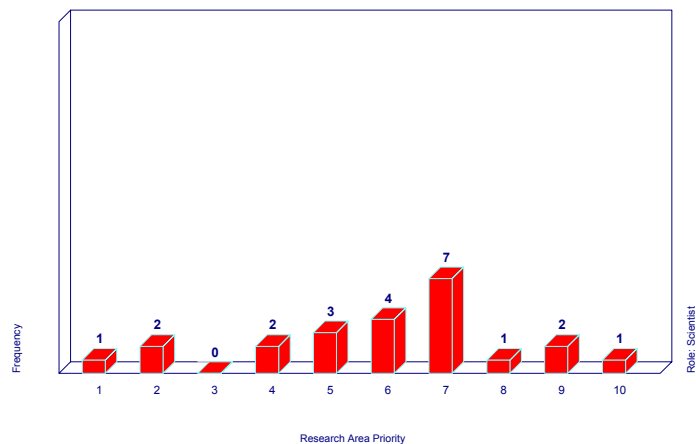
I- Characterize / Model Groundwater Systems



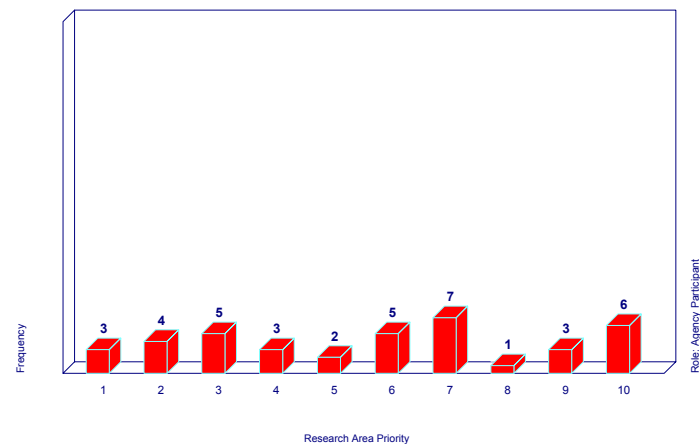
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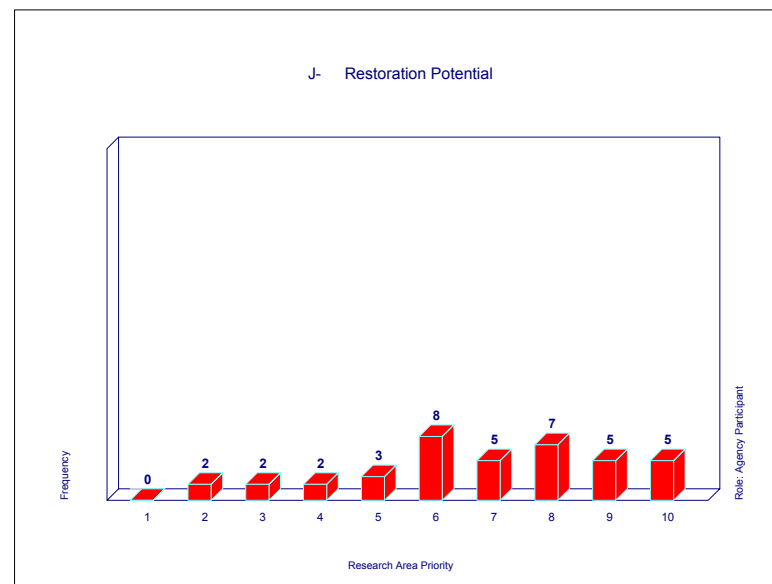
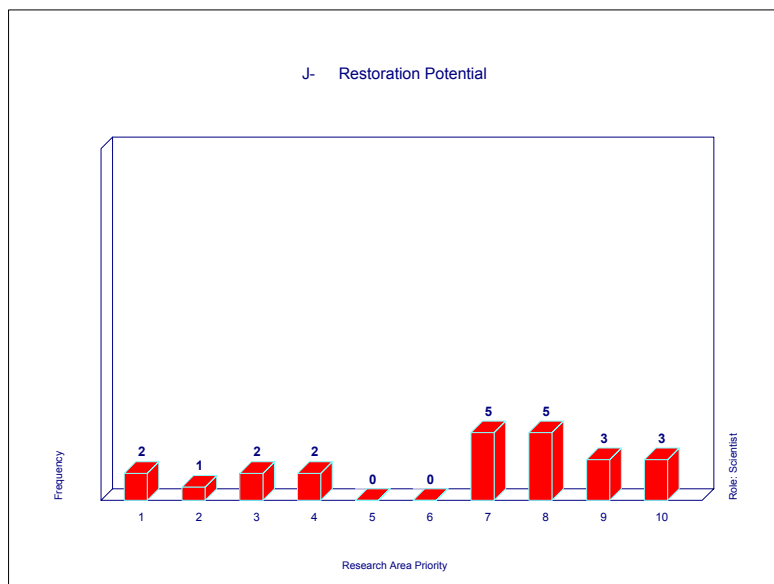
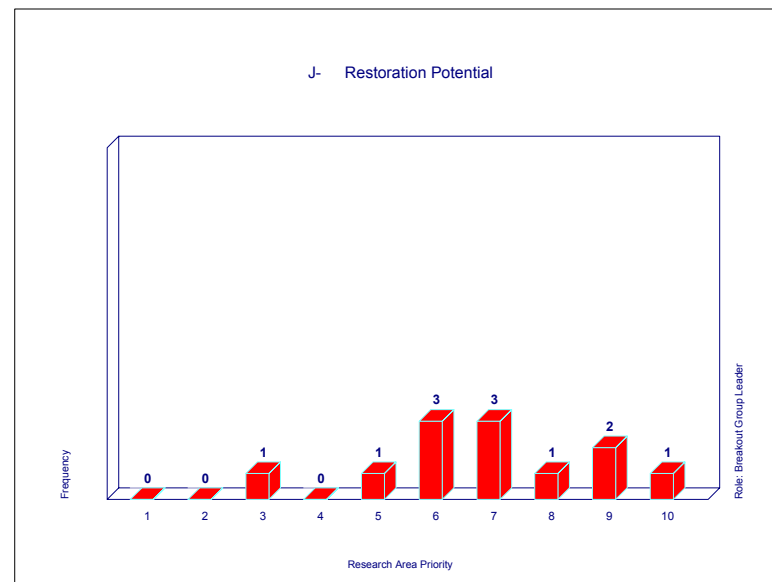
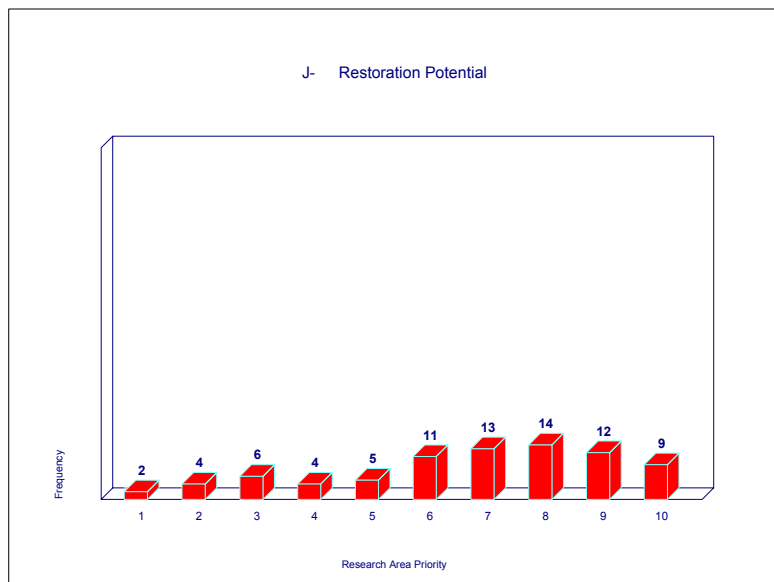
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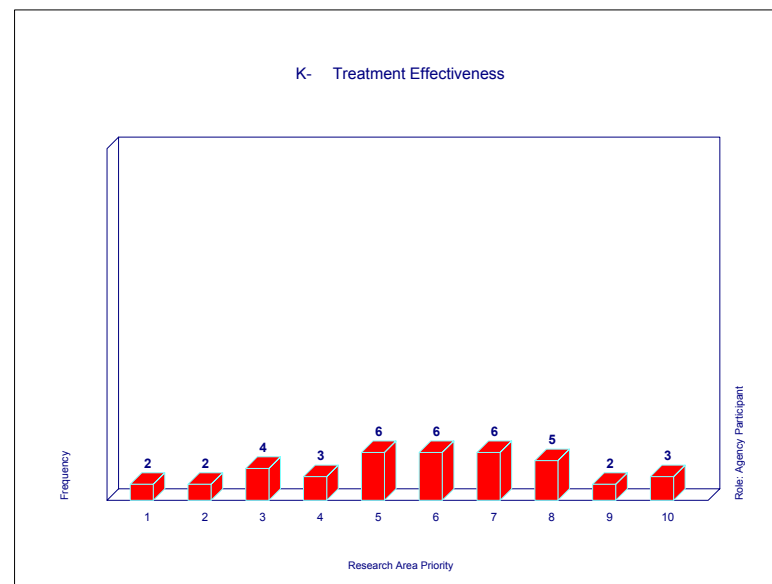
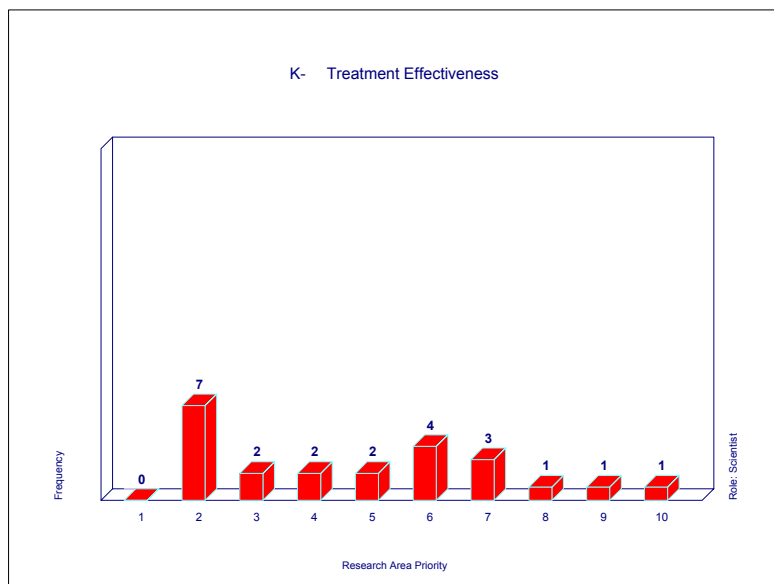
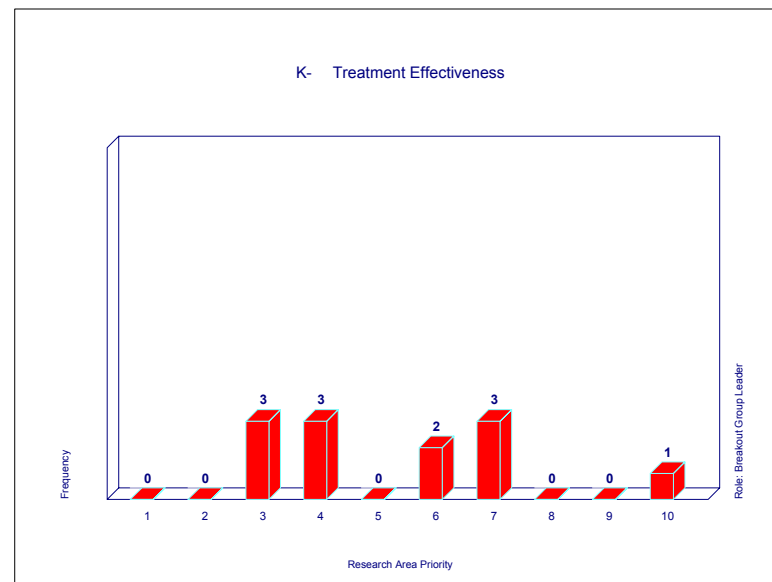
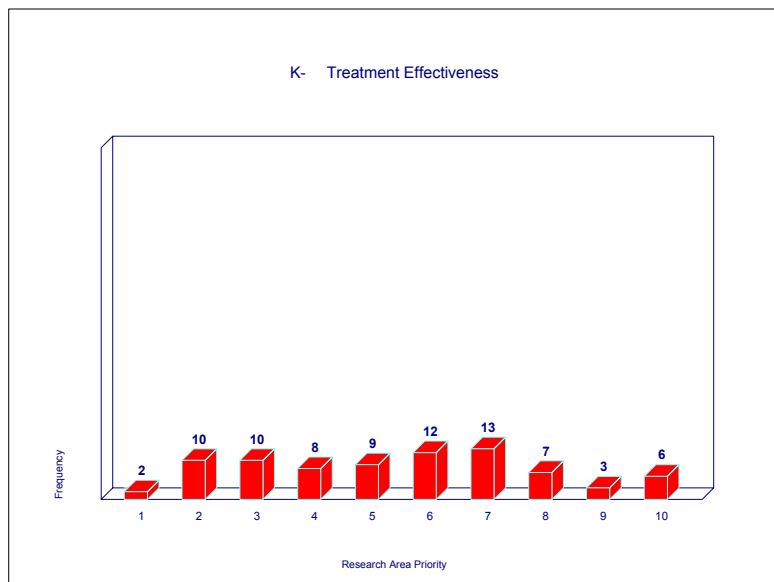


