SIERRA CLUB
FOUNDED 1892

December 18, 2009

California Energy Commission
Attn: John Kessler, Project Manager
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512

Re: **Ivanpah Solar Electric Generating System, Docket No. 07-AFC- 5**

Dear Mr. Kessler,

Please find enclosed for filing the original and one copy of Sierra Club's Opening Testimony and Witness and Exhibits Lists. The Sierra Club submits testimony for just one contested issue, project alternatives. If you have any questions or need additional information, please contact me at (415) 977-5766 or violet.lehrer@sierraclub.org. Thank you for your attention to this matter.

Sincerely,

Violet Lehrer

Violet Lehrer
Program Assistant
Sierra Club Environmental Law Program
85 Second Street, 2nd Floor
San Francisco, CA 94105

STATE OF CALIFORNIA

Energy Resources Conservation and Development Commission

In the Matter of:	)	
	)	
The Application for Certification for the	)	Docket No. 07-AFC-5
IVANPAH SOLAR ELECTRIC	)	
GENERATING SYSTEM	)	
	)	

SIERRA CLUB'S OPENING TESTIMONY AND WITNESS AND EXHIBITS LISTS

December 18, 2009

Gloria D. Smith
Sierra Club
85 Second Street, Second floor
San Francisco, CA 94105
(415) 977-5532 Voice
(415) 977-5739 Facsimile
gloria.smith@sierraclub.org

Devorah Ancel, Law Fellow
Sierra Club
85 Second Street, Second floor
San Francisco, CA 94105
(415) 977-5721 Voice
(415) 977-5739 Facsimile
devorah.ancel@sierraclub.org

STATE OF CALIFORNIA

Energy Resources Conservation and Development Commission

In the Matter of: The Application for Certification for the *IVANPAH SOLAR ELECTRIC* *GENERATING SYSTEM*	))))))	Docket No. 07-AFC-5

SIERRA CLUB'S OPENING TESTIMONY AND WITNESS AND EXHIBITS LISTS

Pursuant to the Committee's revised scheduling order dated November 23, 2009, the Sierra Club provides the following opening testimony and witness and exhibits lists concerning the Ivanpah Solar Electric Generating System (ISEGS) evidentiary hearings scheduled for January, 2010.

The Sierra Club reserves the right to supplement or revise its testimony at any time up to and including the close of the evidentiary hearings.

I. The Sierra Club's Contested Issue: Project Alternatives

The Sierra Club has reviewed the FSA, the applicant's opening testimony and other project-related materials and disputes that the ISEGS project will comply with applicable LORS. In fact, all evidence shows that the ISEGS project will result in significant, unmitigated impacts to biological resources, such as the state and federally threatened desert tortoise and eight special-status plant species. The FSA did not comply with applicable LORS because it omitted adequate protections for all of the biological resources impacted by the proposed project. And, related, the FSA failed to fully and adequately assess the Sierra Club's proposed alternative submitted to the Commission in June 2009. Proper investigation and disclosure of the Sierra Club's alternative would have shown that many of the ISEGS' project-related impacts to biological resources could have been avoided.

II. Testimony Submitted

Testimony of Scott Cashen, Scientifically Valid Comparison of the FSA's I-15 Alternative's and Proposed Project's Impacts on Biological Resources; declaration; resume.

III. Exhibit List

Doc. No.	Author Title
600	Sierra Club's June 2009 letter proposing an alternative to the ISEGS' site configuration
601	Nussear KE, TC Esque, RD Inman, LL Gass, KA Thomas, CSA Wallace, JB Blainey, DM Miller, RH Webb. 2009. Modeling habitat of the desert tortoise (*Gopherus agassizii*) in the Mojave and parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona: U.S. Geological Survey Open-File Report 2009-1102, 18 p.
602	Collis S, HW Avery. 2000. Proximate constraints affecting the reproductive output and mortality of desert tortoises [abstract]. Proceedings of the Desert Tortoise Council 2000 Symposium. pp. 12-13.
603	Curriculum Vitae for Jim Cornett
604	Cashen, Scott. Map of areas in the Project and I-15 alternative sites surveyed for desert tortoise burrows.
605	LaRue EL, Jr. 1992. Distribution of desert tortoise sign adjacent to Highway 395, San Bernardino County, California. Proceedings of the Desert Tortoise Council 1992 Symposium. pp. 190-204.
606	Nicholson L. 1978. The effects of roads on desert tortoise populations. Proceedings of the Desert Tortoise Council 1978 Symposium. pp. 127-129.
607	Boarman WI. 2002. Threats to Desert Tortoise Populations: A Critical Review of the Literature. U.S. Geological Survey, Western Ecological Research Center. Sacramento (CA): 86 p.
608	Boarman WI, M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101.
609	CDFG. 2009 Oct 27. Comments on the Preliminary Staff Assessment and Recommendations for the Final Staff Assessment for the Ivanpah Solar Electric Generating System (CEC Docket # 07-AFC-5). Letter from Kevin Hunting, Deputy Director, Ecosystem Conservation Division to John Kessler, Program Manager, Siting, Transmission & Environmental Protection Division, California Energy Commission.
610	Thomas KA, T Keeler-Wolf , J Franklin, P Stine. 2004. Mojave Desert Ecosystem Program: Central Mojave Vegetation Mapping Database. Western Regional Center, US Geological Survey. Technical Report.

Documents Sierra Club Relied Upon, and Already Entered as Exhibits by the Applicant

- CH2MHILL. 2009 Aug 12. Supplemental Data Response, Set 2I, Ivanpah Solar Electric Generating System (07-AFC-5). Letter from John Carrier, Program Manager to John Kessler, Project Manager, California Energy Commission.

- CH2MHILL. 2008 Sep 12. Data Response, Set 2D, Ivanpah Solar Electric Generating System (07-AFC-5). Letter from John Carrier, Program Manager to Che McFarlin, Project Manager, California Energy Commission.

- Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

Dated: December 18, 2009

Respectfully submitted,

Original Signed By:

Gloria Smith, Senior Attorney
Sierra Club
85 Second Street, Second floor
San Francisco, CA 94105
(415) 977-5532 Voice
(415) 977-5739 Facsimile
gloria.smith@sierraclub.org

STATE OF CALIFORNIA

Energy Resources Conservation and
Development Commission

In the Matter of:	)	
	)	
The Application for Certification for the	)	Docket No. 07-AFC-5
IVANPAH SOLAR ELECTRIC	)	
GENERATING SYSTEM	)	
___________________________________	)	

Testimony of Scott Cashen
Ivanpah Solar Electric Facility Generating System Project

Re: Biological Resource Impacts of the Ivanpah Solar Electric Facility Generating System Project

Docket 07-AFC-5

Qualifications

Education

I have a Master's of Science Degree in Wildlife and Fisheries Science from the Pennsylvania State University, University Park. The degree program included coursework in Landscape Ecology, Biometrics, Statistics, Conservation Biology, and Wetland Ecology. For my thesis, I conducted seven seasons of independent research on avian use of restored wetlands. The U.S. Fish and Wildlife Service subsequently used my technical report as a model for other habitat restoration monitoring projects in Pennsylvania.

Work Experience

My employment experience has included work in the fields of wildlife biology, forestry, and natural resource consulting. Much of my work over the past two and a half years has involved review of environmental documents associated with development of large-scale solar energy facilities. To date, I have served as an expert witness on eight different solar projects, five of which are being sited in the Mojave Desert. I am currently entering the second year of a two-year contract I hold with the State of California to conduct surveys for the Peninsular bighorn sheep near Anza-Borrego Desert State Park. I serve as a member of the scientific review team responsible for assessing the effectiveness of the US Forest Service's implementation of the Herger-Feinstein Quincy Library Group Act.

For the past two years I have served as a self-employed consultant. I previously served as a Senior Biologist for TSS Consultants and ECORP Consulting. Other positions I have held have included conducting wildlife research for the National Park Service, the Point Reyes Bird Observatory, and the University of California. While in graduate school I served as an instructor of Wildlife Management and as a teaching assistant for a course on ornithology. A summary of my education and professional experience is attached to this testimony.

The testimony contained herein is based on my review of the environmental documents prepared for the Ivanpah Solar Electric Generating System Project ("Project"), and review of scientific literature on the biological resources known to occur in the Project area. In addition, I have conducted my own investigations and analyses on the Project's potential environmental impacts and alternatives. My testimony is based on the activities described above and the knowledge and experience I have acquired during more than 17 years of working in the field of natural resources management.

STATEMENT

I. The FSA Omitted a Scientifically-Valid Assessment of the I-15 Project Alternative

The record is clear that the proposed Project would substantially affect many sensitive plant and wildlife species, and it would eliminate a broad expanse of relatively undisturbed Mojave Desert habitat.[1] In addition to direct loss of habitat, the Project would fragment and degrade adjacent habitat, which is also relatively undisturbed.[2] In the FSA, staff discussed the alternative of moving a portion of the Project closer to the I-15 freeway (i.e., slightly east).[3] The "I-15" alternative is advantageous in that it would allow the Project to meet its objectives while remaining in the Ivanpah Valley.[4] As a result, assessment of potential impacts resulting from the I-15 alternative was the focus of my review.

Staff concluded impacts to biological resources at the I-15 alternative site would be comparable to those at proposed project location.[5] Staff's conclusion was based on the presumption that the alternative site would not reduce direct impacts to sensitive plant and wildlife species.[6]

In my opinion, the I-15 alternative location would still result in some impacts to biological resources. Importantly, however, the I-15 alternative would not have the same ecological *system-level* impacts as the proposed Project site, and its impacts to individual plant and animal species would be less severe that the proposed Project. Staff failed to consider this level of analysis in the FSA. Because the I-15 alternative is located adjacent to the freeway and the Primm Valley Golf Club, it would result in less habitat fragmentation and community-level disturbance. Habitat fragmentation and community-level disturbance are known threats to the

---

[1] [FSA] Final Staff Assessment, p. 6.2-1.
[2] *Id.*
[3] *See* FSA, p. 4-43.
[4] *Id*, p. 4-44.
[5] *Id*, p. 4-45.
[6] *Id.*

long-term viability of many plant and animal species.[7] In my opinion, reducing these threats would benefit the sensitive species known to occur in the Ivanpah Valley.

Reduction of system-level impacts does not subjugate the need to evaluate organism-level impacts or otherwise assess the overall impacts associated with each alternative. As a result, I evaluated the validity of the FSA's conclusions on impacts that would result from implementation of the I-15 alternative.

A. The FSA Devoted Insufficient Time and Resources to Site Comparisons for the I-15 Alternative

According to the FSA, a "reconnaissance" survey of the proposed project and I-15 alternative sites was conducted on August 15, 2009.[8] During the survey, a biologist examined representative samples of habitat in each of the sites.[9] The survey included examination of habitat for quality and evidence of wildlife activity.[10] In addition, the biologist rated (a) micro-relief; (b) soil texture; (c) vegetation; (d) ground cover; (e) plant diversity; (f) likelihood of desert tortoise occurrence; (g) likelihood of special-status species occurrence; (h) quality of surrounding habitat; (i) special features; and (j) overall quality of habitat for wildlife and desert tortoises.[11] The biologist took field notes, photographed the habitat, and completed evaluation forms.[12] The FSA does not identify the biologist that conducted the survey; nor does it provide the biologist's field notes, photographs, or evaluation forms.

Access to portions of both the proposed Project and I-15 alternative sites is relatively good; however, access to other portions is relatively time consuming. The two sites overlap by approximately 25 percent.[13] Given the Project would occupy approximately 4,073 acres,[14] the FSA implied that a single biologist was able to representatively sample 7,128 acres (i.e., the area occupied by the two sites) in a single day, and that that biologist was able to collect data on approximately 11 variables at each sampling location. In my opinion, adequately completing these tasks in one day is essentially impossible. Because the FSA did not specify the sampling locations or the observed variance, it is impossible to evaluate how representative the samples were. Nonetheless, given the minimal level of effort that was devoted to such a large area, few samples could have been conducted and/or the field data were hastily collected. Under either scenario, the data do not provide a reliable comparison of the two sites.

---

[7] Meffe GK, CR Carroll. 1997. Principles of Conservation Biology, 2nd edition. Sinauer Associates, Inc., Sunderland, MA.
[8] FSA, p. 4-44.
[9] *Id.*
[10] *Id.*
[11] *Id.*
[12] *Id.*
[13] *Id.*
[14] FSA, p. 6.2-8.

B. Staff Inadequately Analyzed the Relative Impacts to the Desert Tortoise in the I-15 Alternative Analysis

According to the FSA, the I-15 alternative site is located in high quality, relatively undisturbed habitat for desert tortoises, and it provides no less value to the organism than the proposed Project site.[15] In my opinion, these findings are not supported by the evidence, and the FSA omitted a scientifically valid justification for its conclusions. For example, in presenting the alternatives analysis, the FSA did not quantify or discuss several of the variables that are considered statistically significant predictors of desert tortoise habitat.[16] These include landscape surface roughness, rockiness, soil bulk density, perennial plant cover, and annual plant potential.[17] Other significant predictors (e.g., precipitation) were not properly considered. Research in the Ivanpah Valley has shown micrographic differences in rainfall and primary productivity of annual vegetation can result in significant differences in desert tortoise fecundity and mortality.[18] Information provided in the FSA indicates there are differences in average precipitation among regions of the Project and alternative sites.[19] Surveys for annual plant vegetation were not conducted on the alternative site, and the reconnaissance visit described in the FSA was conducted during the time of year (i.e., late summer) when many annual plants would not have been identifiable.

By focusing solely on habitat "quality", the FSA ignored the critical importance of distinguishing between the *physiological* (fundamental or potential) niche and *ecological* (realized or actual) niche of organisms.[20] A major problem with the FSA's oversimplification of habitat is that features measured can stay the same while use of important resources by an animal within that habitat can change—for example, changes in the species or size of prey taken by a bird foraging on shrubs.[21] The difficulty in, and need to: (a) identify constraints on exploitation of critical resources; and (b) consider critical limiting factors; has been the topic of much of the recent literature on recovery of the desert tortoise population.[22]

C. Relative Abundance of Desert Tortoises at the Project Site Compared to the I-15 Alternative Site.

Because the FSA omitted a meaningful comparison of the I-15 alternative site's impacts on desert tortoises, I led a field study that was specifically designed to attain information on tortoise resources and occupancy at the proposed Project and I-15 alternative sites. The

---

[15] *Id*, p. 4-44, 45.
[16] *See* Nussear KE, TC Esque, RD Inman, LL Gass, KA Thomas, CSA Wallace, JB Blainey, DM Miller, RH Webb. 2009. Modeling habitat of the desert tortoise (*Gopherus agassizii*) in the Mojave and parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona: U.S. Geological Survey Open-File Report 2009-1102, 18 p. (Exhibit 601)
[17] *Id.*
[18] Collis S, HW Avery. 2000. Proximate constraints affecting the reproductive output and mortality of desert tortoises [abstract]. Proceedings of the Desert Tortoise Council 2000 Symposium. pp. 12-13. (Exhibit 602)
[19] FSA, Chapter 19b, Soil and Water –Figure 2.
[20] Morrison ML, BG Marcot, and RW Mannan. 2006. Wildlife-Habitat Relationships: Concepts and Applications. 3rd ed. Washington (DC): Island Press. 493 p.
[21] *Id.*
[22] E.g., *See* Tracy CR, R Averill-Murray, W Boarman, D Delehanty, J Heaton, E McCoy, D Morafka, K Nussear, B Hagerty, P Medica. 2004. Desert Tortoise Recovery Plan Assessment. Available at: http://www.fws.gov/nevada/desert_tortoise/dtro_recover_plan_assess.html.

objectives of the study were to:

1. Collect empirical data on tortoise abundance, such that I could test whether there was a significant difference in relative abundance between the two sites.
2. Thoroughly evaluate the two sites, such that I could assess the presence, distribution, and abundance of tortoise resources and threats at the two sites.
3. Evaluate the suite of biological resources present in the region so that I could formulate an educated opinion on whether the I-15 alternative site was appropriately configured to minimize impacts to sensitive biological resources.

1. Methodology

Before collecting field data, I reviewed the FSA, Project maps, environmental documents submitted on behalf of the applicant, information provided in the California Natural Diversity Database (CNDDB), and other literature pertaining to the desert tortoise. Jim Cornett and I then developed a plan to meet the study's objectives. Mr. Cornett is the principal of JWC Ecological Consultants, the only ecological consulting firm specializing in biological surveys and impact analyses in the California deserts. Mr. Cornett has provided consulting services since 1974, he is the former Director of Natural Science at the Palm Springs Desert Museum, and he is a recognized authority on desert organisms and environments. Mr. Cornett's qualifications are presented as Exhibit 603.

a. Field Techniques

Our field survey methods replicated those performed by the applicant's consultants at the Project site, and those recommended in the U.S. Fish and Wildlife Service's protocol survey guidance for the desert tortoise.[23] Specifically, we used the line-transect method to survey each of the two sites. Before initiating the surveys, Mr. Cornett instructed a survey crew consisting of eight members of American Conservation Experience (ACE) on the techniques for locating burrows, and on the methods for distinguishing (a) tortoise burrows from those created by other species (e.g., American badger, desert kit fox); and (b) winter desert tortoise burrows from summer burrows.

The terms "burrow," "pallet," "form," "winter den," and "summer hole" have been used by other investigators to indicate cover types of both general and specific nature used by terrestrial turtles.[24] For the purpose of our study, we defined any subterranean refuge site that appeared to have been excavated and used by a desert tortoise as a "burrow". We further defined "active winter" burrows as those that showed relatively recent signs of excavation and/or use, and that had a length of at least four feet. We defined "recent summer" burrows as those that appeared to have been excavated and/or used during the 2009 activity period, but that were less than four feet in length. To estimate whether a burrow had been recently excavated and/or used, we examined the burrow to determine whether (a) it contained debris (e.g., leaf litter); (b) the

---

[23] USFWS. 2009. Preparing for any action that may occur within the range of the Mojave desert tortoise (*Gopherus agassizii*). Available at: http://www.fws.gov/ventura/speciesinfo/protocols_guidelines/.
[24] Burge BL. 1978. Physical characteristics and patterns of utilization of cover sites used by *Gopherus agassizi* in southern Nevada. Proceedings of the Desert Tortoise Council 1978, pp. 80-111.

burrow opening had spider webs or indications of weathering; (c) soil outside the burrow was compacted or showed evidence of precipitation; and (d) the burrow exhibited evidence of use by another organism (e.g., rodent, burrowing owl).

On December 6, 2009, the entire survey team traveled to the Project site so that we could begin fieldwork early the following day. The eight members of ACE were responsible for conducting the line-transect surveys. Surveys began at 0700 each day beginning on December 7, 2009. The surveys concluded on December 10, 2009, and except for the final day (which ended at 1200), surveys were conducted until dark (approximately 1730). Prior to each day of surveys, Mr. Cornett and I provided the survey team with instructions on the regions to survey, and the alignment of the transect lines (expressed in degrees on a compass). The surveyors then searched for desert tortoise burrows along the pre-assigned transect lines, and in the area between transect lines. As they walked, the surveyors used hand-held compasses and GPS units to maintain parallel transect lines and constant spacing between lines. For the first approximately five hours of surveys (conducted on the alternative site), the transect lines were spaced 15 feet apart. During that time, the group convened when anyone located a burrow. At each burrow, the group discussed their interpretation of its characteristics (e.g., organism that created it), and Mr. Cornett answered any questions. Once Mr. Cornett was confident in the groups' ability to identify desert tortoise burrows, the ACE team proceeded with transects that were spaced 30 feet apart.

Because any desert tortoises were hibernating at the time of our surveys, we used the presence of tortoise burrows as an index of relative abundance. Surveyors used GPS units to record the geographic coordinates of each active winter, and recent summer, desert tortoise burrow that was detected. They also recorded the beginning and end points of each transect line such that we had accurate data on the areas that were surveyed. Recent summer burrows were defined as ones that appeared to have been used during the summer of 2009. Surveyors also recorded field notes on each burrow that was detected. Surveyors flagged any burrows that they were unable to (a) positively identify as associated with a desert tortoise; (b) determine whether the burrow was active or inactive; or (c) distinguish whether the burrow was created during the summer or winter. Mr. Cornett and I then inspected these burrows and we made a final determination on burrow classification. We then discussed our interpretation with the group such that we collectively developed a consistent approach to burrow classification.

We walked approximately 87 miles of transect lines within the I-15 alternative site and approximately 64 miles of transect lines within the proposed Project site.[25] The protocol survey guidance suggests transects that are 30 feet apart will provide 100 percent coverage of the survey area. Because detecting tortoises and burrows is relatively more difficult than detecting burrows only, we assume our surveys covered nearly 100 percent of the respective survey areas, and that survey effort was relatively consistent among the various regions that we surveyed. Assuming 100 percent coverage, we surveyed approximately 316 acres within the alternative site and approximately 233 acres within the proposed Project site.

On the afternoon of December 7, and for the entire day on December 8, 2009, Mr. Cornett and I both walked and drove throughout the two sites to assess the tortoise resources that

[25] A map of the areas surveyed is provided as Exhibit 604.

were present. Our assessment included examination of (a) vegetation composition, distribution, and abundance; (b) vegetation community layers (e.g., shrub and sub-shrub) and structure; (c) soil characteristics; (d) different types of disturbance present within the two sites; and (e) other potential threats to the resident desert tortoise population (e.g., fire, garbage, invasive species).

b. Analysis

Research indicates desert tortoises may use some "burrows" year-round.[26] Therefore, I calculated the sum of all recent desert tortoise burrows that were detected regardless of whether the surveyor had classified the burrow as "summer" or "winter". This eliminated any error in classification and augmented the sample sizes.

I calculated the total length of transects walked at each site through use of the GPS data we collected in the field. I then conducted a Fisher exact test to determine if there was a statistically significant difference between the number of desert tortoise burrows between the two sites.

c. Results

We detected significantly more burrows on the Project site than on the I-15 site ($P < 0.01$). Forty-three recent desert tortoise burrows were detected on the Project site compared to 26 recent desert tortoise burrows on the I-15 site. **We encountered desert tortoise burrows at a frequency of 0.67 burrows/mile on the Project site, and 0.30 burrows/mile on the I-15 site.**

D. Discussion and Management Implications for Desert Tortoise

1. Other Survey Data

In the Mojave Desert, desert tortoise habitat has been characterized as having a high diversity of perennial plant species (among other variables).[27] As a result, the applicant conducted vegetation surveys to determine if the lands proposed for desert tortoise translocation (some of which are now the I-15 Alternative site) had the same shrub and succulent species composition, diversity, and richness as the Project area.[28] Results of those surveys indicated that species richness at approximately half the sampling locations that now coincide with the I-15 Alternative did not meet the California Department of Fish and Game's (CDFG) criteria that the translocation areas have comparable ecological make up as the habitat where the tortoises currently reside.[29] Both of these sampling locations are within the I-15 alternative site.[30]

---

[26] Burge BL. 1978. Physical characteristics and patterns of utilization of cover sites used by *Gopherus agassizi* in southern Nevada. Proceedings of the Desert Tortoise Council 1978, pp. 80-111.
[27] Luckenbush (1982) and others cited *in* CH2MHILL. 2009 Aug 12. Supplemental Data Response, Set 2I, Ivanpah Solar Electric Generating System (07-AFC-5). Letter from John Carrier, Program Manager to John Kessler, Project Manager, California Energy Commission.
[28] CH2MHILL. 2009 Aug 10. Supplemental Data Response, Set 2I, Ivanpah Solar Electric Generating System (07-AFC-5). Letter from John Carrier, Program Manager to John Kessler, Project Manager, California Energy Commission.
[29] *Id*. p. 8.
[30] *See* Figure BR5.2A-1 of *Id.*

Therefore, there are empirical data that the I-15 alternative site has a lower abundance of both desert tortoises and plant resources than does the Project site. These empirical data are considerably more reliable than the unsubstantiated opinion presented in the FSA's I-15 alternative analysis. The FSA did not provide any data to support the conclusion that the I-15 alternative is of equal value to the desert tortoise. The only evaluation techniques described in the FSA are those that were conducted by a single biologist during a 1-day trip to the alternative and Project sites. In my opinion, such an evaluation does not comport with recognized standards.

2. Adverse Effects of Roads on Desert Tortoise Populations

The significantly lower number of desert tortoise burrows we detected at the I-15 alternative site may be a result of the site's proximity to the highway. Negative impacts to desert tortoises from roads and highways have been well documented.[31] [32] Road kills are considered a significant source of mortality to desert tortoises. Boarman and Sazaki (1996) reported a conservative estimate of one tortoise killed per 3.3 km (2 mi) of road surveyed per year.[33] A common mitigation for the impacts of roads and highways is a barrier fence, which has been shown to be highly effective at reducing mortality in tortoises and other vertebrates in the west Mojave.[34] However, fences only increase the fragmenting effects of roads.[35] Preliminary results of an eight-year long study indicate that culverts are used by tortoises to cross highways,[36] but it is unknown whether their use is sufficient to ameliorate the fragmenting effects of fenced highways.[37]

In addition to direct mortality, roads and highways are believed to have several indirect effects on tortoise populations. Habitat fragmentation by satellite urbanization and high-density highways (e.g., I-15) may be preventing essential desert tortoise metapopulation processes and, ultimately, species recovery.[38] The presence of roads and highways may lead to increased predation on desert tortoises (and other species) by providing a travel corridor and reliable food

---

[31] LaRue EL, Jr. 1992. Distribution of desert tortoise sign adjacent to Highway 395, San Bernardino County, California. Proceedings of the Desert Tortoise Council 1992 Symposium. pp. 190-204. (Exhibit 605)
[32] Nicholson L. 1978. The effects of roads on desert tortoise populations. Proceedings of the Desert Tortoise Council 1978 Symposium. pp. 127-129. (Exhibit 606)
[33] Boarman WI, M Sazaki. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. Pages 169 - 173 in Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. G Evink, D Zeigler, P Garrett, J Berry, editors. U.S. Department of Transportation, Federal Highway Administration, Washington, DC.
[34] *Id.*
[35] Boarman WI. 2002. Threats to Desert Tortoise Populations: A Critical Review of the Literature. U.S. Geological Survey, Western Ecological Research Center. Sacramento (CA): 86 p. (Exhibit 607)
[36] Boarman WI, T Goodlett, GC Goodlett. 1998. Review of radio transmitter attachment techniques for chelonian research and recommendations for improvement. Herpet. Rev. 29:26-33.
[37] Boarman WI, M Sazaki. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. Pages 169 - 173 in Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. G Evink, D Zeigler, P Garrett, J Berry, editors. U.S. Department of Transportation, Federal Highway Administration, Washington, DC.
[38] Tracy CR, R Averill-Murray, W Boarman, D Delehanty, J Heaton, E McCoy, D Morafka, K Nussear, B Hagerty, P Medica. 2004. Desert Tortoise Recovery Plan Assessment. Available at: http://www.fws.gov/nevada/desert_tortoise/dtro_recover_plan_assess.html.

source.[39] For example, common ravens, which are predators on juvenile tortoises, are known for cruising road edges.[40]

Roads and highways are a vector for introduced plant and animal species, which may affect desert tortoises and other native species in adjacent areas.[41] Other potentially harmful activities that likely occur in greater numbers near roads include: mineral exploration, illegal dumping of garbage and toxic wastes, release of ill tortoises, vandalism, handling and harassing of tortoises, illegal collection of tortoises, and anthropogenic fire.[42]

The numerous direct and indirect adverse effects of roads and highways may drain desert tortoise populations two miles or more away.[43] Research studies conducted by Boarman and Sazaki (2006); Nicholson (1978); Von Seckendorff Hoff and Marlow (1997); and other researchers have detected a statistically significant relationship between road distance and presence of desert tortoise sign.[44] Our results are consistent with these studies.

In sum, numerous studies have demonstrated roads and highways have several adverse impacts on desert tortoise populations. Many of these impacts result in habitat degradation, which may significantly reduce habitat quality for tortoises.[45] The cumulative effects of habitat loss and degradation have been implicated as causes in the extirpation and drastic reductions in tortoise populations in several locations.[46]

The results of several research studies, and our site-specific data, suggest I-15 has adverse effects on the local tortoise population. The proposed Project location would contribute to the cumulative effects of these adverse effects; it conflicts with principles of conservation biology; and it is in direct opposition to the Desert Tortoise Recovery Plan.[47] Therefore, it is my professional opinion that there is ample evidence suggesting locating the Project adjacent to the freeway would cause less impacts to the desert tortoise (and other sensitive wildlife) than the currently proposed location.

---

[39] Boarman WI, M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101. (Exhibit 608)
[40] Boarman WI. 2002. Threats to Desert Tortoise Populations: A Critical Review of the Literature. U.S. Geological Survey, Western Ecological Research Center. Sacramento (CA): 86 p. (Exhibit 607)
[41] Boarman WI, M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101. (Exhibit 608)
[42] Boarman WI. 2002. Threats to Desert Tortoise Populations: A Critical Review of the Literature. U.S. Geological Survey, Western Ecological Research Center. Sacramento (CA): 86 p. (Exhibit 607)
[43] *Id.*
[44] *See* Boarman WI, M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101. (Exhibit 608)
[45] Boarman WI. 2002. Threats to Desert Tortoise Populations: A Critical Review of the Literature. U.S. Geological Survey, Western Ecological Research Center. Sacramento (CA): 86 p. (Exhibit 607)
[46] *Id.*
[47] U.S. Fish and Wildlife Service. 1994. Desert Tortoise (Mojave Population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon.

3. My Findings are Consistent with the Recommendation of Expert Agency, California Department of Fish And Game.

In response to the Preliminary Staff Assessment (PSA), the California Department of Fish and Game (CDFG) requested that the FSA's conclusions be supported by "the best available data for impacts to desert tortoise and plant species of concern that clearly indicate a comparable or at least higher level of impact to those resources than they are being impacted by the Project."[48] The CDFG further recommended that the FSA present a "full analysis of alternate siting locations and scenarios…given the fact the current Project area is excellent tortoise habitat [and]…lower quality habitat is clearly within the range to potentially reduce the overall Project impacts to endangered and sensitive species."[49] The FSA did not heed CDFG's recommendations. Below are examples of how the FSA was inconsistent with CDFG's recommendations.

1. As shown in this testimony, the best available data indicate highways have a significant adverse impact on desert tortoises, and that locating the Project adjacent to the highway would likely have considerably less of an impact on the species than the proposed location.
2. The FSA concluded the I-15 alternative site "is all high quality tortoise habitat"; "there is very little difference in value for desert tortoise [over the proposed site]; and "it is difficult to value one [site] higher than the other."[50] These conclusions are not supported by the best available data, and they do not incorporate "full analysis." The FSA failed to report that no desert tortoises were reported within the action area during the development of the Primm Valley Golf Club.[51] The Primm Valley Golf Club is located immediately adjacent to the I-15 alternative site; it occupies a similar range of elevations as the I-15 site; and similar to the I-15 site, it is at least partially within the zone characterized as a "sink" for tortoises because of its proximity to the highway. Furthermore, a research study conducted in the Ivanpah Valley demonstrated that availability of desert tortoise food resources increased with higher elevation; tortoise reproductive output was greater; and mortality was lower, at the higher elevation along a short elevational and rainfall gradient.[52]
3. The FSA erroneously stated: "surveys conducted in 2007 identified 20 individual desert tortoise within the area that would be eliminated from the project under this [I-15] alternative."[53] Surveys conducted for the Project detected five tortoises within the "Ivanpah 1" project area and an additional tortoise 1,200 feet east of the "Ivanpah 1"

---

[48] CDFG. 2009 Oct 27. Comments on the Preliminary Staff Assessment and Recommendations for the Final Staff Assessment for the Ivanpah Solar Electric Generating System (CEC Docket # 07-AFC-5). Letter from Kevin Hunting, Deputy Director, Ecosystem Conservation Division to John Kessler, Program Manager, Siting, Transmission & Environmental Protection Division, California Energy Commission. (Exhibit 609)
[49] *Id.*
[50] FSA, p. 4-45.
[51] CH2MHILL. 2008 Sep 12. Data Response, Set 2D, Ivanpah Solar Electric Generating System (07-AFC-5). Letter from John Carrier, Program Manager to Che McFarlin, Project Manager, California Energy Commission.
[52] Collis S, HW Avery. 2000. Proximate constraints affecting the reproductive output and mortality of desert tortoises [abstract]. Proceedings of the Desert Tortoise Council 2000 Symposium. pp. 12-13. (Exhibit 602)
[53] FSA, p. 4-44.

boundary.[54] Assuming the I-15 alternative site encompasses the Ivanpah 1 site and all land to the east (to I-15), survey data have only demonstrated the presence of six tortoises within the alternative project area.

II. The Proposed Project's Impacts on Sensitive Plant Species

The FSA provided very little evidence to support its conclusion that the I-15 alternative would have comparable impacts to sensitive plant species. Specifically, staff concluded that "[t]he I-15 alternative would not reduce the impact to special-status plant species that would be directly impacted by construction of the proposed ISEGS project. A good diversity of plants exists at both sites."[55] Staff supports its conclusion by stating "[t]he plant associations, associated soils, hydrology and microtopography associated with the rare plants at ISEGS site are all present in the I-15 alternative, particularly the portion of the alternative above the 2,750-foot elevation contour, at which point the diversity and microtopography improves and the vegetation reflects the same species composition and structure associated with the ISEGS site rare plant occurrences."[56]

In my opinion, the FSA's conclusion on impacts to sensitive plant species is not valid for the following reasons:

1. Staff made <u>no effort</u> to identifying the composition, distribution, and abundance of sensitive botanical resources on the I-15 alternative site. In fact, the FSA supports the presumption that a valid conclusion cannot be made in stating: "[w]ithout protocol rare plant surveys, it is not possible to compare in detail the alternative to the proposed project."[57]
2. According to the FSA, "[o]ver approximately 60% or more of the I-15 alternative offers good to excellent habitat for the same suite of rare plants found at ISEGS and many or all of the same rare plant taxa found at the ISEGS site are expected to occur on I-15 Alt as well."[58] If this is true, it still suggests that approximately <u>40%</u> of the I-15 alternative site does not offer the same level of quality habitat as the Project (ISEGS) site. The FSA supported this conclusion by stating "[b]elow that point [2,750 feet in elevation], nearer to the Primm Valley Golf Course, the topography [of the I-15 alternative] flattens out, the habitat lacks the microtography and soil textures upon which many of the rare plants depend, and the overall plant diversity is reduced, and important indicators such as the cacti and succulent component drop out of the species composition."[59] The FSA has demonstrated the I-15 alternative is feasible, and that approximately 40% of the alternative site is likely to posses fewer sensitive biological resources than the proposed Project site. Importantly, further modifications to the alternative's footprint could result in an even greater percentage of lands with fewer sensitive biological resources.
3. The FSA's statement that 60% of the I-15 site has the same plant species composition

---

[54] PSA, Figure 5.2-9.
[55] FSA, p. 4-45.
[56] *Id*.
[57] *Id.*
[58] *Id.*
[59] *Id.*

and structure associated with the ISEGS' site rare plant occurrences is not sufficient scientific evidence to support a conclusion that impacts to sensitive plant species would be the same. In the Mojave Desert, vegetation composition can change dramatically over short distances as a function of terrain position.[60] Furthermore, the microenvironment conditions along edges (e.g., the boundary between I-15 and native habitat) are known to be different than in the interior (e.g., Project site). These include temperature, humidity, light, chemical inputs, and other variables.[61] Each of these variables, as well as their synergistic effects, may have a strong influence on the presence and distribution of individual plant species.[62] Therefore, even if the elevations, soils, climate, and hydrology (among other variables) of the I-15 alternative site were identical to the proposed Project site, plant composition would likely differ due to the site's location adjacent to the highway (a sharp edge).

4. Of the five sensitive plant species occurring on the Project site, and for which staff has concluded impacts would be significant, the applicant's consultant has reported two (nine-awned pappus grass and Mojave milkweed) occupy <u>distinctive</u> microhabitats.[63] The FSA did not demonstrate that these microhabitats are present (or as equally abundant) within the I-15 alternative site. Conversely, there is scientific evidence that suggests the I-15 alternative site does not contain suitable habitat for several of the sensitive plant species known to occur on the Project site. I provide this evidence in the subsequent section.

A. Habitat Suitability for Sensitive Plant Species at the I-15 Alternative Site

This section provides a review of literature describing the habitat requirements (or associations) of several of the sensitive plant species known to occur on the Project site. Eight special-status plant species would be directly impacted by construction of the Project at the proposed location.[64] Of these, the FSA concludes impacts to five species would be significant according to CEQA guidelines because the Project would eliminate a substantial portion of their documented occurrences in the state.[65] Staff further concluded impacts to at least two of the species would remain significant even after the FSA's proposed impact avoidance and minimization measures.[66]

Topographic position (elevation, slope angle, slope aspect) exerts a strong influence on plant distributions at a finer spatial scale than bioclimatic gradients. This is important in the

---

[60] Thomas KA, T Keeler-Wolf , J Franklin, P Stine. 2004. Mojave Desert Ecosystem Program: Central Mojave Vegetation Mapping Database. Western Regional Center, US Geological Survey. Technical Report [Online] Available at: http://www.dfg.ca.gov/biogeodata/vegcamp/pdfs/VegMappingRpt_Central_Mojave_Vegetation_Database.pdf. (Exhibit 610).
[61] Boarman WI. 2002. Threats to Desert Tortoise Populations: A Critical Review of the Literature. U.S. Geological Survey, Western Ecological Research Center. Sacramento (CA): 86 p. (Exhibit 607)
[62] *Id.*
[63] Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.
[64] FSA, p. 6.2-1.
[65] *Id.*
[66] *Id.*

Mojave, where vegetation composition can change dramatically over short distances as a function of terrain position.[67] The FSA discussed the correlation between elevation and the occurrence of sensitive plant species at the Project and alternative site.[68] However, the FSA provided erroneous information on the elevations within the proposed Project area. The FSA's conclusion on the similarity of impacts to sensitive plant species between the two sites may have been based on this erroneous elevation data. Elevations in the Project area range from approximately 3,500 feet[69] [70] in the northwest corner (not 3,150 feet as reported in the FSA)[71] to approximately 2,850 feet in the southeast corner. The FSA did not provide the elevations of the I-15 alternative site, although it indicates approximately 40 percent of the alternative site is below 2,750 feet in elevation.[72] Using topographic maps, I estimated approximately 85 percent of the alternative site is located below 3,000 feet in elevation.

1. Plant Species for which the FSA Concluded Significant Impacts

a. Mojave Milkweed

Mojave milkweed occurs in Mojavean desert scrub and pinyon and juniper woodland communities.[73] Within these communities, it occurs in washes and on dry slopes from about 3,000 to 5,100 feet in elevation.[74] The FSA did not provide a detailed map of the I-15 alternative. However, it appears that most of the I-15 alternative is located below 3,000 feet in elevation.[75] Furthermore, the FSA listed *Atriplex* scrub as one of the two dominant habitat types present on the I-15 alternative site.[76] Mojave milkweed is not reported to be associated with *Atriplex* scrub.[77] Given this information, the I-15 alternative is likely to have considerably less of an impact on Mojave milkweed.

b. Nine-awned Pappus Grass

Nine-awned pappus grass occurs on rocky slopes, crevices, and calcareous soils in desert

---

[67] Thomas KA, T Keeler-Wolf , J Franklin, P Stine. 2004. Mojave Desert Ecosystem Program: Central Mojave Vegetation Mapping Database. Western Regional Center, US Geological Survey. Technical Report [Online] Available at: http://www.dfg.ca.gov/biogeodata/vegcamp/pdfs/VegMappingRpt_Central_Mojave_Vegetation_Database.pdf. (Exhibit 610)

[68] *See* FSA, p. 4-45.

[69] *See* US Geological Survey. 1985. Ivanpah Lake [7.5 minute topographic map quadrangle]. Denver: US Dept of Interior Geological Survey.

[70] *See* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[71] FSA, p. 6.2-9.

[72] FSA, p. 4-45.

[73] CNPS. 2008. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[74] Baldwin et al. 2002. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[75] US Geological Survey. Ivanpah Lake and Mineral Hill [7.5 minute topographic map quadrangles]. Denver: US Dept of Interior Geological Survey.

[76] FSA, p. 4-44.

[77] California Natural Diversity Database. 2009. Rarefind [computer program]. Version 3.1.0. Nov 1, 2009. Sacramento (CA): Wildlife & Habitat Data Analysis Branch. California Department of Fish and Game.

woodlands.[78] In Ivanpah Valley, it occurs within Mojave Creosote Bush Scrub plant community located on the Ivanpah Valley alluvial fan, at 2,900 to 3,400 feet elevation.[79] Much of the I-15 alternative site is outside of the known elevation range for this species. Additionally, nine-awned pappus grass is not reported to be associated with the *Atriplex* scrub plant community that occurs on the alternative site.[80] Given this information, the I-15 alternative is likely to have considerably less of an impact on nine-awned pappus grass.

c. Desert Pincushion

Details on the distribution of desert pincushion in California are imperfectly understood.[81] The *Jepson Desert Manual* describes its habitat as limestone soils from approximately 3,000 to 7,000 feet elevation.[82] However, the California Native Plant Society (CNPS) *Online Inventory* describes its habitat as Joshua tree woodland, Mojavean desert scrub, and pinyon-juniper woodland at elevations from 150 to 4,500 feet.[83] The applicant's consultant concluded the lower elevation limit of 150 feet is probably an error.[84] Because the distribution of desert pincushion in California is imperfectly understood, the FSA had no justification for its conclusion that the I-15 alternative would have similar impacts as the proposed project location. However, assuming the lower elevation limit provided by the CNPS is an error, much of the I-15 alternative site is outside of the currently known elevation range for the species.

d. Parish's Club-cholla

There is conflicting information on habitat associated with occurrences of Parish's club-cholla. The *Jepson Desert Manual* describes its habitat as sandy flats from 2,950 to 3,935 feet elevation.[85] However, the CNPS *Online Inventory* indicates it occurs in sandy areas within Mojavean desert scrub, Sonoran desert scrub, and Joshua tree woodland communities. The CNPS reports the species has an elevation range of 985 to 5,000 feet.[86] The lowest known occurrence reported in the CNDDB is 2,950 feet (which would be consistent with the *Jepson Desert Manual*).[87] Assuming the lower elevation limit provided by the CNPS is an error, much

---

[78] Baldwin et al. 2002. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[79] Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[80] California Natural Diversity Database. 2009. Rarefind [computer program]. Version 3.1.0. Nov 1, 2009. Sacramento (CA): Wildlife & Habitat Data Analysis Branch. California Department of Fish and Game.