I- Characterize / Model Groundwater Systems

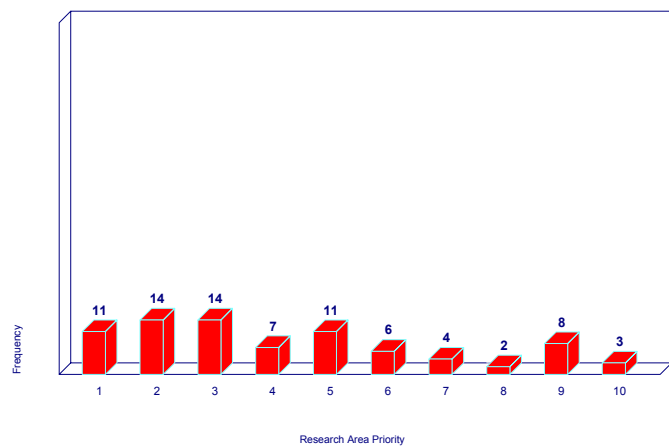


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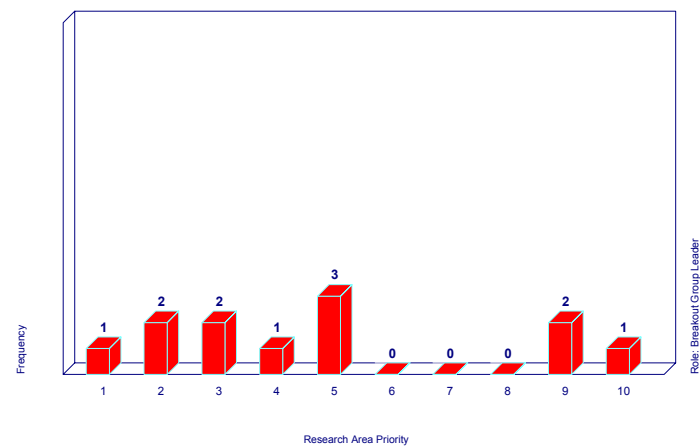




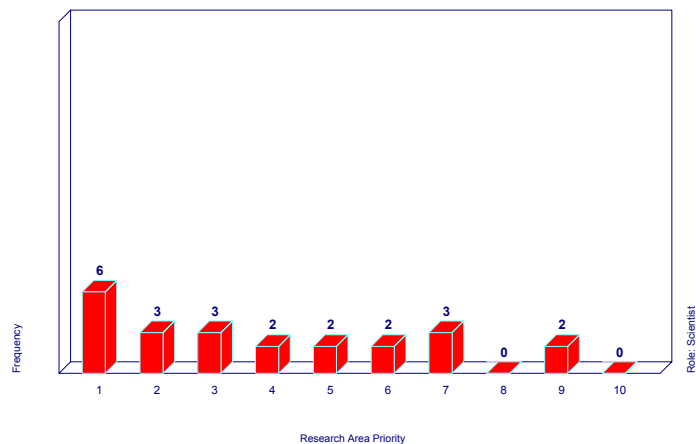
L- Plant Establishment Techniques



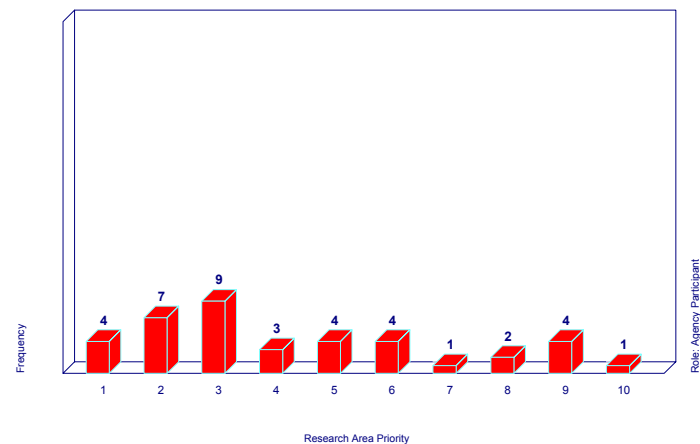
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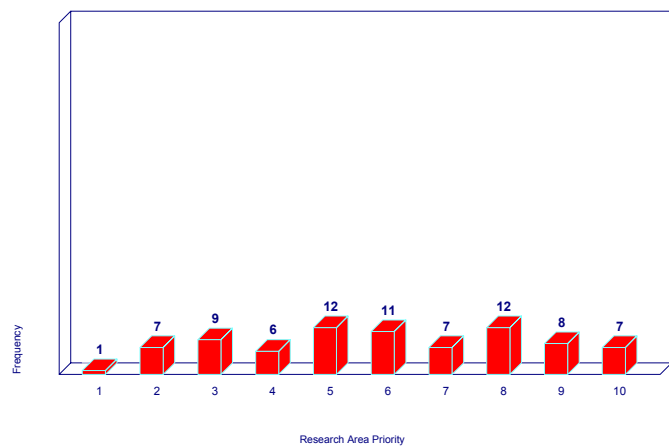
L- Plant Establishment Techniques



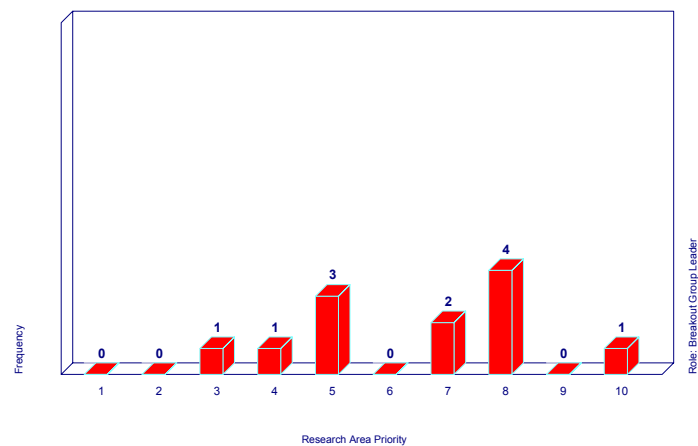
L- Plant Establishment Techniques



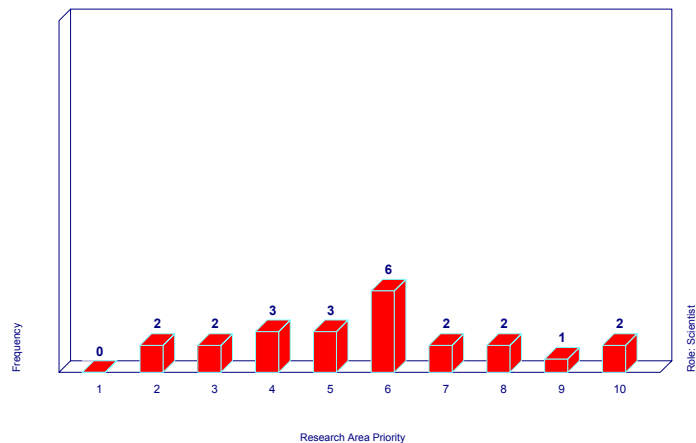
M- Prioritize for Conservation by Filling Information Gaps



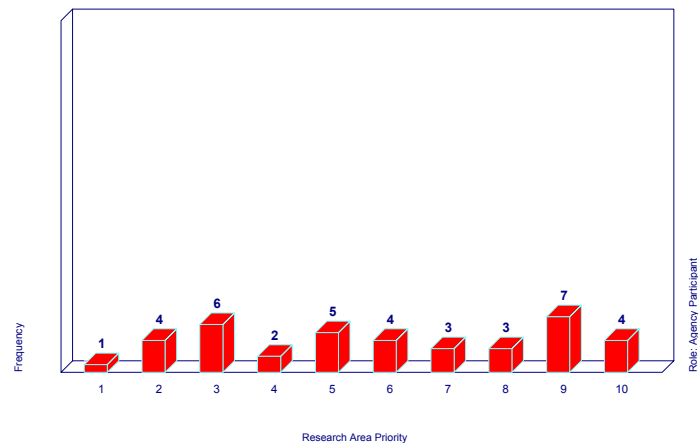
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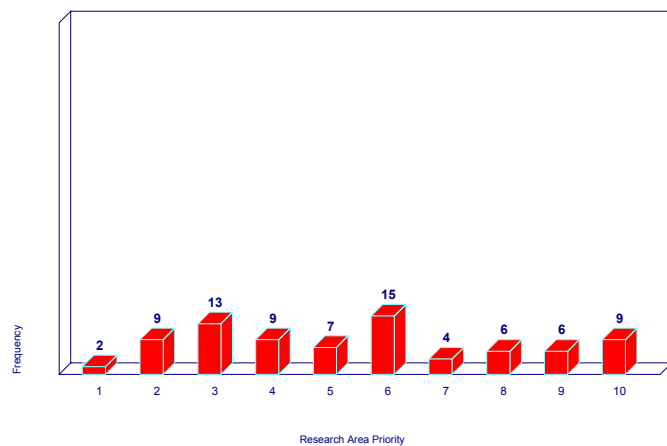
M- Prioritize for Conservation by Filling Information Gaps



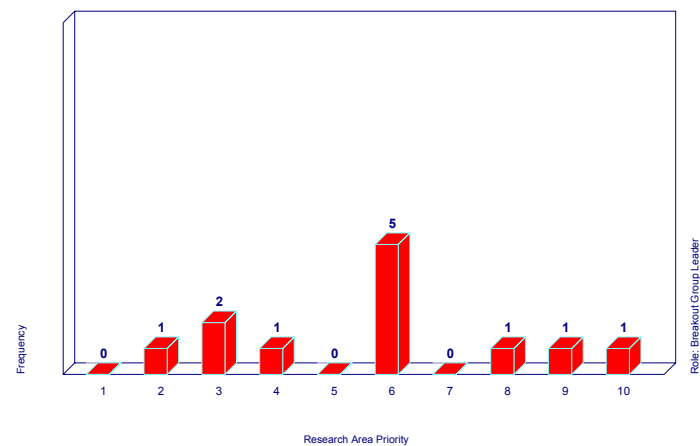
M- Prioritize for Conservation by Filling Information Gaps



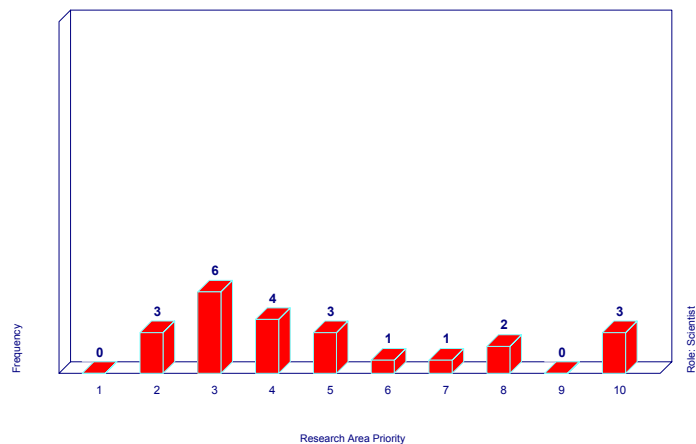
N- Fulfill Information Gaps Necessary for Conservation of Critical Species of Concern



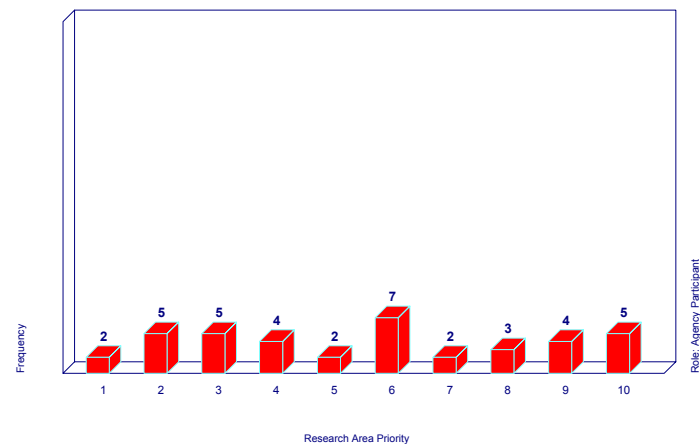
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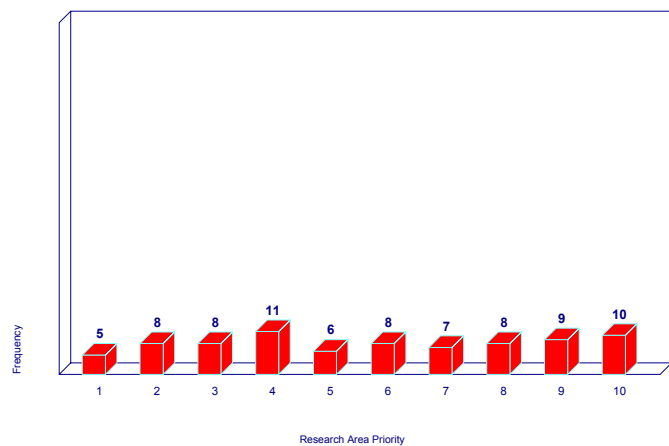
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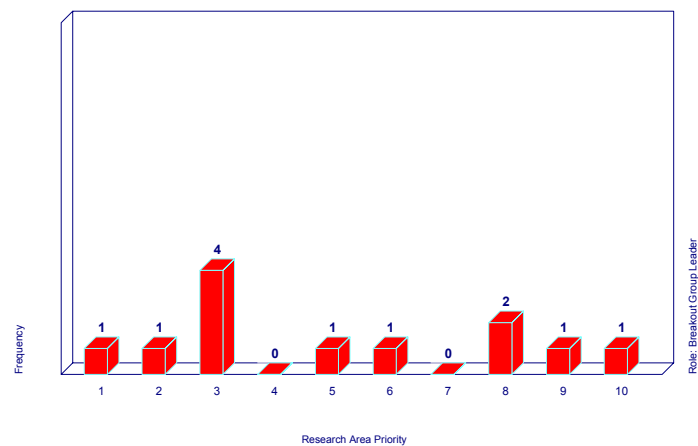
N- Fulfill Information Gaps Necessary for Conservation of Critical Species of Concern



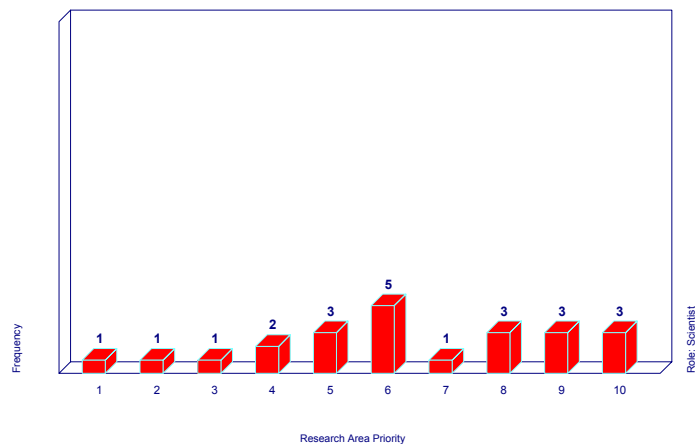
O- Threshold Level of Natural or Artificial Habitat



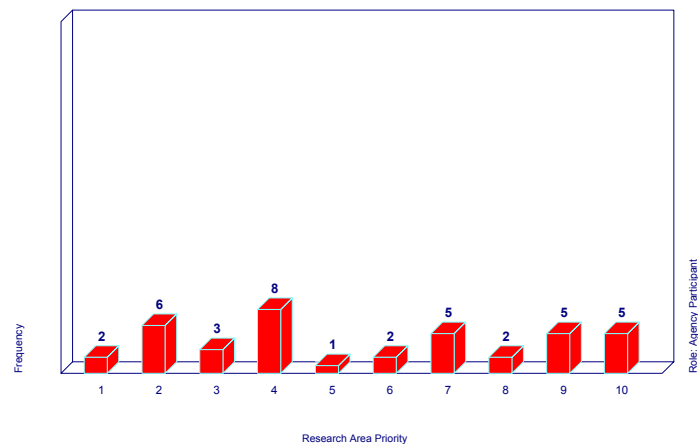
O- Threshold Level of Natural or Artificial Habitat



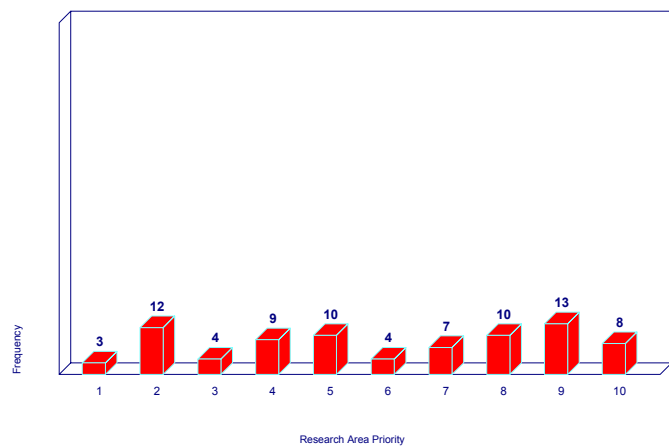
O- Threshold Level of Natural or Artificial Habitat



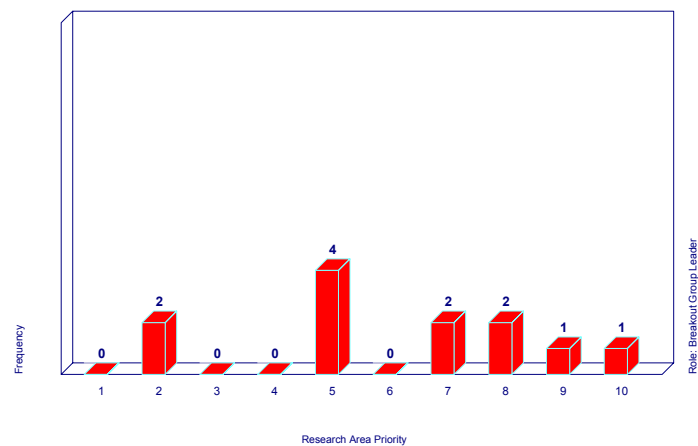
O- Threshold Level of Natural or Artificial Habitat



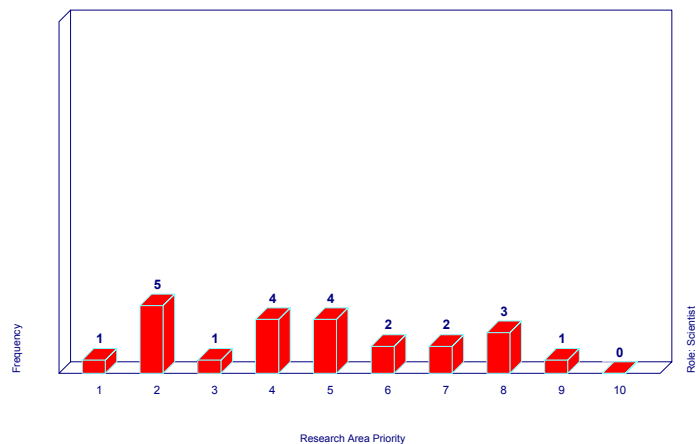
P- Visitor Use Patterns and Characteristics



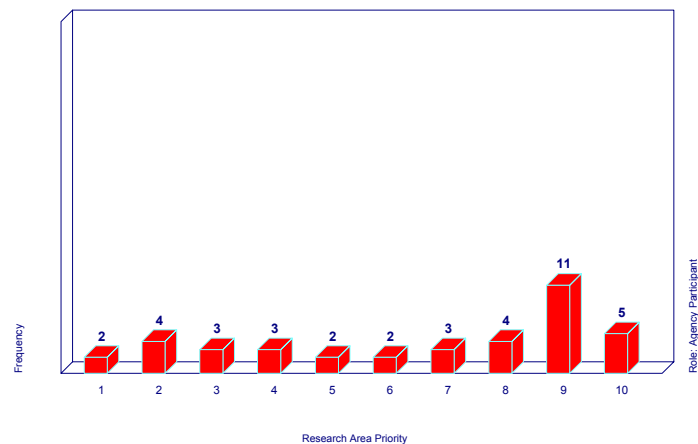
P- Visitor Use Patterns and Characteristics



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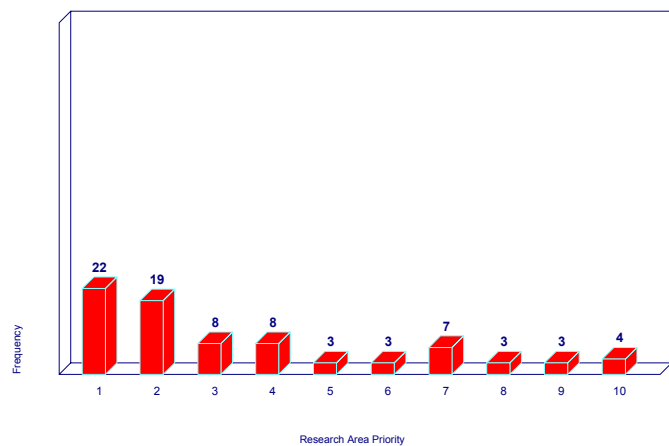


P- Visitor Use Patterns and Characteristics

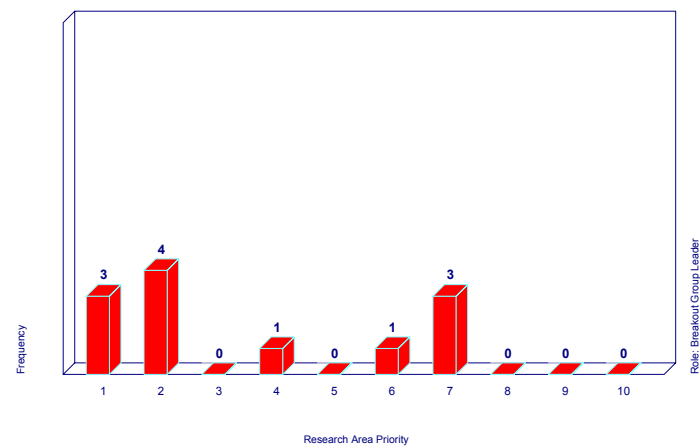


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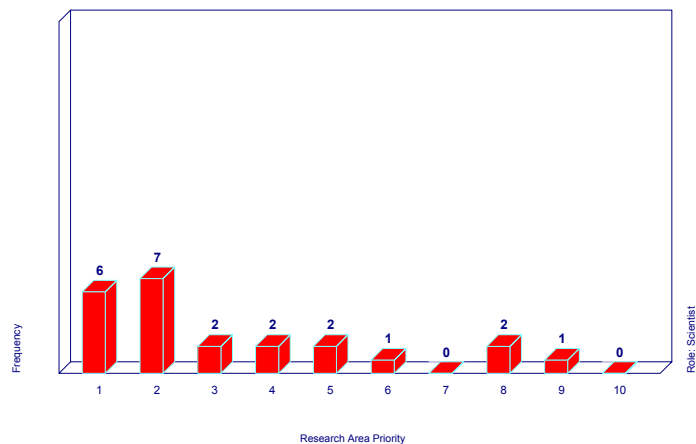
Q- Agency Resource Needs