[81] Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[82] Baldwin et al. 2002. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[83] CNPS. 2008. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[84] Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[85] Baldwin et al. 2002. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[86] CNPS. 2008. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.

[87] California Natural Diversity Database. 2009. Rarefind [computer program]. Version 3.1.0. Nov 1, 2009. Sacramento (CA): Wildlife & Habitat Data Analysis Branch. California Department of Fish and Game.

of the I-15 alternative site is outside of the currently known elevation range for the species.

e. Rusby's Desert Mallow

There is conflicting information on habitat associated with occurrences of Rusby's desert mallow. The *Jepson Desert Manual* describes its habitat as desert scrub from 3,900 to 4,500 feet in elevation.[88] However, the CNPS *Online Inventory* indicates it occurs on Mojavean desert scrub and Joshua tree woodland from 2,925 to 4,500 feet.[89] Under either scenario, much of the I-15 alternative site is outside of the currently known elevation range for the species.

2. Species for which the FSA Concluded Less than Significant Impacts

a. Small-flowered Androstephium

The FSA concluded that Project impacts to small-flowed androstephium would be less than significant. According to the FSA, numerous new occurrences of small-flowered androstephium have been found in recent years during surveys conducted for other development projects.[90] For this reason (combined with a larger total number of documented occurrences), staff considers the Project effects to this species not significant under CEQA.[91]

The FSA provided a discussion of cumulative impacts analysis and its context in the regulatory environment:

> "A project may result in a significant adverse cumulative impact where its effects are cumulatively considerable. "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects (Cal. Code Regs, tit. 14, § 15130). Cumulative impacts must be addressed if the incremental effect of a project, combined with the effects of other projects is "cumulatively considerable" (14 Cal Code Regs §15130(a)). Such incremental effects are to be "viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects" (14 Cal Code Regs §15164(b)(1))."[92]

The FSA did not consider the cumulative impacts of the Project on the continued viability of small-flowered androstephium in California. Of the 82 known occurrences reported in the CNDDB, 70 (85%) are threatened by proposed development projects.[93] These include nearly all of the "[m]any new occurrences …found in recent years" used in staff's justification.[94] [95]

---

[88] Baldwin et al. 2002. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.
[89] CNPS. 2008. Cited *in* Garcia and Associates. 2008. Technical Report: Botanical Resources of the Ivanpah Solar Electric Generating System.
[90] FSA, p. 6.2-37.
[91] *Id.*
[92] FSA, p. 6.2-66,67.
[93] California Natural Diversity Database. 2009. Rarefind [computer program]. Version 3.1.0. Nov 1, 2009. Sacramento (CA): Wildlife & Habitat Data Analysis Branch. California Department of Fish and Game.
[94] *Id.*

The FSA further justified the conclusion that the Project will result in less-than-significant impacts to small-flowered androstephium with the assertion that the Project area includes only a very small portion of the species' total distribution in California.[96] The FSA's conclusion appears to contradict CEQA guidelines, which advise lead agencies to address impacts to locally unique botanical resources regardless of their status elsewhere in the state.[97] Outside of the Project area, the next closest occurrence of small-flowered androstephium is approximately 31 miles away.[98] Therefore, the potential elimination of all known occurrences of small-flowered androstephium within the Ivanpah Valley should be considered a significant impact under CEQA.

III. Conclusion

Based on my review of the literature, Project-related documents, and the FSA, I have concluded that impacts to the state and federally threatened desert tortoise would be reduced by selection of the I-15 alternative site. My conclusion is supported by the results of my site-specific field study, which identified a statistically significant greater number of desert tortoise burrows on the Project site than on the I-15 alternative site. Although the timing of my study prevented scientific study of other taxa (e.g., birds, plants), my qualitative field observations have led me to conclude selection of the I-15 alternative site would reduce impacts to other sensitive species known to occur in the Project region. This conclusion was based on (a) the lower diversity (structural and species) of plant resources; and (b) the greater number of anthropogenic disturbances within the I-15 alternative site.

Through my review, I also have concluded the I-15 alternative site is unlikely to have the same magnitude of impacts to sensitive botanical resources as the currently proposed Project area. My conclusion is based on a thorough literature review, and many of the same reasons provided above.

The FSA did not define the precise boundaries of the I-15 alternative site. As a result, the site assessment that Jim Cornett and I conducted encompassed areas that we believed extended beyond the alternative site's boundaries. Our assessment led us to two conclusions that I believe are important to convey to the Commission:

1. The southern portion of the alternative site (i.e., near Nipton Road) posses an extremely high diversity and abundance of plant and animal resources that should be avoided by the Project.
2. There are opportunities to reconfigure the alternative site's footprint so that impacts to sensitive biological resources are further reduced. I encourage staff to explore additional site configurations that may further minimize (or eliminate) impacts to sensitive biological resources. For example, staff should explore the possibility of

---

[95] FSA, p. 6.2-19.
[96] *Id.*
[97] CEQA §15125 (c)
[98] California Natural Diversity Database. 2009. Rarefind [computer program]. Version 3.1.0. Nov 1, 2009. Sacramento (CA): Wildlife & Habitat Data Analysis Branch. California Department of Fish and Game.

extending the alternative site slightly west and/or north in order to eliminate impacts to resources in the vicinity of the Clark Mountain Range.

Scott Cashen, M.S.

Senior Biologist / Forest Ecologist

3264 Hudson Avenue, Walnut Creek, CA 94597. (925) 256-9185. scottcashen@gmail.com

In his 17 years in the profession, Scott Cashen has consulted on projects pertaining to wildlife and fisheries ecology, avian biology, wetland restoration, and forest management. Because of his varied experience, Mr. Cashen is knowledgeable of the link between the various disciplines of natural resource management, and he is a versatile scientist.

Mr. Cashen's employment experience includes work as an expert witness, wildlife biologist, consulting forester, and instructor of Wildlife Management. He has worked throughout California, and he is knowledgeable of the different terrestrial and aquatic species and habitats present in the state.

Mr. Cashen is an accomplished birder and is able to identify bird species by sight and sound. His knowledge has enabled him to survey birds throughout the United States and instruct others on avian identification. Mr. Cashen's research on avian use of restored wetlands is currently being used by the United States Fish and Wildlife Service to design wetlands for specific "target" species, and as a model for other restored wildlife habitat monitoring projects in Pennsylvania. In addition to his bird experience, Mr. Cashen has surveyed for carnivores, bighorn sheep, and other mammals; special-status amphibian species; and various fish species.

PROFESSIONAL EXPERIENCE

Litigation Support / Expert Witness

Mr. Cashen serves as the biological resources expert for the San Francisco law firm of Adams Broadwell Joseph & Cardozo. He is responsible for reviewing CEQA/NEPA documents, assessing biological resource issues, preparing written comments, providing public testimony, and interfacing with public resource agencies.

REPRESENTATIVE EXPERIENCE

- <u>Victorville 2 Solar-Gas Hybrid Power Project</u>: Victorville, CA (338-acre natural gas and solar energy facility) – Review of CEQA equivalent documents and preparation of written documents.
- <u>Avenal Energy Power Plant</u>: Avenal, CA (148-acre natural gas facility) – Review of CEQA equivalent documents and preparation of written documents.
- <u>Ivanpah Solar Electric Generating System</u>: Ivanpah, CA (3700-acre solar facility) – Review of CEQA equivalent documents and preparation of written documents.
- <u>Carrizo Energy Solar Farm</u>: San Luis Obispo County, CA (640-acre solar energy facility) – Review of CEQA equivalent documents. Preparation of data requests, comments on Preliminary Staff Assessment, comments on wildlife corridor model (CEQA equivalent

documents).

- Live Oak Master Plan: Hanford, CA (390-acre housing development) – Review of CEQA documents and preparation of comment letter.
- Rollingwood: Vallejo, CA (214-unit housing development) – Review of CEQA documents and preparation of comment letter.
- Columbus Salame: Fairfield, CA (430,000 ft^2 food processing plant) – Review of CEQA documents and preparation of comment letter.
- Concord Naval Weapons Station: Concord, CA (5028-acre redevelopment) – Review of CEQA documents, preparation of comment letters, and provision of public testimony at County hearings.
- Chula Vista Bayfront Master Plan: Chula Vista, CA (556-acre development) – Review of CEQA documents and preparation of comment letter.
- Beacon Solar Energy Project: California City, CA (2012-acre solar facility) – Review of CEQA equivalent and NEPA documents. Preparation of data requests, comments on Preliminary Staff Assessment, comments on Incidental Take Permit Application. Expert witness providing testimony at California Energy Commission hearings.
- Solar One Power Project: San Bernardino County, CA (8230-acre solar facility) – Review of CEQA equivalent and NEPA documents and preparation of data requests. Expert witness providing testimony at California Energy Commission hearings.
- Solar Two Power Project: Imperial County, CA (6500-acre solar facility) – Review of CEQA equivalent and NEPA documents. Preparation of data requests and other documents for case record. Expert witness providing testimony at California Energy Commission hearings.
- Alves Ranch: Pittsburgh, CA (320-acre housing development) – Review of CEQA documents.
- Roddy Ranch: Antioch, CA (640-acre housing and hotel development) – Review of CEQA documents and preparation of comment letter.
- Aviano: Antioch, CA (320-acre housing development) – Review of CEQA documents.
- Western GeoPower Power Plant and Steamfield: Geyserville, CA (887-acre geothermal facility) – Review of CEQA documents and preparation of comment letter.
- San Joaquin Solar I & II: Fresno County, CA (640-acre hybrid power plant) – Review of CEQA equivalent documents and preparation of data requests.
- Sprint-Nextel Tower: Walnut Creek, CA (communications tower in open space preserve) - Review of project documents and preparation of comment letter.

Project Management

Mr. Cashen has managed several large-scale and high profile natural resources investigations. High profile projects involving multiple resources often require consideration of differing viewpoints on how resources should be managed, and they are usually subject to intense scrutiny. Mr. Cashen is accustomed to these challenges, and he is experienced in facilitating the collaborative process to meet project objectives. In addition, the perception of high profile projects can be easily undermined if inexcusable mistakes are made. To prevent this, Mr. Cashen bases his work on solid scientific principles and proven sampling designs. He also solicits input from all project stakeholders, and provides project stakeholders with regular feedback on project progress. Mr. Cashen's educational and project background in several different natural resource disciplines enable him to consult on multiple natural resources simultaneously and address the many facets of contemporary land management in a cost-effective manner.

REPRESENTATIVE EXPERIENCE

- Forest health improvement projects – Biological Resources *(CDF: San Diego and Riverside Counties)*
- San Diego Bark Beetle Tree Removal Project – Biological Resources, Forestry, and Cultural Resources *(San Diego Gas & Electric: San Diego Co.)*
- San Diego Bark Beetle Tree Removal Project - Forestry *(San Diego County/NRCS)*
- Mather Lake Resource Management Study and Plan – Biological Resources, Hydrology, Soils, Recreation, Public Access, CEQA compliance, Historic Use *(Sacramento County: Sacramento)*
- "KV" Spotted Owl and Northern Goshawk Inventory *(USFS: Plumas NF)*
- Amphibian Inventory Project *(USFS: Plumas NF)*
- San Mateo Creek Steelhead Restoration Project – TES species, Habitat Mapping, Hydrology, Invasive Species Eradication, Statistical Analysis *(Trout Unlimited and CA Coastal Conservancy: Orange County)*
- Hillslope Monitoring Project – Forest Practice Research *(CDF: throughout California)*
- Placer County Vernal Pool Study – Plant and Animal Inventory, Statistical Analysis *(Placer County: throughout Placer County)*
- Weidemann Ranch Mitigation Project – Mitigation Monitoring and Environmental Compliance *(Toll Brothers, Inc.: San Ramon)*
- Delta Meadows State Park Special-status Species Inventory – Plant and Animal Species Inventory, Special-status Species *(CA State Parks: Locke)*
- Ion Communities Biological Resource Assessments – Biological Resource Assessments *(Ion Communities: Riverside and San Bernardino Counties)*
- Del Rio Hills Biological Resource Assessment – Biological Resource Assessments *(The Wyro Company: Rio Vista)*

Biological Resources

Mr. Cashen has a diverse background in biology. His experience includes studies of a variety of fish and wildlife species, and work in many of California's ecosystems. Mr. Cashen's specialties include conducting comprehensive biological resource assessments, habitat restoration, species inventories, and scientific investigations. Mr. Cashen has led investigations on several special-status species, including ones focusing on the foothill yellow-legged frog, mountain yellow-legged frog, steelhead, burrowing owl, California spotted owl, northern goshawk, willow flycatcher, and forest carnivores. Mr. Cashen was responsible for the special-status species inventory of Delta Meadows State Park, and for conducting a research study for Placer County's Natural Community Conservation Plan.

REPRESENTATIVE EXPERIENCE

Avian

- <u>Study design and Lead Investigator</u> - Delta Meadows State Park Special-status Species Inventory *(CA State Parks: Locke)*
- <u>Study design and lead bird surveyor</u> - Placer County Vernal Pool Study *(Placer County: throughout Placer County)*
- <u>Surveyor</u> - Willow flycatcher habitat mapping *(USFS: Plumas NF)*
- <u>Independent surveyor</u> - Tolay Creek, Cullinan Ranch, and Guadacanal Village restoration projects *(Ducks Unlimited/USGS: San Pablo Bay)*
- <u>Study design and Lead Investigator</u> - Bird use of restored wetlands research *(Pennsylvania Game Commission: throughout Pennsylvania)*
- <u>Study design and surveyor</u> - Baseline inventory of bird species at a 400-acre site in Napa County *(HCV Associates: Napa)*
- <u>Surveyor</u> - Baseline inventory of bird abundance following diesel spill *(LFR Levine-Fricke: Suisun Bay)*
- <u>Study design and lead bird surveyor</u> - Green Valley Creek Riparian Restoration Site *(City of Fairfield: Fairfield, CA)*
- <u>Surveyor</u> - Burrowing owl relocation and monitoring of artificial habitat *(US Navy: Dixon, CA)*
- <u>Surveyor</u> - Pre-construction raptor and burrowing owl surveys *(various clients and locations)*
- <u>Surveyor</u> - Backcountry bird inventory *(National Park Service: Eagle, Alaska)*
- <u>Lead surveyor</u> - Tidal salt marsh bird surveys (*Point Reyes Bird Observatory: throughout Bay Area*)

Amphibian

- Crew Leader - Red-legged frog, foothill yellow-legged frog, and mountain yellow-legged frog surveys *(USFS: Plumas NF)*
- Surveyor - Foothill yellow-legged frog surveys *(PG&E: North Fork Feather River)*
- Surveyor - Mountain yellow-legged frog surveys *(El Dorado Irrigation District: Desolation Wilderness)*
- Crew Leader - Bullfrog eradication *(Trout Unlimited: Cleveland NF)*

Fish and Aquatic Resources

- Surveyor - Hardhead minnow and other fish surveys *(USFS: Plumas NF)*
- Surveyor - Weber Creek aquatic habitat mapping (*El Dorado Irrigation District: Placerville, CA*)
- Surveyor - Green Valley Creek aquatic habitat mapping *(City of Fairfield: Fairfield, CA)*
- GPS Specialist - Salmonid spawning habitat mapping *(CDFG: Sacramento River)*
- Surveyor - Fish composition and abundance study (*PG&E: Upper North Fork Feather River and Lake Almanor*)
- Crew Leader - Surveys of steelhead abundance and habitat use *(CA Coastal Conservancy: Gualala River estuary)*
- Crew Leader - Exotic species identification and eradication *(Trout Unlimited: Cleveland NF)*

Mammals

- Principal Investigator – Peninsular bighorn sheep resource use and behavior study (*California State Parks: Freeman Properties*)
- Scientific Advisor – Red Panda survey and monitoring methods. Study on red panda occupancy and abundance in eastern Nepal *(The Red Panda Network: CA and Nepal)*
- Surveyor - Forest carnivore surveys *(University of CA: Tahoe NF)*
- Surveyor - Relocation and monitoring of salt marsh harvest mice and other small mammals *(US Navy: Skagg's Island, CA)*

Natural Resource Investigations / Multiple Species Studies

- Scientific Review Team Member – Member of the science review team assessing the effectiveness of the US Forest Service's implementation of the Herger-Feinstein Quincy Library Group Act.
- Lead Consultant - Baseline biological resource assessments and habitat mapping for CDF management units *(CDF: San Diego, San Bernardino, and Riverside Counties)*
- Biological Resources Expert – Peer review of CEQA/NEPA documents (*Adams Broadwell Joseph & Cardoza: California)*

- Lead Consultant - Pre- and post harvest biological resource assessments of tree removal sites *(SDG&E: San Diego County)*
- Crew Leader - T&E species habitat evaluation for BA in support of a steelhead restoration plan *(Trout Unlimited: Cleveland NF)*
- Lead Investigator - Resource Management Study and Plan for Mather Lake Regional Park *(County of Sacramento: Sacramento, CA)*
- Lead Investigator - Wrote Biological Resources Assessment for 1,070-acre Alfaro Ranch property *(Yuba County, CA)*
- Lead Investigator - Wildlife Strike Hazard Management Plan *(HCV Associates: Napa)*
- Lead Investigator - Del Rio Hills Biological Resource Assessment *(The Wyro Company: Rio Vista, CA)*
- Lead Investigator – Ion Communities project sites (*Ion Communities: Riverside and San Bernardino Counties*)
- Surveyor – Tahoe Pilot Project: CWHR validation *(University of California: Tahoe NF)*

Forestry

Mr. Cashen has five years of experience working as a consulting forester on projects throughout California. During that time, Mr. Cashen has consulted with landowners and timber harvesters on best forest management practices; and he has worked on a variety of forestry tasks including selective tree marking, forest inventory, harvest layout, erosion control, and supervision of logging operations. Mr. Cashen's experience with many different natural resources enable him to provide a holistic approach to forest management, rather than just management of timber resources.

REPRESENTATIVE EXPERIENCE

- Lead Consultant - CDF fuels treatment projects *(CDF: San Diego, Riverside, and San Bernardino Counties)*
- Lead Consultant and supervisor of harvest activities – San Diego Gas and Electric Bark Beetle Tree Removal Project *(SDG&E: San Diego)*
- Crew Leader - Hillslope Monitoring Program *(CDF: throughout California)*
- Consulting Forester – Inventory and selective harvest projects *(various clients throughout California)*

EDUCATION / SPECIAL TRAINING

M.S. Wildlife and Fisheries Science, The Pennsylvania State University (1998)

B.S. Resource Management, The University of California-Berkeley (1992)
Forestry Field Program, Meadow Valley, California, Summer (1991)

PERMITS
U.S. Fish and Wildlife Service Section 10(a)(1)(A) Recovery Permit for the Peninsular bighorn sheep

CA Department of Fish and Game Scientific Collecting Permit

PROFESSIONAL ORGANIZATIONS / ASSOCIATIONS
The Wildlife Society

Society of American Foresters

Mt. Diablo Audubon Society

OTHER AFFILIATIONS
Scientific Advisor and Grant Writer – *The Red Panda Network*

Scientific Advisor – *Mt. Diablo Audubon Society*

Grant Writer – *American Conservation Experience*

Land Committee Member – *Save Mt. Diablo*

TEACHING EXPERIENCE
Instructor: Wildlife Management, The Pennsylvania State University, 1998

Teaching Assistant: Ornithology, The Pennsylvania State University, 1996-1997

Declaration of Scott Cashen
Ivanpah Solar Electric Generating System Project

Docket 07-AFC-5

I, Scott Cashen, declare as follows:

1) I am an independent biological resources consultant. I have been self-employed for the past two years. Prior to starting my own business I was the Senior Biologist for TSS Consultants.

2) I hold a Master's degree in Wildlife and Fisheries Science. My relevant professional qualifications and experience are set forth in the attached testimony and are incorporated herein by reference.

3) I prepared the testimony attached hereto and incorporated herein by reference, relating to the biological resource impacts of the Ivanpah Solar Electric Generating System Project.

4) I prepared the testimony and map attached hereto and incorporated herein by reference relating to the distribution of solar energy generation infrastructure in San Bernardino County.

5) It is my professional opinion that the attached testimony and map are true and accurate with respect to the issues that they address.

6) I am personally familiar with the facts and conclusions described within the attached testimony and map, and if called as a witness, I could testify competently thereto.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Dated: 12/10/09 Signed: [signature]

At: Walnut Creek, CA

EXHIBIT 600

SIERRA CLUB
FOUNDED 1892

SAN GORGONIO CHAPTER

1225 Adriana Way, Upland, CA 91784
(909) 946-5027

Regional Groups Serving Riverside and San Bernardino Counties: Big Bear, Los Serranos, Mojave, Moreno Valley, Mountains, Santa Margarita, Tahquitz.

June 22, 2009

Via Electronic Mail

Tom Hurshman
BLM Project Manager
2465 South Townsend Ave.
Montrose, CO 81401
tom_hurshman@co.blm.gov

Re: Draft Environmental Impact Statement for the Ivanpah Solar Electric Generating System

Dear Mr. Hurshman:

We write to propose a project alternative for incorporation into the BLM's upcoming draft environmental impact statement for the proposed Ivanpah Solar Electric Generating System project ("Project"). We provide this NEPA-based alternative in the spirit of cooperation, and with the goal of achieving timely resolution of the dual-track Project approval processes for the BLM and California Energy Commission so that the project can be under construction by 2010.

We strongly support environmentally responsible renewable energy, including appropriately-sited, large-scale solar development. Specifically, it is the Sierra Club's policy that large-scale, renewable energy be developed, whenever possible, on previously disturbed, preferably privately-held, lands.[1] Unfortunately, the Project as proposed would be built on unspoiled public land presenting significant, unmitigated impacts on the state and federally listed desert tortoise and on sensitive plant communities, some of which are also listed. Concerning desert tortoise, the Energy Commission staff determined:

> The applicant's proposed mitigation, acquisition, and enhancement of approximately 4,065 acres would be insufficient to avoid significant direct, indirect, and cumulative impacts to biological resources of the Ivanpah Valley, and fails to meet the California Department of Fish and Game's full mitigation standard for desert tortoise. Staff also believes this proposed mitigation will be inadequate to compensate for cumulatively significant impacts to other special-status plant and animals inhabiting the project site…"[2]

[1] Testimony of Carl A. Zichella, Director of the Sierra Club's Western Renewables Program before the Subcommittee on Energy and Mineral Resources Committee on Natural Resources (May 11, 2009).
[2] Preliminary Staff Assessment at p. 5.2-2.

Many of the Project's negative effects occur because the proposed configuration was mapped out before anyone had conducted meaningful surveys of the site's biological resources and drainage issues. Indeed, the current footprint is situated on the best habitat for wildlife and special-status plant species, while the most disturbed lands, closest to existing development and Interstate 15 would serve as translocation lands for the listed desert tortoise. From a biological perspective, this is an utterly backward use of public land. Similarly, the Project would be built on lands with the most challenging drainage problems while the translocation lands are relatively flat and pose fewer drainage issues. In short, the lower elevation lands near Interstate 15 appear to be much more suitable for large-scale solar development than the current, upslope habitat where more than 20 desert tortoises and other imperiled species reside. The optimum lower elevation alternative in terms of protecting biological resources is the south end of the Ivanpah Dry Lake. If siting the Project on the dry lake is not feasible, we propose the following.

We request that the BLM include an EIS alternative that (1) relocates the Project's three power blocks closer to the areas adjacent to Interstate 15 currently mapped as translocation sites; (2) leaves the desert tortoise undisturbed and designates its habitat at Ivanpah as an area of permanent protection such as that provided by areas of critical environmental concern (ACEC); and (3) retires the Clark Mountain grazing allotment.

1. Biological Basis for the Sierra Club's Alternative

In a May 13, 2009, Energy Commission filing, the Western Watersheds Project presented evidence showing how the areas along Interstate 15, currently proposed as tortoise translocation areas 1 and 2, have historically supported few desert tortoises.[3] In that filing to the Energy Commission, Western Watersheds Project provided survey data from Kristin Berry estimating tortoise density in the Project footprint in the range 50-100 desert tortoises per square-mile; whereas the low lying areas along Interstate 15 supported approximately 20-50 desert tortoises per square-mile or less than half.

It is clear that the lands near Interstate 15 have served as a major sink for tortoises, depleting nearby populations, either as a result of cars colliding with tortoises, predation or possibly due to truck- and automobile-related pollutants in the soil, or all three factors. Translocating the listed tortoise to sites known not to support them simply makes no sense. Even a casual inspection of the Project site and the translocation areas shows that the native plant life at the Project site is much more extensive and varied than at the translocation lands. The areas currently designated as Ivanpah 2 and 3 provide the highest quality tortoise burrowing habitat and food sources. In contrast, due to the dirt road paralleling Interstate 15, and the grazing operations in and around the corral adjacent to the highway, the translocation lands are denuded and contain exotic plants. In short, completely avoiding habitat lands eliminates translocation, thereby, avoiding the Ft. Irwin pattern of desert tortoise mortalities. It is well established that desert tortoise translocation results in very high mortality.

Similarly, there are approximately 2,000 ephemeral washes that occur throughout the project site. The lower elevations adjacent to the highway present far fewer drainage challenges because of the reduced slope. Relocating the three power blocks to the lower elevations would reduce or eliminate drainage issues that arise with heavy rains.

---

[3] Letter to John Kessler, Commission staff project manager from Michael J. Connor, Western Watersheds Project (May 13, 2009) properly filed on or about June 17, 2009.

The Sierra Club's Project alternative stems from a deep concern for the remaining tortoises in the California portion of the Northeastern Mojave Desert Tortoise Recovery Unit. This particular unit is one of six recovery units designated in the U.S. Fish and Wildlife Service's recovery plan.[4] Because the Mojave Desert tortoise is listed as a threatened species under state and federal law, and because the entire California population of this particular unit is found within the Ivanpah area, protecting these individuals must be a high priority for all of the approving agencies, including the BLM. A simple reconfiguration of the Project along with an ACEC designation for the most densely populated portions of Ivanpah Valley would significantly protect this recovery unit, and stands to facilitate timely resolution of Project approval.

2. <u>The BLM Should Consider Analyzing the Designate Portions of the Current Project Footprint as Areas of Critical Environmental Concern</u>

The BLM should include in the EIS an analysis of designating the portions of Ivanpah Valley currently proposed for development as Ivanpah 2 and 3 as areas of critical environmental concern. The Sierra Club seeks permanent protection for these lands because a reconfiguration of the Project footprint only makes sense if the habitat protected by the change remains off limits to development permanently.

A critical factor for whether an ACEC designation is appropriate in terms of species protection is whether the area contains wildlife resources, including habitat for endangered or threatened species, or habitat essential for maintaining species diversity. The area bounded on the west by the eastern portion of the Clark Mountains, on the north by the Nevada State line and on the south and east by I-15 fulfills this criterion. Project surveys to date document the presence of wildlife resources, namely desert tortoise, other wildlife of concern, and special-status plant species. The PSA is clear that the Project area is excellent tortoise habitat, with a low level of disturbance and high plant species diversity.[5] In addition, the BLM designated portions of the valley as Category I desert tortoise habitat in its documentation for the Northern and Eastern Mojave Desert Management Plan (NEMO).[6] Although the NEMO boundary for the nearby Desert Wildlife Management Area excluded the Northern Ivanpah Valley Unit, an ACEC designation is necessary to protect the important biological resources throughout the higher elevation portions of the valley.

Permanent protection via an ACEC designation is further warranted because the desert tortoise population in Ivanpah Valley is unique given that the individuals residing there are at the highest elevation known anywhere in the state. The elevations range from approximately 3,150 to 2,850 feet above mean sea level. Given new impacts based on climate change affecting food availability and other vital factors, it has become increasingly important to protect higher elevation habitat.

3. <u>The BLM Should Retire the Clark Mountain Grazing Allotment</u>

Finally, the BLM should retire the Clark Mountain grazing allotment as a component of the ACEC designation. Grazing is simply not compatible with protecting wildlife and plant species in the Ivanpah Valley. This particular allotment is rarely used based on the records at the Needles Office. Those records reveal that no animal unit months were billed for the allotment

[4] Desert Tortoise (Mojave Population) Recovery Plan.
[5] PSA, at 5.2-30.
[6] NEMO Appendix A.

from 2007 to 2009 (to the end of March). And it appears from the Moon's letter of September 4, 2008 to Sterling White of the Needles BLM Office that the permit holders are willing to accommodate a retirement of the allotment were the BLM to issue a right-of-way in connection with the Project.

4. Conclusion

NEPA requires the BLM to include a reasonable range of meaningful alternatives in its Project EIS. Specifically, BLM must "study, develop, and describe appropriate alternatives to recommend courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources."[7] A full analysis of alternate siting scenarios is warranted for the Project given the potential conflict from developing renewable solar energy on intact desert public lands supporting imperiled plant and wildlife species. The Sierra Club believes such a conflict can be avoided in the Ivanpah Valley by situating the Project in a manner that completely avoids much of the highest quality desert tortoise habitat while keeping the Project at its proposed scale, thereby maximizing solar generation.

Respectfully Submitted
Sid Silliman JB
Sidney Silliman
Sierra Club San Gorgonio Chapter and Desert Committee

[7] 42 U.S.C. § 4332(2)(E).

BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION OF THE STATE OF CALIFORNIA
1516 NINTH STREET, SACRAMENTO, CA 95814
1-800-822-6228 – WWW.ENERGY.CA.GOV

APPLICATION FOR CERTIFICATION FOR THE *IVANPAH SOLAR ELECTRIC GENERATING SYSTEM*

DOCKET NO. 07-AFC-5

PROOF OF SERVICE
(Revised 5/27/09)

APPLICANT

Solar Partners, LLC
John Woolard,
Chief Executive Officer
1999 Harrison Street, Suite #500
Oakland, CA 94612

Steve De Young, Project Manager
***Todd A. Stewart, Project Manager**
E-MAIL PREFERRED
Ivanpah SEGS.
1999 Harrison Street, Ste. 2150
Oakland, CA 94612
sdeyoung@brightsourceenergy.com
tstewart@brightsourceenergy.com

APPLICANT'S CONSULTANTS

John L. Carrier, J. D.
2485 Natomas Park Dr. #600
Sacramento, CA 95833-2937
jcarrier@ch2m.com

COUNSEL FOR APPLICANT

Jeffery D. Harris
Ellison, Schneider
& Harris L.L.P.
2600 Capitol Avenue, Ste. 400
Sacramento, CA 95816-5905
jdh@eslawfirm.com

-

INTERESTED AGENCIES

California ISO
e-recipient@caiso.com

Tom Hurshman,
Project Manager
Bureau of Land Management
2465 South Townsend Ave.
Montrose, CO 81401
tom_hurshman@blm.gov

Sterling White, Field Manager
Bureau of Land Management
1303 South Highway 95
Needles, CA 92363
sterling_white@blm.gov

Becky Jones
California Department of
Fish & Game
36431 41st Street East
Palmdale, CA 93552
dfgpalm@adelphia.net

INTERVENORS

California Unions for Reliable Energy ("CURE")
Tanya A. Gulesserian
Marc D. Joseph
Adams Broadwell Joseph & Cardozo
601 Gateway Boulevard, Ste 1000
South San Francisco, CA 94080
tgulesserian@adamsbroadwell.com

Gloria Smith, Joanne Spalding
Sidney Silliman, Sierra Club
85 Second Street, 2nd Fl.
San Francisco, CA 94105
gloria.smith@sierraclub.org
joanne.spalding@sierraclub.org
gssilliman@csupomona.edu
E-mail Preferred

Joshua Basofin, CA Rep.
Defenders of Wildlife
1303 J Street, Ste. 270
Sacramento, CA 95814
jbasofin@defenders.org
E-MAILED PREFERRED

ENERGY COMMISSION

JEFFREY D. BYRON
Commissioner and Presiding Member
jbyron@energy.state.ca.us

JAMES D. BOYD
Vice Chairman and
Associate Member
jboyd@energy.state.ca.us

Paul Kramer
Hearing Officer
pkramer@energy.state.ca.us

John Kessler
Project Manager
jkessler@energy.state.ca.us

Dick Ratliff
Staff Counsel
dratliff@energy.state.ca.us

Elena Miller

Public Adviser publicadviser@energy.state.ca.us

DECLARATION OF SERVICE

I, Violet Lehrer, declare that on June 22, 2009, I served and filed copies of the attached letter, dated June 22, 2009. The original document, filed with the Docket Unit, is accompanied by a copy of the most recent Proof of Service list, located on the web page for this project at: **[www.energy.ca.gov/sitingcases/ivanpah]**. The document has been sent to both the other parties in this proceeding (as shown on the Proof of Service list) and to the Commission's Docket Unit, in the following manner:

(***Check all that Apply***)

FOR SERVICE TO ALL OTHER PARTIES:

______ sent electronically to all email addresses on the Proof of Service list;

X by personal delivery or by depositing in the United States mail at Sierra Club 85 2nd St., 2nd Floor SF, CA 94105 with first-class postage thereon fully prepaid and addressed as provided on the Proof of Service list above to those addresses **NOT** marked "email preferred."

AND

FOR FILING WITH THE ENERGY COMMISSION:

X sending an original paper copy and one electronic copy, mailed and emailed respectively, to the address below (***preferred method***);

OR

______ depositing in the mail an original and 12 paper copies, as follows:

CALIFORNIA ENERGY COMMISSION
Attn: Docket No. 07-AFC-5
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512
docket@energy.state.ca.us

I declare under penalty of perjury that the foregoing is true and correct.

Violet Lehrer

EXHIBIT 601

Modeling Habitat of the Desert Tortoise (*Gopherus agassizii*) in the Mojave and Parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona

Open-File Report 2009-1102

U.S. Department of the Interior
U.S. Geological Survey

COVER PHOTOGRAPH

(2005) Mojave Desert Tortoise found in Piute Valley in Clark County, Nevada (Kenneth E. Nussear)

Modeling Habitat of the Desert Tortoise (*Gopherus agassizii*) in the Mojave and Parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona

By Kenneth E. Nussear, Todd C. Esque, Richard D. Inman, Leila Gass, Kathryn A. Thomas, Cynthia S. A. Wallace, Joan B. Blainey, David M. Miller, and Robert H. Webb

Prepared as a part of the
Department of the Interior on the Landscape – Mojave Project
for the Western Region, of the U.S. Geological Survey

Open-File Report 2009-1102

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

Suggested citation:
Nussear, K.E., Esque, T.C., Inman, R.D., Gass, Leila, Thomas, K.A., Wallace, C.S.A., Blainey, J.B., Miller, D.M., and Webb, R.H., 2009, Modeling habitat of the desert tortoise (*Gopherus agassizii*) in the Mojave and parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona: U.S. Geological Survey Open-File Report 2009-1102, 18 p.

Contents

Figures

Tables

Conversion Factors, Datums, and Abbreviations and Acronyms

Conversion Factors

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile (mi)
millimeter (mm)	0.03935	inch (in.)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F+(1.8\times°C)+32.$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations and Acronyms

AGP – Annual Growth Potential
AUC – Area Under the ROC Curve
CV – Coefficients of Variation
DEM – Digital Elevation Map
EVI - Enhanced Vegetation Index
MODIS –Moderate Resolution Imaging Spectroradiometer
NAD –North American Datum
NED – National Elevation Database
RBG – Random Background
ROC – Receiver Operating Characteristic
STATSGO - State Soil Geographic (STATSGO) Database
USGS – U.S. Geological Survey

Modeling Habitat of the Desert Tortoise (*Gopherus agassizii*) in the Mojave and Parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona

By Kenneth E. Nussear, Todd C. Esque, Richard D. Inman, Leila Gass, Kathryn A. Thomas, Cynthia S. A. Wallace, Joan B. Blainey, David M. Miller, and Robert H. Webb

Abstract

Habitat modeling is an important tool used to simulate the potential distribution of a species for a variety of basic and applied questions. The desert tortoise (*Gopherus agassizii*) is a federally listed threatened species in the Mojave Desert and parts of the Sonoran Desert of California, Nevada, Utah, and Arizona. Land managers in this region require reliable information about the potential distribution of desert tortoise habitat to plan conservation efforts, guide monitoring activities, monitor changes in the amount and quality of habitat available, minimize and mitigate disturbances, and ultimately to assess the status of the tortoise and its habitat toward recovery of the species. By applying information from the literature and our knowledge or assumptions of environmental variables that could potentially explain variability in the quality of desert tortoise habitat, we developed a quantitative habitat model for the desert tortoise using an extensive set of field-collected presence data. Sixteen environmental data layers were converted into a grid covering the study area and merged with the desert tortoise presence data that we gathered for input into the Maxent habitat-modeling algorithm. This model provides output of the statistical probability of habitat potential that can be used to map potential areas of desert tortoise habitat. This type of analysis, while robust in its predictions of habitat, does not account for anthropogenic changes that may have altered habitat with relatively high potential into areas with lower potential.

Introduction

Spatial models that predict areas of potential habitat for plants and animals are extremely useful for evaluating management actions, particularly recovery plans for threatened or endangered species (Graham and others, 2004). Using spatially defined environmental variables, which may be either continuous numbers, integers, or categorical data, these habitat models can be very robust at detailed scales and are useful when designing of conservation programs and evaluating changes in species distributions owing to anthropogenic effects or global change. Data on species occurrence, combined with spatially explicit environmental data, can be used with recently developed statistical techniques and analytical tools without specific absence data (Elith and others, 2006; Phillips and others, 2006; Phillips and Dudik, 2008).

The desert tortoise (*Gopherus agassizii*, cover photograph) occupies a variety of habitat types in the Mojave Desert including creosotebush – white-bursage (*Larrea tridentata* – *Ambrosia dumosa*) communities (Fig. 1). The species is widely distributed in southwestern North America, ranging from the Sierra Nevada in California to southwestern Utah and southwards into Sonora and Sinaloa, Mexico (Fig. 2). North and west of the Colorado River, the desert tortoise is a federally listed threatened species owing to reductions in habitat quality and extent caused by human activities, land-use practices, increasing populations of subsidized predators, disease, and other factors (Luckenbach, 1982; Department of the Interior, 1990; Berry and others, 2002). Urbanized areas within Clark County, Nevada, typify several fast-growing urban areas within former tortoise habitat (*http://www.censusscope.org/us/m4120/chart_popl.html*) that have caused significant displacements of these animals. Land-use practices leading to habitat degradation or destruction include development (urban and rural), military training activities, habitat fragmentation from roads and utility corridors, recreational activities, livestock grazing, and previously uncommon fires fueled mostly by non-native species (Tracy and others, 2004). Extensive habitat changes and reduction in populations prompted wildlife managers to create a recovery plan (U.S. Fish and Wildlife Service, 1994) and a subsequent revision of the recovery plan (Tracy and others, 2004; U.S. Fish and Wildlife Service, 2008). The results of this modeling project will be a useful element of the Revised Recovery Plan.

Figure 1. Creosote scrub habitat (one type of preferred desert tortoise habitat) in the Mojave Desert.