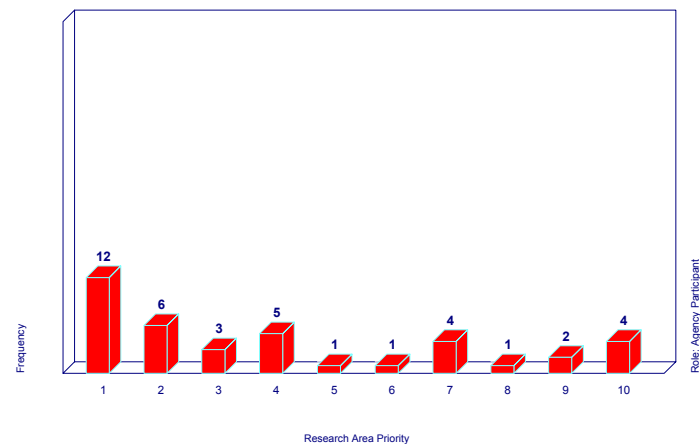
Q- Agency Resource Needs



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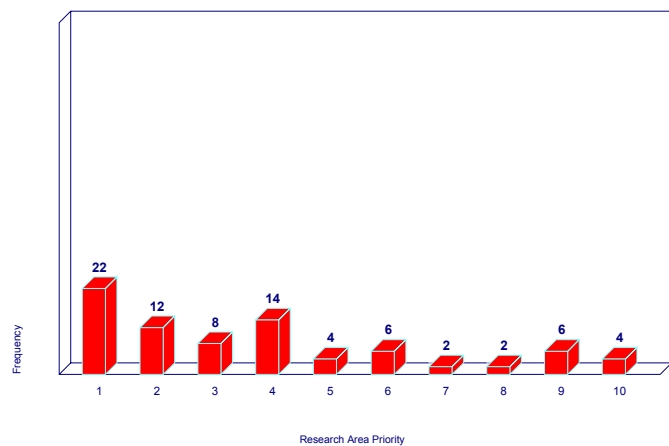


Q- Agency Resource Needs

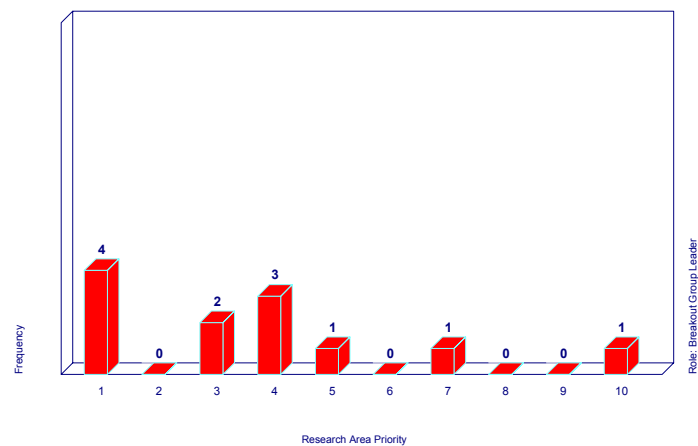


Strategic Initiatives

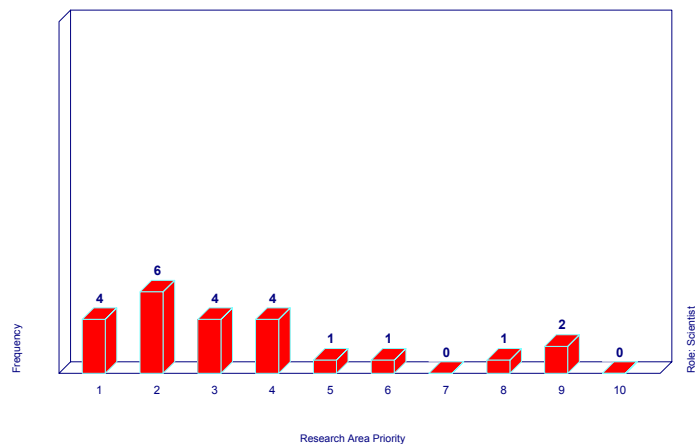
R- Outreach Programs Analysis



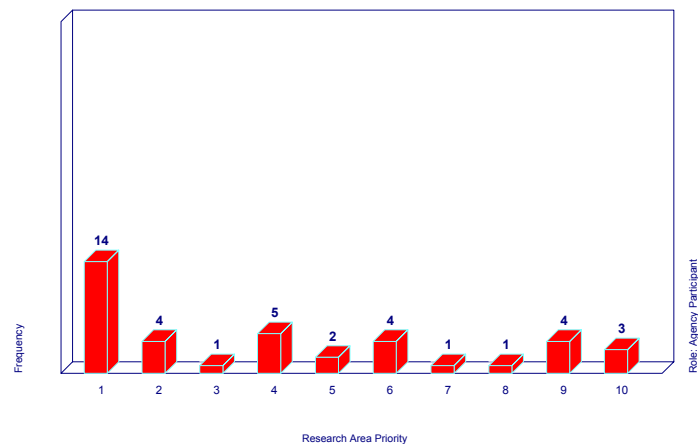
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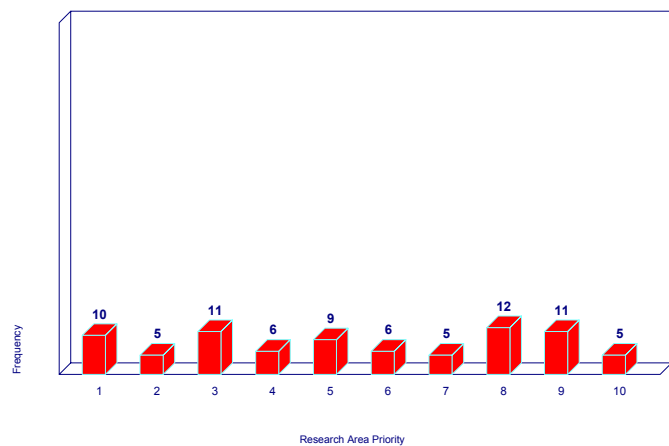
R- Outreach Programs Analysis



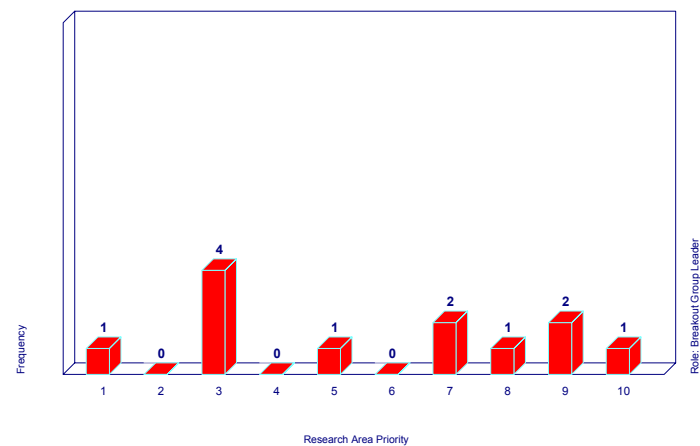
R- Outreach Programs Analysis



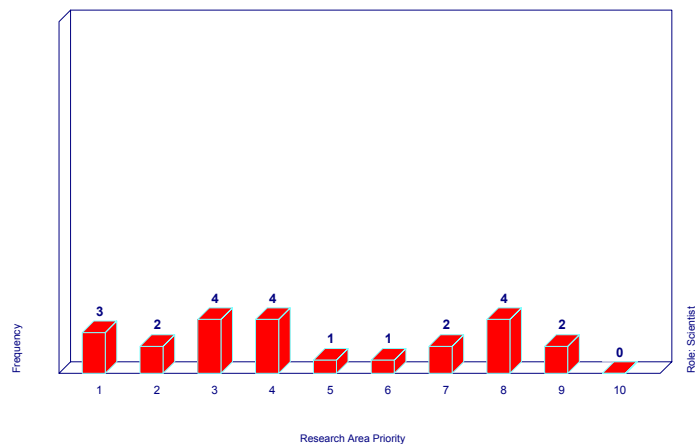
S- Geologic, Geomorphic and Pedologic Patterns



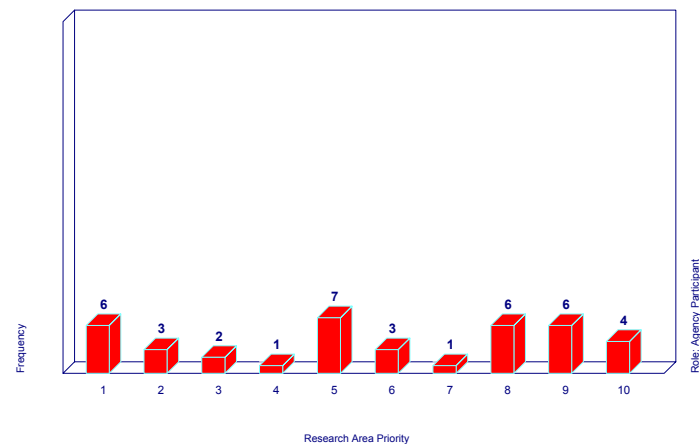
S- Geologic, Geomorphic and Pedologic Patterns



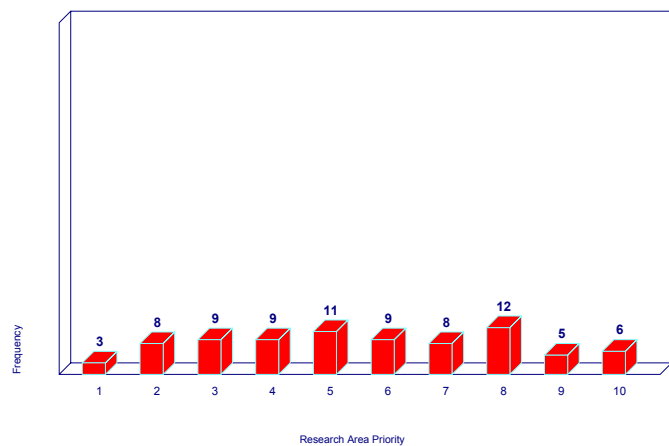
S- Geologic, Geomorphic and Pedologic Patterns



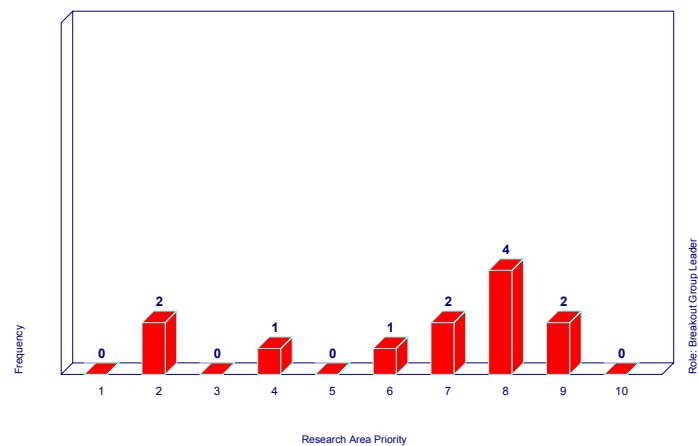
S- Geologic, Geomorphic and Pedologic Patterns