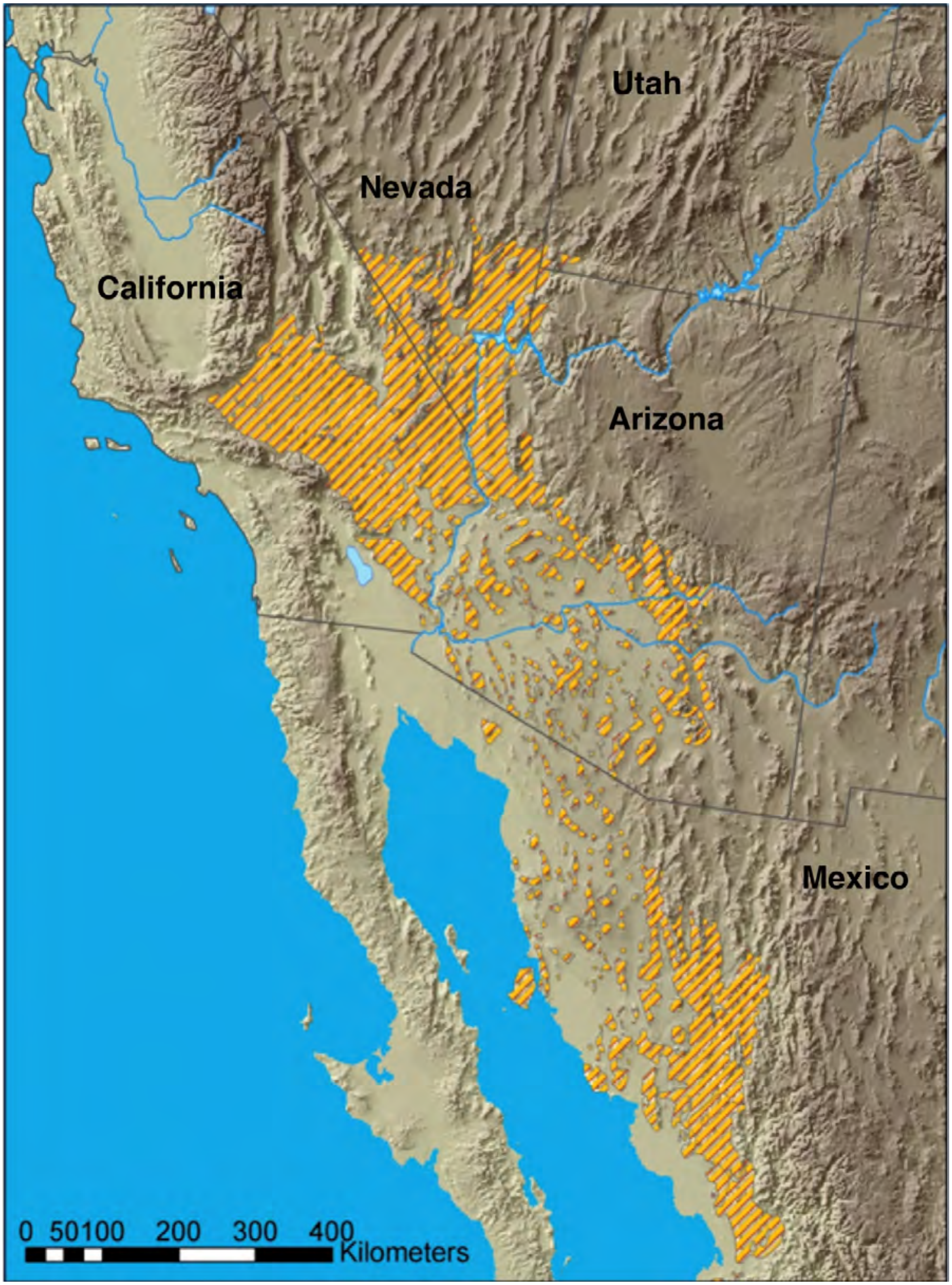


Figure 2. Map showing distribution of desert tortoise (*Gopherus agassizii*) in western North America (adapted from Germano and others, 1994).

We assembled an interdisciplinary team to create a model of potential habitat for the listed Mojave Desert populations of the desert tortoise. After assembling a unique set of presence data (Fig. 3) gleaned from the scientific literature, state and federal land-management agencies, scientists, and biologists, we used a series of innovative techniques (for example; remote sensing and spatial interpolation; Blainey and others, 2007; Wallace and Gass, 2008; Wallace and Thomas, 2008; Wallace and others, 2008) to develop environmental data layers at a common spatial scale of 1 km^2 to help define potential habitat. We used the Maxent algorithm (Phillips and others, 2006) to predict potential desert tortoise habitat in the Mojave Desert and parts of the Sonoran Desert.

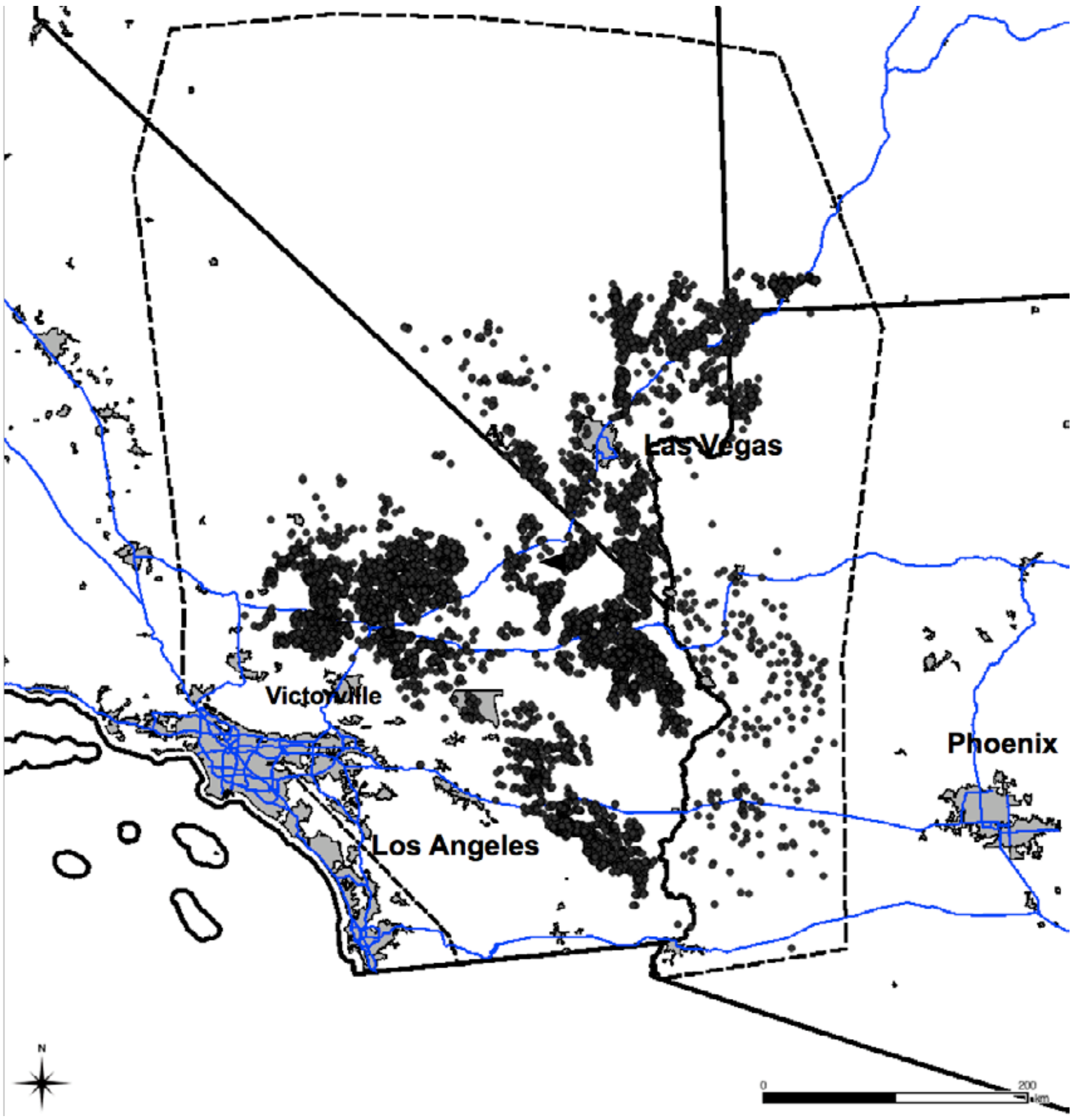


Figure 3. Distribution of desert tortoise (*Gopherus agassizii*) presence observations at sites in the Mojave Desert and parts of the Sonoran Desert of California, Nevada, Utah, and Arizona. *Solid circles* indicate records of one or more observations of live or dead tortoises. The dashed line indicates the study area boundary for the habitat model. Major highways are indicated by blue lines, and urban areas are indicated by gray shaded areas.

Purpose and Scope

The purpose of this report is to document the methods and data sources used to model the potential habitat of the desert tortoise in the Mojave and parts of the Sonoran Desert and to present a map showing this potential habitat. We discuss some of the limitations of our data and caution that our results do not account for other factors that affect habitat quality, notably significant changes brought about by land-use practices.

Background

Geography and Topography

Our study encompasses the range for the Mojave population of desert tortoises north and west of the Colorado River, as well as a small portion of the northwest Sonoran Desert, and comprises 336,594 km^2 of basin-and-range topography (Fig. 3). The study area was used to create spatially coincident environmental-data layers for environmental variables known from the literature and our experience for defining potential habitat. Within this area, we created a spatial grid of 1-km^2 cells for which we assessed habitat potential. Although the habitat for the desert tortoise is thought to occur primarily at elevations between 600 and 1,200 m above sea level (Germano and others, 1994, Fig. 2), we used the entire elevation range within the distributional limits of this species, which ranges from the rugged mountain ranges to the flat-lying playa systems that characterize the study area.

Climate

Owing to relatively sparse climatological data for the study area, the range in temperatures and precipitation within the current desert-tortoise habitat is only generally known. In the Mojave Desert, annual precipitation within known habitat ranges from 100 to 210 mm (Germano and others, 1994), mostly occurring during the winter months (> 50-75%) and infrequently as snow below 1,200 m. The temperature range of known habitat is extreme, with average daily low temperatures in January typically at or slightly below 0 ºC and average daily high temperatures in July ranging from 37 to 43 ºC (Germano and others, 1994). Both precipitation and temperature are strongly and complexly related to elevation, aspect, and position within this desert; the closed-basin playa systems that characterize the Mojave Desert tend to control air movement, leading to low-level temperature inversions in winter and thermal trapping of heat in some valleys during summer. Winter precipitation is usually dependent on frontal storms or the residual effects of gulf storms penetrating northward with increasing amounts of rain or snow at higher elevations. Summer precipitation is associated with the North American monsoon, which is more reliable in the easterly parts of the desert tortoise range. Precipitation events, especially the monsoon, may be highly local depending strongly on orographic effects.

The complex interactions between topography and climate are perhaps best illustrated by the differing results of studies of preferred aspect by the desert tortoise. Weinstein (1989) found a significantly greater abundance of desert tortoises on northwest to north-northwest facing slopes, a result that he attributed to ground heating and possibly illumination. However, Andersen and others (2000), working in a different part of the Mojave Desert, found a preference for southwestern facing slopes, again for possible effects of soil heating during winter. This apparent shift in habitat preference on the basis of aspect underscores the complexity of topography and climate interactions as they affect habitat preference for this species and illustrates the need for robust environmental data over the entire range of this species.

Other Environmental Constraints on Habitat

The characteristics of high-quality habitat for the desert tortoise have been proposed by numerous researchers, possibly beginning with Woodbury and Hardy (1948) and Miller (1932, 1955) and more recently including Luckenbach (1982), Weinstein (1989), Germano and others (1994), U.S. Fish and Wildlife Service (1994), and Andersen and others (2000). A conceptualized array of these environmental characteristics are related to the core variables of soils, landscape, climate, and biological characteristics (Fig. 4). As summarized most recently in U.S. Fish and Wildlife Service (2008), desert tortoise habitat typically consists of alluvial fans and plains and colluvial/bedrock slopes with vegetation alliances of creosote bush (*Larrea tridentata*) or, less commonly, blackbrush (*Coleogyne ramosissima*), Joshua tree (*Yucca brevifolia*), and even juniper (*Juniperus* sp.) at higher elevations and saltbush (*Atriplex* sp.) at lower elevations. In general, tortoises prefer *Larrea* habitat with high diversity and cover of perennial species and high production of ephemeral plants, which comprise their primary diet (Esque, 1994; Jennings, 1997; Avery, 1998).

Soils tend to be of sufficient strength to accommodate burrows without collapse but allow excavation by the animals (Andersen and others, 2000); in some cases, tortoises take advantage of natural shelters in rock formations or exposed calcic soil horizons. Both from constraints on mobility and their inability to easily construct shelters, tortoises tend not to use rocky or shallow bedrock habitat, particularly on very steep slopes, in the Mojave Desert. Home ranges of desert tortoises can cover 3.9 km^2 (Berry, 1986) or more over their long lifespans, suggesting that a spatial modeling unit of 1 km^2 is appropriate.

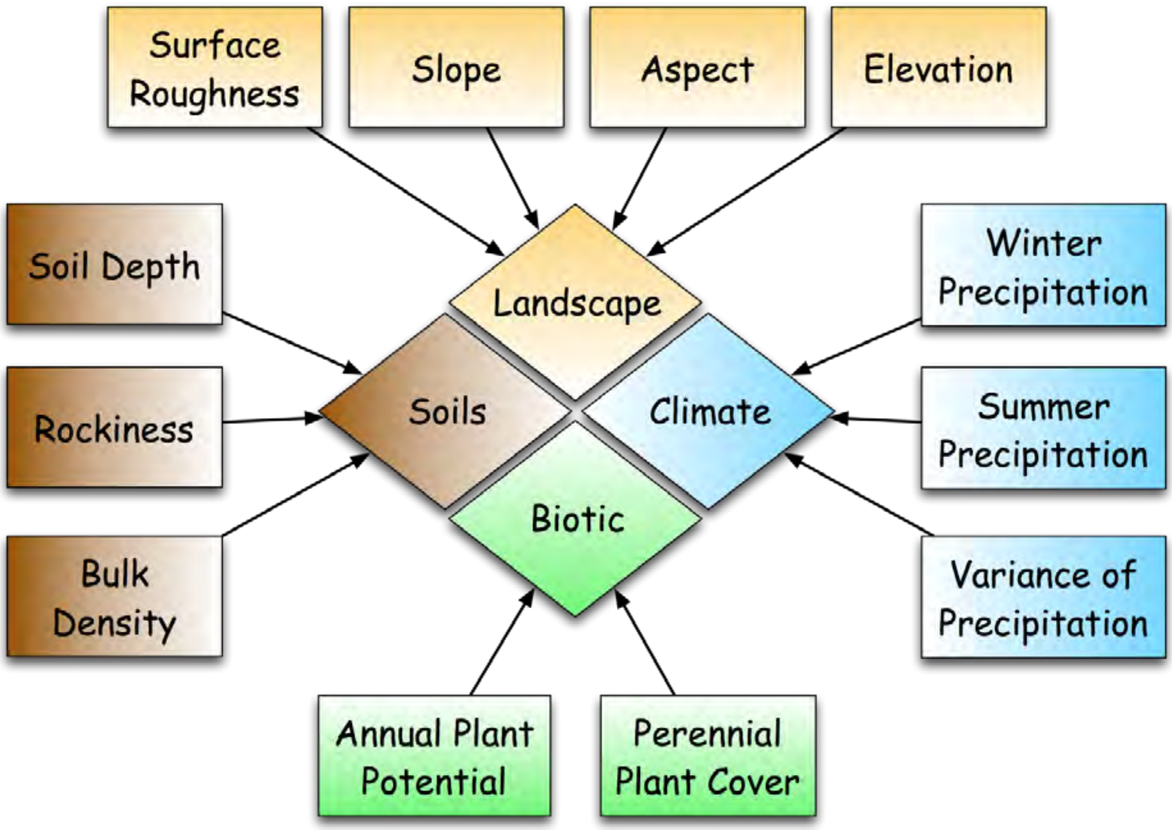


Figure 4. Array of variables used to predict desert tortoise habitat. Environmental variables were generally related to four categories of influence on the landscape and were hypothesized to influence tortoise ecology/habitat potential through a variety of mechanisms.

Methods

Tortoise Presence Data

We combined several datasets of desert tortoise occurrence collated from a variety of sources to assemble presence points in the Mojave and parts of the Sonoran Deserts (see Acknowledgments). Presence records included data from 1970 through 2008, although most of the data were collected after 1990. These data resulted from at least 23 different data-collection initiatives. Although methods of data collection varied among the primary sources, we were able to use the observations of tortoises (live or dead) as point sources of presence. We used only data involving evidence of live tortoises or carcasses, discarding locations reported on the basis of burrows, scat, or other sign, as these can be easily misidentified. The locations represent "potential" presence because carcasses may have been moved into unsuitable habitat by predators or humans. Our geospatial database includes 15,311 points representing presence (Fig. 3).

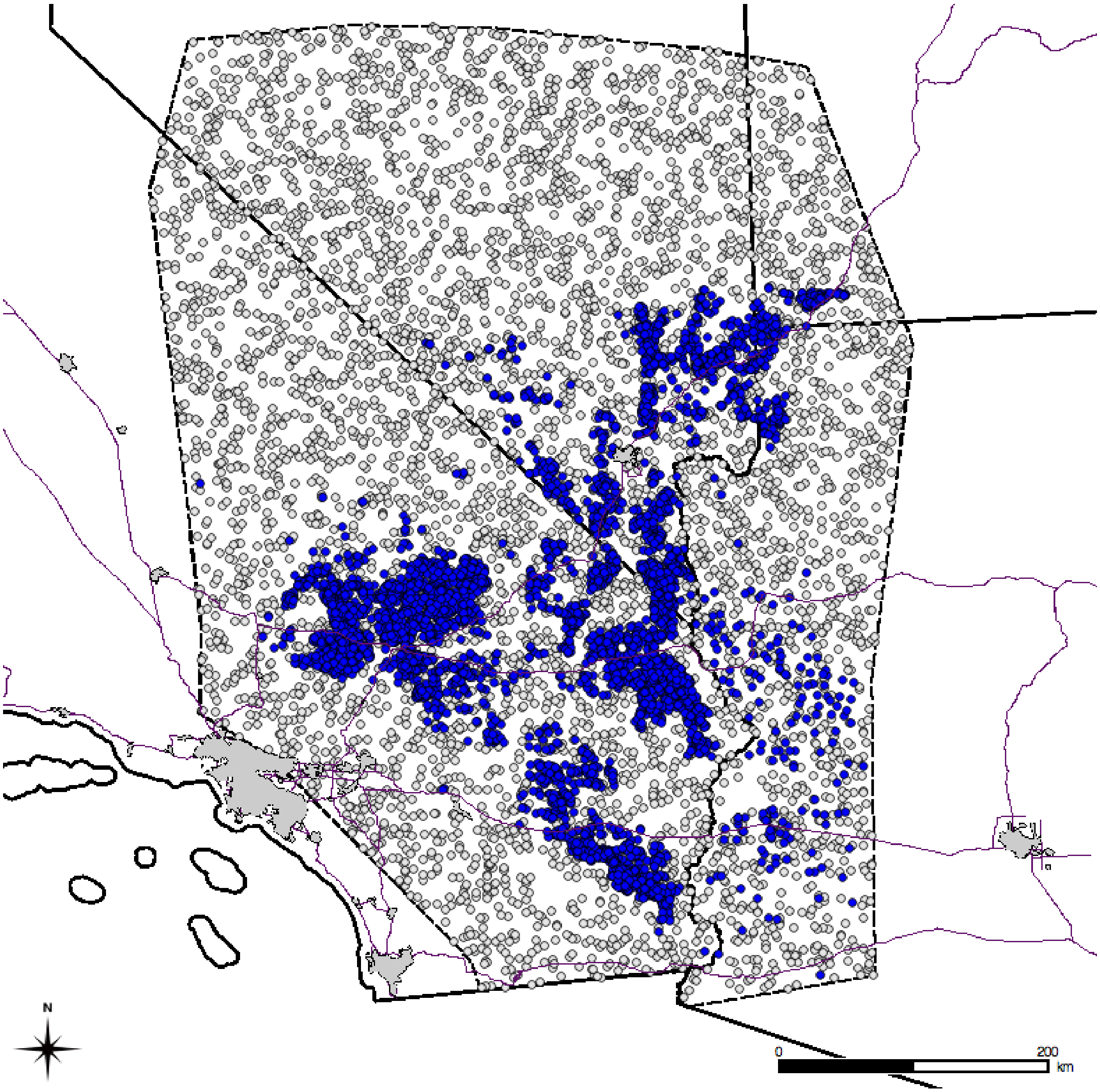


Figure 5. Distribution of presence data (blue circles) and random background data (gray circles) used in habitat modeling. Urban areas are defined by the gray shaded polygons.

We aggregated the presence observations to the 1-km^2 grid by merging all points within each grid cell to a single point at the grid-cell center. This reduced the 15,311 occurrences to 6,350 grid-cell points (Fig. 5). We randomly selected 20% of the presence points (1,270 points) for model testing; the remaining 80% (5,080 points) were used for model training.

Environmental Data Layers

Using the literature (e.g., Luckenbach 1982) and the experience of the authors of this report, we developed 16 environmental data layers that define or influence desert tortoise habitat. These data, assembled by an interdisciplinary team, include soil characteristics, perennial and annual vegetation, elevation and extracted topographic variables, and seasonality and variability of precipitation (Table 1). All environmental datasets were resampled to match our standard spatial grid using tools available in GRASS 6.4 (GRASS Development Team, 2008)

Table 1. Environmental data used in modeling potential habitat of the desert tortoise in the Mojave and parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona.

[Dry season, May through October; wet season, November through April with statistics for 1961 to 1990 used as the climatic normal and coefficient of variation]

Description of Environmental Data Layer	Source of Environmental Data
CLIMATE	
Mean dry season precipitation for 30-year normal period	Blainey and others (2007)
Dry season precipitation, spatially distributed coefficient of variation *	Blainey and others (2007)
Mean wet season precipitation for 30-year normal period	Blainey and others (2007)
Wet season precipitation, spatially distributed coefficient of variation *	Blainey and others (2007)
TOPOGRAPHY	
Elevation	30 m NED DEM (USGS)
Slope *	derived from 30 m NED DEM (USGS)
Northness (aspect) *	derived from 30 m NED DEM (USGS)
Eastness (aspect) *	derived from 30 m NED DEM (USGS)
Average surface roughness	derived from 30 m NED DEM (USGS)
Percent smooth	derived from 30 m NED DEM (USGS)
Percent rough *	derived from 30 m NED DEM (USGS)
SOILS	
Average soil bulk density	STATSGO database
Depth to bedrock	STATSGO database
Average percentage of rocks > 254 mm B-axis diameter	STATSGO database
BIOLOGICAL CHARACTERISTICS	
Perennial plant cover	Wallace and others (2008)

* Environmental layers that were dropped from the final model after evaluation of the jackknife analyses.

Climate data consisted of two seasonal data layers representing average summer (May–October) and average winter (November–April) precipitation. Based on climatic normals calculated from conditions between 1961 and 1990, we used spatially distributed coefficients of variation (CV) for both seasons (Blainey and others, 2007). We did not use temperature as a variable, although some studies show a relation between temperature and tortoise physiological response (Naegle, 1976; Spotila and others, 1994; Rostal and others, 2002). In our experience, no data published to date definitively show direct temperature limitations on the extent of desert tortoise habitat. Temperature is likely to influence tortoises ecologically at several time periods and life history stages, which would require several complex hypothetical temperature interactions to be created as GIS layers of temperature, and was beyond the scope of this project. Despite this, temperatures indirectly were used in our model owing to their strong correlation with elevation and position, particularly in the northern parts of the study area.

We derived six topographic data layers from a 30-m DEM that, along with elevation, provided the suite of topographic variables that influence desert tortoise habitat at a 1-km^2 scale using methods similar to Wallace and Gass (2008). Surface roughness was calculated at a 30-m cell size using the method specified by Hobson (1972). Average surface roughness was calculated as the average value of surface roughness in each 1-km^2 grid cell. Separately, the percentage of each 1-km^2 cell that was "smooth" and "rough" was assessed by measuring the proportion of 30-m average roughness grid cells that were < 1.01 (threshold for smooth) or > 1.11 (threshold for rough), where the 25% and 75%quartiles of the 30-m surface roughness grid were used to define the thresholds, respectively.

The aspect of each 1-km^2 grid cell was represented by eastness and northness (Zar, 1999), which are variables that represent aspect by converting the 1 to 360º range of possible azimuths into a range of -1 to 1, where -1 = south or west and 1 = north or east for northness and eastness, respectively. This transformation avoids identical aspects (e.g., 0 and 360 degrees) and creates two data layers with unique numerical representation of aspect, and was calculated using

$$\mathrm{E} = \sin\left(\frac{A \times \pi}{180}\right) \text{ and} \qquad \text{eqn. (1)}$$

$$\mathrm{N} = \cos\left(\frac{A \times \pi}{180}\right), \qquad \text{eqn. (2)}$$

where E = eastness, N = northness, and A = aspect.

Spatial data for average soil bulk density, depth to bedrock, percent area with depth to bedrock greater than 1 m, and percent of soil mass with rocks greater than 254 mm B-axis (intermediate) diameter were previously created from the STATSGO database by the Natural Resource Conservation Service and modified by USGS (Bliss, 1998).

The total perennial plant cover data were modeled using Moderate Resolution Imaging Spectroradiometer (MODIS) Enhanced Vegetation Index (EVI) collected by the MODIS satellite and composited over 16-day intervals (Wallace and others, 2008), combined with field measurements of total perennial cover, estimated from line intercept transects at locations across the Mojave Desert (Webb and others, 2003, 2009; Thomas and others, *unpublished data*; Wallace and others, 2008). Total perennial cover was related to elevation and 2001 through 2004

MODIS-EVI data at the transect locations ($R^2 = 0.82$), and the resulting model was used to extrapolate cover estimates for the remaining study area. The resulting data used in our study represented the absolute cover of all perennials irrespective of species composition (Wallace and others, 2008).

Annual growth potential is an environmental data layer that is a proxy for annual plant biomass, which reflects potential forage for tortoises. This data layer was derived by calculating the difference in greenness (a measure of plant growth) between two highly contrasting years of annual plant production (Wallace and Thomas, 2008). The difference between MODIS-EVI images for 2002 (a very dry year) and 2005 (a very wet year) had high correlation with field measurements of annual plant cover collected on 36 plots in the Mojave National Preserve in 2005 ($R^2 = 0.63$, p=0.01). The proxy measure of annual growth potential, AGP, was calculated as

$$\mathrm{AGP} = \left(\frac{EVI(2005) - EVI(2002)}{EVI(2005) + EVI(2002) + 1}\right) * 100, \qquad \text{eqn. (3)}$$

where EVI (2005) and EVI (2002) are the average MODIS-EVI values for the years 2005 and 2002. This formula is analogous to the Normalized Difference Vegetation Index of Huete and others (2002). The resulting values represent the potential for site specific food availability for desert tortoise.

Background Data

If both presence and absence data are available, many statistical techniques exist to predict potential habitat (Guisan and Zimmermann, 2000). However, absence data are rarely available or reliable for animals that hibernate in shelters for part of the year, in part, because their absence from specific areas is difficult to confirm (Guisan and Thuiller, 2005; MacKenzie and others, 2005; Thompson, 2004). Moreover, current ranges for species that have been extirpated from a larger area are misleading when it comes to development of recovery plans. Models built with presence-only data do not incorporate information on the frequency of occurrence of a species in a region, and therefore, they cannot accurately predict probability of presence; these models only estimate a relative index of habitat potential (Elith and others, 2006). We used a random background set of data to serve as “absences.” Although these data do not reflect true absences, they do create comparable models for testing a variety of algorithms and models with different environmental data without embedding assumptions of pseudo-absence point generation models into the habitat model, and they perform similarly to models using pseudo-absence (Phillips and Dudik, 2008).

We created random background points, which we refer to as RBG, by selecting random cells throughout our study area in locations constrained only to cells where desert tortoises were not observed. A total of 6,350 RBG points were selected; 20% of the RBG points (1,270) were used for model testing, and 80% (5,080) points were used for model training.

The Maxent Model

We modeled potential habitat using the Maxent algorithm (version 3.2.19, Phillips and others, 2006). Maxent uses a maximum entropy probability distribution to compare samples of occurrence data with background environmental data. Each of the included predictor variables were assessed using a jackknife test of variable importance and percent contribution (Phillips and others 2006). We used the logistic model output to represent an index of the potential of the habitat in a cell given the training data (Phillips and Dudik, 2008).

To assess the performance of this model, we used area under the curve (AUC) of the receiver operating characteristic (ROC) as a threshold-independent measure of model performance (Elith and others, 2006). ROC is plotted for all possible thresholds, with sensitivity (true positive rate) on the y-axis and 1-specificity (false positive rate) on the x-axis (Fawcett, 2003). The AUC characterizes the performance of the model at all possible thresholds and is summarized by a single number ranging from 0 to 1, where 1 indicates perfect model performance, 0.5 indicates the equivalent of a random guess, and less than 0.5 indicates performance worse than random. Here AUC tests the model discrimination between presence and the random background points rather than presence and true absence; therefore, the maximum possible AUC < 1 and random chance is AUC = 0.5 (Phillips and others, 2006). We also calculated the correlation between the test presence and RBG points (1 or 0) and the predicted values as Pearson's correlation coefficient (Zheng and Agresti, 2000; Elith and others, 2006). This performance metric is similar to AUC, but provides a more direct measure of how the model predictions vary from observations (Elith and others, 2006). The predicted habitat values from Maxent were continuous numbers between 0 (no habitat) to 1 (habitat), which we then binned into 12 intervals to represent various levels of potential habitat. These results were mapped to graphically represent potential habitat.

Results

The Maxent model produced a map of potential desert tortoise habitat for parts of the Mojave and Sonoran Deserts (Fig. 6). This model had a high AUC test score (0.93) and had a significant Pearson's correlation coefficient of 0.74 ($p < 0.01$), indicating a substantial agreement between the predicted habitat and the observed localities of desert tortoises. The final selected model excluded 6 of 16 habitat variables including eastness, northness, winter precipitation CV, summer precipitation CV, percent roughness, and slope (Table 1). These variables were dropped due to their low overall contributions to the model performance in jackknife tests. The model produced output with habitat-potential scores ranging from 0 to 1 (Fig. 7), plus an area that was not estimable because environmental data were not available for one or more layers (Fig. 6). These scores were placed in 12 different bins to provide an index of habitat potential (Table 2). Tortoises were present in 1-km^2 cells that spanned the entire range of model outputs. The mean model score for all tortoise presence cells was 0.84, and 95% of the cells with known presence had a model score greater than 0.7 (Fig. 7). The total area occupied by each of the 12 bins used as an index for habitat potential is presented in Table 2.

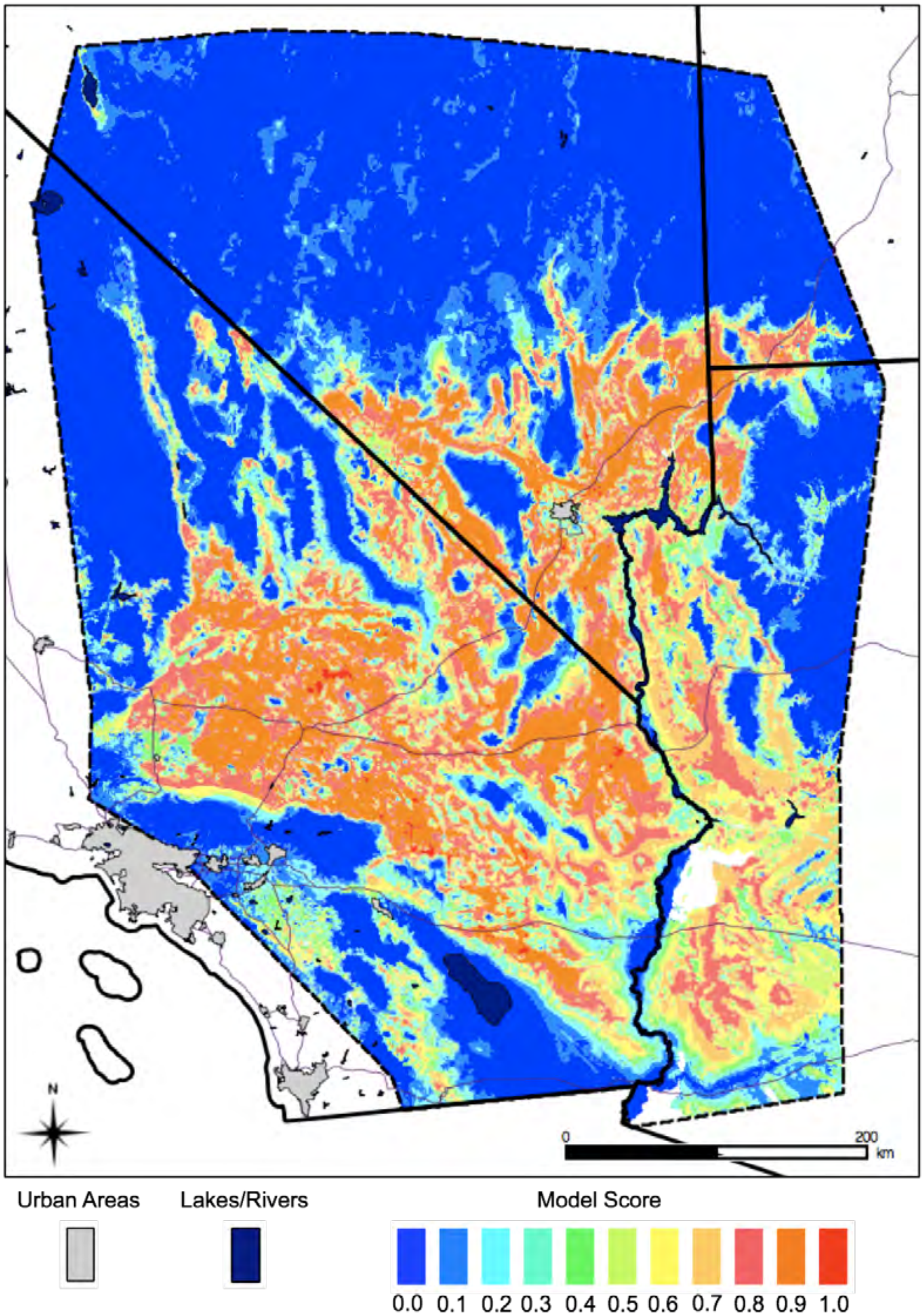


Figure 6. Spatial representation of the predicted habitat potential index values for desert tortoise (*Gopherus agassizii*) in the Mojave and parts of the Sonoran Deserts of Arizona, Nevada, Utah, and Arizona. White patches within the study area indicate areas where no environmental data were available for one or more layers. The Maxent model output used to develop this figure available as an ESRI ASCII GRID file at http://pubs.usgs.gov/of/2009/1102/.

Table 2. Total predicted area of desert tortoise habitat for each of 12 bins representing habitat potential values in the habitat potential model of the Mojave and parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona.

[The item labeled as Not Estimable represents a relatively small area where supporting data layers were not available]

Habitat Potential Index Value	Area km^2
1	677
0.9	27,303
0.8	31,216
0.7	23,835
0.6	15,191
0.5	12,880
0.4	13,119
0.3	14,612
0.2	15,100
0.1	30,493
0	147,249
Not Estimable	4,919
Study Area Total	336,594

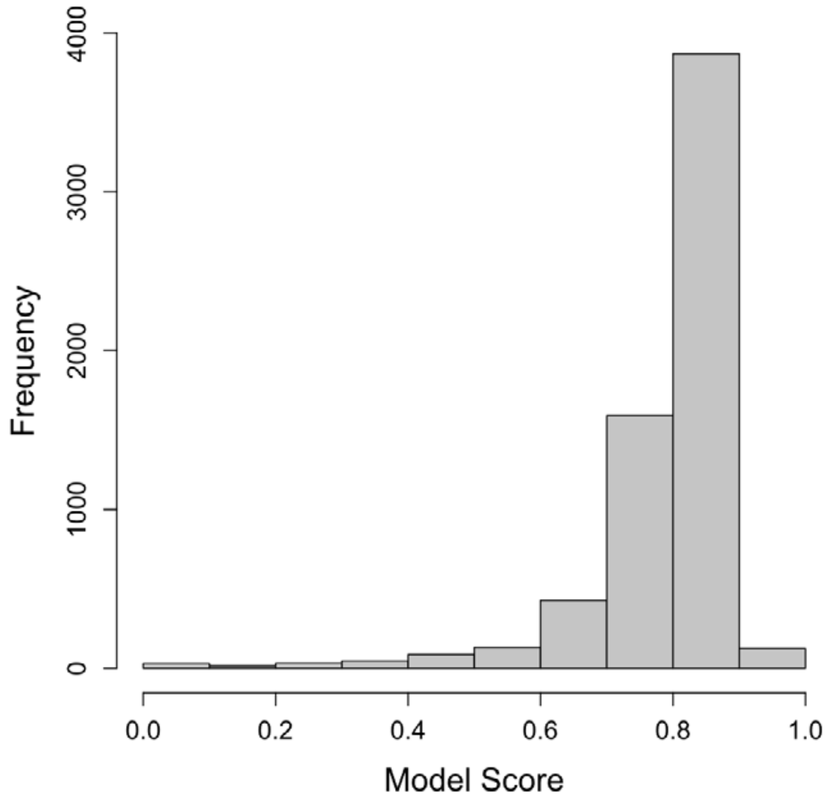


Figure 7. Frequency of the habitat potential index values for the 6,350 1-km^2 grid cells with known tortoise presence in the Mojave and parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona.

Study Limitations

The quality of the spatial data used in this report is strongly dependent on the accuracy of previously reported presence points for desert tortoises and on the data used to calculate the environmental layers. Though all possible efforts were made to create a seamless and robust dataset, discrepancies are unavoidable since data were collected by different groups using different measurement techniques and sampling frequencies. Model scores reflect a hypothesized habitat potential given the range of environmental conditions where tortoise occurrence was documented. As such, there are likely areas of potential habitat for which habitat potential was not predicted to be high, and likewise, areas of low potential for which the model predicted higher potential. Finally, the map of desert tortoise potential habitat that we present does not account either for anthropogenic effects, such as urban development, habitat destruction, or fragmentation, or for natural disturbances, such as fire, which might have rendered potential habitat into habitat with much lower potential in recent years. Those topics are important foci for future analyses.

Acknowledgments

R. Averill-Murray provided guidance as well as tortoise-occurrence data. Other data were obtained from D. Bedford, S. Dudash, L. Amoroso, J. Stock, K. Schmidt, B. Hagerty, S. Schwartz, C. Everly, A. Mcluckie, P. Medica, N. Pratini, C. Jones, A. Owens, the Bureau of Land Management, the National Park Service, Arizona Game and Fish, and the Arizona and Utah Natural Heritage Programs. Support from the Desert Managers Group in southern California was influential in securing adequate funding for this project. This report benefitted greatly from the reviews and comments provided by R. Averill-Murray, B. Hagerty, J. Heaton, K. Phillips, R. Scofield, J. Yee, R. Kirby, M. DeBortoli, and two anonymous reviewers. This project was funded by the U.S. Geological Survey, Western Regional Office.

References Cited

Andersen, M.C., Watts, J.M., Freilich, J.E., Yool, S.R., Wakefield, G.I., McCauley, J.F., and Fahnestock, P.B. (2000) Regression-tree modeling of desert tortoise habitat in the central Mojave Desert. *Ecological Applications*, 10, 890-200.

Avery, H.W. (1998) Nutritional ecology of the desert tortoise (*Gopherus agassizii*) in relation to cattle grazing in the Mojave Desert. Ph.D. Dissertation. University of California, Los Angeles.

Berry, K.H. (1986) Desert tortoise (*Gopherus agassizii*) relocation: Implications of social behavior and movements. *Herpetologica*, 42, 113-125.

Berry, K.H., Morafka, D.J., and Murphy, R.W. (2002) Defining the desert tortoise(s): Our first priority for a coherent conservation strategy. *Chelonian Conservation and Biology*, 4, 249-262.

Blainey, J. B., Webb, R.H. and Magirl, C.S. (2007) *Modeling the Spatial and Temporal Variation of Monthly and Seasonal Precipitation on the Nevada Test Site, 1960-2006.* U.S. Geological Survey Open-File Report 2007–1269. http://pubs.usgs.gov/of/2007/1269/. Accessed October 21, 2008.

Bliss, N. (1998) *Soils1 and Soils2.* Digital data distributed on CD-ROM by the Mojave Desert Ecosystem Program.

Department of the Interior. *(1990) Fish and Wildlife Service, 50 CFR part 17, RIN 1018-AB35. Endangered and threatened wildlife and plants; determination of threatened status for the Mojave population of the desert tortoise (final rule). Federal Register* 55 (63): 12178-12191.

Elith, J., Graham, C.H., Anderson, R.P, Dudı´k, M. Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J McC., Peterson, A.T., Phillips, S.J., Richardson, K., Scachetti-Pereira, R., Schapire, R.E., Soberón, J., Williams, S., Wisz M.S. and Zimmermann, N.E. (2006) Novel methods improve prediction of species' distributions from occurrence data. *Ecography,* 29, 129-151.

Esque, T.C. (1994) Diet and diet selection of the desert tortoise (*Gopherus agassizii*) in the northeastern Mojave Desert. Master's Thesis. Colorado State University, Fort Collins.

Fawcett, T. (2003) *ROC graphs: notes and practical considerations for data mining researchers.* Technical Report HPL-2003-4, Palo Alto, CA:HP Laboratories. 27 pp.

Germano, D.J., Bury, R.B., Esque, T.C., Fritts, T.H., and Medica, P.A. (1994) Range and habitats of the desert tortoise. In: R.B. Bury and D.J. Germano (eds.) Biology of North American Tortoises. *Fish and Wildlife Research*, 13, 73-84.

Graham, C.H., Ferrier, S., Huettman, F., Moritz, C. and Peterson, A.T. (2004) New

developments in museum-based informatics and applications in biodiversity analysis. *Trends in Ecology and Evolution,* 19, 497-503.
GRASS Development Team, 2008. Geographic Resources Analysis Support System (GRASS) Software, Version 6.4.0. http://grass.osgeo.org
Guisan, A. and Thuiller, W. (2005) Predicting species distribution: offering more than simple habitat models. *Ecology Letters,* 8, 993-1009.
Guisan, A. and Zimmermann, N.E. (2000) Predictive habitat distribution models in ecology. *Ecological Modelling,* 135, 147-186.
Hobson, R.D., (1972). Surface roughness in topography: quantitative approach. In: Chorley, R.,J. (ed) Spatial analysis in geomorphology. Metheur, London, p. 225-245.
Huete, A.R., Didan, K., Miura, T., Rodriquez, E.P, Gao, X. and Ferreira, L.G. (2002) Overview of the radiometric and biophysical performance of the MODIS vegetation indices. *Remote Sensing of Environment*, 83, 195-213.
Jennings, W.B. (1997) Habitat use and food preferences of the desert tortoise, *Gopherus agassizii*, in the western Mojave and impacts of off-road vehicles. Pages 42-45 in J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York
Luckenbach, R.A. (1982) Ecology and management of the desert tortoise (*Gopherus agassizii*) in California. North American Tortoises: Conservation and Ecology. U.S. Fish and Wildlife Service, *Wildlife Research Report 12*, 1-37.
MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, J.A. and Langtimm, C.A. (2005) Estimating site occupancy rates when detection probabilities are less than one. *Ecology,* 83, 2248-2255.
Miller, L. (1932) Notes on the desert tortoise (*Testudo agassizii*). Transactions of the San Diego Society of Natural History, 7, 191-202.
Miller, L. (1955) Further observations on the desert tortoise, *Gopherus agassizii*, of California. *Copeia*, 1955, 113-118.
Naegle, S. R. (1976) *Physiological responses of the desert tortoise, Gopherus agassizii.* PhD dissertation, University of Nevada, Las Vegas.
Phillips, S.J., Anderson, R.P. and Schapire, R.E. (2006) Maximum entropy modeling of species geographic distributions. *Ecological Modelling,* 190, 231-259.
Phillips, S.J., Dudik, M. (2008) Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation.
Rostal, D.C., Wibbels, T., Grumbles, J.S., Lance V. and Spotila, J.R. (2002) Chronology of sex determination in the desert tortoise (*Gopherus agassizii*). *Chelonian Conservation and Biology,* 4, 313-318.
Spotila, J. R., Zimmerman, L.C., Binckley, C.A., Grumbles, J.S., Rostal, D.C., List, A.J., Beyer, E.C., Phillips, K.M., and Kemp, S.J. (1994) Effects of incubation conditions on sex determination, hatching success, and growth of hatchling desert tortoises *Gopherus agassizii*. *Herpetological Monographs*, 8, 103–116.
Thompson, W.L. 2004. Sampling rare or elusive species. Island Press, Washington DC, USA.
Tracy, C. R., Averill-Murray, R.C., Boarman, W.I., Delehanty, D.J., Heaton, J.S., McCoy, E.D., Morafka, D.J., Nussear, K.E., Hagerty, B.E., and Medica, P.A. (2004) *Desert Tortoise Recovery Plan Assessment.* Technical Report to US Fish and Wildlife Service, Reno, NV. 254pp.
U.S. Fish and Wildlife Service. (1994) *Desert Tortoise (Mojave Population) Recovery Plan.* http://ecos.fws.gov/docs/recovery_plans/1994/940628.pdf. Accessed October 21*, 2008.*

U.S. Fish and Wildlife Service. (2008) *Draft Revised Recovery Plan for the Mojave Population of the Desert Tortoise. http://www.fws.gov/nevada/desert%5Ftortoise/documents/recovery_plan/DraftRevRP_Mojave_Desert_Tortoise.pdf.* Accessed 4/15/2009.
Wallace, C.S.A. and Gass, L. (2008). Elevation derivatives for Mojave desert tortoise habitat models. Geological Survey Open-File Report 2008–1283. http://pubs.usgs.gov/of/2008/1283/. Accessed March 26, 2009.
Wallace, C.S.A., Thomas, K.A. (2008) An annual plant growth proxy in the Mojave desert using MODIS-EVI data. Sensors, 6, 7792-7808.
Wallace, S.A., Webb, R.H. and Thomas, K.A. (2008) Estimation of perennial vegetation cover distribution in the Mojave Desert using MODIS-EVI data. GIScience & Remote Sensing, 45(2), 167-187.
Webb, R.H., Murov, M.B., Esque, T.C., Boyer, D.E., DeFalco, L.A., Haines, D.F., Oldershaw, D., Scoles, S.J., Thomas, K.A., Blainey, J.B. and Medica, P.A. (2003) *Perennial vegetation data from permanent plots on the Nevada Test Site, Nye County, Nevada*. Washington, DC: U.S. Geological Survey Open-File Report 03-336.
Webb, R.H., Belnap, J., and Thomas, K.A. (2009) Natural recovery from severe disturbance in the Mojave Desert, in Webb, R.H., Fenstermaker, L.F., Heaton, J.S., Hughson, D.L., McDonald, E.V., and Miller, D.M. (editors). *The Mojave Desert: Ecosystem Processes and Sustainability*. Reno, University of Nevada Press, p. 343-377.
Weinstein, M.N. (1989) Modeling desert tortoise habitat: Can a useful management tool be developed from existing transect data? Los Angeles, University of California, unpublished Ph.D dissertation, 121 p.
Woodbury, A.M, and Hardy, R. (1948) Studies of the desert tortoise, *Gopherus agassizii*. *Ecological Monographs*, 18, 145-200.
Zar, J. H. (1999). *Biostatistical Analysis*. 4th Edition. Prentice Hall, New Jersey. 931 pp.
Zheng, B. and Agresti. A. (2000) Summarizing the predictive power of a generalized linear model. *Statistics in Medicine,* 19, 1771-1781.

EXHIBIT 602

to relatively high uptake from a contaminated substrate or, more commonly, to surface contaminated resulting from wind borne dust. Most high concentrations are thus not the result of natural accumulation in an uncontaminated area.

Two ill adult tortoises were salvaged from the Rand district and necropsied. One of the two contained the highest level of As (15 mg/kg wet weight) in keratin (scute) recorded to date in necropsied tortoises. The ingestion by tortoises of plants from these mineralized or contaminated areas may thus represent a potential threat to their health and longevity.

LITERATURE CITED

Jacobson, E. R., J. M. Gaskin, M. B. Brown, R. K. Harris, C. H. Gardiner, J. L. LaPointe, H. P. Adams, and C. Reggiardo. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). J. of Wildlife Diseases 27:296-316.

Homer, B. L., K. H. Berry, M. M. Christopher, M. B. Brown, and E. R. Jacobson. 1994. Necropsies of desert tortoises from the California deserts and elsewhere in the Southwest. Final Report to the U.S. Dept. of the Interior, Bureau of Land Management, Contract No. B950-C1-0062, Riverside, CA. 85 pp.

Homer, B. L., K. H. Berry, and E. R. Jacobson. 1996. Necropsies of eighteen desert tortoises from the Mojave and Colorado deserts of California. Final Report to the U.S. Dept. of the Interior, National Biological Service, Research Work Order No. 131, Riverside, CA. 120 pp.

PROXIMATE CONSTRAINTS AFFECTING THE REPRODUCTIVE OUTPUT AND MORTALITY OF DESERT TORTOISES

Shannon Collis and Harold W. Avery, Ph.D.

U.S. Geological Survey, Canyon Crest Field Station, Dept. of Biology, University of California, Riverside, CA 92521

Understanding the affects of resource availability on reproduction is critical to the study of life history and demography of animal populations. The desert tortoise (*Gopherus agassizii*), a long-lived species with delayed sexual maturity, is dependent on stored nutrients and water to minimize fluctuations in reproductive output. Tortoise populations are subject to lower fecundity and higher mortality in unpredictable desert ecosystems following extended periods of decreased resource availability. In an ongoing study, we measured the reproductive output of female tortoises from a population at Ivanpah Valley, California, located within the Mojave National Preserve, from 1997 - 1999. We measured egg and clutch size, and clutch frequency in 42 female tortoises using a portable x-ray unit. Eleven rain gauges were used to monitor monthly precipitation across three study sites within Ivanpah valley to measure variance in rainfall. Perennial plant cover and annual plant biomass were also measured. Precipitation was significantly greater at higher elevations across a 10 km distance characterized by a 400 m increase in elevation. Availability of food plants increased with higher elevation as well. Tortoise reproductive output was greater and recent mortality was lower, at the higher elevation along this short elevational and rainfall gradient. Resource variability is a defining feature of desert ecosystems, yet the importance of micro-geographic variation of these resources to desert tortoise populations has not been previously determined. Our study shows that micrographic differences in rainfall and primary productivity of annual vegetation can result in significant differences in survivorship and mortality of the threatened desert tortoise. These findings have important implications to designing reserves, managing public lands, and other conservation issues relevant to the desert tortoise.

THE DESERT TORTOISE PRESERVE COMMITTEE: A QUARTER CENTURY OF PROGRESS

Michael J. Connor

Desert Tortoise Preserve Committee, 4067 Mission Inn Ave, Riverside, CA 92501;
Phone: (909)-683-DTPC; E-mail: dtpc@pacbell.net

Since 1974, the nonprofit Desert Tortoise Preserve Committee has been driven by its mission to protect the welfare of the desert tortoise in its native wild state. Starting from a small group of volunteers working to build and protect a preserve in the Fremont Valley-Rand Mountain area, the Committee has developed into a highly effective force for the conservation of the tortoise and associated species throughout the West Mojave Desert. Examples of the Committee's many accomplishments from the last twenty-five years that have significantly benefited tortoise conservation include: development of creative strategies to acquire significant numbers of privately held small land parcels within the Desert Tortoise Research Natural Area, implementation of fencing mitigation commitments along Harper Lake Road, long-term protective management and recovery at the Pilot Knob grazing allotment, and the development and use of innovative educational programs. The Committee's success in meeting these challenges reflects its relative freedom from bureaucratic and political constraints, its flexibility to adaptively manage to make the most of opportunities that arise, and its ability to complement the work of state and federal government agencies to further its mission.

EXHIBIT 603

DESERT TORTOISE EXPERIENCE
COMPLETED BY JAMES W. CORNETT - ECOLOGICAL CONSULTANTS

James W. Cornett Ecological Consultants has conducted more than 500 studies involving the presence or absence and habitat utilization of the desert tortoise. In business since 1974, no other individual or company has conducted as many tortoise studies as has JWC.

In addition to field work involving the desert tortoise, Mr. Cornett is the author of *The Desert Tortoise: Answers to Frequent Questions* published by the Palm Springs Desert Museum and Nature Trails Press. This book has been approved for sale in every national and state park in which the desert tortoise occurs. In addition, Mr. Cornett is the only individual authorized by University of California Extension to teach their Ecology of The Desert Tortoise.

Some of the field studies conducted by JWC Ecological Consultants include:

ADAMS 34 RANCH PARTNERSHIP
Biological survey and focused desert tortoise survey on a 660-acre residential development abutting the Indio Hills, Colorado Desert, wash and hillside habitats, near Indio, California.
Smith, Peroni & Fox, Planning Consultants
Lead Planning Agency: County of Riverside

ALTAMIRA PLANNED COMMUNITY
Biological survey and report on 550 acres of Colorado Desert wash and hillside habitats; focus on threatened Desert Tortoise as well as other sensitive species.
City of Palm Desert
Palm Desert, California

ANDREAS COVE COUNTRY CLUB
Biological survey and report on 450-acre resort on desert riparian habitat; also focused study on Desert Tortoise, Bighorn Sheep and endangered Least Bell's Vireo.
Andreas Cove County Club, Inc.
Palm Springs, California

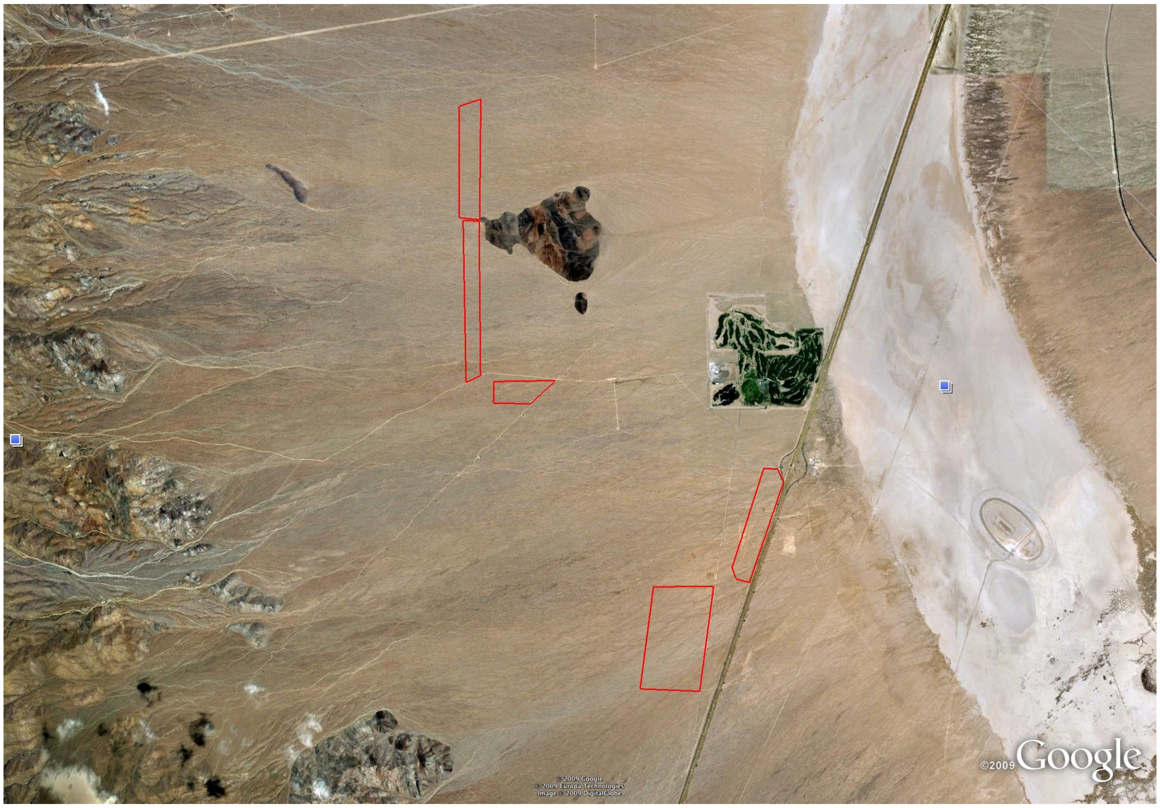
CHINO CANYON RESORT
Focused tortoise surveys on a 360-acre hotel project in Chino Canyon of the San Jacinto Mountains. .
DDRM Company
Palm Springs, California

JOSHUA TREE WATER DISTRICT
Biological survey and focused Desert Tortoise surveys on expansion pipeline routes in Mojave Desert wash and hillsides habitats near the town of Joshua Tree, San Bernardino County, California.

MARINE CORPS COMBAT CENTER
General biological and focused Desert Tortoise surveys on 200-acre expansion of base residential area on Mojave Desert alluvial fan and hillside habitat.
U.S. Department of the Navy
Twentynine Palms, California

JOSHUA HILLS PLANNNED DEVELOPMENT
Focused Desert Tortoise surveys on a 1,100-acre site to be developed into a multi-use planned community located in the city of Coachella, Riverside County, California.

EXHIBIT 604



Locations surveyed for desert tortoise burrows in December 2009. Boundaries of survey areas (indicated in red) may be inexact due to manual entry.

EXHIBIT 605

Distribution of Desert Tortoise Sign Adjacent to Highway 395, San Bernardino County, California

Edward L. LaRue, Jr.

Abstract. Between November 1991 and January 1992, desert tortoise (*Gopherus agassizii*) sign, including scat, burrows, and carcasses were observed on 17 study plots along the eastern side of Highway 395 between Adelanto and Red Mountain, southwestern San Bernardino County, California. Each plot was 305 m (1000 ft) perpendicular to Highway 395 and 174 m (570 ft) parallel to it, or about 5.3 ha (13.1 ac). Plots were surveyed by transects placed at 9 m (30 ft) intervals, for 20 transects per plot, effecting 100% coverage of each plot. When found, the distance between the tortoise sign and Highway 395 was recorded. Disturbances observed on each of the surveyed transects were also recorded.

Cumulatively, on the 17 plots, there were 142 tortoise scat, 38 burrows, and 20 carcasses found. Spatial distribution of scat and burrows indicated that the numbers of scat and burrows steadily increased with increasing distance from the highway. The correlation coefficient for the number of scat and burrows relative to the distance from the highway was $r = 0.92$, $P < 0.0005$ and $r = 0.89$, $P < 0.0005$, respectively, indicating a linear relationship between the amount of sign and the distance from the highway. The correlation coefficient for carcasses ($r = 0.56$, $P = 0.025$) indicated a less predictable relationship between the number of carcasses and the distance from the road. Four of 38 burrows (10.5%) and 15 of 142 scat (10.6%) were found within 91 m (300 ft) of the highway, whereas 12 of 20 carcasses (60%) were found within the same 91 m interval.

Disturbances and their frequencies of occurrence on the 340 transects surveyed on the 17 plots included off-highway vehicle traffic (98% occurrence; i.e. off-highway vehicle traffic was detected on 332 of 340 transects); presence of sheep scat (81%); canine sign, including tracks, digs, and scat (65%); established dirt roads (51%); human foot prints (18%); Caltrans erosion ditches (16%); horse sign, including tracks or scat (10%); trash dumping (7%); rifle shells (3%); shotgun shells (3%); and miscellaneous ground disturbances (1%).

INTRODUCTION

Few studies have been performed to determine the impacts of established roads and highways on adjacent tortoise populations. In 1977, Nicholson surveyed for tortoise sign along 10 paved roads in the western Mojave Desert that included Interstates 15 and 40, Highways 395 and 58, and secondary roads, including Shadow Mountain Road and Barstow Road (Nicholson 1978). Her study indicated, generally, that there was an increase in tortoise sign with increasing distance from the road. She concluded that paved roads and vehicular traffic have a detrimental effect on tortoise populations within 1 km (3,281 ft) of a road. She identified two potential impacts, including mortality resulting from vehicular collision and removal of tortoises by passing motorists, as adversely affecting tortoises. The Bureau of Land Management (BLM) has found 48 tortoise carcasses along Highway 58 between Kramer Junction and Barstow (BLM 1991).

The BLM is presently conducting a study along Highway 58 that is designed to determine the effects of fencing on tortoise populations in adjacent areas (Boarman 1993). The study's preliminary findings indicate that, prior to fencing the highway, numbers of tortoise sign increase with increasing distance from the highway. In the Rand Mountain-Fremont Valley area, Goodlett has found that there is a "band of influence" approximately 275 ft wide (84 m) adjacent to unimproved roads where off-highway vehicle traffic is more common than in areas farther out than 275 ft (Goodlett and Goodlett 1991).

The Nicholson and BLM studies are similar to one another because they surveyed for tortoise sign at distinct intervals adjacent to paved roads. BLM's study, for example, surveyed for tortoises at the fence line, which is within 61 m (200 ft) of the highway, at 402 m (1/4 mi), 805 m (1/2 mi), and 1610 m (1.0 mi) distant from Highway 58. The present study is different from these two studies in that a continuous area, beginning at the shoulder of the highway and ending 305 m (1,000 ft) out from the road, is surveyed, so that all scat, burrows, and carcasses found within that area are located relative to the highway. A primary assumption of this study is that tortoises use of an area can be determined by the presence of their sign (i.e., scat and burrows), and that tortoises are either absent or not commonly found in areas where their sign is not found. This assumption is fundamental to United States Fish and Wildlife Service (USFWS) tortoise survey protocol, which is designed to determine the presence or absence of tortoises in an area, and makes the assumption that they are absent from the area if sign is not found (USFWS 1992).

Previous tortoise surveys performed by the author where tortoise sign were found (Tierra Madre Consultants 1991a, 1991b, 1992) seem to indicate that few, if any, tortoise scat and burrows are found within approximately 91 m (300 ft) of well-traveled highways. In one case in Helendale, California, (Tierra Madre Consultants 1991a), National Trails Highway (old State Route 66) passes through the middle of an 80-acre parcel, whose southeast corner coincides with the northwest corner of the adjacent 80-acre parcel (Fig. 1). The 80-acre parcels were surveyed on consecutive days, and the spatial distribution of tortoise sign found on those parcels is shown in Fig. 1. Two collapsed, inactive burrows were found 43 m (140 ft) and 104 m (340 ft) from the highway, and the nearest intact, active burrow was approximately 213 m (699 ft) south of the highway. Tortoise burrows found on the adjacent 80-acre parcel, which was not bisected by the highway, were randomly distributed throughout that parcel, had more intact tortoise burrows (82 versus 9), more tortoises (16 versus 4), and more tortoise scat (214 versus 82). Surveys, such as this one, seem to indicate that tortoises are impacted by well-traveled highways.

METHODS

<u>Study plots</u>. The 17 study plots were chosen along the eastern side of Highway 395 because electrical power lines and associated maintenance roads occur on the western side of the same stretch of highway. The plots were chosen to avoid unimproved roads, residences, and dry washes, which may affect the spatial distribution of tortoise sign (Baxter 1988; Tierra Madre Consultants 1991c). The locations of the 17 plots are shown in Figure

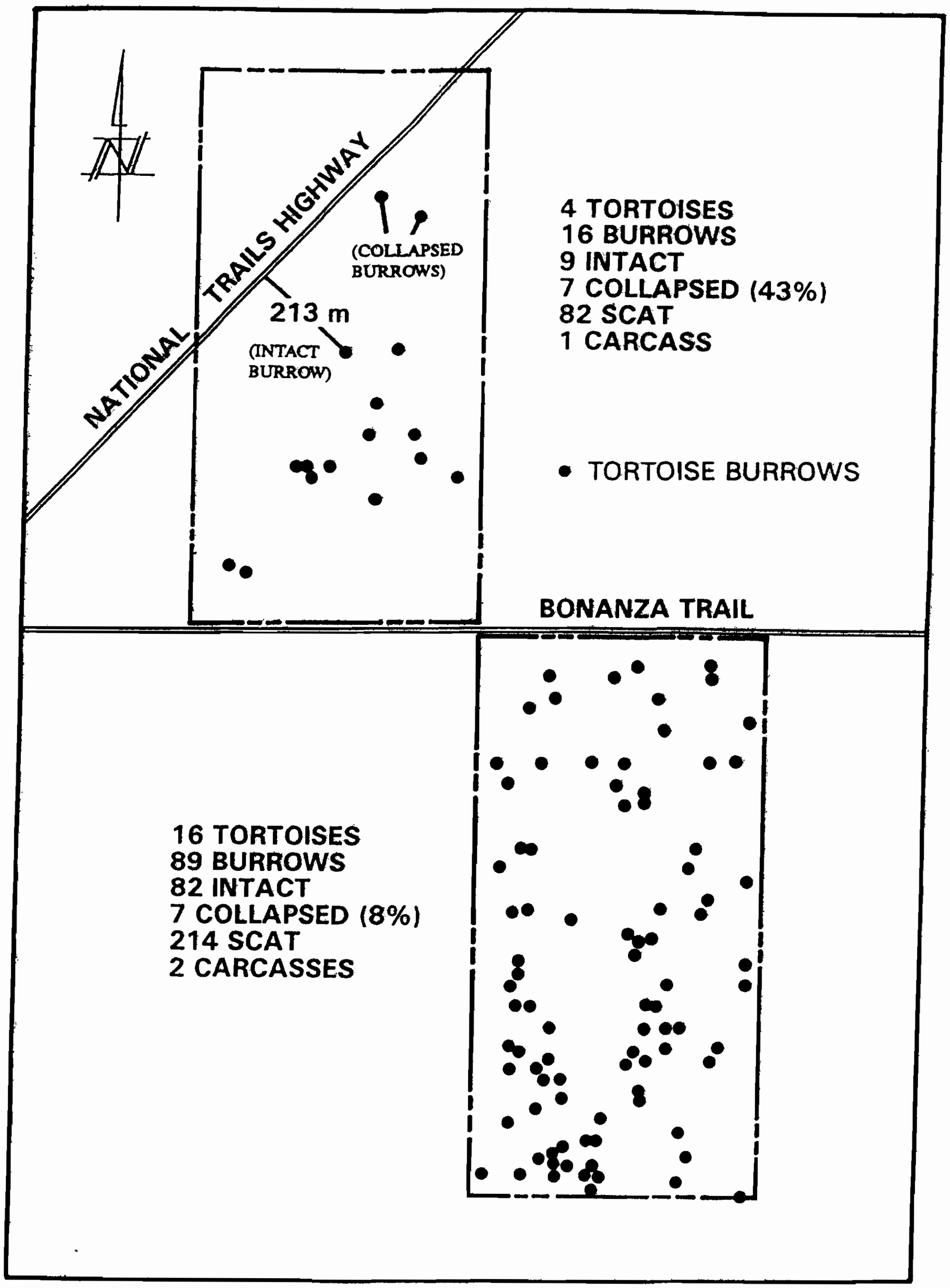


Figure 1. Spatial distribution of desert tortoise sign found on the two 80-acre parcels near Helendale, California.

2. Plots were not chosen south of #1 in the vicinity of Adelanto, north of #17 in the Randsburg/Johannesburg area, or between #11 and #12 in the Kramer Junction area because human disturbances not associated with the highway (residences, businesses, mining activities, etc.) are relatively more common in those areas and may have affected the distribution of tortoise sign.

The 17 plots were surveyed between 22 November 1991 and 12 January 1992. For each plot, 20 transects, spaced at 9-m (30-ft) intervals, perpendicular to Highway 395, beginning at the vegetated side of the highway [approximately 3.6 m (12 ft) to 4.6 m (15 ft) east of the pavement], and extending 305 m (1,000 ft) to the east, were surveyed. The lengths of transects and the distances between transects were paced. Every third or fourth transect was paced to ensure that the survey marker [a 3 m (10 ft) PVC pole] remained 305 m from the roadside. The plots were surveyed for an average of 1.96 hours (range 1.66 hours to 2.30 hours). A constant pace during each transect was sought, and the amount of tortoise sign present may have slowed the total time for some plots (i.e. data recordation slowed the pace).

Tortoise sign. The distance between each tortoise scat, burrow, and carcass and Highway 395 was recorded. Additionally, the relative age of the scat ("this year" versus "not this year") and age class (based on the relative size of the scat: juvenile, subadult, adult) was recorded. Width, height, depth, and general condition of each burrow ("poor," "fair," "good," "excellent" as per BLM criteria) were determined and recorded. Each accumulation of tortoise bones was recorded as one tortoise carcass. Once found, the area around the initial find was searched for additional bones. Bones found on other transects, or on the same transect, that were not found with the initial search were recorded as a second carcass.

Statistics. Bill Boarman, Hal Avery, and Jeff Lovich, of the BLM, indicated that 17 plots and the amount of tortoise sign found was sufficient to perform statistical analysis (pers. comm., February 1992). They also made recommendations for those analyses. A regression analysis was performed on the data using Lotus 1-2-3 (Lotus 1990). The independent variable (x) was the amount of tortoise sign found at a given distance from the road, and the dependent variable (y) was the distance from the road at which the sign were found. The distance from the highway at which tortoise sign were found was regressed on the amount of tortoise sign, which resulted in the regression coefficients and equations given in the results section of this report.

Disturbances. Detectable disturbances were recorded for each transect, yielding a "percent occurrence" for each of 13 disturbances observed during this study. The disturbances included off-highway vehicle traffic (OHV); evidence of sheep grazing, usually scat; evidence of domestic canine use, usually tracks and digs, occasionally scat; presence of unimproved dirt roads; human foot traffic; Caltrans erosion ditches; evidence of horseback riding, usually tracks, occasionally scat; trash dumping, not including windblown litter; common ravens observed; rifle shells present; shotgun shells present; area burned; and miscellaneous ground disturbances, such as excavated pits or trenches. Disturbances were not recorded to distinguish between a single occurrence and many occurrences on a given transect; e.g. a single rifle shell and 40 rifle shells on two different transects were both recorded as "present."

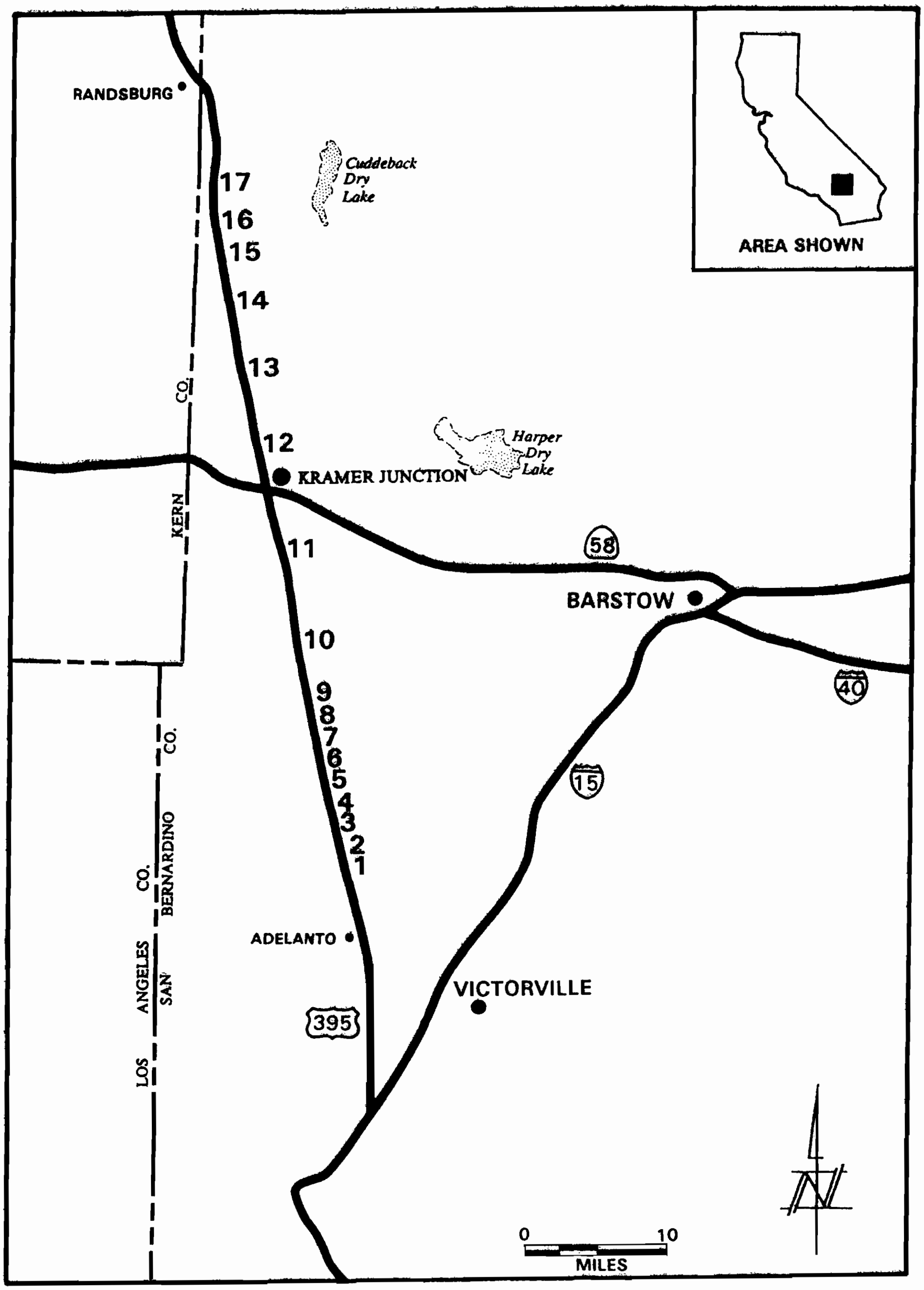


Figure 2. Locations of 17 study plots along the eastern shoulder of State Route 395.

RESULTS

<u>Tortoise sign</u>. Cumulatively, 142 tortoise scat, 38 burrows, and 20 carcasses were observed on the 340 transects surveyed. The most tortoise sign (16 scat, 5 burrows, and 2 carcasses) was observed on the plot 2.9 miles north of Shadow Mountain Road (Fig. 3, #8), although 16 scat, 2 burrows, and 4 carcasses were found near the north end of the study area (Fig. 3, #15), and 15 scat, 5 burrows, and 2 carcasses were found near the south end of the study area (Fig. 3, #2). The plot 3.3 miles north of Kramer Junction (Fig. 3, #12) yielded the fewest amount of tortoise sign, 1 scat and 1 carcass. Tortoise carcasses were found on 8 of 11 plots (73%) south of Kramer Junction, and on 2 of 6 plots (33%) north of Kramer Junction.

Prior to this study, I suspected that little or no tortoise sign occurs within about 90 m (300 ft) of a well-traveled highway, such as Highway 395. The null hypothesis was that tortoise sign is found randomly throughout the area. The experimental hypothesis was that the tortoise sign is not randomly distributed, but that the highway would have some negative impact on the numbers of tortoises immediately adjacent to the highway.

The spatial distribution of the tortoise sign is shown in Fig. 4. Fifteen (15) of 142 scat (10.6%) and 4 of 38 burrows (10.5%) were found within 91 m (300 ft) of the highway, whereas 12 of 20 carcasses (60.0%) were found within the same area. One of 38 burrows (2.6%) and three of 142 scat (2.1%) were found within 61 m (200 ft) of the highway, whereas 11 of 20 carcasses (55.0%) were found within the same 61 m interval. Two of 142 scat (1.4%) and no burrows were found within 30.5 m (100 ft) of the highway, and 6 of 20 carcasses (30.0%) were found in that area. Similar numbers of scat and burrows were found within 91 m (10.6% of the scat and 10.5% of the burrows) and 61 m (2.6% of the scat and 2.1% of the burrows) of the highway.

The four burrows found within 91 m (300 ft) of the highway were intact and apparently active: two of them "good" and two of them "excellent." Two of these four burrows were on the same plot, and, based on the sizes of the burrows, belonged to the same tortoise. One of these two burrows was in the side of a Caltrans erosion ditch, which diverts runoff from Highway 395 into adjacent areas. The only two scat found within 30.5 m (100 ft) of the highway were on the same plot and of similar size, and were likely deposited by the same tortoise. These two scat were in the vicinity of a Caltrans erosion ditch, which concentrates water in a small area and may attract tortoises into that area.

The frequency distributions for tortoise scat, burrows, and carcasses relative to the highway are shown in Fig. 5. The graph shows a step-wise increase in the numbers of tortoise scat and burrows as the distance from the highway increases. Most of the carcasses (11 of 20) are found within 60 m (197 ft) of the highway, although there is not an apparent trend between numbers of carcasses and distance from the highway.

Regression analyses were performed to determine if there is a correlation between the amount of sign and the distance from the road at which the sign occurs. The distance from the highway (y) was regressed on numbers of scat (s), burrows (b), scat and burrows combined (s + b), and carcasses (c) found along each transect, resulting in the following equations, coefficients, and significance levels:

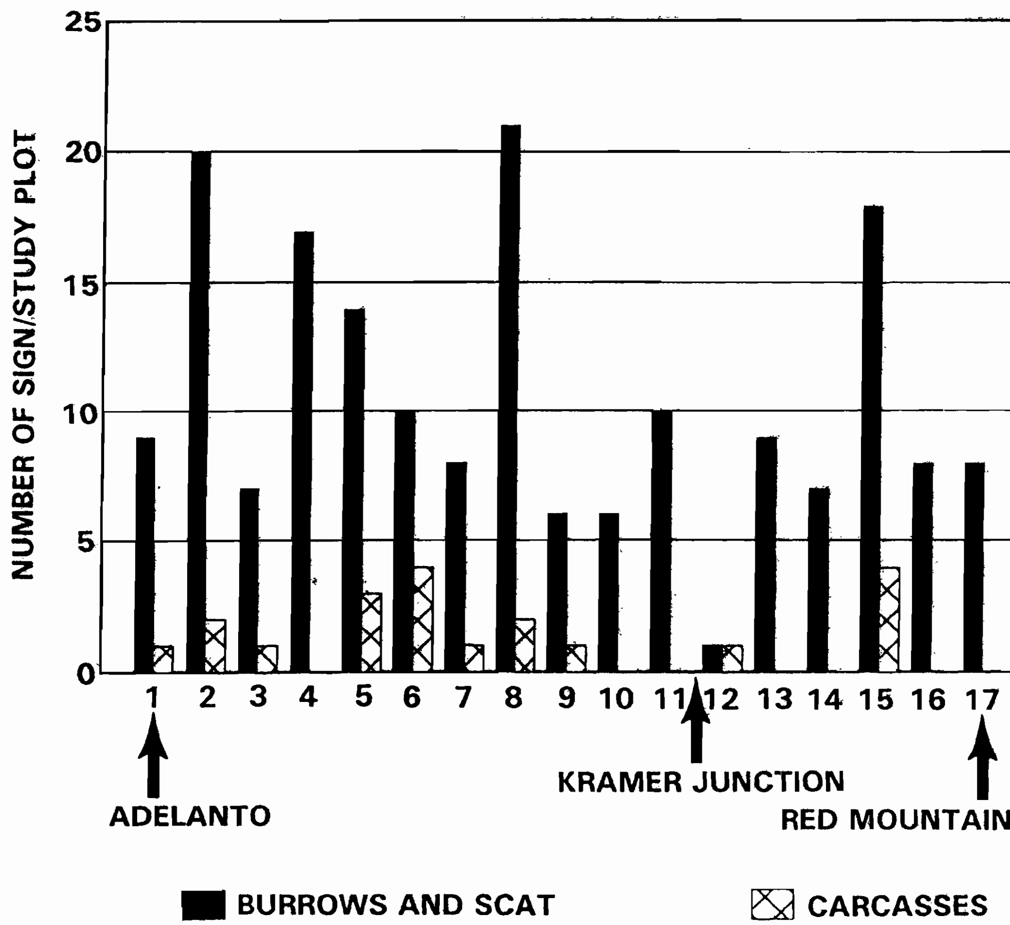


Figure 3. All sign found on the 17 plots, beginning south near Adelanto, and extending north to near Red Mountain, California.

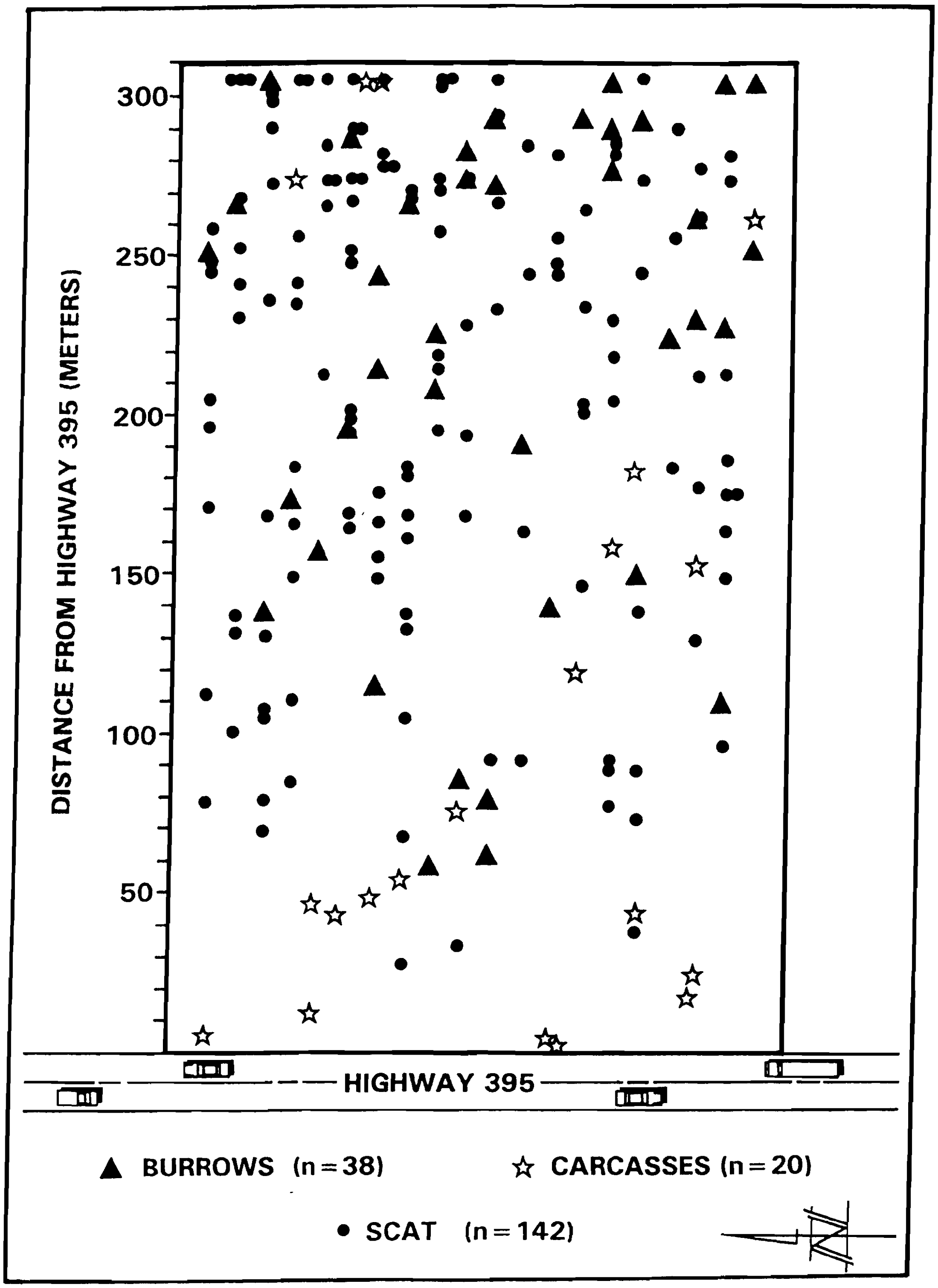


Figure 4. Spatial distribution (scattergram) of desert tortoise sign found on all 17 study plots along State Route 395.