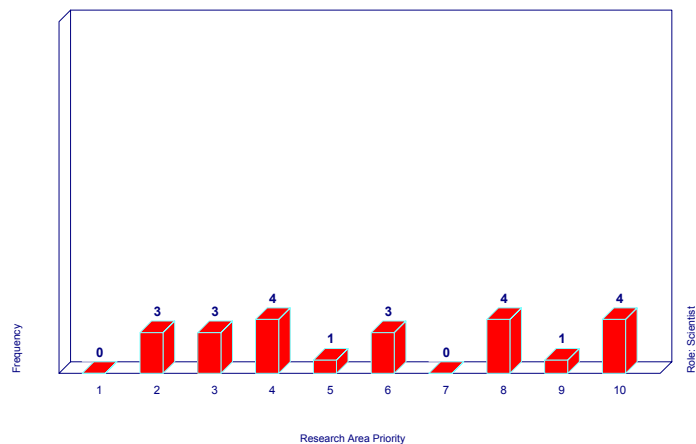
T- Soil-Edaphic Relationships



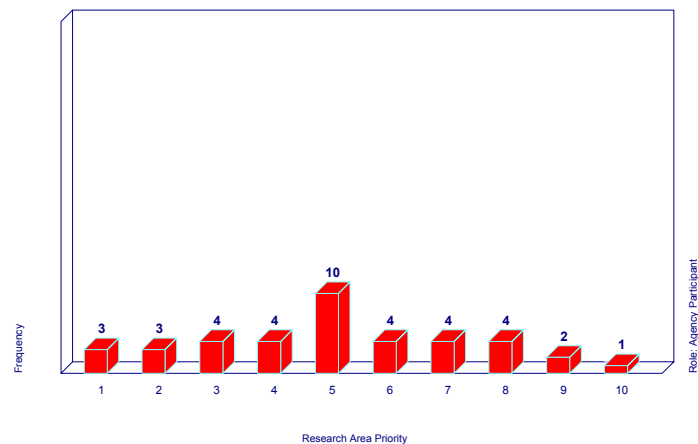
T- Soil-Edaphic Relationships



T- Soil-Edaphic Relationships

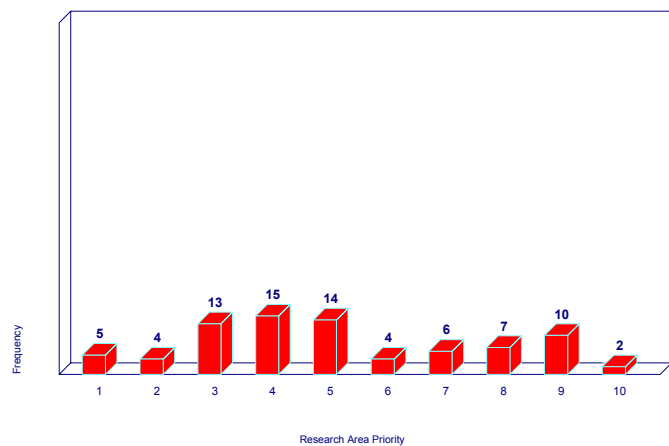


T- Soil-Edaphic Relationships

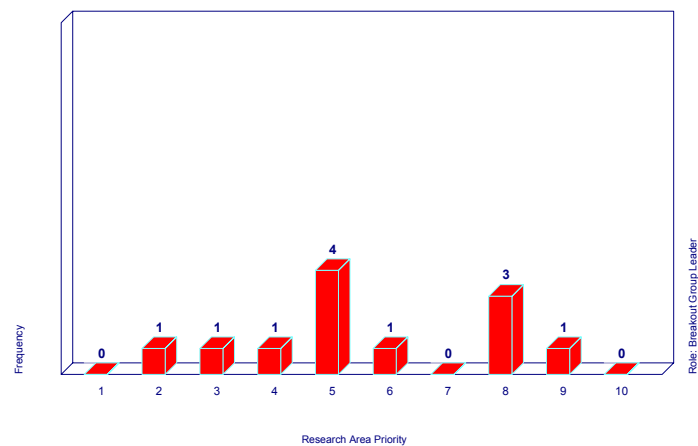


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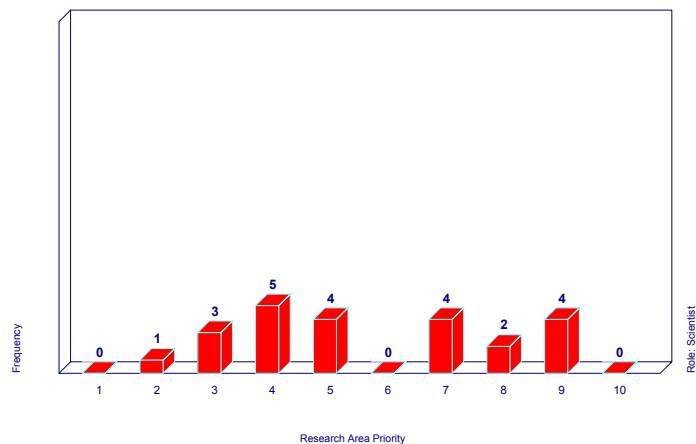
U- Loss of Soil Function, Recovery, and Indicators of Soil Health



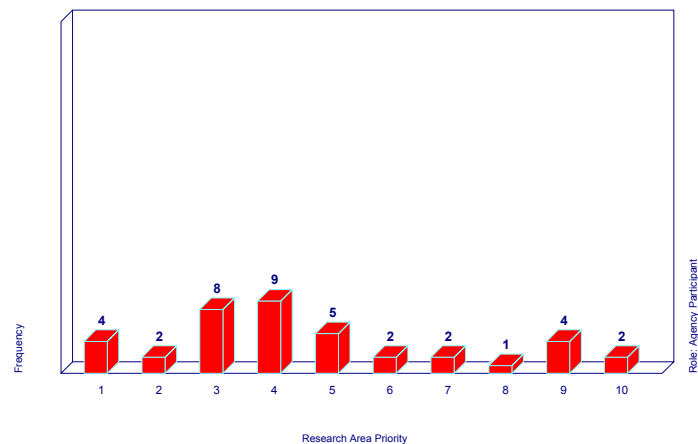
U- Loss of Soil Function, Recovery, and Indicators of Soil Health

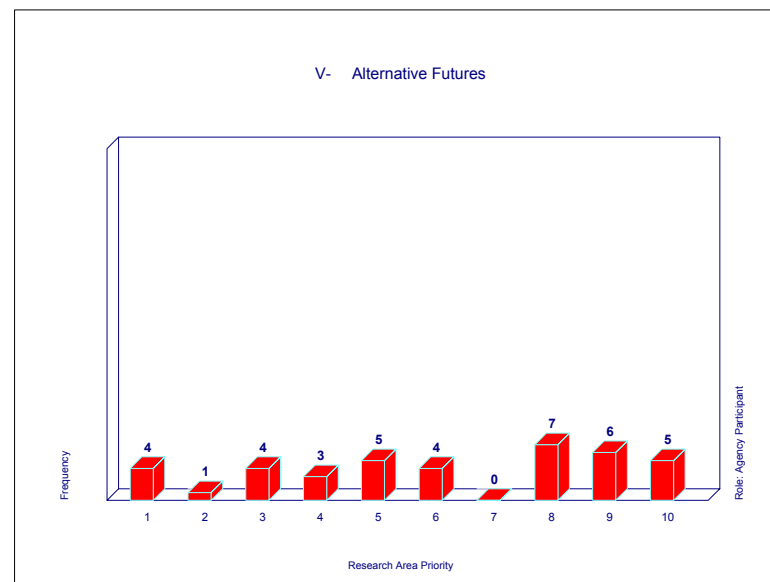
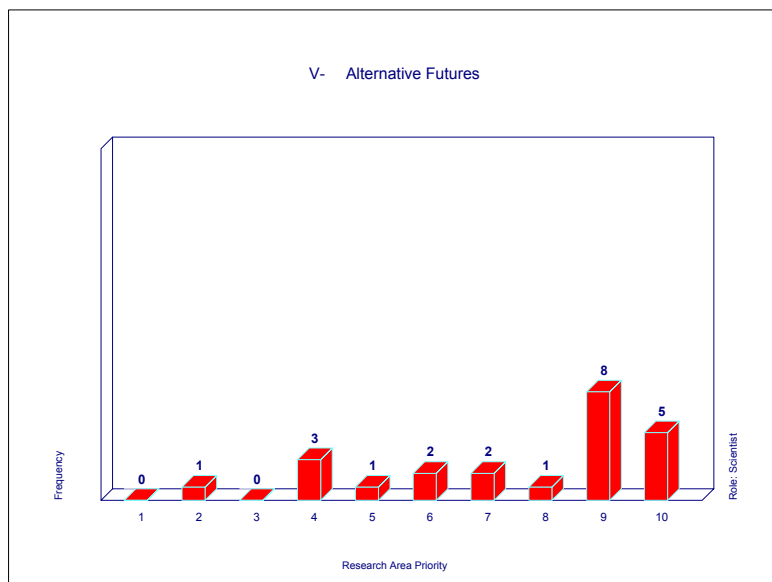
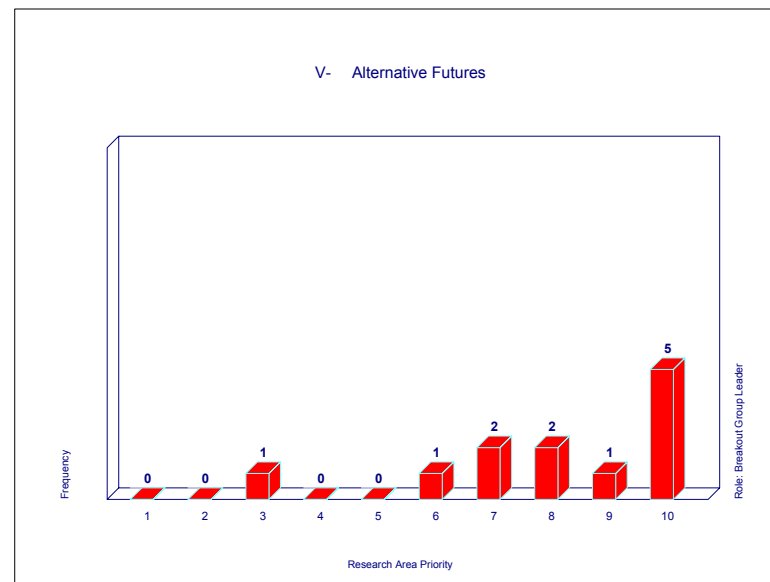
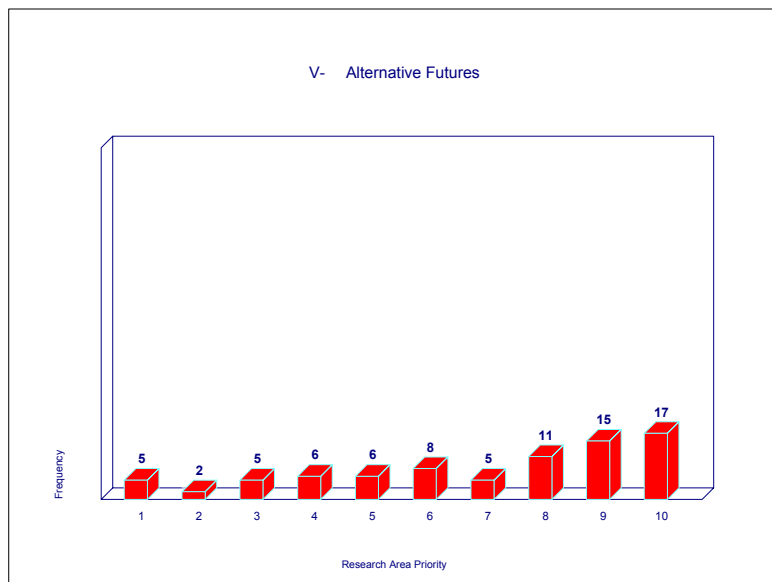