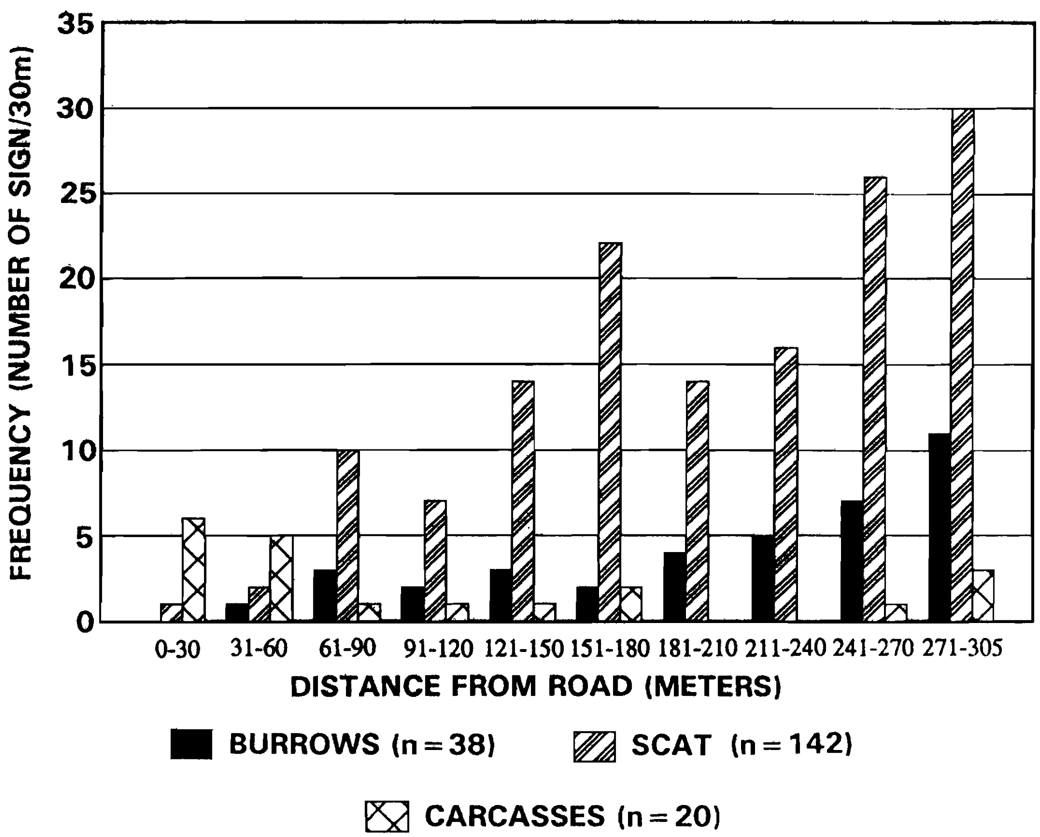


Figure 5. Frequency distribution of all sign found on 17 study plots relative to the distance from the road at which the sign was found.

Independent variable	Regression equation	Regression coefficient
Scat	$y = 10.0s + 41.3$	$r = 0.92, P < 0.0005$
Burrows	$y = 25.4b + 71.5$	$r = 0.89, P < 0.0005$
Scat and burrows	$y = 5.7s + 14.6b + 41.5$	$r = 0.94, P < 0.0005$
Carcasses	$y = -24.9c + 217.7$	$r = 0.56, P = 0.025$

The regression coefficients and level of significance were sufficiently high to indicate that there is a predictable relationship between the number of "living tortoise sign" (scat and burrows) and the distance from the road at which "x" amount of sign would be expected. For example, using the regression equation for scat, one would expect to find about 20 scat at about 241 m (790 ft) from the highway [241.3 m = 10.0(20) + 41.3], and only one scat 51 m (168 ft) from the highway [51.3 = 10.0(1) + 41.3]. For scat, burrows, and scat and burrows combined, these analyses indicate that there is a linear relationship between the amount of living tortoise sign and the distance from the road at which it occurs: the farther one goes from the road, out to 305 m, the more living tortoise sign one encounters.

During March 1991, the BLM removed 33 tortoise carcasses from alongside Highway 395, beginning seven miles south of Kramer Junction and extending 15 miles south of there (to 22 miles south of Kramer Junction) (Boarman et al. in press). Therefore, eight months prior to the present study, the BLM had removed all carcasses from the shoulder of 395 on nine of 11 plots occurring south of Kramer Junction (Figure 3, #2 through #10). Therefore, even more carcasses occurred along the shoulder of Highway 395, south of Kramer Junction, than were found during this study. Boarman said that 13 new carcasses were removed from the same stretch of Highway 395 15 months after the initial removal, indicating that 13 roadkills had occurred during those 15 months (Boarman et al. 1993).

The correlation coefficient between the numbers of carcasses and the distance from the road for this study was $r = 0.56$, with a significance level of $P = 0.025$. Therefore, there does not appear to be a linear relationship between the number of carcasses and the distance from the road at which they occur. The relationship would be even less linear if the BLM had not removed the carcasses; i.e., more carcasses would be found along the shoulder of the highway than were found during the present study.

Caltrans indicated that the Average Daily Trips (ADT) for 24 hours along Highway 395 south of Randsburg was 3,600 in 1991. The ADT at the northern end of Adelanto was 10,000 and the ADT at Kramer Junction was 7,000. This indicates that the stretch of highway between Kramer Junction and Randsburg is used about half as often as the stretch between Kramer Junction and Adelanto. Tortoise carcasses were found on 8 of 11 plots (72.7%) south of Kramer Junction, and on two of six plots (33.0%) north of Kramer Junction. More tortoises may have been killed south of Kramer Junction because of more traffic, or because more tortoises occur in those areas and there are consequently more carcasses, regardless of vehicle collisions.

Disturbances. The prevalence of disturbances throughout the 17 plots is shown in Table 1. No single disturbance was observed on all transects, although four of them: OHV traffic, sheep grazing, canine sign, and dirt roads were observed on more than half of the transects. Even though dirt roads were consciously avoided during the present study, they were still present on more than half (51%) of the surveyed transects. This is because the dirt road was not observed until after the plot survey was begun. In one case, a plot was abandoned when the first tortoise sign observed was a crushed tortoise carcass several meters from a dirt road. No similar observations were made for the 17 plots that are included in this study.

Table 1 shows the prevalence of disturbances on the two plots (Fig. 3, #2 and #8) where the most scat and burrows were observed (Most sign), the two plots (Fig. 3, #10 and #12) where the least number of scat and burrows were observed (Least sign), and the prevalence of disturbances on all 17 plots (All plots). Table1:

	Percent Occurrence		
Disturbance	Most Sign	Least Sign	All Plots
OHV traffic	100%	100%	98%
Sheep grazing	50%	90%	81%
Dirt roads	23%	70%	51%
Canine sign	75%	58%	65%
Caltrans erosion ditch	30%	30%	16%
Human foot traffic	20%	25%	18%
Miscellaneous ground disturbance	0%	33%	1%
Common ravens observed	3%	13%	7%
Horse sign	3%	13%	10%
Trash Dumping	10%	5%	7%
Rifle shells	5%	8%	3%
Area burned	0%	0%	1%
Shotgun shells	5%	3%	3%

Sheep grazing, dirt roads, and miscellaneous ground disturbance (an old railroad bed at Site #12) are much more prevalent on the plots where the least amount of tortoise sign were observed. Human foot traffic, common raven observations, horseback riding, and rifle shells are slightly more prevalent on those two plots. Domestic dog sign, trash dumping, and shotgun shells are somewhat more prevalent on the two plots where the most tortoise sign were observed.

DISCUSSION

Desert tortoise spatial distribution. When surveys are performed at distinct intervals adjacent to a given roadway, the density of tortoise sign decreases as one approaches that roadway (Nicholson 1977; BLM, in press). The present study indicates that within 305 m of Highway 395, there is a predictable decrease in the amount of tortoise sign as one approaches the highway, which implies that the highway is negatively affecting tortoises immediately adjacent to it. This study found evidence of only one living tortoise within 30.5 m (100 ft) of the highway. Tortoises, as evidenced by the locations of their scat and burrows, occur within 305 m of Highway 395, but they are more common away from the highway than immediately adjacent to it. If the assumption is correct that tortoises only occur in areas where tortoise sign is found, then tortoises may seldom be found within 30.5 m (100 ft) of the highway, and Highway 395 may serve as a barrier to tortoises occurring to the east and west.

During the 17th Annual Desert Tortoise Council Symposium, Dr. Peter Brussard said that one of the eight management areas identified in the Recovery Plan for the desert tortoise (the Fremont/Kramer Management Area) is proposed to occur along Highway 395 in the area of this study. Highway 395 bisects the proposed Fremont/Kramer Management Area. If tortoises do not often approach Highway 395 there is a limited mix of genes between tortoises occurring east and west of the highway. If this assumption is true, the Fremont/Kramer Management Area may actually consist of two distinct populations, effectively separated by Highway 395. The BLM Highway 58 study and others may show how often tortoises approach well-traveled roads. These studies may either support the conclusion that the highway effectively fragments a given population into two separate populations, or may refute that idea and show that there is a mix of genes between tortoises occurring on either side of a given highway.

If no tortoises were killed by vehicles on Highway 395, one would expect to find a random distribution of carcasses between the highway and 305 m east of it. Tortoises do occasionally approach Highway 395 as evidenced by the number of crushed carcasses found during this study. The BLM has shown that many tortoises have been killed by vehicular collision along Highway 58 (BLM 1991). Boarman (1993) has shown that as many as 13 tortoises may have been killed along Highway 395 between March, 1991 and June, 1992. Many of the tortoise carcasses found along Highway 395 during the present study had been crushed, as evidenced by their unnatural disarticulation. I believe that more carcasses occur between 0 and 61 m (200 ft) of the highway (55% of those found) than between 61 m and 305 m because the tortoises were trying to cross the road and were killed by vehicles. Tortoise carcasses persist in nature for many years (Kristin Berry, pers. comm.), and those found between 61 m and 305 m on the study plots likely include mostly tortoises that have died naturally and a few that have been killed by vehicular collisions.

<u>Effects of disturbances on tortoise densities</u>. Within the 17 study areas, it appears that certain disturbances, such as foot traffic, horseback riding, canine sign, and certainly Caltrans erosion ditches are more prevalent immediately adjacent to Highway 395 than farther out from the highway. The highway serves as a focal point for people walking through the desert or those traveling by horseback. Motorcycles and all-terrain vehicles may ride parallel to the highway on established and unestablished routes. Vehicles stop on the shoulder of the highway and passengers leave their cars, often with their pets, to go into adjacent desert areas. Dumping is most often associated with unimproved roads, which in turn are more common along major highways than in open, untraveled desert areas. Ravens are known to congregate along highways, using distribution towers for nesting, and may travel in straight lines alongside a highway (Knight and Kawashima, in press). There are unknown variables, such as heavy vehicle vibrations in adjacent areas, that may affect the prevalence of tortoise sign adjacent to Highway 395. Any one or all of these disturbances may result in fewer tortoises immediately adjacent to Highway 395.

Figure 6 shows the results of the disturbance analysis that was conducted for the two 80-acre parcels in Helendale, California. Five of the 10 disturbances observed on the 80-acre parcel bisected by National Trails Highway were observed on 100% of the transects surveyed; only sheep grazing and OHV tracks were observed on all transects on the southern parcel. Horse sign, dog sign, foot traffic, and trash dumping appeared to be associated with National Trails Highway, and were more prevalent on the northern parcel than the southern one. Figure 1 shows that there is an obvious difference in tortoise density between these two parcels. I believe that the difference is due to the presence of the well-traveled highway through the northern parcel. Human disturbances and accessibility associated with the highway have reduced the prevalence of tortoises on the northern parcel, relative to the southern one, and have resulted in fewer tortoise sign and more collapsed burrows on the northern parcel.

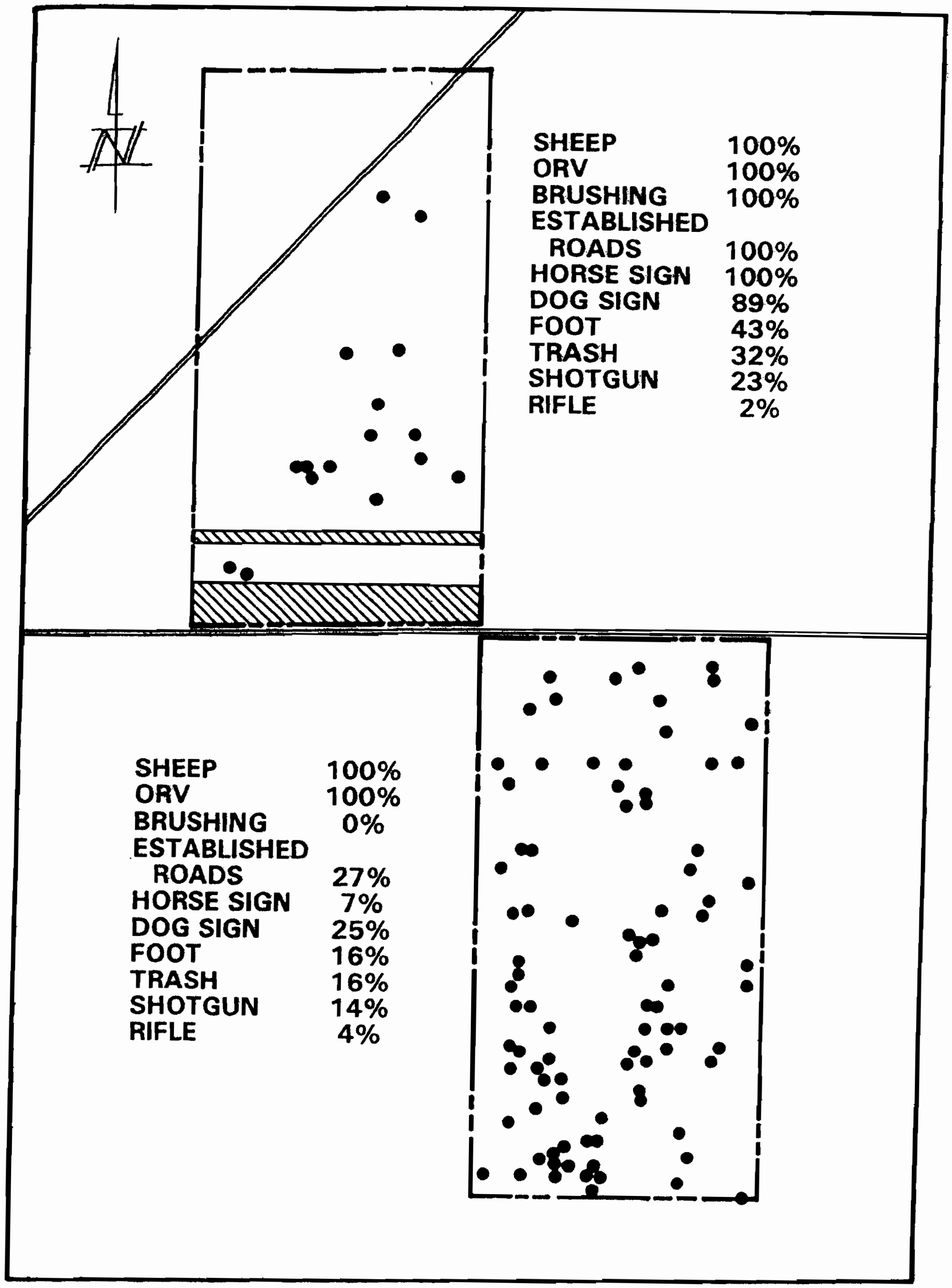


Figure 6. Prevalence of disturbances on the two 80-acre parcels near Helendale, California.

There have long been plans to widen Highway 395, and tortoise-proof fences may be constructed along either side of the widened highway. I suspect that the prevalence of disturbances adjacent to the widened highway will decrease if tortoise-proof fences are installed. Human encroachment into adjacent areas, particularly OHV traffic, human foot traffic, and canine sign, would likely be reduced if a tortoise-proof fence is attached to a barbed wire fence. It is strongly recommended that Caltrans conduct baseline disturbance analyses so that disturbances prior to fencing and after fencing can be compared. Caltrans should also determine if the installation of the tortoise-proof fence encourages tortoises to come closer to the road. Those tortoises that are trying to cross the road would likely wander the fenceline until they were given access to the other side by means of a culvert or other underpass structure. Still, if disturbances are minimized in areas adjacent to the highway, and those disturbances were responsible for the lesser amount of tortoise sign, then one would expect that more tortoise sign would be found closer to the road after the fences are installed. Data collected during the present study may serve as baseline information to answer such a question, although it is recommended that Caltrans collect more data over a longer period of time so that the effects of tortoise-proof fences can be more accurately determined.

ACKNOWLEDGEMENTS

I am grateful to B. Boarman, H. Avery, and J. Lovich for their statistical advice. M. Pantoja did a wonderful job on the graphics. This was an unfunded project, conducted exclusively by the author. Thanks to S. Dougherty for understanding all the weekends away from home to perform surveys. Thanks to Tierra Madre Consultants, Inc. for use of its computers and facilities to produce this paper.

LITERATURE CITED

Baxter, R.J. 1988. Spatial distribution of desert tortoises (*Gopherus agassizii*) at Twentynine Palms, California: Implications for relocations. A paper presented at the symposium: Management of Amphibians, Reptiles, and Small Mammals in North America, Flagstaff, Arizona, July 19-21, 1988. Flagstaff, Arizona.

Boarman, W.I. 1993. Effectiveness of fences and culverts for protecting desert tortoises along California State Highway 58: Summary of second field season. Report to California Energy Commission. Bureau of Land Management, Riverside, California.

Boarman, W.I., M. Sazaki, K.H. Berry, G.O. Goodlett, W.B. Jennings, and A.P. Woodman. In press. Measuring the effectiveness of tortoise-proof fences and culverts: Status report from the first field season. Proc. Symp., Desert Tortoise Council. 1992.

Bureau of Land Management. 1991. Effectiveness of fences and culverts for protecting deserttortoises along California State Highway 58: Final report on study design. Report prepared by the California Desert District, Bureau of Land Management, Riverside, California for the California Energy Commission. Contract No. 700-89-007; Task 2.3.

Goodlett, G.O. and G.C. Goodlett. 1991. Studies of unauthorized off-highway vehicle activity in the Rand Mountains and Fremont Valley, Kern County, California, during Fall, 1991. A report contracted by the Desert Tortoise Preserve Committee and prepared by Enviro Plus Consulting. Ridgecrest, California.

Knight, R.L. and J.Y. Kawashima. 1992. Responses of common raven and red-tailed hawk populations to linear right of ways. Journal of Wildlife Management. In Press.

Lotus 1-2-3. 1990. Lotus 1-2-3 Release 3.1. Cambridge, Massachusetts.

Nicholson, L. The effects of roads on desert tortoise populations. Proc. Symp., Desert Tortoise Council. 1978:127-129.

Tierra Madre Consultants, Inc. 1991a. Focused desert tortoise survey on Tentative Tract 15199, Helendale, California. A report contracted by Jay Vanderwal. Job #91-061. Riverside, California.

Tierra Madre Consultants, Inc. 1991b. Focused desert tortoise survey for Tentative Parcel Map 13882, Joshua Tree, California. A report contracted by Al Scharton. Job #91-081. Riverside, California.

Tierra Madre Consultants, Inc. 1991c. Focused desert tortoise survey for Phase 1 and 2 of Tentative Tract 13989, Helendale, California. A report contracted by National Land Corporation. Job #91-017. Riverside, California.

Tierra Madre Consultants, Inc. 1992. Focused desert tortoise survey for the Valley Community Chapel and Good Shepherd Lutheran Church sites, Yucca Valley, California. A report contracted by Art Miller, Jr. Job #92-004. Riverside, California.

United States Fish and Wildlife Service. 1992. Field survey protocol for any non-federal action that may occur within the range of the desert tortoise. Ventura, California.

EXHIBIT 606

The Effects of Roads on Desert Tortoise Populations

Lori Nicholson

The effect of vehicular travel upon paved roads on the desert tortoise *(Gopherus agassizi)* in the Mojave Desert, California, was investigated from September through November 1977. Ten study sites were selected adjacent to paved roads. The location of each road, year paved, number of lanes, and traffic volume (Average Daily Traffic-vehicles/day) are as follows:

1) Highway 58, west of California City Boulevard; 1946; 2 lanes; ADT 4950 (1976).

2) Neuralia Road, north of Phillips Road; 1955; 2 lanes; ADT 150 (1977).

3) Redrock—Randsburg Road, 6 kilometres west of Randsburg; 1935; 2 lanes; ADT 140 (1977).

4) Highway 395, north of Twenty-Mule Team Road; 1933; 2 lanes; ADT 2250 (1976).

5) Highway 95, north of Turtle Mountain Road; 1933; 2 lanes; ADT 1100 (1976).

6) Interstate 15, 10 km south of Barstow; 1961; 4 lanes; ADT 17700 (1976).

7) Interstate 40, Ward Valley; 1931; 4 lanes; ADT 6000 (1976).

8) Interstate 40, east of Daggett Interchange; 1965; 4 lanes; ADT 7000 (1976).

9) Barstow Road, 19 km south of Barstow; 1953; 2 lanes; ADT 340 (1976).

10) Shadow Mountain Road, 2 km east of Highway 395; 1974; 2 lanes; ADT 285 (1977).

Vegetation and topography throughout each site were nearly homogeneous. All sites were dominated by creosote bush *(Larrea tridentata)* and burrobush *(Ambrosia dumosa)*, however other perennial species, percent vegetative cover, soils, and human impacts varied between sites. Four transects, 4.83 km long by 9.14 metres wide, were walked parallel to each road at distances of 91.4, 365.6, 804.3, and 1608.6 metres, respectively, from the road. All observed tortoise sign (burrows, shells, live individuals, scats, etc.) within each transect area were recorded on a Bureau of Land Management standard tortoise survey form. The total number of sign per transect provides a relative measure of tortoise density.

Generally, the data indicated an increase in tortoise sign with increasing distance from the road. The increase in sign averaged approximately 8X from the 91.4 to 1608.6 metre transects. At 9 of the 10 sites there was an increase in sign up to the 804.3-m transect. At 6 of the 9 sites there was an increase from the 804.3- to the 1608.6-m transects, at 2 a slight decrease in sign, and at the other site, Barstow Road, sign number decreased sharply at the 1608.6-metre transect. The sharp decline was attributed to sampling error, which was probably caused by very low tortoise densities adjacent to Barstow Road. An increased sampling area may be required to adequately measure very low number of sign. Tortoise sign at the remaining site, Shadow Mountain Road, increased with increasing distance from the road except at the 804.3-m transect, which intersected an area receiving excessive off-road-vehicle use. This may have caused a reduction in tortoise sign in the area. Excluding Barstow and Shadow Mountain roads because of the aforementioned biases in the data, the correlation coefficient for data from 8 sites was .87. At these 8 sites, the average difference in number of sign between the 2 transects farthest from the road was less than the average differences between other transects, indicating that tortoise densities beyond the 804.3-metre transect may become relatively constant. The decrease in tortoise densities adjacent to roads presumably is a result of mortality via vehicular collision or from removal by passing motorists.

Of all road parameters examined (age, width, and traffic volume) the most distinctive trends in sign increase were among sites adjacent to roads paved either relatively recently or long ago. Sign increase of 4 roads paved between 1931 and 1935 was gradual and nearly linear. The correlation coefficient for these roads was .95. In comparison, 3 roads paved in 1961, 1965, and 1974 exhibited a sharp increase in sign from the 91.4- to 365.6-metre transects, and beyond the 365.6-metre transect there was a significantly lesser increase. These 3 new roads had a correlation coefficient of .73, probably lower because the relationship was more curvilinear. Apparently the newer roads have not existed long enough to affect tortoises more than 0.4 km away, whereas the older roads may have reduced tortoise numbers up to 2 about 2 km away.

These data indicated that paved roads and vehicular traffic have a detrimental effect upon tortoise populations within about a kilometre of a road. Considering the many kilometres of paved roads and additional kilometres of unpaved roads throughout desert habitats occupied by tortoises, roads may be a major factor contributing to the reduction of tortoise populations.

California Desert Program
Bureau of Land Management
3610 Central Avenue, Suite 402
Riverside, California 92506

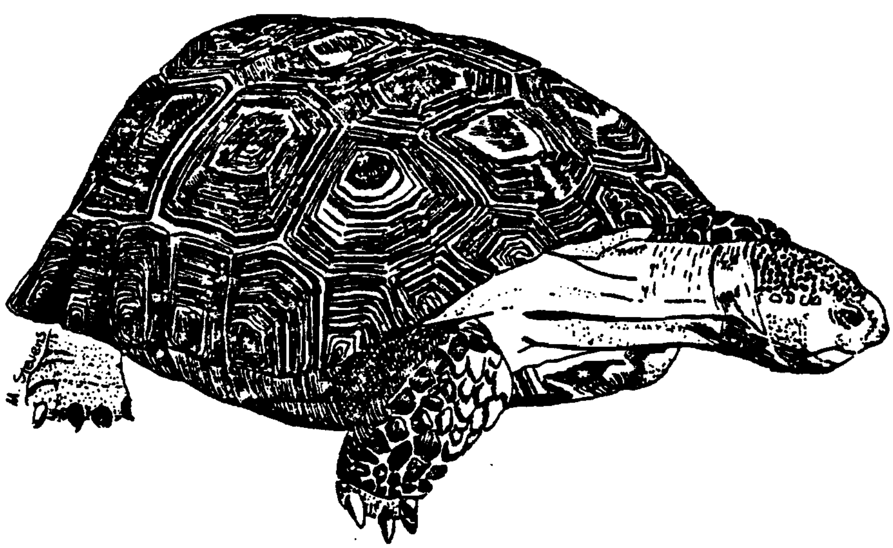


EXHIBIT 607

Threats to Desert Tortoise Populations: A Critical Review of the Literature

Prepared for:

West Mojave Planning Team,
Bureau of Land Management

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Threats to Desert Tortoise Populations: A Critical Review of the Literature

By William I. Boarman, Ph.D.[1]

U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Prepared for:

West Mojave Planning Team
Bureau of Land management

[1]San Diego Field Station
USGS Western Ecological Research Center
5745 Kearny Villa Road, Suite M
San Diego, CA 92123

Sacramento, California
Aug 9, 2002

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, SECRETARY

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information, contact:

Center Director
Western Ecological Research Center
U.S. Geological Survey
7801 Folsom Blvd., Suite 101
Sacramento, CA 95826

TABLE OF CONTENTS

INTRODUCTION

Decisions in resource management are generally based on a combination of sociopolitical, economic, and environmental factors, and may be biased by personal values. These three components often contradict each other resulting in controversy. Controversies can usually be reduced when solid scientific evidence is used to support or refute a decision. However, it is important to recognize that data often do little to alter antagonists' positions when differences in values are the basis of the dispute. But, supporting data can make the decision more defensible, both legally and ethically, especially if the data supporting all opposing viewpoints are included in the decision-making process.

Resource management decisions must be made using the best scientific information currently available. However, scientific data vary in two important measures of quality: reliability and validity. The reliability of the data is a measure of the degree to which the observations or conclusions can be repeated. Validity of the data is a measure of the degree to which the observation or conclusion reflects what actually occurs in nature. How the data are collected strongly affects the reliability and validity of ecological conclusions that can be made. Research data potentially relevant to management come from different sources, and the source often provides clues to the reliability and, to a certain extent, validity of data. Understanding the quality of data being used to make management decisions helps to separate the philosophical or value-based aspects of arguments from the objective ones, thus helping to clarify the decisions and judgements that need to be made.

The West Mojave Plan is a multispecies, bioregional plan for the management of natural resources within a 9.4 million-acre area of the Mojave Desert in California. The plan addresses the legal requirements for the recovery of the desert tortoise (*Gopherus agassizii*), a threatened species, but also covers an additional approximately 80 species of plants and animals assigned special status by the Bureau of Land Management, U. S. Fish and Wildlife Service, and California Department of Fish and Game. Within the planning area, 28 separate jurisdictions (counties, cities, towns, military installations, etc.) seek programmatic prescriptions that will facilitate stream-lined environmental review, result in expedited authorization for development projects, and protect listed and unlisted species into the foreseeable future to avoid or minimize conflicts between proposed development and species' conservation and recovery. All of the scientific data available concerning the biology and management of these approximately 80 species and their habitats must be evaluated to develop a scientifically credible plan.

This document provides an overview and evaluation of the knowledge of the major threats to the persistence and recovery of desert tortoise populations. I was specifically asked to evaluate the scientific veracity of the data and reports available. I summarize the data presently available with particular focus on the West Mojave Desert, evaluate the scientific integrity of those data, and identify major gaps in the available knowledge. I do not attempt to provide in-depth details on each study or threat; for more details I encourage the reader to consult the individual papers or reports cited throughout this report (many of which are available at most university libraries and at the West

Mojave Plan office in Riverside, California). I also do not attempt to characterize or evaluate the past or present management actions, except where they have direct bearing on evaluation of threats, nor do I attempt, for the most part, to acquire, generate, or evaluate new or existing, but uninterpreted data.

Two Important Caveats

Lack of scientific evidence supporting a purported impact should not be confused with automatically supporting the alternative, that there is no impact, and vice versa. Or as it is sometimes said: "absence of evidence is not evidence of absence." It may just mean that credible or definitive studies testing the hypothesized effects have either not been conducted or not been reported adequately.

Additionally, when I critique a particular study I am neither criticizing the scientist's ability or intent. Often, studies have inherent weaknesses that are completely or largely out of the control of the researcher. For example, as discussed below, it is often very difficult to have a proper control for a study in nature and it is often too expensive or impossible to adequately replicate a natural study. Rather than abandoning the questions altogether, scientists forge ahead with the study in spite of its limitations and collect data that hopefully are useful for managers. I point out the weaknesses here so managers will understand the limitations of such data, not to criticize the researchers not to render the studies useless. Virtually all studies have some inherent value, but their utility falls at different points on the continuum of risk to managers depending in part on how they were conducted and reported.

USE OF DATA TO MAKE MANAGEMENT DECISIONS

Scientific investigations follow an orderly, repeatable process. Many such investigations begin with anecdotes from ranchers, recreationists, or casual observers of nature. These might include issues of concern to managers, such as "I'm seeing fewer tortoises these days" or "tortoises and cattle can coexist." Anecdotes are useful for pointing out to researchers what critical problems may need to be solved through scientific investigation. Most scientific research follows up anecdotes that seem plausible with more craftily constructed hypotheses and direct observation by experienced observers. If such observations warrant further investigation, scientifically based observational studies are initiated. Most studies pertaining to desert tortoises fall into this category. However, observational studies may have problems, such as lack of adequate controls, insufficient sample sizes, or researcher bias in study design or interpretation. In a few cases, experiments are used to objectively test hypotheses that were developed from anecdotal or observational data. Experiments or carefully designed observational studies may lead to development of conceptual or mathematical theories that can then be used to predict responses of valued resources to management actions. Theory can then be tested with further experimentation or well-designed observations. Very little theory has been applied to problems related to land-management practices in the Mojave Desert.

Types of Data

The quality of data depends on how the questions were formulated and how the data were collected. Research questions in tortoise biology and management rarely employ a standard scientific method called “strong inference” (Platt 1964). For strong inference, progress is generally made by devising clear, falsifiable alternative hypotheses and conducting experiments designed to test competing predictions of these hypotheses. The strongest support for one alternative comes from experimental results that exclude other alternatives. Studies that test only one hypothesis are weak because they fail to show that the same results cannot be explained by other hypotheses. In tortoise research we generally see studies that are designed to support a pre-determined “ruling theory” or “working hypothesis” (Chamberlin 1965) or to simply describe nature. Such studies do little to explicate the phenomenon and to truly advance the management objectives supported by the research.

There are several types of studies that vary by how the data were collected. These categories are listed below in descending order from those generally providing the strongest, most valid conclusions to those providing the weakest, least reliable information. Value specifically refers to the level of risk a manager is taking when making a decision based on the data. The lower the value, the higher the risk. The actual conclusion may be right on target, but if it is from a risky type of data collection, the manager runs a higher risk of making an unsound decision.

Experiment

The strongest scientific data, those demonstrating cause and effect relationships, are generated via well-controlled and replicated experiments (Hairston 1989, Lubchenco and Real 1991). Such experiments involve manipulating one variable (treatment, such as presence of cattle) while holding all other variables constant (such as tortoise density or soil type). Such a design must have a control (or reference site) wherein ideally the only difference is the lack of the treatment. Any resultant change in the treatment area is likely to be caused by the particular treatment. However, one of many uncontrollable factors may occur that could result in a change independent of the treatment. These uncontrollable features, called random error, can fatally compromise the results. To reduce the effects of random errors (or chance), a properly designed study must have replicates - two or more sites that serve as control and two or more sites that serve as the treatment sites (Hurlbert 1984). The more replicates there are, the lower the chance that differences observed between treatment or control sites can be caused by random error. Another source of error that is mitigated by replication is uncontrollable (or unrecognized) differences among study sites (e.g., soil type, grazing history, and slope).

Any experiment that fails to have an adequate number of replicate treatment and control sites fails to satisfy an essential requisite for strong inference. Admittedly, it is often difficult or even impossible in natural settings to establish true control sites where the only difference is the lack of a treatment, not to mention have multiple replicates of the treatment and control. But having a proper control is an important feature and conclusions drawn from studies that lack a control suffer as a result.

Furthermore, the strength of any experiment, its ability to be broadly applicable, is bolstered by sample size. However, when comparing a given treatment with a given control, the sample size is the number of replicate study sites, not the number of measurements taken within each site. It is all too common for studies, particularly non-peer reviewed ones, to artificially inflate their sample sizes thus often reporting a significant effect (i.e., difference between treatment and control caused by the treatment factor) when in fact one did not occur or when the study was inadequately designed or carried out to discern a difference if one indeed existed. For example, when studying the effect of a factor like off-road vehicle (ORV) activity on desert habitat, it is common to measure number of plants and plant species within an ORV area versus outside of the area. If the researcher measured number of plants and plant species along ten transects within a single plot inside and ten transects within a single plot outside, the sample size is not 10 (nor 20) rather it is 1, because there is only one pair of plots being compared. Any differences observed may actually be caused by other factors such as different elevation or vegetation type. To avoid the random error of non-replication, multiple plots should be studied and these should be inside and outside of several ORV areas.

Correlation

Many studies in natural environments measure how a given factor (e.g., animal density) varies at different levels of some treatment (e.g., intensity of cattle grazing). This type of experiment can only show a correlation between the two factors. It provides no evidence that one factor causes a change in the other. Any correlation may just as well be from some unmeasured feature of the environment that affects both factors measured or it may be caused by chance. A cause and effect relationship can only be demonstrated if it can be shown that varying one factor (the independent variable) causes a predictable and consistent change in the other factor (dependent variable). Unfortunately, this is often the only means we have to study phenomena in the natural environment.

Description/Observation

Many studies simply describe a particular physical state or phenomenon (e.g. amount of trash or number of tortoises in a study area). The description can be simply qualitative (e.g., “a lot” or “many”) or may be quantitative involving complex statistics (e.g., means, standard deviations, confidence intervals). Such studies may provide excellent descriptions, but cannot test for cause and effect relationships.

Anecdote

Generally, a non-quantitative description limited in scope (usually a single observation of the given phenomenon) and depth of detail is considered an anecdote. An example of an anecdote is: “in 1978 I saw a tortoise eat a balloon.” Anecdotes usually lack any formal documentation and are most often made by untrained, casual observers, but professionals often report anecdotal observations. Sample sizes are extremely limited. Anecdotes are highly risky for basing management decisions because of their lack of rigor, repeatability, and objectivity.

Anecdotes need to be properly evaluated using sound scientific methodology. They can often form the basis for more formal observations, hypothesis development, or experimentation. Occasionally, there are attempts to legitimize anecdotes by compiling many into a single report and attempting a quantified or statistical treatment. These are misguided attempts because the extreme weakness and subjectivity of the basic data limit entire analyses: the anecdote. An appropriate expression is “the plural of anecdote is not data” (Green 1995).

Speculation

People will often make guesses about possibilities for which there are no hard data. When those guesses are based on clearly stated and well-founded assumptions, the guesses are called hypotheses and can help to direct future conceptual and experimental pursuits (Resnik 1991). When assumptions are weak or unstated the guesses are speculations. An example of a speculation is that fallout from nuclear tests in Nevada in the 1950s is responsible for the prevalence of disease in tortoises today. There is no evidence that fallout from nuclear testing can cause the diseases harming tortoises and no reports detailing the amount of fallout that occurred in tortoise habitat. There are no attempts to correlate probable fallout amounts with incidence of disease. The assertion is strictly a speculation because, on the face of it, it makes some sense.

Speculations may be seductive; often they present a series of progressively dependent statements that have an internal logic of their own. The logic may appear compelling and is often bolstered by attempts to provide "proof" through analogies. Such argumentation often collapses when primary assumptions are nullified or when they are tested against real data, but too often the test is never made. Although they may sometimes form the basis for hypotheses and experiments, speculations are risky to base management decisions on because there is essentially no way to evaluate them and their predictive value is low.

Source of Data

Data sources fall into several categories with varying probabilities of adequate reliability and validity. The source of data provides some indication of its quality. However, it is possible that a particular conclusion based on data from a less reliable source is more true or accurate than one from a more reliable source, but the likelihood of this being the case is low. Thus it is less risky to base judgements on data obtained from more reliable sources. The basic sources of data follow, in order of increasing risk to management (i.e., decreasing reliability):

Peer Reviewed Open Literature

Open literature refers to articles readily available in university and public libraries and published in professional, publicly available outlets. Easy availability allows anyone to obtain and evaluate the data on which decisions are made.

Peer review is a cornerstone of the scientific process. Rigorous peer review has two essential components: 1) thorough review by two or more scientists (generally anonymous) knowledgeable on the topic and 2) the possibility of rejection if the report does not meet generally accepted scientific standards. The latter component is an important feature that is lacking in less reliable data sources. The review process helps to ensure (but does not guarantee) that: 1) only reliable data with valid conclusions are published because the reviewers make certain that data are presented in sufficient detail to allow adequate evaluation of the conclusions; 2) the collection and analysis methods followed modern scientific standards and were appropriate for making the tests reported, 3) were reported in sufficient detail to allow someone to adequately evaluate and repeat the study; 4) the conclusions follow logically from the data; and 5) relevant related data (e.g., peer-reviewed publications), whether supporting or contradicting the study's conclusions, are cited. Most professional scientific journals (e.g., Ecology, Range Management, Journal of Wildlife Management, Herpetologica, Bulletin of the Wildlife Society) are peer reviewed. The Desert Tortoise Council is now implementing an external review process for its annual symposium proceedings.

Technical Books, Theses, and Dissertations

Most technical books are peer reviewed, but often without the true possibility of rejection. They are often reviewed by an in house editor or panel of editors who may or may not be experts in the particular field. Opinions differ on whether master's theses and doctoral dissertations should be considered peer reviewed. They do not undergo the same blind review that papers in scientific journals do, but they probably receive a much higher level of scrutiny than most papers. Furthermore, there is much more at risk if the thesis or dissertation fails review: the student is not awarded the Masters or Ph.D. In this report, they are treated as technical books being reviewed by a panel (i.e., the student's graduate committee).

Non-peer Reviewed Open Literature

Articles from this source are often used to support decisions or recommendations probably because there are many of them available, the sources are widely available, and the fact that they have been published adds a perception of respectability. However, there are often risks of using this type of data source. The authors and editors may not be specialists in the field they are writing about or are not scientists. Additionally, there is often no attempt at a logical, unbiased, rationally supported presentation. Occasionally, special interest groups that are pushing a specific interest and land ethic (e.g., Audubon Society, Rangelands, Desert Tortoise Council) publish outlets cited.

By definition, non-peer reviewed sources do not follow the established methods of peer review: there is usually no independent, objective evaluation of the data presentation and no guarantee that articles will be rejected if they fail to meet accepted scientific standards. Often missing is information necessary to allow the reader to evaluate the reliability of data collection and analysis. Statements such as “many tortoises were killed by vehicles” or “tortoises depend on cow dung for nutritional needs” are made without details about how the author determined if a vehicle killed a tortoise, how often tortoises actually eat cow pies, or what are the nutritional needs of tortoises.

Most proceedings of meetings (e.g., past issues of the Proceedings of the Desert Tortoise Council Symposium -) as well as abstracts from meetings are incompletely or not peer reviewed, and contents are usually printed verbatim with little or no editing and no possibility of rejection. Proceedings papers and abstracts often contain preliminary analyses of data and conclusions may change following the final complete analysis and rigorous peer review. The same criticisms holds for many official bulletins and newsletters of professional societies (e.g., Bulletin of the Ecological Society of America, Rangelands).

Technical Reports

Technical reports are generally written by agency and contract scientists and biologists and sometimes individuals untrained in the practices of science and biology. Technical reports are probably the most commonly used source of data for basing management decisions. Many agency biologists do not have the time, opportunity, encouragement, need, or training to publish their data. Sometimes reports are generated for the purpose of providing a quick analysis for management decisions that cannot wait for the one to two years often necessary to become published in a peer reviewed outlet. Such reports may not be subjected to review by competent scientists and are rarely rejected. “Draft” reports may never be finalized and become widely used even though they may be incomplete or fatally flawed. Because they do not appear in the open literature, refutations or critiques of the reports are rarely available. Finally, they may be difficult to locate, which prevents independent evaluation of their findings.

Reports by government biologists and biological consultants are variable in quality. Many are well designed, researched, and written and draw adequately on the existing body of scientific knowledge. Others demonstrate a lack of knowledge of tortoise biology and common management practices; fail to properly cite previous studies, particularly when contrary to the conclusions or recommendations being made in the report; make recommendations that are untested or unwarranted; and have not been peer reviewed. Such reports form the basis of many management decisions that have or are being made and may result in implementation of non-standard mitigation measures and speculative conclusions that were not tested for their efficacy.

Unpublished Data

There are many data sets (e.g., raw data, tables of compiled data, GIS maps, etc.) that are cited and used even though they may not have been checked for errors, analyzed, or adequately documented (e.g., data collection methods may be unknown). Reliance on such data for making decisions is risky particularly when there is no documentation (e.g., metadata) of how the data were collected and limitations of the data are not discussed.

Professional Judgement

When the proper research has not been conducted or completed, or time or expertise is not readily available, managers often rely on the professional judgement of staff biologists or other scientists. Reliance on professional judgement requires managers to use data that are unreliable if only because they cannot necessarily be independently evaluated or examined. The judgement may involve unsupported speculation, data that have been improperly or incompletely analyzed, or may involve faulty recall of the facts. On the other hand, professional judgements may be very sound, reliable, and based on an objective evaluation of the information available. The manager may not be able to separate good from poor judgements because there is generally too little information to evaluate. Judgements solicited from several competent professionals is advisable when possible. Also, the professionals chosen to provide input should provide citations and critical analyses of the data they are using to make the judgement. They should clearly state where the strengths and weaknesses in their judgements lie. Following steps like these can help to ensure the value of professional judgement.

Science Lore

Science lore, best defined as being the collective knowledge of the scientific, resource professional, or layperson community, is often based more on observation, assumption, and speculation than on scientifically-collected and analyzed data. Facts entrenched in science lore are not necessarily incorrect. They are unreliable because the connection between the hard data and the interpretation may be unknown. Common sources of Science Lore include Television programs, hobbyist journals, newsgroups, and casual conversations with professionals and laypersons.

A common example of Science Lore is the statement that "tortoises live to be 100 years old or more." This may be true, but in fact the oldest tortoises for which any documentation exists were two captive animals; one was at least 67 years old and maybe in its mid seventies and the other was probably at least 74 and maybe older (the former was adult-sized when first captured 52 years earlier, Jennings 1981; and the later was adult-sized when captured and grew little in the 59 years before it died, Glenn 1986). No one has followed marked animals in the field long enough to know the average or maximum longevity. In the pair of studies usually cited as evidence for long life, six marked tortoises, recorded as adults by Woodbury and Hardy (1948) in the early 1940's, were refound still living in the 1960's (Hardy 1976). They may have been over 100 or perhaps as young as 30 - 50 years when refound. Since they were of unknown (or unreported) age at the time of capture, we do not know their true age. Using scute annuli (age rings), Germano (1992) estimated that most desert tortoises live 25-35 years, but some live more than 40 years. The cohort of tortoises reported on in Turner et al. (1987a) is still being followed; these known-aged animals are now 40-41 years old (Medica pers. comm.).

The onus is on the scientific community to identify statements that fall into this category. Researches should then investigate the underlying assumptions, find or collect supporting or refuting data and publish the results. Then, fact-based science lore can be elevated to known facts, and unsound lore can be modified or dropped from our lexicon of apparent facts.

This report identifies the quality of the data available on the major threats confronting desert tortoise populations in the hope that the scientific-based components of the final decisions can be clearly separated from the value-based components.

Two Final Caveats

The citation of draft reports or completed but unpublished ones is not normal scientific practice. Because this is a critique of all data that may be relevant to decision making for the West Mojave Plan, draft and incomplete reports are cited. This was done because such documents are often relied upon heavily for making management decisions.

Second, this report includes some papers and observations that are highly speculative or made by laymen, sometimes only in casual conversation. These were included here because they are often pervasive parts of the lore of the tortoise or desert communities and deserve some evaluation even if they were not made in scientific literature.

DESERT TORTOISE BIOLOGY

Knowledge of many characteristics of the basic biology of an organism is essential for making informed decisions concerning the management of that organism. Many aspects of tortoise biology are well known. The reader is referred to the following papers for general summaries of what is known: Berry (1978), Hohman and Ohmart (1980), Bury (1982), Bury and Germano (1994), USFWS (1994), Ernst et al. (1994), Grover and DeFalco (1995), and Boarman (2002). No comprehensive critical summary of tortoise biology exists and is sorely needed. A recent summary of anthropogenic impacts to desert habitat is Lovich and Bainbridge (1999).

SPECIFIC THREATS TO TORTOISE POPULATIONS

Threats occur under two major categories, direct and indirect, although they are not necessarily mutually exclusive. Direct threats are those that affect the survival or reproduction of tortoises (e.g., road mortality, illegal collecting, disease, predation). Indirect threats affect tortoise populations through their effect on other factors, primarily habitat (e.g., drought, habitat alterations from livestock grazing, recreational activities, global warming, etc.). Direct threats are usually more easily measured and therefore more easily evaluated than indirect effects.

To determine the impact of a specific threat on tortoise populations, it is insufficient to measure the threat solely (e.g., number of cars or density of mines in an area.) One must determine the effect the threat has on some aspect of tortoise reproduction or survival. Many parameters of tortoise biology can be measured when attempting to determine impacts of threats. Sometimes, the easiest and most intuitive response is mortality. It is difficult to deny that a motorized vehicle killed a fresh, smashed tortoise found on a paved highway. When tortoises die they leave behind a shell that can last for four years or more (Woodman and Berry 1984). Often that shell bears evidence of the cause of death (e.g., tooth marks, conchoidal fractures, fracture from blunt trauma, etc.). However, interpreting these signs is subjective and little scientific work that can aid interpretation has been conducted (but see, Berry 1985, 1986a) and most assumptions made in interpreting the evidence are not reported. Reproduction is more problematical, but at least clutch size and frequency can be measured with x-rays or sonograms or by locating nests and monitoring hatching success (Gibbons and Greene 1979; Turner et al. 1986, 1987b; Rostal et al. 1994). Survival of the young is an essential component to understanding the effect of threats on tortoise populations, but is very difficult to measure (e.g., Turner et al 1987b, Morafka 1994). Growth (Medica et al. 1975, Germano 1988, Turner et al. 1981, Patterson and Brattstrom 1972), behavior (Ruby and Niblick 1994, Ruby et al. 1994), and physiology (Nagy and Medica 1986, O'Connor et al. 1994a, Christopher et al. 1994) vary with environmental conditions and may be useful parameters for measuring the effect of impacts, but their efficacy at doing so has yet to be demonstrated. Modeling population demography (i.e., age-specific survival and reproduction), when using accurate measures from the population, can be an excellent way of evaluating the effects of threats and management actions on population growth (Congdon et al. 1993, Heppell 1998).

Relative Importance of Threats

The rating of relative importance of different threat factors is a challenging undertaking for several reasons. First, it is very hard to determine the cause of death of animals and it is even harder to determine how much decline is really attributable to the various indirect causes of mortality (e.g., habitat alteration). Educated guesses can be made about causes of death (Berry 1984, 1985, 1986a, 1990 as amended), but most of the methods used have not been described or subjected to experimentation, independent evaluation, or peer review. Second, not enough is known about several potential threats to evaluate their absolute or relative impact. For example, it has been suggested that toxic chemicals may be responsible for a disease of the shell affecting some populations. However, it is not known if chemicals are the causative agent, which chemicals are the problem, or the source of chemicals. Also, little is known about neither the epidemiology of the disease nor how much mortality is actually caused by it. Third, which mortality factors are functioning is very site specific. Highway mortality is an important factor for populations along highways; it may drain populations two miles or more away (von Seckendorff Hoff and Marlow 1997). On the other hand, for populations away from highways, this may be a very low or non-existent threat. Regional differences occur, also. Urbanization and development are major factors in portions of the west Mojave, but are probably relatively unimportant in much of the east Mojave (outside of the Las Vegas and St. George areas). Finally, as discussed above, factors that caused the declines (e.g., disease) may not be the same factors that are preventing recovery (e.g., genetic or demographic consequences of small populations, fragmentation, and raven predation). For all of these reasons the controversial and subjective task of ranking impacts was avoided here.

Specific threats are easy to discuss and identify, but more pervasive problems often exist when multiple threats interact to make for larger environmental problems. The three largest of these broader impacts affecting tortoise populations are habitat loss, degradation, and fragmentation; urbanization and development; and access by humans to tortoise habitat. I will first focus on specific threats then discuss three broader, more cumulative types of threats. There are virtually no published studies looking specifically at the effect of these general factors on tortoise populations.

Agriculture

Probably the greatest affect agriculture has on tortoise populations is through loss of habitat: when tortoise habitat is converted for agricultural use it becomes mostly unusable by tortoises for foraging or burrowing. Indirect impacts could include facilitation of increases in raven population, drawdown of water table, production of fugitive dust, possible introduction of toxic chemicals, and introduction of invasive plants along corridors and when the fields go fallow.

I found no substantiated references in the literature indicating that desert tortoises use agricultural fields, although alfalfa, with its high nitrogen content, could be a healthy source of food for tortoises (Bailey, 1928, provides an anecdotal account from untrained observers of “tortoises eagerly eating alfalfa.”). Berry and Nicholson (1984a) cited one anecdotal report from an individual with unreported credentials as evidence that “tortoises are known to enter...alfalfa fields” (p. 3-21). Disking, plowing, mowing, and baling would destroy burrows and kill tortoises (as they do the marginated tortoise, *T. marginata*, in the Mediterranean region; Stubbs 1989). There are no reports of desert tortoise burrows in agricultural fields.

The Common Raven, a predator on juvenile desert tortoises, makes considerable use of agricultural fields in the west Mojave Desert (Knight et al. 1993, 1999, Knowles et al. 1989). Agricultural fields probably are important sources of food (i.e., insects, rodents, and seeds) and water for ravens during times of the year when those resources are generally in low abundance elsewhere, thus resulting in more ravens surviving the summers and winters (Boarman 1993, unpubl. data). See “Predation,” below, for more discussion.

Pumping of ground water for irrigation can result in a major change in vegetation or habitat type. Koehler (1977) reported that the drawing of water for irrigation from Koehn Dry Lake, near Cantil in the Western Mojave, lowered the water table by 240 ft between 1958 and 1976. Berry and Nicholson (1984a) state that this lowering of the water table has approached the Desert Tortoise Natural Area (DTNA) and imply that it may affect tortoise habitat, although no data were presented to support the implication. Closer inspection of the maps provided in Koehler (1977) show that the water-level decline is lower (30 - 180 ft) near tortoise habitat south and southeast of Koehn Dry Lake. There are no data to indicate what effect this lowering of the water table has on mesquite, other vegetation, or tortoise habitat in the area, but there are data on the effect water table lowering has on mesquite in other arid regions (Nilsen et al. 1984).

Agricultural fields cause dust storms, called fugitive dust (Wilshire 1980). Fugitive dust coats plants, which in turn may reduce photosynthesis and water-use efficiency (Sharifi et al. 1997). The end result is lower productivity of forage plants. Their study did not specifically look at agricultural dust, but the results are probably generalizable.

The finding of “hundreds of...tortoise shells” (with no indication of how long the tortoises had been dead) was reported anecdotally and second hand by Berry and Nicholson (1984a) and was correlated with application of an unspecified pesticide to kill jackrabbits in a nearby (distance unspecified) alfalfa field. Aside from this single unsupported speculation, there are no references to possible toxic effects on tortoises of pesticides, herbicides, and other chemicals used in agriculture. Pesticide use, particularly aerial applications apparently are now very limited in the desert.

Collecting by Humans

Humans collect turtles and tortoises for several reasons, and these activities are responsible for population declines in several of the threatened and endangered species throughout the world (Stubbs 1991). Collecting desert tortoises for pets was probably a major activity in the recent past (Berry and Nicholson 1984a), although most evidence is anecdotal in nature. Since 1961, it has been illegal under State law to collect tortoises in California and since 1989 collecting has been a Federal offense (USFWS 1994). The Desert Tortoise Recovery Plan (USFWS 1994) cites several documented instances of illegal collecting more recent than those in Berry and Nicholson (1984a), including the unauthorized removal of marked study animals from known study areas. It must be cautioned that some of the examples cited in the Recovery Plan are circumstantial or speculative. For instance, Stewart (1993) reported one strongly supported (tortoise found in a car in Idaho) and one speculative (transmitter and human footprints found on ground and tortoise was missing) example of poaching. Berry (1990 as amended) gives purely speculative and circumstantial evidence for poaching (namely, marked drop in estimated density on a study plot over a 5-year period with relatively few carcasses being found coupled with observations of possibly human-excavated burrows nearby and other evidence for poaching several miles away). The available evidence suggests that collecting for pets is still occurring, but perhaps at a level lower than previously, although this statement is speculative at present. Evaluating the extent of the problem is very difficult because of the cryptic nature of the activity.

A newly documented problem is the collection of wild tortoises by recent immigrants for cultural observances (USFWS 1994, Berry et al. 1996). Berry et al. (1996) reported that 7.7% of tortoise burrows found showed evidence of being excavated by humans and that the number of such burrows is greater near versus far from dirt roads. Their study suggests that poaching tends to occur near roads, even lightly maintained ones, thus the presence of roads may help to facilitate poaching. However, there was no statistically significant difference in distance from roads for disturbed versus undisturbed burrows and the method for determining if a burrow was excavated was circumstantial and subjective.

The bottom line is that there is little evidence to suggest that illegal collecting is currently a widespread problem, but there is also little evidence to the contrary.

Construction Activities

Construction activities here refer specifically to the generally short-term effects of actual construction (clearing land, movement of heavy equipment, presence of construction crews, etc.). The lasting effects of the constructed facility, once in place, are discussed in "Urbanization and Development," "Energy and Mineral Development," "Utility Corridors," and "Habitat Loss, Degradation, and Fragmentation" sections below. In many ways, most construction projects have similar impacts on tortoises and their habitat, regardless of what is being constructed. Those impacts may include: loss of habitat by the project footprint; incidental destruction of habitat in a buffer area around the footprint; damage to soil and cryptogams on the periphery; incidental death of unseen tortoises along roads, beneath crushed vegetation, or in undetected burrows; destruction of burrows; handling of tortoises; entrapment of tortoises in pits or trenches dug for transmission or fiber optic lines, water, and gas pipelines and other utilities; attraction of ravens and facilitation of their survival by augmenting food or water; and fugitive dust

(Olson et al. 1992, EG&G 1993, Olson 1996). There are little data on the extent of these potential impacts. But, Olson (1996) reported that a construction of a natural gas pipeline had the greatest impact on tortoises and habitat, construction of a transmission line had intermediate impacts, and a fiber optic line was the most benign. The differences are largely related to the scale of the project, ability of crews to avoid disturbing burrows, and timing of construction to avoid peak activity periods of tortoises (e.g., spring). In an analysis of 171 Biological Opinions issued by the USFWS in California and Nevada, Circle Mountain Biological Consultants (1996, see also LaRue and Dougherty 1999) found that the majority of tortoise mortality occurred along linear construction projects (e.g., pipeline, fiber optic, and transmission lines) with the extensive Mojave-Kern Pipeline causing the greater number of deaths (38). Tortoise mortality also occurred on mining, landfill, and military projects. The total number of deaths reported on the projects was well below the level authorized by the USFWS (59/1096 = 5.4%). This study was strictly an evaluation of known tortoise mortalities occurring during projects authorized by the USFWS under Section 7 of the Endangered Species Act. It therefore likely underestimates actual tortoise mortality (e.g., tortoises buried during construction or otherwise not found, accidentally killed but not reported, etc.) that occurred.

Disease

Disease in general is a normal and natural phenomenon within wild animal populations. Diseases can weaken individuals, reduce reproductive output, and cause mortality. Epidemic outbreaks of some diseases can become catastrophic, particularly in small or declining populations (Dobson and Meagher 1996, Biggins et al. 1997, Daszek et al. 2000). Sometimes disease can be controlled by wildlife managers by attacking the pathogen; isolating diseased from non-diseased individuals, populations, or species; immunizing healthy individuals; or facilitating habitat conditions that increase individual’s immune systems. Other times there may simply be nothing a manager can do. It is important to understand disease etiology and epidemiology before effective management actions, if any, can be determined.

Two diseases have been identified as possibly affecting the stability of some desert tortoise populations: Upper Respiratory Tract Disease (URTD; Jacobson et al. 1991) and cutaneous dyskeratosis affecting the shell (Jacobson et al. 1994). A third disease, a herpesvirus, was recently identified and may have population-level consequences, but very little is known about it (Berry et al. 2002, Origgi et al. 2002). URTD has been found in several populations that have experienced high mortality rates, including some in the west Mojave (Jacobson et al. 1996, Berry 1997). Much is published in peer reviewed journals about the etiology of this disease, which has been found in captive turtles of this and several other species (Jacobson et al. 1991) and in wild populations of the gopher tortoise (*Gopherus polyphemus*; Jacobson 1994). Brown et al. (1994a) showed definitively that URTD can be caused by a bacterium, *Mycoplasma agassizii*. It is likely transmitted by contact with a diseased individual or through aerosols infected with *M. agassizii*. The organism attacks the upper respiratory tract causing lesions in the nasal cavity, excessive nasal discharge, swollen eyelids, sunken eyes, and in its advanced stage, lethargy and probably death (Jacobson et al. 1991, Schumacher et al. 1997, Homer et al. 1998, Berry and Christopher 2001). It must be noted, however, that some of these clinical signs may also be characteristic of other health condition such as dehydration, allergy, or infection with herpesvirus or the bacteria *Chlamydia* or *Pasteurella* (e.g., Pettan-Brewer et al. 1996, Schumacher et al. 1997).

Malnutrition is known to result in immunosuppression in humans and turtles (Borysenko and Lewis 1979) and is associated with many disease breakouts. It is possible that nutritional deficiency in tortoises caused by human-mediated habitat change and degradation may be partly responsible for the apparent spread of URTD and its perceived impact on tortoise populations (Jacobson et al. 1991, Brown et al. 1994a). Short-term droughts may temporarily reduce immune reactions and increase susceptibility to URTD (Jacobson et al. 1991), although this is speculative. Whereas animals may become debilitated by chronic immune stimulation, no biochemical indicators of stress have been identified in diseased compared to non-diseased turtles (Borysenko 1975, Grumbles 1993, Christopher et al 1993, 1997).

Although evidence indicates a correlation between high rates of mortality and incidence of URTD within populations (Berry 1997), there is little direct evidence that URTD is the cause of the high rates of loss. In two preliminary analyses (Avery and Berry 1993, Weinstein 1993), animals exhibiting clinical signs of (both studies) or testing positively for (latter study) URTD were no more likely to die over a one year period in the west Mojave than were those not exhibiting signs or testing positive. This may be because factors other than disease caused much of the mortality or many animals not showing clinical signs of disease in the field were still infected. A serological test for presence of antibodies against *M. agassizii* has been developed and is now being used to document presence and spread of the disease (Schumacher et al. 1993). But, the test, an enzyme-linked immunosorbent assay (ELISA) does not indicate present infection, only a probability of past exposure. A polymerase chain reaction (PCR) test, which has been developed for *M. agassizii* is more effective for determining active infection (Brown et al. 1995). Lance et al. (1996) reported that infected tortoises had significantly lower testosterone and estradiol levels and that diseased females tended to lay eggs less often. Finally, there is some evidence that animals at the DTNA, where URTD breakout has been particularly intense, may recover from infection (Brown et al. 1994a, b). Interestingly, Berry (2002) reported that none of 119 wild tortoises tested at 9 locations throughout the California deserts in 2000 and 2001 tested positive for URTD. No discussion of this result was provided. A thorough epidemiological study is badly needed to identify the factors involved in the incidence, spread, and virility of the disease in wild populations (D. Brown pers. comm.).

A shell disease, cutaneous dyskeratosis (CD), has been identified in desert tortoise populations (Jacobson et al. 1994). CD consists of lesions along scute sutures of the plastron and to a lesser extent on the carapace. Over time, the lesions spread out onto the scutes. This disease may be caused by the toxic effect of chemicals in the environment, but evidence is lacking to test this hypothesis. Naturally-occurring or human-introduced toxins such as selenium, chlorinated hydrocarbons, organophosphates, nitrogenous compounds, and alkaloids have all been implicated (Homer et al. 1998), but there are no data showing a direct link. The disease may also be caused by a nutritional deficiency (Jacobson et al. 1994). It is not known whether or not CD is caused by an infectious pathogen or if secondary pathogens act to enhance the lesions (Homer et al. 1998, Homer pers. comm.). It is unclear if the disease is actually lethal or responsible for declines in infected tortoise populations (Homer et al. 1998). Only one documented case of CD from the West Mojave Desert was found in the literature (Homer et al. 1998).

If the shell diseases are toxicoses, toxic responses to environmental toxins (e.g., heavy metals, chlorinated hydrocarbons, organophosphates, and selenium), then there may be a direct link between these diseases and human activities unless the toxin is a natural component of the physical environment. Chaffee et al. (1999) found no significant correlation between elevated levels of metals in organs of ill tortoises and in the soil where the tortoises came from. If there is a link to human activities, then we can consider solutions that would reduce levels of input of the toxic chemical. However, this link is currently highly speculative.

There is some recent, albeit weak, preliminary evidence linking heavy metals to disease in tortoises. In necropsies of 31 mostly ill tortoises, Homer et al. (1994, 1996) found elevated levels of potentially toxic metals and minerals in the liver or kidney of one or more of the animals. Since most of the animals were ill to begin with, an association was made between the presence of the toxicants and presence of the disease. However, that study is strictly correlative, and fails to demonstrate a cause and effect relationship. Berry (1997) claims that "the salvaged tortoises with cutaneous dyskeratosis had elevated concentrations of toxicants in the liver, kidney, or plasma...and/or nutritional deficiencies." However, closer examination of the data presented in Homer et al. (1994, 1996) and cited in Berry (1997) reveals a remarkably low association with only 1 out of 12 tortoises with CD having at least one toxicant concentration greater than two standard deviations above the mean. Four other animals also had unusually high levels of at least one toxicant, but did not suffer from CD. Furthermore, Homer et al. (1994, 1996) identified abnormally high levels as being those concentrations that are greater than two standard deviations from the average concentration found in the 31 tortoises. In a normally distributed set of 20 randomly selected values, 1 will, by definition, fall outside of 2 standard deviations from the mean, because 2 standard deviations is defined as including only 95% of the samples. So if 100 comparisons are made, then 5 levels will be considered abnormally high or low just by chance. In the study, 689 values would be reported, thus 34 (or 95%) would be expected to be greater than twice the standard deviation from the mean just by chance. In fact, 32 were identified as falling outside this range of two standard deviations. These data are in need of a thorough statistical analysis. Homer (pers. comm.) has found significantly higher levels of iron (in liver) and cadmium (in kidneys and liver) of tortoises with URTD compared to those in a control group. It is not known if the levels identified by Homer et al. (1994, 1996, pers. comm.) as being abnormally high are biologically significant. Homer (pers. comm.) has found significantly reduced levels of calcium in the livers of tortoises with CD, which suggests a nutritional deficiency may be involved in the disease.

Several other diseases and infections have been identified in desert tortoises (Homer et al. 1998). These include a poorly known shell necrosis, which can result in sloughing of entire scutes; bacterial and fungal infections; and urolithiasis, a solid ball-like deposition of urate crystals in the bladder (i.e., bladder stones; Homer et al. 1998). There is no evidence to suggest that any of these diseases are at this time widespread, threatening population stability, or hindering population recovery.

Beyond taking precautions to avoid spreading the disease when handling many animals (Rosskopf 1991, Berry and Christopher 2001), educate the public against releasing potentially-diseased captive animals (Berry 1997), include only healthy individuals in translocation efforts (Brown 1994a), the practical management implications of the disease data are unclear. Tully (1998) states, without explanation, that URTD infections are not likely to be controlled by immunizations. Improving habitat conditions may help reduce stress-induced immunosuppression (Brown 1994a), but the link between stress from poor habitat quality and susceptibility to URTD is only speculative.

Drought

A drought is an extended period of abnormally low precipitation. Unlike kangaroo rats and some other desert vertebrates, tortoises acquire much of their water, and maintain and overall positive energy balance, from standing sources (Peterson 1996). O'Connor et al. (1994a) showed that water deprivation in a group of semi-wild tortoises caused higher levels of physiological stress (using several blood assay profiles) compared to a group of semi-wild tortoises with water supplements and a group of free-ranging tortoises. Peterson (1994a) recorded abnormally high levels of mortality in two tortoise populations (west and east Mojave) during a three-year period of an extended drought. The deaths in one population (Ivanpah Valley) were attributed to drought-induced starvation and dehydration and occurred in the third year of study. Ken Nagy (pers. comm.) has stated that tortoises can probably survive 1-2 years without drinking water but will start dying of dehydration after that. The primary source of mortality, which occurred throughout the three-year study, at the DTNA was coyote predation. The coyotes may have switched to the less desirable tortoises following hypothesized drought-induced reduction in coyotes' normal prey (black-tailed jackrabbits; see also Jarchow 1989). Alternatively, tortoises may have been in a weakened condition due to URTD, but Peterson (1994a) found little evidence of disease in his study animals. Low rainfall can also reduce reproductive output with tortoises producing fewer eggs or suspending egg-laying altogether in low-rainfall years (Turner et al. 1984, Lovich et al. 1999). Avery et al. (2002) documented higher survival and reproduction among females at higher elevation site that received more rain than a lower one in Ivanpah valley. Tortoises may survive drought periods by eating less nutritious cacti and shrubs (Turner et al. 1984, Avery 1998).

Much of the desert experienced short-term drought conditions in the late 1980s (Corn 1994a, Hereford 2002), a period when rapid declines and high mortality were reported in some tortoise populations (Berry 1990 as amended, Corn 1994a, Peterson

1994a). However, Corn (1994a) reported that, between 1977-1989 there was no correlation between winter precipitation and relative abundance of large (≤ 180 mm median carapace length [MCL]) or small (<180 mm MCL) tortoises, but there was a significant correlation between summer precipitation and relative abundance of small tortoises. Some reports exist of dehydrated and emaciated tortoises being found (Berry 1990 as amended, Peterson 1994a, Homer et al. 1996).

Drought is a normal phenomenon in the Mojave Desert (Peterson 1994a, Hereford 2002). Desert tortoises have lived in the Mojave Desert for over 10,000 years and probably have evolved under similar boom-bust conditions (Peterson 1994 a,b, 1996; Henen 1997; Nagy and Medica 1986). It is possible that drought can cause episodic mortalities punctuated by periods of low mortality during years with more abundant rainfall. It is reasonable to speculate that drought-induced stress in concert with other threats (e.g., disease, predation) resulted in significant mortality (Peterson 1994a), but there are little data to test this hypothesis. An epidemiological study is needed to evaluate the effect drought has on tortoise populations.

Energy and Mineral Developments

Energy and mineral development includes: presence of utility lines, transmission lines, and gas pipelines; development of land for oil and gas leases; geothermal and solar energy generation; and digging exploratory pits for and extraction of minerals. Impacts from energy and mining developments can include habitat destruction and direct mortality from off-road travel to explore and access sites; habitat loss to road and development construction, leachate ponds, tailings, rubbish, etc.; introduction of toxins; fugitive dust and soil erosion; and urban-type developments to support large mining operations. The extent of area directly affected by energy and mining is difficult to assess because the data are not readily available. According to Luke et al. (1991), as of 1984, 41% of high density tortoise habitat rangewide was leased or partially leased for oil or gas and 2% was directly impacted by mining operations or leased for geothermal development. However, no indication was given for how these figures were obtained. Most mining operations are point sources of disturbance with potentially little effect beyond the immediate site of development. The greatest effect may come from the cumulative impact of many relatively small mining-related disturbances combined with facilitation of rural or urban development (e.g., Randsburg) to support the mining operations in a given area. However, large-scale operations that depend on frequent haul trucks to transport excavated minerals may also present vehicle-related impacts such as increased road kills and air pollution.

There are few data on the effects of energy and mineral development on tortoise populations. Mortalities have occurred in association with mining activities (LaRue and Dougherty 1999). Hard rock mining, particularly pit mining and operations in dry lakebeds, can be a major source of fugitive dust (Wilshire 1980). Loss of habitat and soil and vegetation disturbance can be substantial and major, depending on the size of the area. Although illegal, cross-country travel to drill and access test pits, stake claims, and evaluate mineral potentials still occur (pers. obs.) and needs to be properly documented and evaluated.

Energy development has similar impacts, particularly direct and indirect loss of habitat, fragmentation of habitat and population, and effects of access roads, which are likely to be relatively light once construction has ended (Brum et al. 1983). Construction of transmission lines requires grading of new roads for construction of towers and maintenance of the lines, and clearing or terracing of habitat for tower placement. Not only is habitat lost (0.16 to 0.24 mi^2 per mile of transmission line; Robinette 1973, cited in Luke et al. 1991), but the new road may help to fragment the population and provide access to areas for other human-related impacts (see "Utility Corridors" section, below). The access roads are also an important source of windblown dust and attendant erosion (Wilshire 1980). The presence of new utility lines, necessary to distribute the electricity, may help facilitate nesting by ravens in specific areas they did not nest in before, if those areas did not have adequate nesting substrates before the new towers were erected (Boarman 1993, Knight and Kawashima 1993). For more discussion, see "Utility Corridors" section, below.

Aside from loss of habitat and other consequences associated with access roads and transmission lines, there is little evidence that energy generation negatively impacts tortoise populations. If designed and managed properly, wind generation may be compatible with tortoise populations (Lovich and Daniels 2000). Tortoises made extensive use of wind turbine pads for burrow cover and, by restricting access, the wind park served as a de facto reserve that minimized several other harmful human activities such as ORV travel, vandalism, and illegal collections. The only study found on solar energy impacts showed that here were only very small changes in air temperature, wind speed, and evaporation rates downwind from a solar power plant in the western Mojave Desert (Rundel and Gibson 1996). They did not study impacts to tortoise populations.

Fire

Fire, once considered a rare event in the Mojave Desert (Humphrey 1974), now occurs with ever-increasing frequency causing a greater threat to tortoises and their habitat (USFWS 1994, Brooks 1998). Fire frequency has increased with the proliferation of introduced plants, particularly the grasses, red brome (*Bromus rubens)* and split grass (*Schismus barbatus* and *S. arabicus*), which provide fuel for fires (Brown and Minnich 1986, Brooks 1999b). These plants help to spread fire because they are often common, tend to grow in large relatively dense mats, and fill the intershrub spaces, which are largely devoid of native vegetation (Brown and Minnich 1986, Rundel and Gibson 1996, Brooks 1999b). Fires cause direct mortality when tortoises are burned or inhale lethal amounts of smoke, which can happen both in and out of burrows. Documented cases of tortoises being burned by fires are uncommon, but do occur (e.g., Woodbury and Hardy 1948 - circumstantial, secondhand account of 14; Homer et al. 1998, reports 1; Esque et al. in press, reports 5, which is 4-13% of the study population; Lovich, pers. comm., found 1). Fires are probably most hazardous to tortoises when they occur during the active season for tortoises (e.g., spring in the West Mojave). Previously rare, frequency of spring fires are now on the increase (Brooks 1998).

There are several possible indirect impacts of fires. Fires remove dry and some living forage plants. They facilitate proliferation of non-native grasses (Brown and Minnich 1986, Brooks and Berry 1999). The effect this has on tortoises is as yet unresolved. There is some evidence that tortoises may selectively avoid exotic grasses (Jennings 1993, Avery 1998), but Esque (1994) showed that tortoises may choose to eat a majority of non-native plants, particularly in drier years. The physiological consequences of foraging on non-native grasses is also not entirely known, but, in a manipulative study with semi-captive tortoises, Nagy et al. (1998) showed that grasses, native and non-native) provided tortoises with much less nitrogen than did forbs and tortoises tended to loose water when eating them. Avery (1998) also showed that tortoises eating only split grass lost weight, assimilated less protein, and were in a negative nitrogen balance, whereas those that were fed a native forb (*Camissonia boothii*) maintained their weight and experienced a positive nitrogen balance. Those tortoises that fed on both plat types maintained their weight but experienced a net loss of protein. By removing vegetation, fires may alter the thermal environment by increasing temperature extremes experienced by seeds, plants, and burrowing tortoises (Esque and Schwalbe 2002). Soil erosion is enhanced by the loss of stabilizing vegetation, roots, and cryptogamic crusts (Ahlgren and Ahlgren 1966). Fires fragment tortoise habitat by creating patches of unusable habitat, at least over the short term. There is some evidence of an increase in availability of nitrogen and other nutrients for a short while following fires (Loftin 1987), but none demonstrating that plant growth is stimulated by this nutrient flush. Overall effects on vegetation are variable, and may depend in large part on the intensity of the fire, characteristics of the plants, and post-fire precipitation (Esque and Schwalbe 2002). Brown and Minnich (1986) found an increase in annual vegetation following a fire during an unusually rainy period. On the other hand, O'Leary and Minnich (1981) found no difference during a drier year.

The structural characteristics of vegetation in years following fires has been studied. Following burns in creosote scrub community in the Colorado Desert, Brown and Minnich (1986) found 23% higher cover by annual forbs, most of which were exotics. Cover by some native forbs, including ones preferred by tortoises, were also higher in burned vs. unburned areas. They also found that perennial plants, particularly creosote bush, were damaged and exhibited low levels of stump sprouting and germination following more intense fires. A change in dominant shrub type resulted, but the study only reported on 3-5 years post-burn; no data were presented on possible long-term successional changes or recovery. Dense cover by annuals, particularly introduced grasses, provides higher fuel loads, which results in more fires that are also hotter (Brown and Minnich 1986, USFWS 1994, Brooks 1999b).

The amount of tortoise habitat burned by recent fires is relatively low, but increasing. For example, between 1980 and 1990, 243,317 acres burned in the Mojave Desert in California, which is an average of 38 mi^2 per year (USFWS 1994). The increase in number of fires per year over the ten-year period was statistically significant. Tracy (1995) reports that fires occur much more frequently near roads and towns, but no data were presented in this abstract. Duck et al. (1995) reported that tortoises may be killed by fire-fighting activities, including by large fire trucks driving off of roads in tortoise habitat, and recommended training and fire management techniques to reduce the problem.

Through its destructive effect on woody shrubs, fire has been used to manage (i.e., improve for cattle foraging) desert grasslands. In desert grassland of southern Arizona, fire removed 9-90% of targeted shrubs (i.e., mesquite, *Prosopsis juliflora*; burro-weed, *Aplopappus tenuisectus*; prickly pear cactus, *Opuntia occidentalis*; and cholla, *Opuntia* sp.; Reynolds and Bohning 1956). This work was not conducted in tortoise habitat and the efficacy of using fire in similar ways has not been tested in the Mojave Desert nor has its effectiveness at improving habitat for tortoises been tested.

Garbage and Litter

Garbage illegally dumped in the desert is unsightly, may cause local habitat alteration, and may affect individual tortoises. Indeed, in a popular article, Burge (1989) cited an instant of a tortoise losing its leg after getting it caught in the string of a disposed balloon. She also reports finding foil and glass chips in tortoise scat. No details were provided. There are no data to suggest that litter is a widespread or major problem for tortoise populations. The relationship between organic litter and raven predation on tortoises is covered under "Predation," below.

Illegal dumping of hazardous wastes is an increasing problem in the California deserts (John Key, pers. comm.) Toxins are known to cause a myriad of problems for wildlife (Jacobson et al. 1994), and presumably elevated levels (see "Disease" section, above) of certain metals (e.g., cadmium, copper, molybdenum, mercury, lead) have been found in the tissues of desert tortoises (Homer et al. 1994, 1996, 1998). The distribution and limited size of illegal dumps and hazardous spills suggests that this is a minor problem for tortoise populations as a whole, but they may be of concern on a localized basis. Metals and other pollutants may enter the environment from other sources including mining and air pollution, but their effects on tortoise populations remain speculative.

Handling and Deliberate Manipulation of Tortoises

Handling and deliberate manipulation of tortoises includes curious members of the public picking them up and sometimes removing them from the wild, biologists relocating and translocating them to new sites, pet owners releasing captive tortoises into the wild, and researchers manipulating tortoises for scientific experimentation. The effects can be manifold, depend on the type of handling, and remain largely unstudied.

Members of the public will sometimes pick up tortoises when they find them on roads or alongside trails. They do so out of curiosity or to remove the animal from harm's way (Ginn 1990; picking up a tortoise to cause harm is covered in the

“Vandalism” section, below). Any such handling or even disturbance of a tortoise is illegal under the Endangered Species Act, although it is unlikely that USFWS would prosecute a person who moves a tortoise out of harm’s way (pers. obs.).

There are several possible effects of this type of well-meaning handling, but most of them fit into the realm of speculation or science lore. First, when tortoises are handled they sometimes void the contents of their bladder, which may represent loss of important fluids and it is thought this loss could be fatal (Averill-Murray 1999). Averill-Murray (1999) provided some evidence that handling-induced voiding may jeopardize survivability, although usually relatively small amounts of fluid are discharged. Smaller animals were more likely to void, but, if the animal was recaptured at a later date, its growth was not inhibited as a result of voiding previously. The statistical significance of his results may be compromised by his decision not to adjust the level of significance to account for making multiple tests (a problem similar to that noted about Homer 1994, 1996, in the “Disease” section above). Nonetheless, the results suggest there may indeed be a trend towards voiding affecting tortoise survival, particularly in drought years, and this should be followed up with more experimentation.

Other problems with handling tortoises can occur. Diseases might be transferred between tortoises if people handle more than one tortoise without sterilizing their hands or using different clean or sterilized gloves for each handling (Rosskopf 1991, Berry and Christopher 2001). It is claimed that turning over a tortoise to look at its underside will harm its internal organs, break eggs, or cause shock (Rosskopf 1991), but there is no evidence to support this contention. It may be detrimental to a handled tortoise if it is released outside of its home range, far from known burrows, or away from shade (e.g., Stewart 1993). This could be particularly hazardous during hot, dry weather or late in the afternoon, but again no data exist to support this likely speculation. Finally, the disruption of behavior by handling or just approaching the tortoise could be harmful if the disruption causes the animal to withdraw into its shell long enough to prevent it from being able to eat, drink, or retreat to a safe cover site (e.g., burrow, pallet, or shrub) for the night, thus leaving it exposed to predators or harsh environmental conditions. The probability of this disruption being hazardous to the tortoise is likely low, unless disruptions occur extremely frequently. Tortoises can go many months without eating or drinking (Peterson 1996), so a few minutes of disruption is not likely to alter their nitrogen, energy, or water balance. All of these claims need further study to substantiate their validity.

Relocation of animals to a new area is frequently recommended, and is occasionally implemented to save tortoises from construction and other ground disturbing activities. Possible problems with translocation efforts include increased risk of mortality, spread of disease, and reduced reproductive success. There have been a few studies of the effectiveness of relocation efforts, and most of the relocations generally have been marginal to unsuccessful. A study summarized in Berry (1986b) found that 22% (13/43) of the animals translated 16 to 88 km from their capture sites stayed at their relocation sites for more than several days, but only five remained for 15 months to 6 years. Few mortalities were observed, but many disappearances from unknown causes occurred; these animals may have died or wandered away. In another relocation effort, 91% (10/11) stayed within the relocation area, which was only about 450 m from where they were moved, for at least 3 months and at least 36% (4/11) were present after 16 months (Stewart and Baxter 1987). In a third effort, 56% (9/16) of relocated tortoises stayed in the area (5.6 km from their original home ranges) for at least 1.5 years (Stewart 1993). At least 25% (4/16) died within about 2.5 years. A fourth relocation effort was conducted in Nevada. Several tortoises were moved to an area immediately adjacent to a development site (Corn, 1994b, 1997). These 13 animals were moved to areas 2 km away, which was still within or very close to their pre-translocation home ranges. There was no difference in survival, but displaced animals had larger home ranges than did the residents. A preliminary analysis of a fifth study showed that mortality was significantly greater among guests (tortoises moved to a pen immediately adjacent to their capture sites) than hosts (resident tortoises; Weinstein 1993). All of these relocation studies covered short time periods and only measured movements and survival. None of them looked at reproductive success or long-term survival, two of the most important measures of success.

An ongoing project translocating tortoises many miles from their capture site apparently is showing success, but no reports or publications (other than abstracts) are available. Apparently, survivorship and reproduction are equivalent between relocated tortoises and resident tortoises (Nussear et al. 2000). Relocated tortoises did move more during their first year in the new site, but after that their movements were not significantly different than those of resident tortoises. Tortoises released in Utah also moved more than did resident tortoises there (Wilson et al. 2000). Both of these studies need further analyses and complete presentations before their results can be adequately evaluated. The success of desert tortoise relocations probably depends on distance of relocations, habitat quality, density of host population, rainfall, and health condition of the relocated and host animals.

Probably tens of thousands of desert tortoises are held in captivity throughout southern California, Nevada, and elsewhere, some were taken from the wild, others were reared in captivity. There are several documented cases of captive tortoises being released into the wild (Howland 1989, Ginn 1990), an activity that is now illegal. Release of captives may be detrimental to both captives and resident tortoises. Released captive tortoises may die (Berry et al. 1990) because they do not know how to fend for themselves in the wild; will not initially know where to find cover sites, good forage, sources of water, or essential minerals; and may not have genetic adaptations necessary to survive in the particular area. However, 25 formerly-captive tortoise were released in Nevada (Field et al. 2000). The animals were equipped with radio transmitters and followed for 14 months. The unpublished results indicate that movements and weights did not differ between released and resident tortoises. No adults died (released or resident) and 2 (out of 8) released juveniles died compared to neither of the two residents studied.