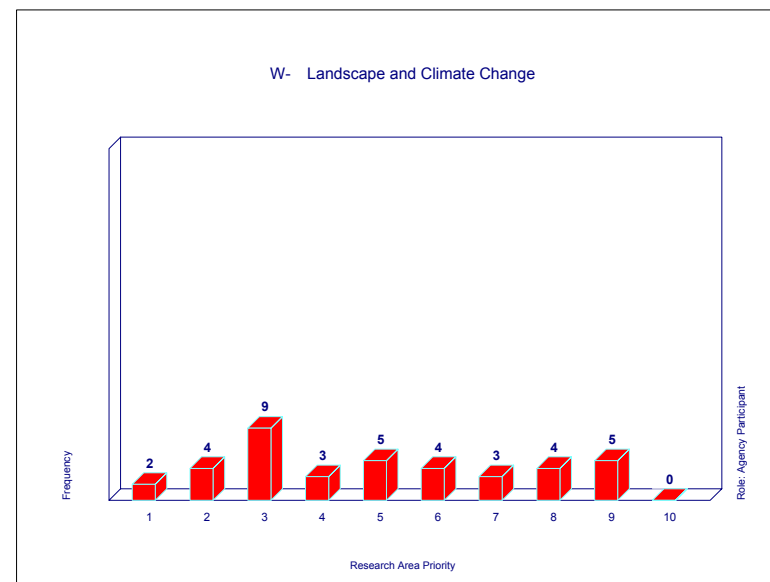
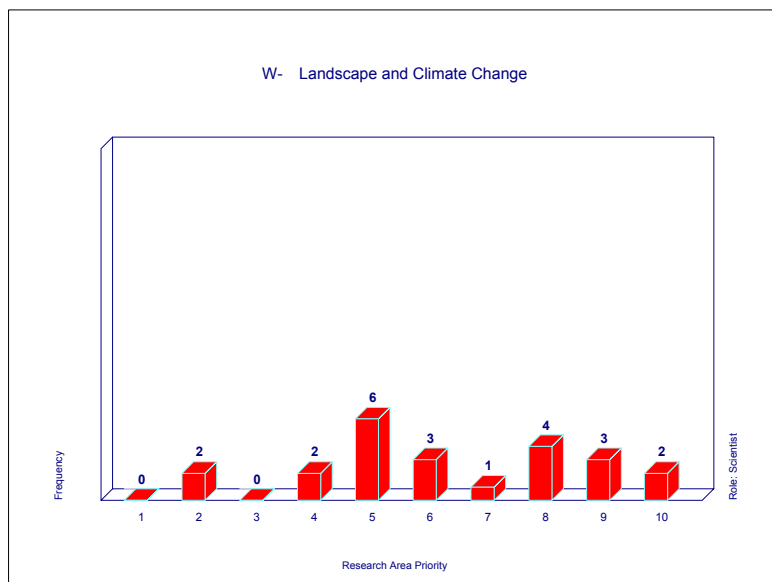
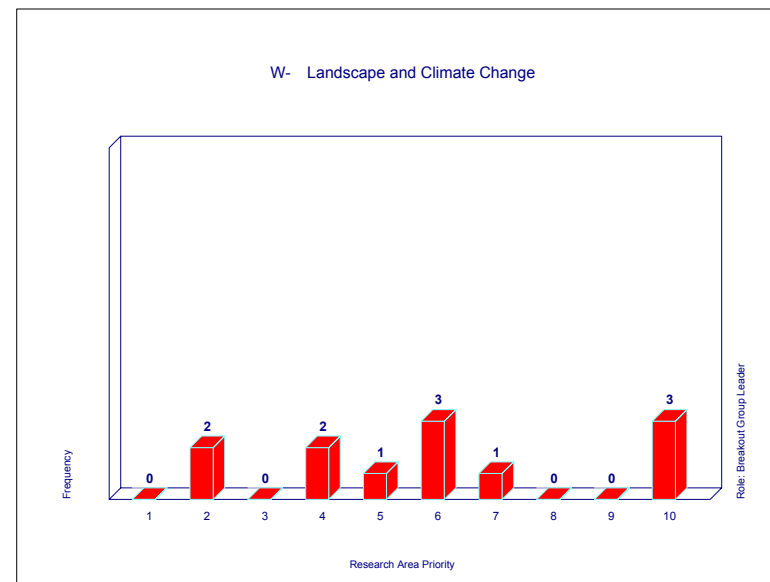
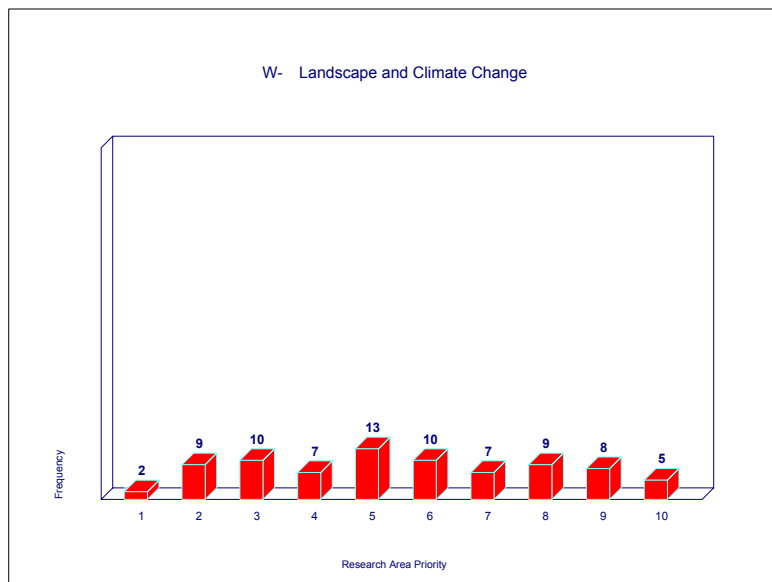
U- Loss of Soil Function, Recovery, and Indicators of Soil Health



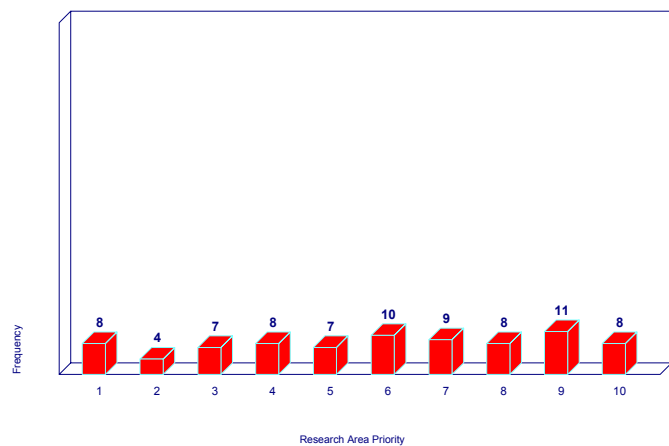
U- Loss of Soil Function, Recovery, and Indicators of Soil Health



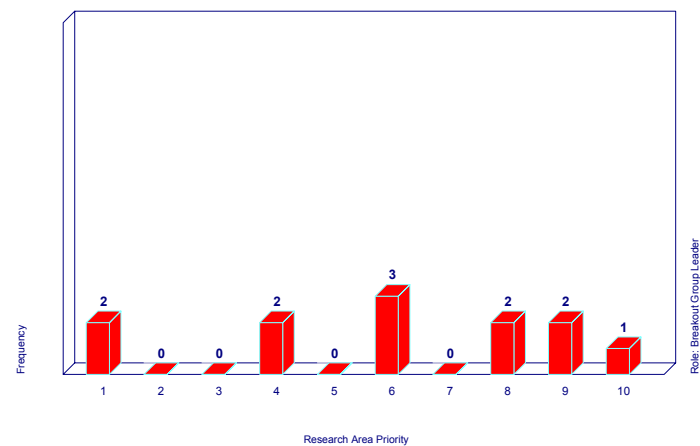




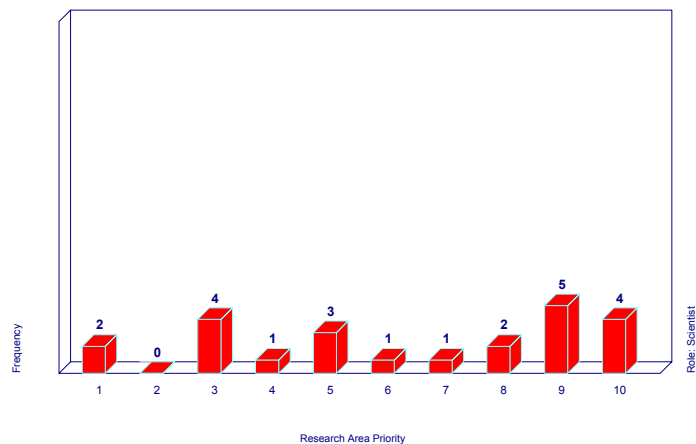
X- Urbanization Effects



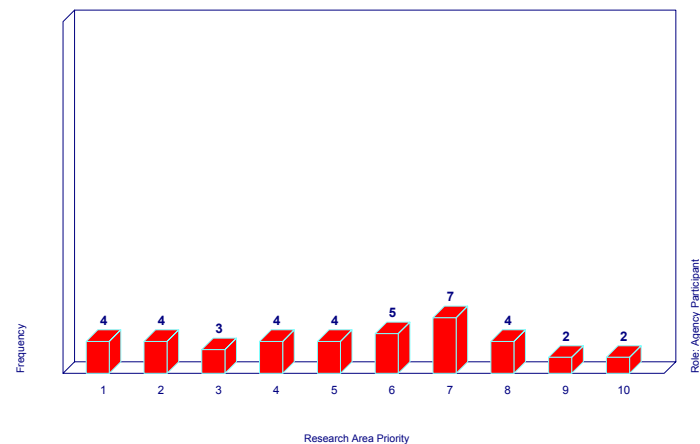
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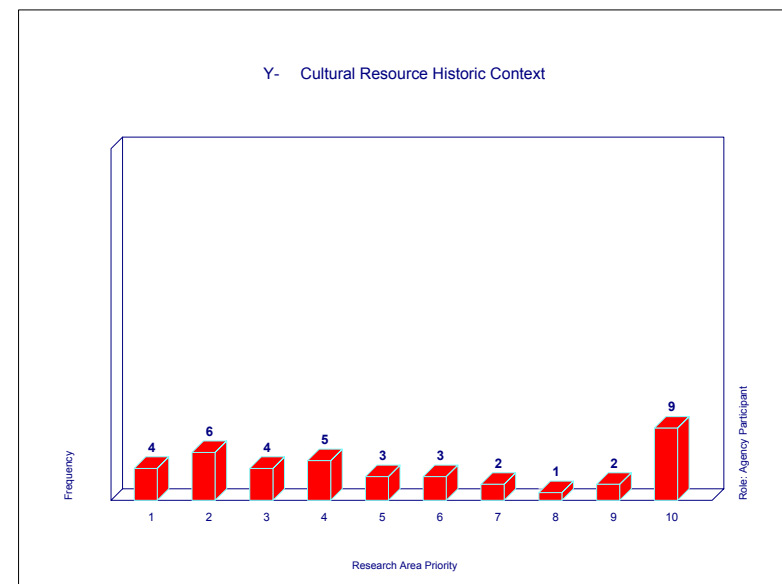
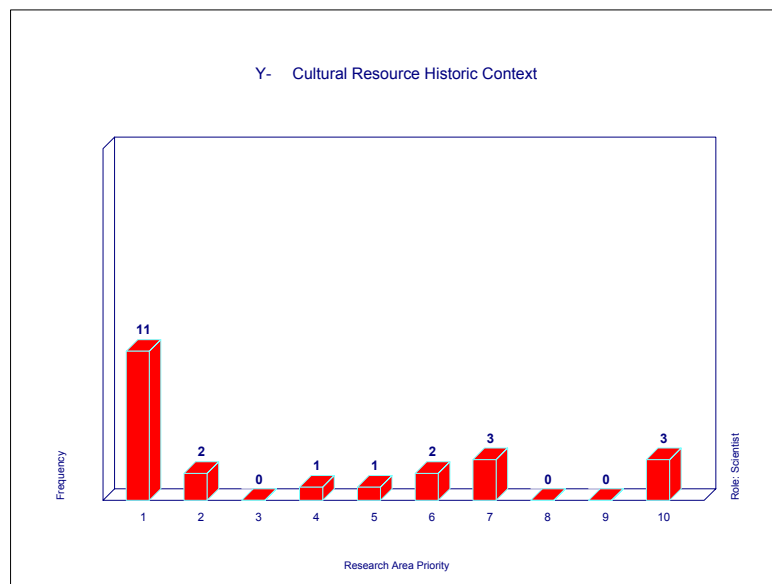
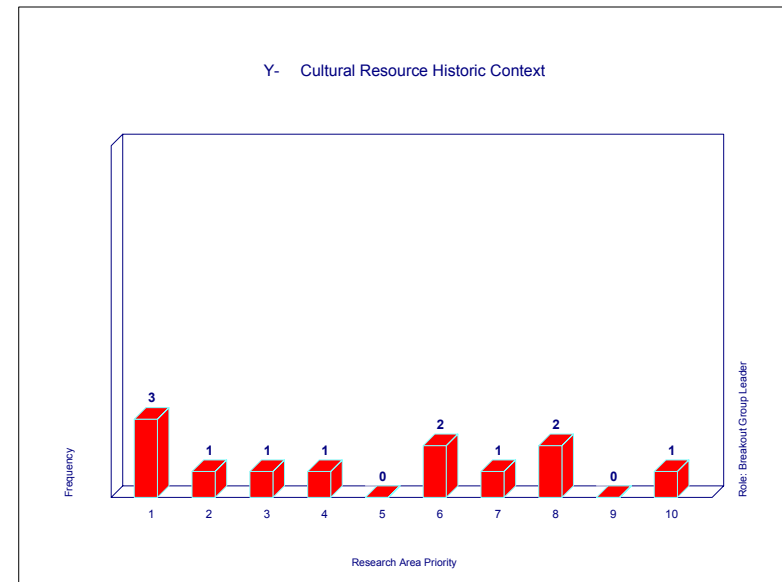
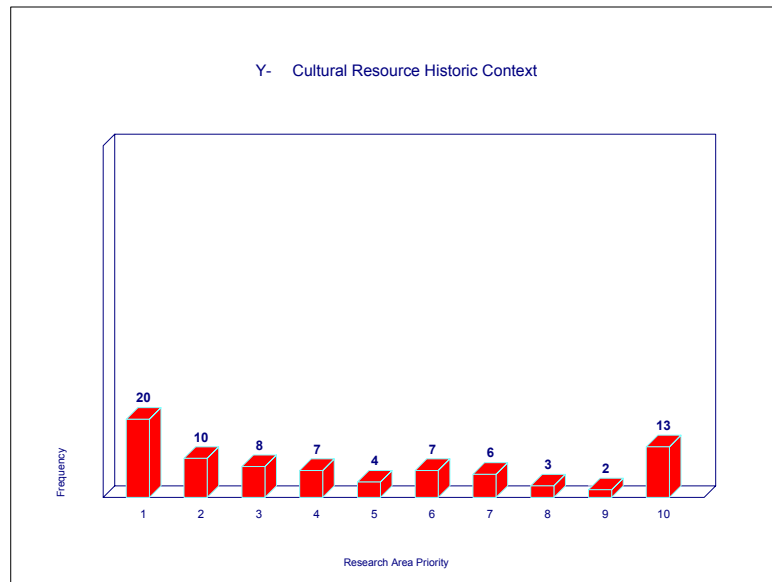