Of greater concern for the stability or recovery of tortoise populations is the possible impact of the released captives on resident (host) tortoises. The greatest likely effect is the introduction of disease to the wild population. URTD, the disease presently believed by many to have detrimental effects on several wild tortoise populations (see

"Disease" section, above), is commonly found in captive tortoises (Berry et al. 2002, Johnson 2002). Releasing into the wild tortoises that are infected with URTD may introduce the disease-causing bacterium, *Mycoplasma agassizii*, to previously uninfected individuals and populations. There is some evidence that the incidence of disease is greater in areas of known releases of captives and around urban areas where release or escape of captives is likely to be relatively frequent (Jacobson 1993, Berry pers. comm.). However, data on the rangewide incidence of disease have not been peer reviewed and are not generally available, so it is not possible to evaluate this hypothesis.

Desert tortoises have been manipulated in many ways as part of scientific studies. They have been probed, stuck with needles, affixed with transmitters, implanted with transponders, weighed, measured, pulled and sometimes dug out of burrows, tom name a few. All manipulative research involving desert tortoises must be permitted by USFWS to ensure that risk of harm to the tortoises is minimized. USFWS closely evaluates methods and qualifications of researchers before issuing a permit. There is very little written on the effects of research manipulation. In a preliminary analysis from one study, Weinstein (1993) reported that significantly fewer animals whose blood was sampled on a regular basis subsequently died compared to those whose blood was not sampled. In an evaluation of the possible effects of one research tool, Boarman et al. (1998) summarized from the literature on possible impacts to turtles of different ways of attaching radio transmitters. They concluded that there is little evidence of negative impacts of transmitters on turtles and particularly tortoises. Their concluded this partly because of paucity of published accounts of problems experienced. There are a few undocumented reports of individual animals dying from excessive bleeding following blood extraction and possible excessive mortality of animals that had blood extracted 3-4 times per year for several years, but none of this is reported in the literature and thus remains anecdotal. Kuchling (1998) hypothesized that X-rays, used to measure reproductive success, are hazardous to turtles. Using empirical data, Hinton et al. (1997) argued that x-rays are safe when extremely low dosages of radiation are employed, which can be accomplished with use of rare earth screens.

Invasive Plants

The introduction and proliferation of invasive plants is a continuing and increasing problem in the desert. The most common invasive plants found in tortoise habitat in the west Mojave Desert are cheatgrass (*Bromus tectorum*), red brome (foxtail chess, *Bromus madritensis rubens*), split grass (*Schismus barbatus*, and *S. arabicus*), redstem filaree (*Erodium cicutarium*), Russian thistle (tumbleweed, *Salsola tragus*), Sahara mustard (*Brassica tournefortii*), and fiddleneck (*Amsinckia tessellata*; Kemp and Brooks 1998). Fiddleneck is a native species to the U. S., but others are natives to Eurasia, Africa, or South America (Kemp and Brooks 1998, Esque et al. in press). By one estimate, alien annuals comprised 9-13% of all annual plant species but 3 species (red brome, split grass, and redstem filaree) comprised 66% of all annual plant biomass in one wet year (Brooks 1998, 2000). Other less common weedy species are listed in USFWS (1994, p. D21) and Kemp and Brooks (1998).

Invasive grass species (e.g., split grass) tend to have thin, filamentous roots that spread quickly and easily through shallow compacted soil where the surface crust has been broken (Adams et al. 1982a, b). The root structure allows plants with filamentous roots to quickly take advantage of small amounts of water in the soil following light rains and may allow them to outcompete native, non-weeds, which often grow slower, have thicker tap roots that are less efficient at pushing through dense, compacted soil (Adams et al. 1982a, b). There is some empirical evidence that split grass and red brome inhibit or prevent the growth of native plants, including fiddleneck (Brooks 2000), indicating that competition may be occurring and that the native plants are less available to foraging tortoises. However, in Nevada, Hunter (1989, cited in USFWS 1994, p. D22) found no correlation between native plant density and density of red brome.

In general, invasive plants tend to proliferate in areas of disturbance (Hobbs 1989), but the effect of disturbance may be weak compared to that of rainfall and soil nutrient levels. Density or biomass of weedy plants in the Mojave Desert may be higher in areas disturbed by ORVs (Davidson and Fox 1974), livestock (Webb and Stielstra 1979, Durfee 1988), paved roads (Frenkel 1970, Johnson et al. 1975), and dirt roads (Brooks 1998, 1999a). In a strictly correlative study, Brooks (1999a) found that the biomass of two annual exotic plants was weakly associated with levels of disturbance (disturbance was from ORVs and sheep grazing). Biomass of the introduced plants was also positively associated with soil nutrient levels and the proportion of total biomass and species richness (number of species in a given area) comprising exotic species was negatively associated with annual rainfall (i.e., relative proportion of exotic annuals was greater in years with low annual rainfall).

An additional factor that may facilitate proliferation of alien plants is increased nitrogen deposition from airborne pollutants (Allen et al 1998). Nitrogen, in the form of nitric acid and nitrate from automobile exhaust, deposits on plants and soil downwind from urban areas (Fenn et al. 1998) and perhaps from roads. Brooks (1998) has shown experimentally that the addition of nitrogen to west Mojave soil increases the biomass of brome and split grass thereby potentially increasing their competitive advantage over native plants (Eliason and Allen 1997). The effect ORV-based exhaust has on desert vegetation has not been established.

It is often stated that non-native plants are of lower nutritional quality than native species preferred as forage by tortoises, but this is not always the case. The difference in nutritional quality may have more to do with the type of plant (e.g., grass versus forb, Nagy et al. 1998) or annual differences in nutritional quality related to precipitation (Oftedal 2001). For example, the non-native split grass, which is often eaten and sometimes preferred by tortoises (Esque 1994), has been shown empirically to deplete tortoises of nitrogen and phosphorus and water and cause weight losses (Avery 1998, Nagy et al. 1998, Hazard et al. 2001), but so does the native Indian rice grass (*Achnatherum hymenoides*, Nagy et al. 1998). Avery (1998) also demonstrated that split grass was lower in overall quality, crude protein, essential amino acids, water, and vitamin concentrations and higher in fiber and heavy metal concentrations than three non-grass species measured (one introduced and two native forbs). The introduced forb, redstem filaree, had higher aluminum and iron concentrations, but was otherwise similar to native forbs. Where lower-quality weedy grasses can outcompete preferred higher-quality forbs (Brooks 2000), forbs may be less available to tortoises, tortoises would have to eat the lower quality invasives, and they would then suffer from a nitrogen and phosphorus (or other nutrient) deficiencies (Hazard et al. 2001). This speculation requires further testing.

Mechanical injury from invasive grasses has been observed with instances of the sharp awn of *Bromus rubens* being stuck in the nares of tortoises as well as impacting the food in the upper jaws of the tortoises (Medica, pers. comm.). The interactive effect that invasives and fires have on tortoises was discussed in the "Fire" section, above.

Landfills

There are approximately 27 authorized sanitary landfills and an unknown number of unauthorized, regularly used dumpsites in the California deserts. In the West Mojave Desert, there are 11 authorized landfills. The potential impacts landfills have on tortoise populations include: loss of habitat, spread of garbage, introduction of toxic chemicals, increased road kills from vehicles driving to or from the landfill, proliferation of predatory raven populations, and possible facilitation of increases in coyote and feral dog populations. Other than for raven predation, there are virtually no data to evaluate most of these possible threats.

Loss of habitat to landfills is relatively minor except when viewed in the context of habitat degradation and fragmentation caused by the myriad of human developments that are proliferating in the desert. Spread of garbage probably poses a very small problem for tortoise populations (see “Garbage and Litter” section, above), but there are no data available to evaluate this. The possible effect of toxic chemicals in general is treated in the “Disease” section, above, but toxins from sanitary landfills are likely to have very little effect on tortoise populations. Modern sanitary landfills are designed to prevent the seepage of toxic chemicals and present a very low level (or probability) of risk, and any seepage from these or less optimally operated landfills would probably affect a very small proportion of tortoises. Landfills do generate methane gas, but because desert landfills are so dry, the generation of methane is extremely low and not likely to affect tortoises. Fugitive dust is probably a localized problem and generally minimized through frequent sprinkling of the dirt. Increase in road kills is probably proportional to the level of traffic, speed of vehicles, density of tortoises, and length of road. For most landfills, these factors are relatively low, so the impact of road kills on tortoise populations from vehicles going to landfills is probably relatively minor, but they do happen (LaRue and Dougherty 1999). However, several landfills are slated to be closed and converted to transfer or community collection stations. The garbage would be deposited into dumpsters or large compactors at these stations, then transported to a small number of larger regional landfills. This activity could increase the amount of traffic at these fewer landfills thereby increasing the number of road kills.

The greatest potential impact landfills have on tortoise populations is through their probable role in facilitating increased predation by ravens, and perhaps coyotes.

Ravens make heavy use of landfills for food (Engel and Young 1992, Boarman et al. 1995, Kristan and Boarman 2001). The food eaten probably helps ravens to survive the summer and winter, when natural sources of food are in low abundance (Boarman 1993, in prep.). As a result, more ravens are present at the beginning of their breeding season (February - June) to move into tortoise habitat, nest, raise young, and feed on tortoises. Healthier ravens are more likely to raise chicks successfully, who in turn will move to the landfills and experience higher than normal levels of survival, and the cycle continues. Predation by ravens is probably relatively low immediately around landfills where tortoise populations are relatively low, but increase as ravens disperse to distant nest sites (Kristan and Boarman 2001). See the "Predation" section, below, for more details.

Livestock Grazing

Grazing by livestock (cattle and sheep) is hypothesized to have direct and indirect effects on tortoise populations including: mortality from crushing of animals or their burrows, destruction of vegetation, alteration of soil, augmentation of forage (e.g., presence of livestock droppings, and stimulation of vegetative growth or nutritive value of forage plants), and competition for food.

Reduce Tortoise Density

There are very few data available to determine if grazing has caused declines in tortoise populations. The Beaver Dam Slope, Utah, was grazed heavily by sheep until 1950's and cattle are still grazing there today (Oldemeyer 1994). Tortoise populations on the Beaver Dam Slope were estimated at 150 tortoises/mi^2 (Woodbury and Hardy 1948), but, using very different methods, the population apparently dropped to 34-47/mi^2 in 1986 (Coffeen and Welker 1987, cited in Bury et al. 1994). The reductions have been attributed to grazing, but another cause may include the potential spread of disease from captive tortoises released in the area (Luke et al. 1991). High mortalities and population declines in Piute Valley, Nevada, have also been attributed to grazing (Mortimer and Schneider 1983, and Luke et al. 1991), but 1981 was a drought year and a high level of recent mortalities may have occurred. Such was the case in Ivanpah Valley where 18.4% of radio-transmittered tortoises died (Turner et al. 1984). It is interesting to note that there appeared to be more tortoise mortalities in the section of the Piute Valley study area that experienced lower levels of recent cattle grazing (Mortimer and Schneider 1983), but the data are insufficient to make a definitive judgement. No population trends in California have been attributed with hard data to livestock grazing.

An alternative hypothesis, proposed by Bostick (1990), is that tortoise population declines paralleled declines in cattle grazing throughout the West that began in 1934 with the implementation of the Taylor Grazing Act. Unfortunately, there are no reliable data to test this hypothesis. But its underlying assumption, that tortoises depend on cattle dung for protein, has no empirical support (see "Cow Dung as a Food Source" section, below).

Direct Impacts

CRUSHING TORTOISES

Some observations of tortoises being crushed by livestock exist in the literature, but often with little or no data to allow in-depth evaluation. Berry (1978, p. 28) stated that "smaller tortoises can be crushed easily by cattle or sheep," but provided no data to support the statement. Berry (1978, pp. 19-21) also reported that "a small two-to-three-year old tortoise with a hole through its shell was found near a temporary watering trough near the DTNA. It appeared to have been killed by sheep within the last few days; the hole in the shell was about the size and shape of a sheep's hoof." Ravens also peck holes in the shells of young tortoises; insufficient information was provided to know if the hole was inconsistent with raven predation. Ron Marlow (pers. comm., cited in Berry 1978) described the disappearance of a marked juvenile tortoise and its small burrow by the trampling by sheep. Apparently the marked tortoise was never observed again, so Marlow determined the sheep killed it. The tortoise may have been killed when sheep trampled the burrow. However, marked juveniles are often never seen again, so the tortoise either survived or died from one of many causes. Any one of these anecdotes may be a true indicator of the nature of tortoise-cattle interactions, but the information provided is inadequate to allow for rigorous evaluation and are very susceptible to alternative explanations.

Sheep and cattle may not step on tortoises because they are very cautious of stepping on uneven ground (rocks, bushes, etc.) for fear of losing their footing. This view is supported by the paucity of documentation of tortoises being crushed by cattle and sheep. One published paper (Balph and Malecheck 1985) reported a test of a related hypothesis: cattle will avoid stepping on clumps of bunchgrass because the clumps form an uneven surface that may cause the cow to trip. Cattle significantly avoided crested wheatgrass (*Agropyron cristatum*) tussocks, avoidance was independent of cattle density, and taller tussocks were less apt to be trampled than short ones. Out of 288 hoofprints recorded, 15 (5%) were on tussocks. This well designed study lends support to the contention that cattle will try to avoid stepping on tortoises, at least large tortoises, but clearly tortoises are not grass tussocks. However, this speculation can be countered by the equally plausible contention that the study's results only shows that cattle will avoid stepping on food; they have no bearing on the propensity for sheep to step on non-food items (e.g., juvenile tortoises).

Sheep, on the other hand, may step on many juvenile tortoises, but appear to avoid stepping on subadult and adult tortoises. Tracy (1996) provides an analysis of data from an aborted BLM study. Without providing details of methods, Tracy (1996) reported that 20% of the Styrofoam model juvenile tortoises placed in natural habitat were trampled by sheep, 87% of those trampled models were crushed. Sheep damaged only about 3% of the subadult models and about 2% of the adult models.

CRUSHING BURROWS

No one has rigorously evaluated whether livestock crush a significant proportion of tortoise burrows. Few cases in the literature document livestock trampling actual burrows and a small number of studies shows increased number of collapsed burrows following grazing. Nicholson and Humphreys (1981) measured impacts of sheep grazing immediately after a band of 1000 sheep passed through their West Mojave study site for 12 days. Sheep trampled and partly collapsed a burrow with an adult female inside; apparently the tortoise was unharmed. Sheep completely destroyed the burrow of a juvenile tortoise while the animal was inside; the field workers extracted the unharmed tortoise. The burrow of an adult male was damaged probably with no tortoise inside. On re-examination of burrows found prior to grazing, 4.3% (7/164) were totally destroyed and 10% were damaged after sheep grazed in the area. Most damaged burrows (86%) were in moderate to heavily grazed areas and were relatively exposed. Most burrows placed beneath shrubs escaped damage (Nicholson and Humphreys 1981). This was an observational study. Webb and Stielstra (1979) reported observing crushed tortoise burrows on the south slope of the Rand Mountains in the western Mojave, but gave no data or additional details. In a report on grazing near the DTNA, Berry (1978) reported that sheep trampled most shallow burrows and pallets that were in the open (no numbers were given), and they also crushed and caved in those near the edges of or within shrubs. Berry (1978) also reported that "cattle and sheep frequently trample shallow tortoise burrows," but provided no data. She further speculated that damage to burrows might be deadly to a tortoise that reaches it on a hot morning only to find it unusable. This is a reasonable expectation based on tortoise behavior and thermal ecology, but no supporting data are available. Avery (1997) found significantly more damaged burrows outside of a cattle exclosure versus inside and also found that tortoises outside the exclosure spent more nights in the open, presumably because many of their burrows were collapsed. There is one account of a tortoise burrow being collapsed by a cow in Utah (Esque pers. comm.). A tortoise was found crushed inside.

Tracy (1996) provided an analysis of data from 2 unpublished BLM studies on the effects of sheep grazing on tortoise burrows: the Tortoise and Burrow Study (TABS study) and Styrofoam model tortoise study (Goodlett unpubl.). The TABS study (cited in Tracy 1996) evaluated the condition of tortoise burrows before and after grazing inside and outside of areas grazed by domestic sheep in the Mojave Desert. They found that 2.5% (8/315) of the tortoise burrows were completely destroyed, which was significantly more than before grazing and more than were destroyed outside the grazing area. In the Goodlett study (unpubl.; cited in Tracy 1996), 3.7% (36/969) of the artificial burrows dug to look like desert tortoise burrows were destroyed after grazing. Significantly more juvenile and immature burrows were destroyed compared to adult burrows and destruction was greatest in the open spaces between shrubs. The proportion of burrows destroyed in these two studies and Nicholson and Humphreys (1981) were not significantly different (Tracy 1996).

Indirect Effects

A commonly held assertion is that the Mojave desert plant species and communities evolved in the presence of, and are probably adapted to, a rich fauna of Pleistocene herbivores (Edwards 1992a, 1992b). Therefore, the argument continues, livestock grazing is compatible with present day plant assemblages, in part because Mojave plants respond to grazing by producing more vegetative material, thus becoming more vigorous in the presence of grazing. This argument has several flaws. First, most large herbivores that coexisted in the Mojave desert region 10,000-20,000 years ago likely primarily browsed leaves from woody shrubs, they did less grazing of grasses and herbaceous annual vegetation, like cattle, sheep, and tortoises primarily do (Edwards 1992a). Second, the mammals of the Late Pleistocene and Early Holocene Mojave existed under considerably different vegetative and climatic conditions ago (Van Devender et al. 1987). A major climatic and vegetative transition occurred between 11,000 and 8,000 years ago. It was more mesic and the area was not a desert. The present vegetation assembly, dominated by creosote shrub, did not arrive in the Mojave Desert region until approximately 8000-10,000 years ago (Van Devender et al. 1987). Third, no one has any idea what density the Pleistocene grazers existed at, so grazing intensity is completely unknown. Thus, there is little justification for arguing that tortoises evolved in the presence of grazers and their survival is thus dependent on cattle, as a surrogate for their coevolved grazing species.

Soil Compaction

Grazing can affect soils by increasing soil compaction and decreasing infiltration rate, the capacity of the soil to absorb water. A lower infiltration rate means less water will be available for plants and more surface erosion may occur. In a review of studies investigating the hydrologic effect of grazing on rangelands, Gifford and Hawkins (1978) concluded that grazing at any intensity reduces the infiltration rate of the soil. Heavy grazing reduced infiltration rate by 50% and light to moderate intensities reduced infiltration by 25% over ungrazed; the differences are statistically significant. Contrarily, Avery (1998) found significantly greater compaction at a livestock water source, but no difference between protected and grazed areas away from the water source.

Soil compaction affects vegetation by reducing water absorption (thereby availability to plants) and making it more difficult for plants to spread their roots, particularly tap roots (Adams et al. 1982a, b). Growth and perhaps spread of split grass (*Schismus barbatus* and *S. arabicus*) is facilitated by compaction because of root structure. This may lead to a conversion in the vegetation community type and increased fire hazard. Although, fire spreads slowly and discontinuously with split grass compared to *Bromus* grasses (Brooks 1999b).

Empirical evidence shows that infiltration is higher in grazed areas. , Rauzi and Smith (1973) conducted a comparative experiment in the central plains of Colorado. They demonstrated that infiltration rate was significantly reduced by heavy grazing (vs. moderate and light grazing). Infiltration rate was significantly correlated with total plant material on the surface (standing crop) in two of the three soil types tested. Species composition was different. Experimental water run-off tests showed moderate grazing areas had 7 times the runoff of light grazing areas and heavily grazed areas had 10 times the runoff as lightly grazed areas. In the Mojave Desert of Nevada and Arizona, signs of increased soil compaction were evident in grazed areas compared to ungrazed areas between highway and highway right-of-way fences (Durfee 1988). Avery (1998) measured soil type, bulk density, and infiltration in an exclosure that cattle were excluded from for approximately 12 years and compared them to grazed areas outside the exclosure. He demonstrated that soil in heavily trampled areas near water tanks was coarser, had higher bulk density, greater penetration resistance, and lower infiltration rates (all are measures of compaction) than in the protected area.

Although they did not measure compaction or infiltration, Nicholson and Humphreys (1981) quantified the proportion of soil disturbed after a band of 1000 sheep spent 12 days foraging and bedding within a 1.6 km^2 study plot. They estimated that 80% of the soil in bedding areas was disturbed, 67% in watering areas, 37% in grazing areas, and 5% in areas not used by sheep. Soil was considered disturbed if the surface crust was broken or missing and was independent of cause. This non-replicated observational study had a control, did not document what effect the measured disturbance had on vegetation or soil parameters, but did suggest the extent of surface disturbance caused by the grazing.

In a comparison of soil conditions following sheep grazing in the Western Mojave, Webb and Stielstra (1979) noted disruption of soil crusts in intershrub spaces and on the coppice mounds of creosote bushes. Surface strength (a measure of compaction) was significantly greater in grazed vs. ungrazed areas, particularly in the upper 10-cm of the soil. Bulk density and moisture content did not differ, perhaps because of the high gravel content of the soil or compaction in both areas from grazing activity in previous years.

CHANGES IN SOIL TEMPERATURE

Another potential indirect effect of livestock grazing on tortoise habitat is alteration of soil temperature due to change in vegetation structure or soil compaction. Steiger (1930 cited in Luke et al. 1991) measured a significant increase in soil temperature at depths of 2.5, 7.5, and 15 cm in clipped versus unclipped plots. Browsing of shrubs may also alter soil temperature, but in unexpected ways. Using models that accurately duplicated the thermal profiles of desert tortoises, Hillard and Tracy (1997), a graduate student from University of Nevada, Reno, found that soils were cooler beneath shrubs with sparse and open undercanopies and hotter when the undercanopy was entirely closed. Apparently, the open undercanopy allowed cooling by both shade and wind, whereas closed undercanopies trapped hot air. Hence, if livestock browse, graze or otherwise reduce density of the undergrowth of a shrub while leaving the canopy with intact shading properties, then soil temperatures may be reduced. Alternatively, if grazing also reduces the shrub's canopy, then soil temperatures may increase. It is unknown what effect grazing-induced changes in soil temperature might have on tortoises. The temperature during incubation (Spotila et al. 1994) determines sex of tortoises: incubation temperatures above 89.3°F result in females, and below result in males. Although this has not been tested in the field, it is possible that significant increases in soil temperature resulting from grazing-induced vegetation changes may significantly skew the sex ratio of the tortoise population in favor of females and vice versa. Also, Spotila et al. (1994) found that hatching success was highest for eggs incubated between 78.8°F and 95.5°F.

CHANGES IN VEGETATION

Grazing by cattle can alter vegetation in several ways: damage from trampling, change in species composition perhaps resulting in type conversion (change in plant community type), and introduction of invasive plants.

TRAMPLING OF VEGETATION AND SEEDS

Livestock may cause direct damage to vegetation when they step on or push into shrubs and herbaceous annuals, and this impact was measured in a few studies. In the west Mojave Desert, none of the perennials on plant transects where sheep grazed were trampled, whereas 17% found in the bedding area were trampled (Nicholson and Humphreys 1981). Webb and Stielstra (1979) reported that sheep trample creosote bush when seeking shade to bed in. Annuals, which are prevalent on coppice mounds beneath creosote, were also trampled or eaten. As noted above, Balph and Malechick (1985) provided empirical evidence that cattle usually avoided stepping on clumps of crested wheatgrass, but still stepped on them 5% of the time.

Trampling by livestock may help to bury seeds and improve germination through their trampling action. In sagebrush scrub of northern Nevada, Eckert et al. (1986) found that light trampling increased germination of perennial grasses, but not perennial forbs, and heavy trampling decreased emergence of perennial grasses while increasing emergence of sagebrush and perennial forbs. Cattle grazing in Chihuahua Desert grassland enhanced revegetation by non-native grasses, but rain may have confounded the results (Winkel and Roundy 1991). Unfortunately, no similar studies from the Mojave Desert are available. However, biomass of seeds in the soil seed bank was significantly higher inside compared to immediately outside the DTNA, a 38 mi^2 fence enclosed preserve, where sheep grazing and ORVs had been excluded for 15 years (Brooks 1995); this in spite of there being more seed-eating rodents inside the DTNA. The biomass of annual vegetation, including the introduced species, was also greater inside the DTNA, but the total biomass of natives was proportionally higher inside than outside. Several other uses occurring outside the DTNA were absent from inside the preserve, thus the differences cannot be attributed solely to grazing. However, the changes noted are the expected effect of removal of surface disturbance from the reserve.

Near the DTNA, sheep trampled and uprooted perennial shrubs, such as burrobush (*Ambrosia dumosa*), goldenhead (*Acamptopappus sphaerocephalus*), and

Anderson thornbush (*Lycium andersoni*). "Even large creosote bushes (*Larrea tridentata*) were uprooted" (Berry 1978, p 512). "In many areas near stock tanks [in Lanfair Valley, California] the ground is devoid of vegetation for hundreds of meters. Trailing is heavy and damage extensive within 4.6 to 6.4 km of the tanks" (Berry 1978, p. 512). These reports are anecdotal; no data or additional details were provided.

PLANT COMMUNITY CHANGES

As early as 1898, range scientists observed that cattle ranges in the southwest were becoming overgrazed and urged that restorative actions were necessary (Bentley 1898). Since then, several studies have documented vegetation changes over the past century by comparing photographs or field notes taken in both centuries (Humphrey 1958, Humphrey 1987). The dominant change was a conversion from grass- to shrub-dominated communities (type conversion). Whereas livestock grazing has been implicated as an important cause for these changes, separation of the effect of grazing from the effects of fire suppression, rodents and other herbivores, competition, and climate changes is difficult (Humphrey 1958, 1987). Several studies compared grazed areas to nearby ungrazed areas particularly in southeast Arizona. They generally show a similar reduction in grass species in the grazed areas. Unfortunately, none of these studies occurred in the Mojave Desert and, because the grass-dominated ecosystem of southeast Arizona is very different from the non-grass deserts of California, there is little value in extrapolating from one to the other.

In 1980, the BLM created a 672-hectare cattle exclosure in Ivanpah Valley, eastern Mojave Desert of California, to determine the effects of cattle grazing on desert tortoises and their habitat. In the study establishing baseline data for a long-term comparison, Turner et al. (1981) found no significant differences between plots in biomass of annuals, weight or length of tortoises, proportion of reproductively active females, and tortoise home range sizes. Sex ratios and size classes of tortoises were comparable between the two plots. The lack of differences could be attributed to: (1) low use by cattle of the non-excluded area in both years of the study; 2) tortoise and vegetation recovery, if they are to happen, are likely to take much longer to be observable; and (3) sample size (n=1) too small to detect differences. Changes in tortoise weight with time, estimated clutch sizes, and concentrations of some nutrients in some plant species differed between plots, indicating that some differences existed between control and treatment at the start of the study. Over so short a time frame, differences are likely due to prior spatial differences in habitat or populations rather than grazing treatment. There was a similar level of differences between control and treatment plots one year later (Medica et al. 1982).

Avery (1998) conducted a follow up study at the Ivanpah study plot in the early 1990's. Avery (1998) compared vegetation inside and outside the exclosure. Compared to the ungrazed exclosure, the grazed area had significantly larger creosote bushes, more dormant or dead burrobush, *Ambrosia dumosa* (a perennial shrub), fewer and smaller, galleta grass, *Pleuraphis [=Hilaria] rigida* (a native, perennial grass) representing less biomass, more of the disturbance-loving shrub, *Hymenoclea salsola*, and lower diversity of winter annuals. They found significantly more desert dandelions (*Malacothrix glabrata*), a plant preferred by both cattle and tortoises, and a greater increase in basal area but not density of the native perennial galleta grass, *P. rigida*, in the protected area. *P. rigida* did increase in basal area over a 12 year period in the grazed area, indicating that level of grazing (0.31 - 2.60 animal unit months) does not cause mortality in *P. rigida*. Biomass, cover, density, and species richness of annuals did not differ. Recovery of Mojave Desert vegetation following alteration by cattle grazing could be very slow (Oldemeyer 1994), so 12 years of exclusion may be insufficient to detect a more significant effect.

A recent study compared soil characteristics, vegetation, and tortoise density within and around three exclosures in the Mojave Desert, including 2 in the west Mojave (Larsen et al. 1997). They reported finding few differences between "grazed" and "ungrazed" plots in percent canopy cover, and the differences found were relatively minor. Grazing reduced native forb density and increased soil compaction. Numbers of live tortoises, tortoise carcasses, and tortoise burrows were no different between grazed and ungrazed areas. Details provided were insufficient to adequately evaluate the methods or results and virtually no statistical analyses were provided.

Durfee (1988) compared structural features of the plant community between ungrazed areas along fenced highways and grazed areas outside of the right-of-way fences. A greater proportion of introduced plants, more bare ground, fewer perennial grasses, and lower spatial heterogeneity in species composition occurred in the grazed areas (see also Waller and Micucci 1997).

As cited above, Brooks (1995) found significantly higher annual plant and seed biomass in the DTNA, an area protected from sheep grazing, compared to an area outside the preserve. Berry (1978) characterized the qualitative effect of sheep grazing near the DTNA: "sheep removed almost all traces of annual forbs and grasses; the desert floor appeared more devoid of herbaceous growth than in drought years." No further data were provided in the latter report.

In all of these studies, spatial differences obtained in soil, weather, and vegetation may be independent of cattle grazing. Furthermore, the size of exclosures may be insufficient to allow the ecosystem to function independent of grazing activities outside the exclosure (which is probably not a big problem at the DTNA, studied by Brooks 1992). Furthermore, many of the above studies, particularly the older and observational ones, were reporting on the effects of long-term heavy grazing, whereas grazing regimes being implemented today are generally much lighter (Oldemeyer 1994).

Water for cattle is usually provided at specific points, at either springs or troughs. Because they will only wander a certain distance from the water source, affect of cattle on the environment will be greatest immediately around the water source and will decrease with distance (e.g. Avery 1998). Fusco (1993), Fusco et al. (1995), Bleecker (1988), and Soltero et al. (1989) recorded significant increases in biomass and density of grasses and other species with distance from water sources. Changing the location of water sources would have the effect of reducing the intensity of impact around each water source, but may increase the impacts at other sites. It is unknown if impacts would be below the (unknown) threshold for significant effect on the environment.

The impact of sheep grazing has been studied only once. In an observational study, Nicholson and Humphreys (1981) noted that areas not grazed by sheep had 2.3 times more cover and 1.6 times higher frequency of annual plants than in sheep bedding areas and 1.8 times more cover and 1.3 times higher frequency than grazed areas. Annual plant cover decreased by 70% in a heavy-use area compared to 50% in a light-use and 40% in a non-use area before grazing versus after grazing one month later. They also found a 96-99% reduction in annual plant cover between April and June in areas receiving heavy and light grazing by sheep. None of the perennials on plant transects where sheep did not graze showed damage after sheep left the area; 18% in the grazed area were damaged and 91 to 99% in the bedding areas were damaged. Apparently, trampling caused most of the damage in the bedding areas whereas most in the light-use area was from browsing. However, differences may be caused by other factors such as soil that may have differed between the sites independent of grazing pressure. Rather than using exclosures, the sheep and herder were allowed to select the areas they grazed. Hence, the sheep avoided ungrazed treatments for this study. This may have biased the results since there may be inherent differences in these areas that caused the sheep to avoid them.

An often cited benefit of grazing is "compensatory growth," growth of plant tissue following clipping, removal, or damage to plants resulting in increased growth or vigor (e.g., Bostick 1990, McNaughton 1985, Savory 1989). The concept is controversial, has gained little empirical support in semi-arid grasslands and ranges (Detling 1988, Bartolome 1989, Weltz et al. 1989, Wilms et al. 1990), may only be viable in wet, fertile, monocultural environments (Painter and Belsky 1993), and has not been tested in the Mojave Desert (e.g., Painter and Belsky 1993). What little evidence exists from the Mojave Desert fails to support the compensatory growth hypothesis. Avery (1998) found that *Pleuraphis [=Hilaria] rigida*, a native grass consumed by both cattle and desert tortoises, was significantly smaller in grazed versus ungrazed areas. More *Ambrosia dumosa*, which is sometimes eaten by cattle in drought years (Medica pers. comm.), was found dead or dormant in the grazed compared to ungrazed plots. Creosote (*L. tridentata*) was larger in grazed areas, but is consumed by neither cattle nor tortoises (Avery 1998).

INVASIVE PLANTS

Grazing has been implicated in the proliferation of invasive plants in the Mojave Desert (Mack 1981, Jackson 1985, Brooks 1995). Webb and Stielstra (1979) noted that *Schismus* and *Erodium* densities remained unchanged between a grazed and ungrazed area probably because they have an adaptive tolerance to environmental disruption such as soil compaction thus giving them a competitive edge over many native annuals. Berry (1978) reported that the heavily grazed Lanfair Valley "now contains a high percentage of weedy, invader, perennial species typical of overgrazed desert lands," but provided no data. Bostick (1990) argued that cattle grazing helped tortoise populations by aiding the spread of cacti. Some evidence from outside the Mojave suggests that grazing does aid in the spread of cacti, but the evidence is equivocal. Also, tortoises do eat cacti, which may be an important source of water and nutrition during drought periods (Turner et al. 1984, Avery 1998). But, the evidence in support of Bostick's hypothesis is weak.

COMPETITION

An important effect livestock grazing may have on tortoise populations is competition for food. Because of the enormous differences in size and energy requirements of the two species, the competition, if it occurs, is likely to be heavily asymmetric, with cattle affecting the tortoise populations, but probably not the converse. Three conditions must be met for asymmetric competition to occur: overlap in use of some resource (e.g., food), the resource must somehow limit or constrain one or both species in question, and use of the resource by one species must negatively affect the other species (Begon et al. 1990). Some data exist to help determine if competition for forage exists between cattle and tortoises, but less exist for sheep.

Many studies provide qualitative insights into forage species of tortoises (Woodbury and Hardy 1948, Burge and Bradley 1976, Hansen et al. 1976, Hohman and Ohmart 1980, Luckenback 1982, Nagy and Medica 1986) and three major studies quantified diet and forage selection in desert tortoises (Jennings 1993, Esque 1994, and Avery 1998). Tortoises primarily eat annual herbs in the spring and switch to grasses, perennial succulents (cacti), and dried annuals later in spring and early summer (Avery 1998). Tortoises are active again in the late spring and early fall as temperatures cool. As a result of localized late summer rains, sporadic green up of the vegetation can occur. At this time annuals germinate and bunch grasses (e.g., *Hilaria rigida*) green up and set seed. Cattle then eat the bunch grasses (Medica et al. 1992). In a drought year, tortoises in Ivanpah Valley consumed little food other than cacti during the latter part of the season (Turner et al. 1984). Thus, cacti may serve as a reserve supply of energy, more importantly as a potential source of water.

Four studies quantified plant foods eaten by cattle in the Mojave Desert (Coombs 1979, Burkhardt and Chamberlain 1982, Avery and Neibergs 1997). Avery and Neibergs (1997) followed cattle on horseback in the eastern Mojave Desert. By recording the species of plant and number of bites taken by the free-ranging cattle they found that foods chosen by cattle varied with season. In winter cattle primarily ate the perennial grass, big galleta grass (*Pleuraphis* [=*Hilaria*] *rigida*) and dried annuals from the previous spring (Medica et al. 1982, documented that cattle and tortoises eat perennial grasses in fall). Contrarily, Burkhardt and Chamberlain (1982) found perennial shrubs to predominate the diet of cattle in winter, annual grasses and green forbs did so in spring. Coombs (1979) found that cattle in the eastern Mojave of Utah particularly ate *Bromus* sp., *Ephedranevadensis*, and *Eurotia lanata* and ate perennial grasses considerably more often than expected based on their relatively uncommon presence. All of these studies illustrated that cattle in the desert eat diverse foods and that the foods eaten vary with season, locality, and availability.

Several studies provided evidence that tortoise and cattle diets overlap (Coombs 1979, Sheppard 1981, Medica et al. 1982, Avery and Neibergs 1997, Avery 1998), three of which did so quantitatively. Coombs (1979) and Sheppard (1981) used fecal samples, which are biased because they overestimate food items that contain large undigestible parts (e.g., silica-containing stems of grasses) and underestimate items that are highly digestible (e.g., moist forbs). Sheppard (1981) showed that plaintain (*Plantago insularis*), filaree, and *Schismus* experienced the highest levels of overlap , but overlap varied considerably between months and years. Coombs (1979) found that overlap existed, but neither study provided a species-by-species comparison or an explanation of how overlap was calculated. *Camassonia boothii*, *Malacothrix glabrata*, *Rafinesquia neomexicana*, *Schismus barbatus*, and *Stephanomeria exigua* were major forage items of both cattle and tortoises in Ivanpah Valley (Avery and Neibergs 1997, Avery 1998). Diet overlap between the two herbivores was greatest in early spring (38% Vs 16% in late spring, Avery and Neibergs 1997, Avery 1998).

Three studies provide data on forage overlap between sheep and tortoises. Webb and Stielstra (1979) reported that in the western Mojave Desert, sheep primarily ate herbaceous vegetation from the coppice mounds around the base of perennial shrubs. By comparing biomass of plants in a grazed area versus a nearby ungrazed area, they determined that three species were primarily removed: *Phacelia tanacetifolia*, *Thelypodium lasiophyllum*, and *Erodium cicutarium*.. Shrubs browsed by the sheep included *Ambrosia dumosa*, *Grayia spinosa*, *Haplopappus cooperi*, and *Acamptopappus sphaerocephalus*. Cover, volume, and biomass of these shrubs were significantly lower in grazed vs. ungrazed areas. However, because measurements were not taken before grazing it is possible that some differences may have existed before grazing commenced. Hansen et al. (1976) estimated that 15% of sheep diet in the western Mojave was composed of grasses and 52% of desert tortoise diets was composed of grasses. Nicholson and Humphreys (1981) reported several species of plants, particularly flowering annuals and burrobush (*Ambrosia dumosa*), that were highly used by sheep, but provided no quantitative data. Several species eaten by sheep were also eaten by tortoises including: split grass (*Schismus arabicus*), checker fiddleneck (*Amsinckia tessellata*), desert dandelion (*Malacothrix glabrata*), filaree (*Erodium cicutarium*), Fremont pincushion (*Chaenactis fremontii*), Parry rock pink (*Stephanomeria parryi*), chickory ((*Rafinesquia neomexicana*), snake's head (*Malacothrix coulteri*), red brome (*Bromus rubens*).

Only two studies directly tested for competition between tortoises and livestock. In an extensive study, Avery (1998) showed that cattle and tortoise diets overlap (38% in early spring, 16% in late spring). He also demonstrated that tortoise foraging was altered in the area where both species co-occurred. In late spring in the absence of cattle, tortoises primarily ate herbaceous perennials (91% of diet), whereas in the grazed areas, tortoises primarily ate annual grasses (59%) followed by herbaceous perennials (21%). The species of herbs also differed: in the exclosure tortoises preferred desert dandelion (*Malacothrix glabrata*), whereas in the grazed areas they ate primarily the exotic grass, splitgrass (*Schismus barbatus*). The availability of desert dandelion was significantly higher in the ungrazed area, which indicates a response to grazing, and of splitgrass was equivalent in the two areas. In one dry year, tortoises spent significantly more time (approximately three times more) foraging in the grazed than in the protected areas, presumably in search of nutritionally-adequate food to fill up on. Thus, two of the three conditions necessary to confirm that cattle compete with tortoises for food were clearly supported empirically. The final condition, that one species must negatively impact the other, was also demonstrated, but more indirectly. In a separate, independent study, tortoises eating primarily *Schismus barbatus* have been shown to be put in a negative water and nitrogen balance (Nagy et al. 1998), which could increase mortality particularly during periods of extended drought (Peterson 1994a, Avery 1998). Furthermore, Henen (1997) demonstrated that lower nitrogen intake reduces reproductive output in female tortoises. A long-term comparison of differential survival and reproductive success of tortoises within and outside an exclosure would be an excellent empirical test of the effect cattle grazing has on tortoise populations.

Tracy (1996) found that in years of very low annual productivity, tortoises lay fewer eggs. They also found that cattle foraging reduced tortoise forage abundance enough to cause tortoises to lay fewer eggs than normal. The conclusion is that, in low rain years, cattle may remove enough forage to reduce tortoise reproductive output, thus competition occurs in those years. The authors did not track hatchling success to determine if the fewer eggs still resulted in the same number of successful hatchlings.

COW DUNG AS A FOOD SOURCE

Bostick (1990) argued that declines in tortoise populations is caused by a reduction in the availability of cow dung which has declined with the reduction in numbers of cattle grazing in the southwest. He argued that cow dung is an important source of food for tortoises. However, Avery (1998) studied tortoise foraging behavior where tortoises coexisted with cattle. He observed over 30,000 bites of items and observed only 231 bites of cow dung. Esque (1994) also observed over 30,000 bites on food objects. He reported that 107 of them were of feces, but none were from livestock. Furthermore, Allen (1999) evaluated the nutritional quality of cow dung and found it to be deficient for tortoises. In fact, even when cow pies were their only choice of food for one month, most tortoises (71%) refused to eat. Those that did eat, assimilated virtually none of the nitrogen. Thus, whereas Bostick (1990) presented an intriguing alternative hypothesis for tortoise population declines, there is no empirical support for its basic assumptions.