X- Urbanization Effects

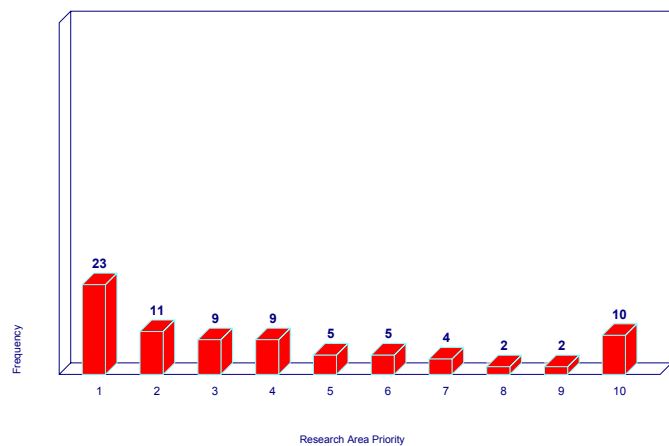


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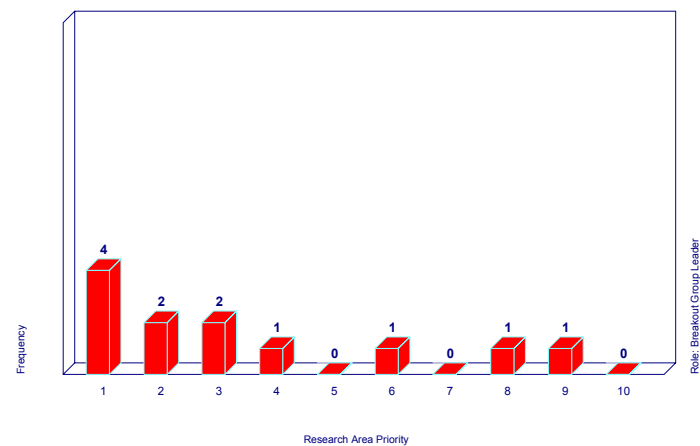




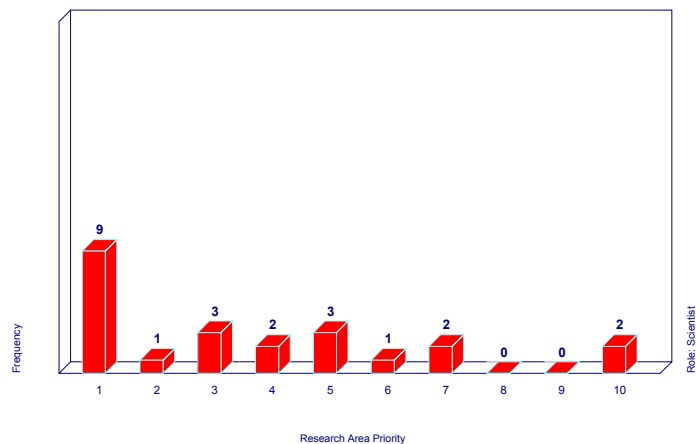
Z- Cultural Resource Inventory



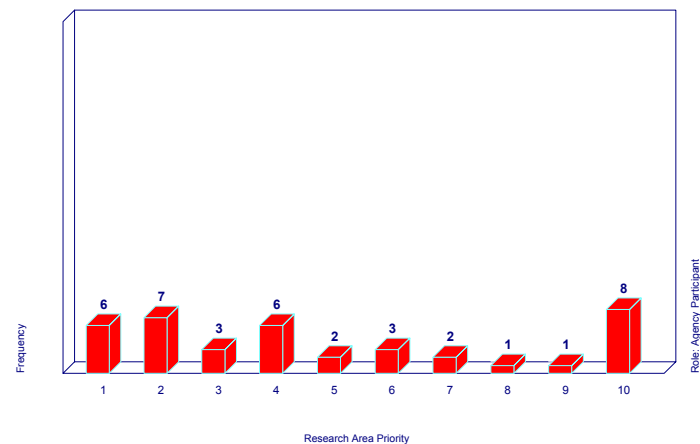
Z- Cultural Resource Inventory

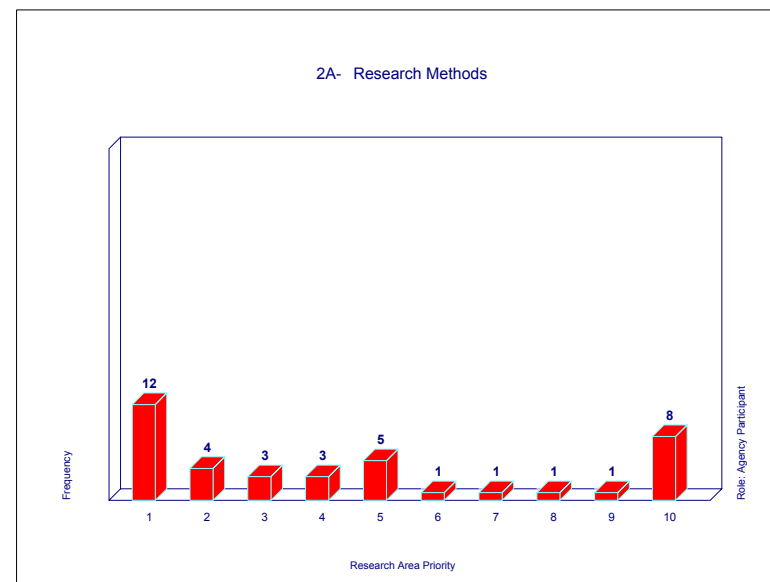
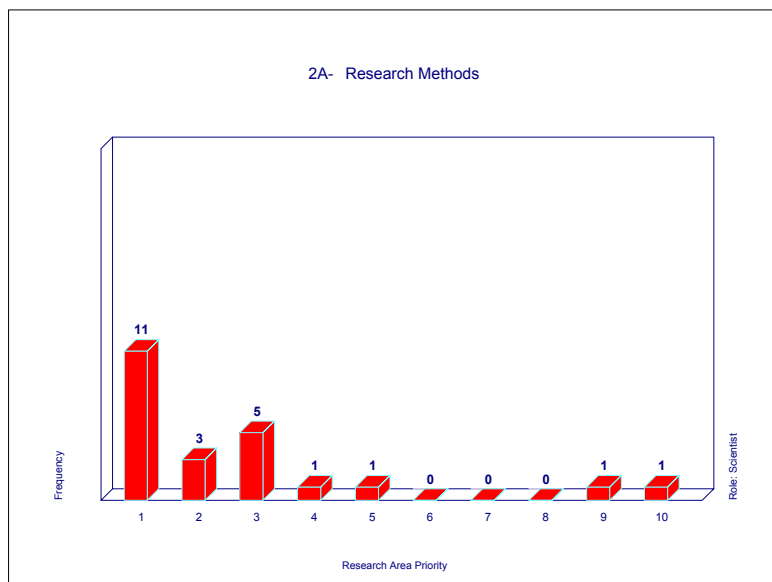
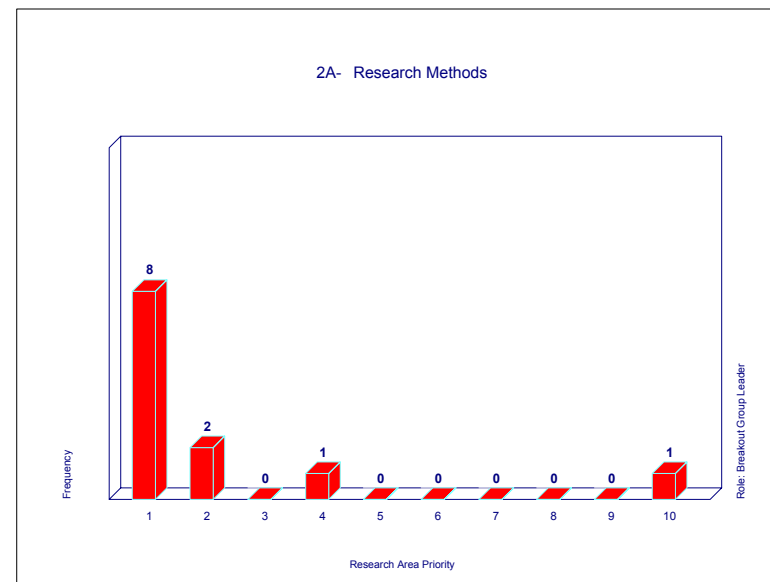
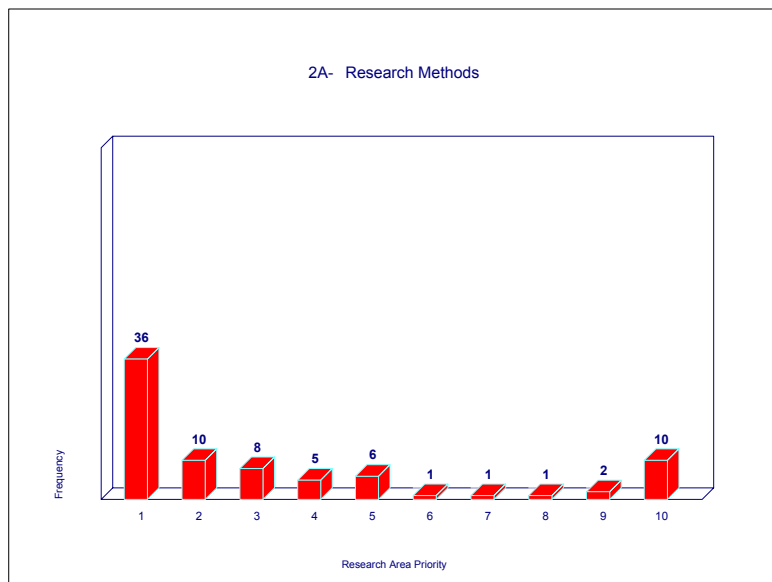


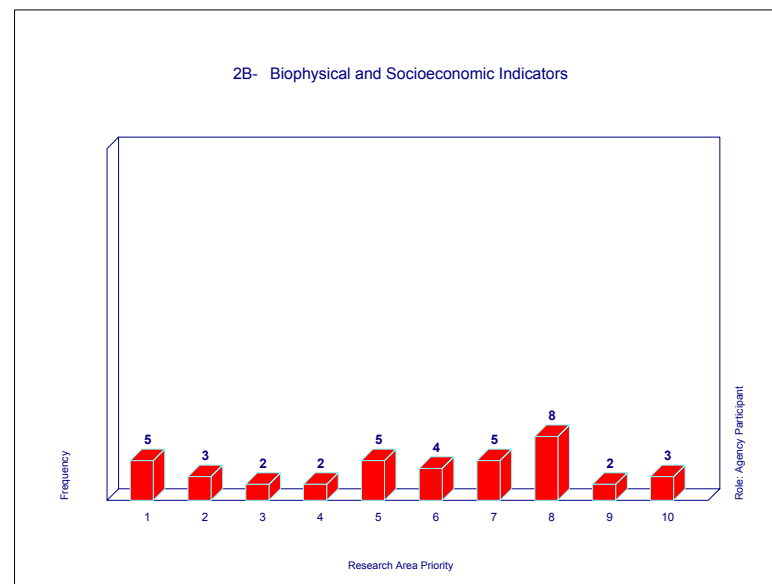
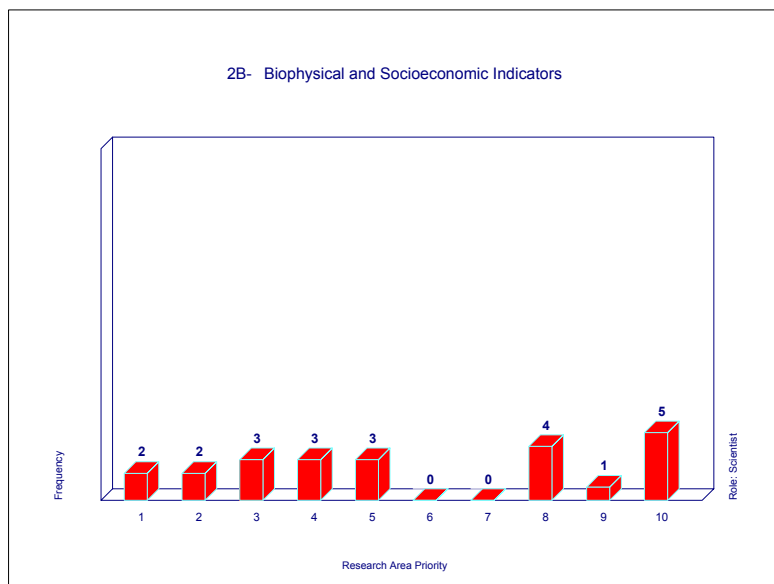
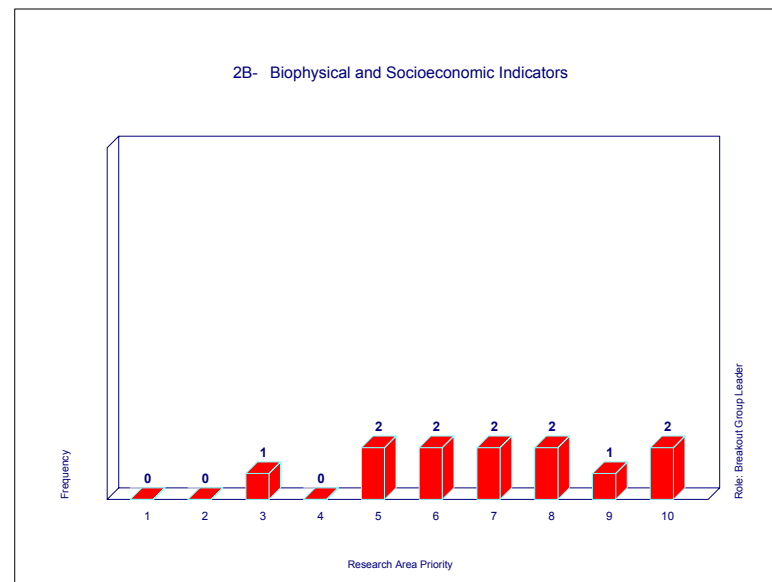
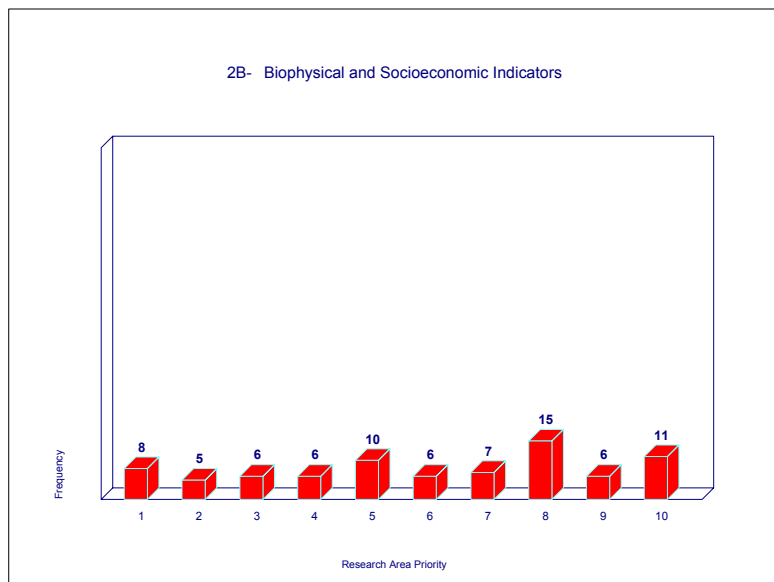
Z- Cultural Resource Inventory



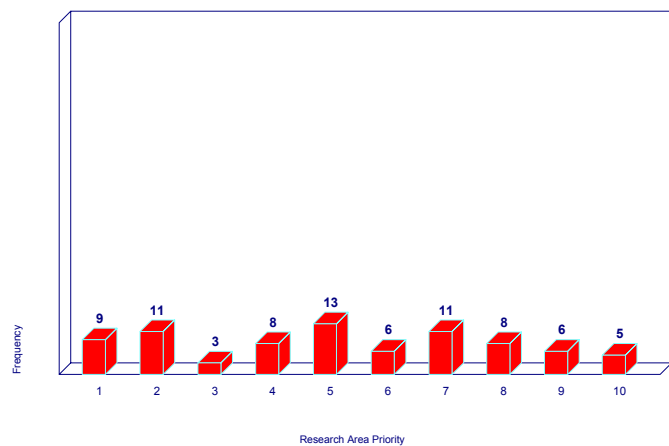
Z- Cultural Resource Inventory



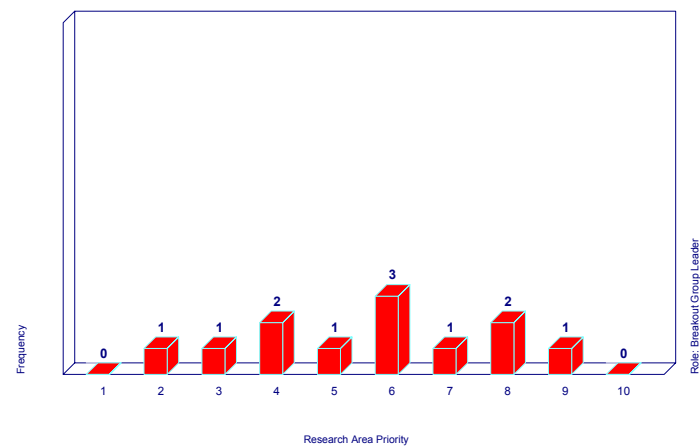




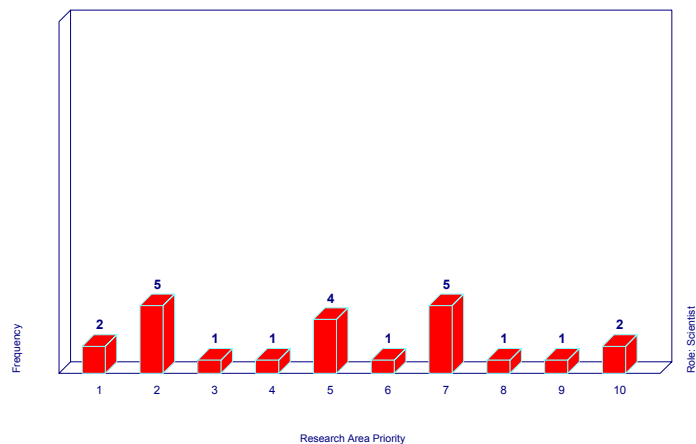
2C- Complete Inventories (Terrestrial and Aquatic)



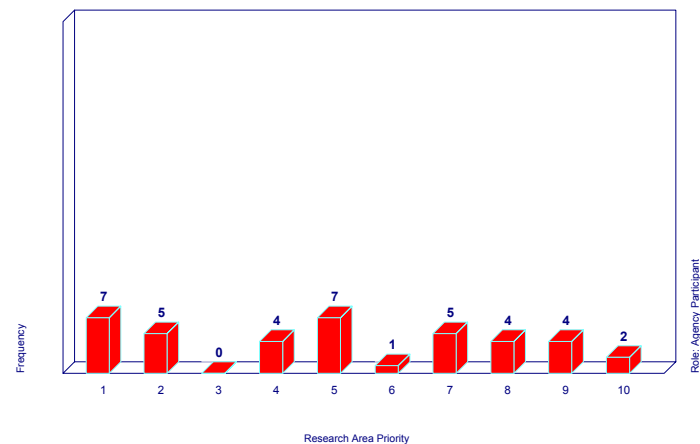
2C- Complete Inventories (Terrestrial and Aquatic)



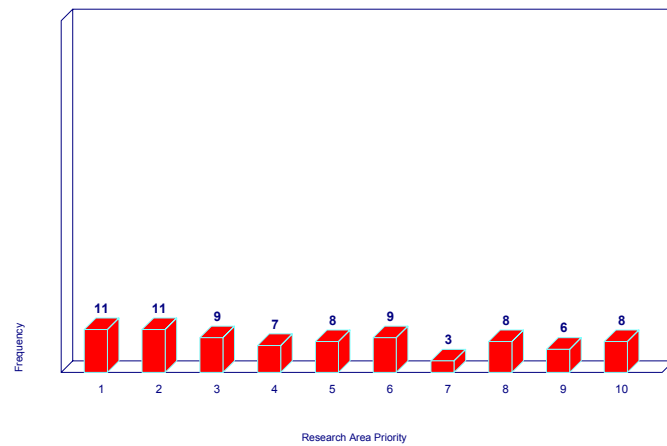
2C- Complete Inventories (Terrestrial and Aquatic)



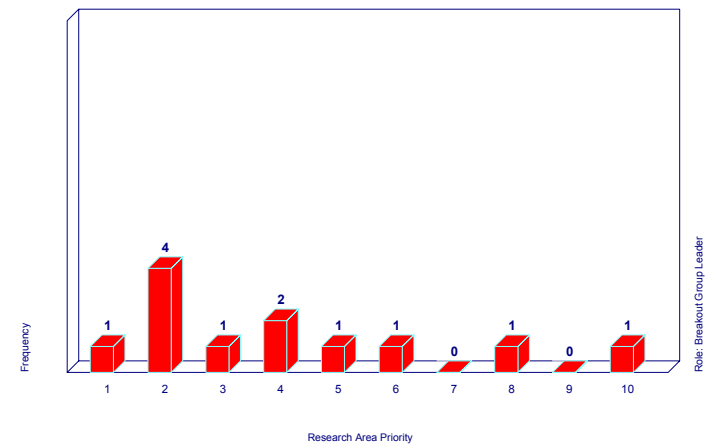
2C- Complete Inventories (Terrestrial and Aquatic)



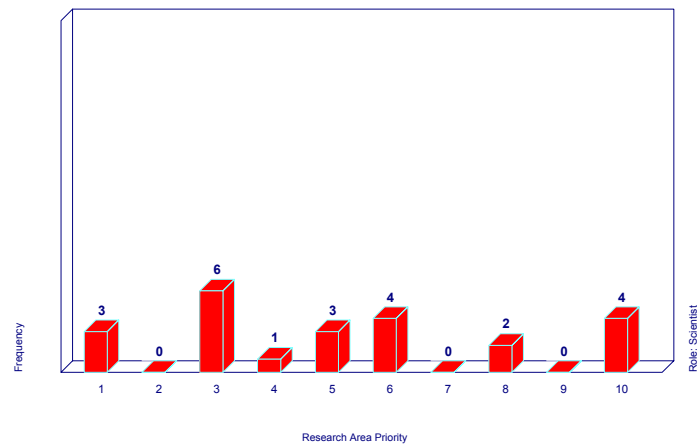
2D- Plan and Implement Monitoring to Support Agency Objectives



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