Summary

Surprisingly little information is available on the effects of grazing on the Mojave Desert ecosystem (Oldemeyer 1994, Rundel and Gibson 1996, Lovich and Bainbridge 1999). Differences in rainfall patterns, nutrient cycling, and foraging behavior of herbivores and how these three factors interact make applications of research from other areas of limited value in understanding the range ecology of the Mojave Desert. The paucity of information is surprising given the controversy surrounding grazing in the

Mojave and the importance of scientific information for making resource management decisions affecting grazing. Studies mostly from other arid and semi-arid regions tells us that grazing can alter community structure, compact soil, disturb cryptogamic soils, increase fugitive dust and erosion. Some impacts to tortoises or their habitat have been demonstrated, but the evidence is not overwhelming.

Military Operations

The California deserts were used for military exercises as far back as 1859 when Fort Mojave was first built (Krzysik 1998). The most extensive use was for World War II training when 18400 mi^2 (47105 km^2) in California and Arizona were designated as the Desert Training Center and used extensively for training with tank and armored vehicles. Today, four major, active military installations occur within the West Mojave and comprise a total of 4165 mi^2 (10663 km^2): Naval Air Weapons Station ("China Lake;" 1731 mi^2, 4432 km^2), National Training Center ("Fort Irwin;" 1016 mi^2, 2600 km^2), Air Force Flight Training Center ("Edwards Air Force Base;" 476 mi^2, 1218 km^2), and Marine Corp Air Ground Combat Center ("MCAGCC" or "Twentynine Palms;" 943 mi^2, 2413 km^2).

As outlined in the Recovery Plan (USFWS 1994), impacts to tortoise populations come from four basic types of military activities:

> "(1) construction, operation, and maintenance of bases and support facilities (air strips, roads, etc.); (2) development of local support communities, including urban, industrial, and commercial facilities; (3) field maneuvers; including tank traffic, air to ground bombing, static testing of explosives, littering with unexploded ordinance, shell casings, and ration cans; and (4) distribution of chemicals." (USFWS 1994, p. D14)

A fifth potential impact is above ground nuclear weapons testing, which took place in Nevada in the 1950s and 1960s.

<u>Construction, Operation, and Maintenance of Bases and Support Facilities</u>

All four major military bases in the west Mojave Desert each have facilitated the growth or development of large internal support communities. The development of these communities destroyed tortoise habitat and likely brought with them all of the other impacts generally associated with large human settlements (fragmentation, ORVs, release of disease, facilitation of raven population growth, domestic predators, etc.), each of which are discussed elsewhere in this report. There is some evidence that the tortoise population around China Lake declined within four decades following development of the base at China Lake (Berry and Nicholson 1984a). However likely this conclusion probably is, the data used were based solely on anecdotal observations (Bury and Corn 1995); and the data only show a correlation, not a cause and effect. Removal (translocation) of tortoises from construction sites, runways, and other heavy use areas to other parts of the desert occurs and may affect the tortoises moved (Berry and Nicholson 1984a; see "Handling and Deliberate Manipulation" section, above). Another impact is the fragmentation of the habitat by the apparent haphazard placement of facilities throughout major portions of habitat (pers. obs.).

Development of Local Support Communities

The four major military bases in the west Mojave Desert have facilitated the growth or development of large external support communities: Ridgecrest, Barstow, Lancaster, Palmdale, and Twentynine Palms, which each have problems for tortoises typical of large suburban areas in the desert (see "Urbanization and Development" section, below).

Field Maneuvers

Tank maneuvers cause some of the most drastic and long-lasting impacts to the Mojave Desert habitats. Extensive tank training operations were conducted in the 1940's and in 1964 over 17,500 mi^2 of desert (Lathrop 1983, Prose and Metzger 1985, Krzysik 1998) and even more intensive maneuvers are currently taking place within an 819 mi^2 area on Fort Irwin (Krzysik 1998) and on MCAGCC (Baxter and Stewart 1990). Direct mortality to tortoises is relatively rare or not often reported, but does occur (Stewart and Baxter 1987, Quillman pers. comm.). Tanks damage vegetation, compact soil, cause fugitive dust, and run over tortoise burrows and tortoises. The results are largely denuded habitat, and altered vegetation composition, abundance, and distribution (Wilshire and Nakata 1976, Lathrop 1983, Baxter and Stewart 1990, Prose et al. 1987, Krzysik 1998). Natural recovery can take a long time; 55 year old tank tracks can still be seen throughout many parts of the desert (Wilshire and Nakata 1976, Krzysik 1998). Krzysik (1998) reported a significant reduction in tortoise densities (62-81% over six years) in active training areas of Fort Irwin and no change or increases in densities in areas with light and no activity. The effect of tank maneuvers was highest in valley bottoms and progressively less in high bajadas, talus slopes, and rugged mountain ranges where training activities were considerably lower.

Bombing and other explosive ordinance cause impacts in some areas, but no documentation was found of their effect on tortoise populations or habitat.

Distribution of Chemicals

It has been suggested that diseases affecting tortoise shells may be caused by residual chemical remains left over from military operations, but the evidence is highly speculative (See "Disease" section, above).

Nuclear Weapons Testing

Between 1951 and early 1963, the U. S. Atomic Energy Commission detonated 100 atomic devices above ground at the Nevada Test Site, Nevada (U. S. Department of Energy 1994). From mid 1960s to early 1990s only underground tests were conducted. Resource Concepts Inc. (1996) argued that radiation released into the atmosphere during these tests might explain tortoise declines. They cited two anecdotal accounts, one of many sheep getting sick near Cedar City, Utah, and another of high Geiger counter levels around the mouth of a cow in the same area. They suggested that nuclear fallout might explain the presence of disease in tortoise populations. Beatley (1967) found only very low levels of radiation at a plant study plot 8 km east of a below-ground test blast and attributed vegetative defoliation to dust from heavy vehicular traffic on a nearby dirt road.

The University of California, Laboratory of Nuclear Medicine and Radiation Biology conducted experimental radioecology research studies in Rock Valley located along the southern boundary of the Nevada Test Site. These irradiation studies involved the chronic exposure of plants and animals from a centrally located 137 cesium source located atop of a 50-ft tower within a 21-ac fenced plot. Rundel and Gibson (1996) provided a brief summary of the results of the Rock Valley irradiation experiment. Beyond direct mortality from the test blasts, there was very little persistent effect of radiation on the surrounding lizard populations. Little long-term effect on the pocket mouse, *Perognathus formosus*, was found (Turner 1975). On the other hand, female lizards at Rock Valley were found to be sterile several years after the experiment began (Turner 1975, Turner and Medica 1977). There were five adult tortoises present throughout most of the study and four still remained in 2001 (Medica pers. comm.).

I could find no data that bear directly on the potential effects of nuclear weapons testing on tortoise populations. The map in Gallagher (1993) suggests that fallout was nearly nonexistent in the west Mojave (which is consistent with predominant wind patterns), where URTD is rampant (Berry 1997). Therefore, if there is an effect from testing, it probably cannot be a universal explanation for rangewide declines nor can it explain the markedly high losses and levels of disease documented in the west Mojave.

Noise and Vibration

The following is largely paraphrased from my contribution to the Desert Tortoise Recovery Plan (USFWS 1994). Anthropogenic noise and vibrations may impact tortoises in several ways including: disruption of communication, and damage to the auditory system. A body of peer reviewed scientific literature exists demonstrating how background noise may mask important vocal signals in insects and amphibians (e.g., Bushcrickets, *Conocephalus brevipennis*, Bailey and Morris, 1986; Green Treefrogs, *Hyla cinerea*, Ehret and Gerhardt, 1980). Hierarchical social interactions, hearing, and vocal communication have all been identified in desert tortoises (Adrian et al. 1938, Campbell and Evans 1967, Patterson 1971, 1976, and Brattstrom 1974, Bowles et al. 1999). Patterson (1976) identified eleven different classes of vocal signals used by desert tortoises in various of social interactions, but he did not demonstrate that animals who hear the signals react or change their behavior in any way, a necessary component in identifying communication. The signals are relatively low amplitude, have fundamental frequencies 200 Hz or lower, and harmonics that reach as high as 4500 Hz (Patterson, 1976).

The portions in the following excerpt from USFWS (1994) pertaining to desert tortoises is purely speculative with no direct empirical support for desert tortoises:

> “ Many anthropogenic noises, such as automobile, jet, and train noises, cover a wide frequency bandwidth. When such sounds propagate through the environment, the high frequencies rapidly attenuate, but the low frequencies may travel great distances (Lyon, 1973). The dominant frequencies that remain after propagation correspond closely to the frequency bandwidth characteristic of desert tortoise vocalizations. Therefore, masking of these signals may significantly alter an animal's ability to effectively communicate or respond in appropriate ways. The same holds true for incidental sounds made by approaching predators; masking of these sounds may reduce a tortoise's ability to avoid capture by the predator. The degree to which masking by noise affects tortoise survival and reproduction depends on the physical characteristics (i.e., frequency, amplitude, and short- and long-term timing) of the noise and the animal signal, propagation characteristics of the sounds in the particular environment, auditory acuities of the tortoises, and importance of the signal in mediating social or predator interactions. There are no studies to test the masking effect of noise on tortoise behavior, but the effect is likely to be relatively low given that vocal communication is probably not extremely important in mediating social interactions and that noises loud enough to mask sounds important to tortoises are generally uncommon and short in duration. The only place the noise would be continuous enough may be alongside heavily traveled roads, where tortoise abundance is generally quite low.
>
> "Loud noises (and associated vibrations) may damage the hearing apparatus of tortoises. Little research has been performed on tortoise ears, but it is clear that tortoises are able to hear, and the relatively complex vocal repertoires demonstrated by tortoises suggests that their hearing acuity is similarly complex. Brattstrom and Bondello (1983) experimentally demonstrated that off-highway vehicle noise can reduce the hearing thresholds of Mojave Fringe-toed Lizards (*Uma scoparia*). Relatively short, single bursts (500 sec) of loud sounds (95 dBA at 5 meters) caused hearing damage to seven test lizards (Brattstrom and Bondello, 1983). Comparable results were obtained when desert iguanas (*Dipsosaurus dorsalis*) were exposed to one to ten hours of motorcycle noise (Bondello, 1976). It is likely that repeated or continuous exposure to damaging noises will cause a greater reduction in auditory response of these lizards. It is not unreasonable to expect loud noises to similarly impact the auditory performance of desert tortoises.”

A study conducted by Bowles et al. (1999) showed very little behavioral or physiological effect on tortoises of loud noises that simulated jet over flights and sonic booms. They also demonstrated that tortoise hearing is fairly sensitive (mean = 34 dB SPL) and was most sensitive to sounds between 125 and 750 Hz, well within the range of the fundamental frequency of most of their vocalizations. The authors concluded that tortoises probably could tolerate occasional exposure to sonic boom level sounds (140 dB SPL), but some may suffer permanent hearing loss from repeated long-term exposure to loud sounds such as from ORVs and construction blasts.

ORV Activities

Like most other threats, off road vehicle (ORV) activities may affect tortoise populations in multiple ways: direct mortality by crushing tortoises on the surface or in burrows, or indirect mortality through habitat alteration from soil compaction, vegetation destruction (direct or indirect via dust), or toxins from exhaust. However, different types of ORV activities will likely have different effects on tortoise populations. There are basically four categories of activity that may have very different impacts: free play where vehicles are not restricted to designated routes and cross travel or off-road and off-trail activity probably occurs regularly; non-competitive recreational uses outside of free play areas are limited to designated roads and trails with any driving off of those routes being illegal; competitive events are organized races that are restricted to designated open areas; and unauthorized cross-country travel for recreational or commercial (e.g., mining exploration) purposes. Hence in this report, ORV refers to motorized vehicle travel off of paved and graded dirt roads whether they are on ungraded dirt roads, trails, or cross country driving. ORVs can include dirt bikes, sport utility vehicles, all-terrain vehicles, sand rails, and any other type of motorized vehicle that travels such roads.

<u>Reduce Tortoise Density</u>

A number of reports document ORVs may directly kill tortoises (see below), however the data are insufficient to evaluate the extent of its overall impact on tortoise populations. We must rely more on other measures such as differences in tortoise densities between areas used by ORVs and those free from such activity. For example, Bury and Luckenback (1986) compared tortoise densities inside and outside of an ORV free-play area. They found 3.8 times more tortoises in a control area lacking ORV activity compared to a nearby open area and the animals were significantly heavier ($p<0.01$) in the control area. They also found 2.8 times the number of burrows, more of which were active, in the control area. Most of the burrows in the ORV area were in the section most lightly used by vehicles. The denser vegetation in the control area made searching much slower, hence 3.6 times more effort was spent searching the control area. The differences in number of tortoises are not likely to be a consequence of differences in search time because identical and consistent methods were used to sample each area (Bury and Luckenbach 1977). As this study was unreplicated (only one control, and one treatment area were surveyed), it is conceivable that the differences detected are due to causes other than ORV activity (e.g., soil or habitat differences or natural patchiness of tortoise populations).

Berry et al. (1986) compared tortoise populations inside of the DTNA and immediately outside where heavy ORV activity occurs. Using methods that are of questionable validity (Corn 1994a), they noted that significant declines occurred over a six-year period among juveniles and immatures in both areas, but that the declines were significantly greater in the adjacent area with more ORV activity.

Berry et al. (1994; for published abstract see Berry et al. 1996), compared evidence of human activity and tortoise sign (i. e., number of tracks, scat, and burrows, which is positively correlated to tortoise density; Turner et al. 1985) along 100 transects conducted in 1977-79 and 150 in 1990. They found that vehicle trails in 1990 were positively associated with areas classified as having low to medium densities of tortoises, but that numbers of vehicle trails and tracks were not directly correlated to actual number of tortoise sign. In one area, ORV activity had been stopped by BLM one year prior to the study, so vehicle tracks had been obliterated or were aged and did not accurately reflect the level of ORV activity the tortoise population had experienced over the past several years. Furthermore, the study lacked an adequate control site, but it is difficult to have good controls in a broad field study like this.

An indirect piece of evidence that ORVs reduce tortoise population density comes from Nicholson (1978). She reports on the findings of sets of transects walked at varying distances from the edges of several paved roads and highways in the Mojave desert. The study was designed to measure the effects of paved roads, not dirt roads or ORV travel on tortoise populations, thus is of little relevance to evaluating ORV impacts. She found that counts of tortoise sign increased with distance from paved roads. However, along Shadow Mountain Road, she found a reduction in tortoise sign 880 meters from the road edge, in an area with "excessive ORV use." She provided no statistical analysis of this observation, nor did she comment on the presence or absence of ORV activity along any of the 39 other transects she walked.

<u>Direct Effects</u>

CRUSHING TORTOISES AND BURROWS

Several accounts occur in the non-scientific literature of tortoises being crushed by ORVs, but most of these are anecdotal or unique incidents. In a popular account of ORV impacts to the desert environment, Luckenbach (1975) states: "I have personally found horned lizards, whiptails, zebra-tails, sand lizards, and tortoises crushed by ORVs;" no documentation or quantification was provided. Similar anecdotal statements were made in Berry and Nicholson (1984a) and Bury and Marlow (1973).

Berry and Nicholson (1984a) observed dead tortoises that were crushed in burrows that were apparently collapsed by ORVs, but no data or details were provided. Bury and Marlow's (1973) popular article about general impacts of ORVs on tortoises also makes the claim that burrows are crushed by ORVs, but provide no data. Fifteen burrows found in 1976 and 1977 in an ORV-use area were collapsed in 1985, their collapse being “related to ORV activity from trails through the area” (Bury and Luckenback 1986), although they gave no further indication of how they determined the cause of collapse. Woodman (1986) and Burge (1986) found no crushed burrows following the Parker 400 and Frontier 500 races, respectively.

Four studies quantified vehicle-related mortality on study sites with frequent ORV traffic. In her preliminary analysis of 1357 tortoise carcasses found on 14 permanent study plots for studying tortoise populations, Berry (1990 as amended) attributed approximately 57 (4%) to vehicles (some of the data were presented in Berry et al. 1986). It must be noted that 787 (58%) of the shells were not evaluated or were unclassifiable either because they bore no diagnostic characteristics or were too fragmented to analyze. Campbell (1985) found 2 vehicle-killed tortoises, one apparently killed by a 4-wheel vehicle on a dirt road inside the preserve and another killed outside the preserve by a sheep watering truck. In their comparative study of ORV impacts, Bury and Luckenback (1986) indicated that one immature tortoise was found crushed in a motorcycle trail. In a review of tortoise population dynamics, Marlow (1974) states that “nine recently crushed tortoises were observed in an area supposedly closed to ORVs. From tracks surrounding most of the carcasses there was little question as to the cause of their deaths.”

It is the correspondence between tortoise and ORV enthusiasts’ habitat preference that is likely responsible for some of the conflicts between the two. Jennings (1997) showed that tortoises spent significantly more time in washes, washlets, and on small hills. This is because their preferred food plants occurred in these habitats and they tend to burrow and travel more in washes and washlets than in other habitats. Jennings (1997) claims these habitats are also preferred disproportionately by ORV recreationists, but presented no supporting data.

Indirect Effects

COMPACTION OF SOIL

Soil becomes compacted, at least temporarily, when a motorized vehicle passes over it, and that compaction changes with the weight of the vehicle, soil type, and moisture content of the soil (Webb 1983). But, the affect this compaction has on tortoise populations depends on the lasting effect of compaction, its effect on vegetation and burrow digging abilities, how widespread the compaction is, and the respective effects on tortoise survival and reproduction.

Davidson and Fox (1974) investigated the effect a motorcycle dual sport race had on Mojave vegetation and soil. The soil, which was of similar type at both sites, was significantly denser and less porous at a pit area and alongside a trail than at a control site several hundred meters away. Significantly fewer plant species, fewer individuals, and less cover were found in impacted areas compared to the control site. However, the study was unreplicated. An increase in bulk density of the soil was measured in an evaluation of the impacts of the 1974 Barstow to Vegas Race (BLM 1975). However, many of the measurements were taken one week after a rain, so, because compaction is intensified on wet and moist soil (Webb 1983), the results may be unreliable.

Babcock and Sons (1973) found 10% or more increase in bulk density in disturbed versus undisturbed sites in alluvial wash, alluvial fan, and desert flat areas, but only a 3% increase in compaction in disturbed sand. Similarly, Wilshire and Nakata (1976) found sand dunes to be more resistant to compaction than playas or alluvial fans. Compaction was relatively light in heavily used dry washes and heavy in well used alluvial fans. Dry playas, which dry out fast after rains, resist compaction more than do wet playas (Wilshire and Nakata 1976), which are moist on or near the surface. Compaction on wet playas was measurable down to 15 cm or more.

In their manipulative experiment on the effect of vehicle type, number of passes, soil type, and soil moisture, Adams et al (1982a, b) measured soil compaction with a penetrometer. They found that compaction by a SUV was greater than that of a motorcycle. The SUV compacted wet soil significantly after only one pass on wet soil and after five passes on dry soil. The motorcycle compacted wet soil after 20 passes. Single passes by motorcycles on wet soil and SUVs on dry soils did not differ significant from the controls. The great variability in environmental conditions makes it difficult to make unambiguous generalizations.

Greater temperature extremes occurred in more compacted soils in heavy ORV use areas, probably from removal of vegetation and changes in soil characteristics from compaction (Willis and Raney 1971, Webb et al. 1978). This possible effect on soil temperature not only affects plant germination and growth, but may have interesting, if unexplored, implications for tortoise growth, development, and morphology. A further likely, but untested potential impact of soil compaction may be to make it difficult for tortoises to burrow, which would not only affect tortoises directly but would also reduce tortoises' role in reducing compaction through soil turnover (Prose et al. 1987).

Infiltration rate is a measure of the soil's ability to absorb moisture. More compacted soils have a lower infiltration rates so less water is available for plants (Webb 1983). Babcock and Sons (1973) found much lower infiltration rates on disturbed versus undisturbed desert sites, except in very sandy areas (dunes and washes). Webb (1983) measured 73% lower infiltration rate compared to a control site after 200 vehicle passes over wet sandy loam. The greatest decrease occurred after the first few passes. Infiltration rates of sands and clays are least affected by compaction, whereas loamy sands and gravelly soils are with a mixture of particle sizes are most affected.

DESTRUCTION OF CRYPTOGAMIC SOILS

Cryptogamic soils are important for reducing soil erosion, controlling water infiltration, regulating soil temperatures, fixing (catching and converting) atmospheric nitrogen, and accumulating organic matter (Cline and Rickard 1973, Pauli 1964, Rogers et al. 1966). Cryptogamic soils are collections of mostly symbiotic bacteria, algae, fungi, and lichen that live on or slightly below the soil surface and create a semi-permeable soil surface. They often occur in the open spaces between desert shrubs and help to facilitate seedling establishment and plant growth (St. Clair et al. 1984, DeFalco 1995).

ORVs, livestock, and other surface disturbances easily damage cryptogamic soils (Belnap 1996). Damage from compaction, even minor, can greatly reduce nitrogen fixation by the crust, an effect that sometimes increases rather than decreases with time since compaction (Belnap 1996). It is not certain how tortoises are affected by damage to cryptogamic soils and a 1980 review of the effects of ORVs on desert soils was inconclusive (Rowlands 1980). DeFalco (1995) found that, in the one season studied, tortoises selectively avoided foraging on plants growing on crusts. Although crusts fix nitrogen and the nitrogen can then be transferred to plants growing in close proximity to the crusts (Maryland and McIntosh 1966), concentration of nitrogen in tortoise forage plants were generally lower on cryptogamic soils (DeFalco 1995). However, many other nutrients are important to tortoises, and it is unknown if their concentrations are augmentated by cryptogams in associated tortoise forage plants. In non-tortoise habitat in southwest Utah, Belnap and Harper (1995) showed that nitrogen, phosphorus, potassium, calcium, magnesium, and iron concentrations were higher in some plant species growing on encrusted soils compared to those growing where there were no crusts. The primary importance of cryptogamic soils to tortoise populations could be in stabilizing the soils against wind and water erosion (Belnap and Gardner 1993, DeFalco 1995), but more research is clearly needed.

Changes in Vegetation

Several studies measured the effect ORVs have on vegetation; most of them evaluated damage from competitive events. Burge (1986) described how many perennial shrubs were damaged along the edge of the Frontier 500 competitive race. She counted 1170 uprooted or crushed shrubs (no species identified) after the race. Davidson and Fox (1974) measured plant diversity, number of individuals, and amount of cover in a pit area (where vehicles were parked), alongside a dual sport race trail, and "several hundred yards away" (i.e., control area). They found significantly lower values for all three parameters in the pit area, moderate values alongside the trail, and the highest values at the control site. Woodman (1986) recorded the destruction of several creosote and burrobushes around the periphery of the pit area for the 1981 Parker 400 race. A BLM report detailing damage to vegetation caused by the 1974 Barstow to Vegas Motorcycle Race (BLM 1975) showed that 0 to 76% of the plants, particularly seedlings and small shrubs, were damaged in each of 26 sites.

Berry et al. (1990) measured habitat changes over a six-year period inside and outside of the DTNA where ORV non-race activity occurred. They found a 23% increase in habitat loss around a staging/pit area and that ORV trails increased in width by 130% and 157% in area.

Vegetation is clearly degraded by heavy ORV activity. Bury and Luckenback (1986) compared vegetation inside (treatment) and outside (control) an ORV use area south of Barstow. There were 1.7 times the number of live perennials on control, and 2.4

times number of dead ones (mostly *Ambrosia dumosa*) on the treatment area. Plant cover was 3.9% higher in the treatment area. This study suffers from a lack of replication. Comparing aerial photographs taken at the same points 19 to 25 years apart in six different locations in the Mojave and Colorado Deserts, Lathrop (1983) measured an average of 49% reduction in shrub density in ORV areas. Ground-based transects in control and treatment (disturbed) sites yielded 48-97% reductions in perennial plant cover in the ORV use areas. Thirty-four to 46% reductions in density resulted from single race events at two separate locations (Lathrop 1983). Luckenbach (1975) reports, that "in one Hounds-and-Hare race, an estimated 140,000 creosote bushes (*Larrea tridentata*), 64,000 burro-weed *(Franseria dumosa*), and 15,000 Mojave yuccas (*Yucca schidigera*) were destroyed or severely damaged over a stretch of 100 miles." No additional details were provided.

Rowlands et al. (1980) and Adams et al. (1982b) conducted one of the only manipulative experiments on ORV effects on Mojave desert vegetation. They studied the effect that different numbers of passes over the same area by a motorcycle and a 4-wheel drive sports utility vehicle (SUV) had on plant growth. They also looked at the interactive effects of soil moisture and soil type. Plant density, biomass, and cover generally were reduced following any level of disturbance with motorcycles requiring a greater number of passes to equal the reduction caused by the SUV. Grama grass (*Bouteloua barbata*), appeared to respond positively to light disturbance, but less so to heavy disturbance. The introduced weed, split grass (*Schismus barbatus)*, was significantly more abundant within tracks than in control areas, probably because the fibrous nature of their roots allowed them to become better established than more tap-rooted natives in compacted soil.

Vollmer et al. (1976) found annual plant density to be significantly lower within experimentally created tracks from two 4-wheel drive vehicles compared to the hump between the tracks and in an area randomly covered by the same vehicles. No difference in density occurred between the randomly driven area compared to the control site. Shrubs in the regularly driven area (42 passes by vehicles) suffered twice as much damage as those in the randomly driven area. This study lacked replication and proper controls, but data collection and analysis were well executed.

Kuhn (1974, cited in Lathrop 1983) reported a reduction in plant density of 24% and plant cover of 85% in ORV-disturbed plots compared to undisturbed controls in foredunes at Kelso Dunes. Similarly, comparing aerial photographs taken 21 years apart, Lathrop (1983) measured a 50% reduction in shrub density in the same foredunes.

EROSION AND LOSS OF SOIL

ORV activity can increase erosion, which removes soil nutrients and soil that is penetrable to roots (Adams and Endo 1980a, Wilshire 1980). ORVs modify various features that help to stabilize the soil against erosion including surface crusts, coarse particles, desert pavements, and vegetation (Hinckley 1983). They also alter the configuration of the ground surface thus affecting water runoff patterns (Hinckley 1983).

The net loss of soil at specific ORV-use areas has been documented. Wilshire and Nakata (1976) estimated 150 metric tons of dirt were lost to erosion from one 68-meter long western Mojave hillside trail with a 44-58% slope. Total estimated loss for the portion of hill used for an unspecified number of years was 11,000 metric tons. Snyder et al. (1976) estimated that 150-230 mm of soil was lost per year along transects in an ORV use area over two to five years at Dove Canyon. That amount is compared to estimates of natural erosion rates of 1.0 to 4.6 mm per year in arid areas (reported in Hinckley et al. 1983). No control or low-impact reference sites were established in this study. Webb et al. (1978) reported a loss of 0.3 to 3.0 metric tons per m^2 from an ORV trail in arid land at a heavily used ORV park in central California. They further reported that erosion was greatest on sand loam and gravelly sandy loam and least on clay and clay loam.

In artificial rain trials, Iverson (1979) found greater sediment yield (soil runoff) in vehicle-disturbed versus undisturbed slopes from loosening of soil and alteration of flow patterns. The difference was thought to be from increased water flow velocity and more channeling of the flow, not from reduced filtration. Consequently the effect would be more pronounced during intense thunderstorms than during more mild winter frontal-type storms. Also using artificial rain, Eckert et al. (1977) looked at infiltration and sedimentation rates at two Mojave desert sites in Nevada following single and multiple passes of truck and motorcycle. Single passes made no measurable difference. Multiple passes increased rates of infiltration and sedimentation, particularly in interplant spaces versus beneath plants. However, the artificial rainfall rates were similar to rare very heavy thunderstorms; they were unlike the winter cyclonic rainfall that is more typical of the western Mojave desert. Furthermore, Reicosky (1979) suggested that movement of water towards vehicle tracks compensates for decreased infiltration rates. Hinckley et al. (1983) suggested that water erosion would be the least in areas that are relatively flat, experience short, low-intensity storms, and have a coarse (gravelly) surface.

Fugitive dust, dust blown from the ground by wind and vehicle activity, can potentially be a problem for desert tortoises. Fugitive dust is related to vehicle speed, surface texture, surface moisture, and probably vehicle type (with heavy four-wheel drive vehicles causing the most dust followed by light four-wheel drive vehicles followed by motorcycles; Adams and Endo 1980b). The threshold velocity for wind erosion (TV), the lowest wind speed necessary to create dust, is highest for desert pavement and areas with hard surface crusts. Soils with a large proportion of fine particles will be more susceptible to wind erosion. Disturbances that lower the TV will increase the incidence of dust storms. Disturbance of sand dunes and sandy washes does not alter their TV. Areas protected by cryptogamic soils and desert pavement had greatest reduction in TV following disturbance, and more so with siltier versus sandy soils (Adams and Endo 1980b, Gillette and Adams 1983). Winds of 20-30 mph at 6 ft above ground caused fugitive dust in these areas. Erodibility also varies with width of disturbed area up to about five meters (Wilshire pers comm., cited in Adams and Endo 1980a)

Satellite images taken on January 1, 1973, captured dust storms from Santa Ana wind conditions (Bowden et al. 1974, Wilshire 1980). Many of the dust plumes, which were 10 to 30-km long and covered 300 km^2, originated in areas of intensive ORV activity in the western Mojave. BLM (1975) measured three to five times more suspended particulate density for fugitive dust during the 1974 Barstow to Vegas race site compared to before the race.

The main effect of wind erosion on productivity is removal and redistribution of surface nutrients, not reduction in soil depth. Loss of soil nutrients found in the top 5 to 10 cm of soil significantly reduced perennial cover in a similar arid environment in Australia (Charley and Cowling 1968). Sharifi et al. (1997, 1999) showed that photosynthesis and plant productivity are hampered by dust on the leaves of desert shrubs, but that the effect may be ameliorated by heavy summer rainfall.

LIGHT ORV USE

Most of the foregoing discussion relates specifically to competitive events and heavy use like what now occurs within open use or freeplay areas. They are of limited applicability to understanding the effect of lighter travel in areas where traffic is legally restricted to designated routes (i.e., dirt roads). Indeed, very little data are available to evaluate these impacts primarily because the focus of most research has been on the effects of heavier ORV use. There are a few studies that demonstrated that occasional vehicles riding off of roads (including for parking or camping within 100 ft of roads, which is currently permitted, Bureau of land Management 1980), can damage the soil and vegetation, the amount of damage being less than heavier off road travel. Webb (1983) found that the greatest increase in compaction occurred the first few time a motorcycle crossed an area and compaction increased with more crossings, but at a lower rate. Similarly, Adams and Endo (1980a) discovered that just a few passes by an SUV were sufficient to significantly increase compaction and a single pass did so in some wet soils. Vollmer et al. (1976) found that there was damage to plants in an area subjected to random four-wheel drive activity, but that damage was higher in areas that were repeatedly driven over. Bury and Luckenbach (1977) reported little difference in the number of creosote shrubs in moderate use versus undisturbed plots, but did find that half were broken or damaged in the moderate use area. Likewise, a “sparsely” used ORV area within the Jawbone Canyon Open Area showed 35% less perennial plant cover than an unused control area (Lathrop 1978). Finally, just stepping on cryptogamic crusts can damage and decrease nitrogen fixing activities of the crusts (Belnap 1996).

All of these studies indicate that some damage is likely to occur when vehicles stray off of established roads. Goodlett and Goodlett (1993) demonstrated that ORV enthusiasts will not always obey signs indicating routes are closed, nor do they always stay on designated routes. However, their study was conducted in an area that had recently changed from an open free play area to a limited use one. Although it is likely that number of tracks will be highest in close proximity to roads (e.g., LaRue, pers obs.), no studies have tested for this pattern. Many of the problems associated with light ORV use likely relate to increased human access the roads and trails afford (see "Human Access to Tortoise Habitat" section, below).

Summary

Although each study comparing tortoise densities inside and outside of ORV areas has limitations, they all lend evidence to reductions in tortoise population densities in heavy ORV use areas. The causes for these declines are less certain. Tortoises and their burrows are crushed by ORVs, although it is difficult to evaluate the full impact this activity currently has on tortoise populations, partly because there are probably relatively few tortoises in most open use areas. ORVs damage and destroy vegetation. Density, cover, and biomass are all reduced inside versus outside of ORV use areas, particularly following multiple passes by vehicles. Split grass (*Schismus barbatus)*, a weedy introduced grass, in particular appears to benefit from ORV activity. Very light, basically non-repeated, vehicle use probably has relatively little long-term impact. Soil becomes compacted by vehicles. The compaction increases with moisture content of the soil, weight of vehicle (particularly high weight to tire surface area ratio), and soil type. Cohesionless sand, such as in sand dunes and washes, are largely immune to compaction while moist soils are much more susceptible than dry ones. Compaction, lower infiltration rates, loss of plants and cryptogamic soils all contribute to increased wind and water erosion and fugitive dust, particularly when such areas are several meters in width. More research is needed to understand the effect light ORV use has on tortoise populations and habitat.

Predation/Raven Predation/Subsidized Predators

Desert tortoises have several natural predators including: coyotes, kit foxes, feral dogs, bobcats, skunks, badgers, common ravens, and golden eagles. The dominant predator probably varies temporally, spatially, and with size of the tortoise (Berry 1990 as amended). Few studies have attempted to quantify or estimate the relative proportion of mortality attributable to the various predators at specific sites, and none attempt to characterize it regionally.

One of the earliest publications reporting that ravens are potentially important predators on desert tortoises was Campbell (1983). He found 140 shells of juvenile tortoises (36 to 103 mm MCL) at the base of fence posts along the 30.5 miles of fencing surrounding the DTNA. He attributed 136 to raven predation, but gave no indication why. Berry (1985) evaluated 403 juvenile tortoise shells found on 27 desert tortoise study plots throughout the Mojave Desert. She determined that ravens killed 35%. Her evaluation was based on circumstantial evidence because the reference collection was shells found beneath perch sites that may have been used by other predators or scavengers. Although the patterns of shell damage she used are consistent with the patterns Boarman and Hamilton (in prep.) obtained from 266 shells collected from beneath raven nests. Also, ravens are scavengers as well as predators, so some of the shells attributable to raven predation may actually have been found and eaten after death (Boarman 1993).

During the first 5 to 7 years of life, the tortoise shell is incompletely ossified; it is soft and easy to puncture and rip open. When pecked open by a raven, the soft shell will bend then dry in place leaving parts of the shell pushed in or pulled out. Carcasses found in this condition were likely pried open when the tortoise was alive or shortly after death. The shell soon dries after death. Once this happens the shell will fracture when pecked open, giving a different appearance. Although based on sound knowledge of the biology of tortoises, this scenario has not been subjected to quantification or controlled experimentation.

Woodman and Juarez (1988) reported finding 250 shells, probably killed over a four year period, dead beneath one raven nest near the Kramer Hills. Some of the carcasses found were of young animals found alive and individually marked by the same researchers several weeks earlier and apparently in healthy condition. This provided the first hard evidence that ravens almost certainly were killing some tortoises, not just scavenging them. Since that time, several observations have been made of ravens carrying away live juvenile tortoises (Boarman 1993). One researcher reported finding a tortoise eviscerated, but still alive, beneath a raven nest (R. Knight pers. comm.). These reports all remain anecdotal, but, because observing the act of predation by a predatory bird is notoriously difficult, it is unlikely we will ever be able to acquire an adequate number of good hard data on the phenomenon. One published account evaluated food of ravens in the Mojave desert by looking at pellets, indigestible portions of food that were coughed up at their nests (Camp et al 1993). They found tortoise remains in only 1.3% of the pellets. However, they did not report the 19 shells they found at several of those nests because they only reported on pellet contents (Camp pers. comm., Boarman pers. obs.); shell fragments usually are not found in pellets. They also did not establish whether all nests studied were in tortoise habitat.

The fact that ravens do kill some tortoises does not alone indicate that the losses are serious enough to warrant management action. We must understand the extent of predation and if it is having an impact on tortoise populations. Evaluating raven predation is perplexing because of the difficulties in finding small carcasses over such a large area of desert and in monitoring small, hard to find young tortoises (Berry and Turner 1986, Shields 1994). The extent of predation can be estimated by evaluating juvenile tortoise carcasses found throughout the desert. Berry (1985) and Boarman and Hamilton (in prep) analyzed the characteristics of 150 and 266, respectively, juvenile tortoise shells found in the deserts of California. Their reports indicate that primarily animals less than 100 mm MCL (less than approximately 5-7 years old) are taken throughout most portions of the desert in California. Beneath 23 transmission towers in Nevada, McCullough Ecological Systems (1995) found the remains of 78 juvenile tortoises, many showing signs consistent with raven predation.

A common argument made against raven predation being of management concern is that we must concentrate on protecting adult female tortoises (Doak et al. 1994). This is partly because adult females are the ones actually reproducing, thus contributing most to the persistence of the population and partly because juvenile animals typically experience high mortality, so losses to ravens are natural and the population can sustain the losses. This is a correct prediction from life history theory for many animal species, but not for long-lived ones that first reproduce later in life (approaching 20 years), like the desert tortoise (Congdon et al. 1993, 2002). Life history theory predicts that stable populations of such animals can sustain annual mortality of juveniles of 25%. However, when adult populations are declining, juvenile mortality must be reduced to approximately 5% to ensure recruitment of new individuals into the breeding population (Congdon et al. 1993). This finding is based on well developed life history theory. Therefore, in tortoise populations that are experiencing overall declines, additional losses of juveniles to ravens may decrease the stability or at least prevent recovery.

A survey of tortoise remains found beneath raven nests was recently completed (Boarman and Hamilton in prep.). It showed that ravens prey on tortoises throughout the Mojave Desert in California, but probably not all ravens nesting in tortoise habitat ate tortoises. The most shells found at one nest in one year between 1991 and 1997 was 28, which were found beneath each of two nests in the eastern Mojave Desert. The results are preliminary and conservative because they pertain only to remains dropped beneath or near the raven nests. Many shells are found at locations well away from nests. During the raven breeding season, however, most foraging is probably done near the nest (Sherman 1993) and most food is likely brought back to or near the nest, so the results are probably relatively accurate if conservative.

There are little data available to determine the effect other predators might have on desert tortoise populations. For example, finding shells chewed by mammals, probably canids, and tortoise remains in coyote scat, Berry (1990 as amended) reported evidence of canid or felid predation at four out of twelve study plots in California. Proportion of deaths attributable to mammalian predators over all 12 plots was 53.% (ranged = 1.8% to 45.3% among the 4 plots where mammal-related mortality determined). Turner et al. (1997b) determined that most tortoise nests that failed were dug up by coyotes or kit foxes, but no data were presented. In 1998 and 1999, 47% and 12%, respectively, of nests studied at Twentynine Palms (MCAGCC) were dug up, probably by kit foxes (Bjurlin and Bissonette 2001). Bjurlin and Bissonette (2001) also believed that feral dogs cause a significant amount of mortality among adult tortoises in the area, but presented evidence for only one such death. They did report a high incidence of canid-like shell damage to live tortoises and the presence of feral dogs and dog packs within their study site. The effect that feral dog predation has on tortoise populations appears to be an emerging problem that warrants further documentation.

Non-ORV Recreation

Non-ORV recreation in the Mojave Desert includes camping, nature study, rock collecting, sight-seeing, hunting, horseback riding, mountain biking, and target practice. There are no studies concerning their impacts on tortoise populations: hence, there may or may not be impacts. Likely impacts include handling and disturbance of tortoises; loss of habitat to campgrounds, picnic areas, scenic pull outs, vandalism, and other support facilities; increase in road kills; and support of ravens when organic garbage is left behind. There could also be soil compaction and damage of vegetation and cryptogamic crusts from off-trail travel by mountain bikes, horses, and hikers. All of these impacts are related to the problems with increased access to tortoise habitat (discussed in "Human Access to Tortoise Habitat" section, below). Given the increased interest in non-motorized recreation in the deserts, this is an important area for future research. There are no studies that directly measured the impacts of non-motorized recreation on tortoise populations or their habitats and only one that showed that hiking off of trails can significantly damage cryptogamic crusts (Belnap 1996).

Hunting and target practicing are two additional recreational activities that may impact tortoises. One of the primary anthropogenic causes for wildfire in the desert is from bullets striking rocks (R. Franklin, BLM Fire Management Officer, pers. comm.), which can occur while hunting or target practicing. The California Department of Fish and Game has constructed an array of small- and big–game guzzlers to help facilitate growth of game species populations. Not only can ravens sometimes access water at the big game guzzlers, but tortoises can get caught and die in some types of small game guzzlers. Hoover (1996) found the remains of 26 tortoises in 89 of the upland game watering devices in California. Finally, people target practicing, which is a very different activity than hunting, might also illegally use tortoises as targets (Berry 1986a, see “Vandalism,” below).

Roads, Highways, and Railroads

Roads, highways, and railroads have several impacts on desert tortoises and their habitat. Direct impacts may include mortality through road and train kills and destruction of habitat (including burrows). Possible indirect effects include degradation of habitat because they serve as corridors of dispersal for invasive plants, predators, development, recreation, and other anthropogenic sources of impact. Roads, highways, and railroads also serve to fragment the habitat and populations (see “Habitat Degradation, Fragmentation, and Destruction,” below).

Many tortoises fall victim to road kills. For instance, Boarman and Sazaki (1996) reported finding 115 tortoise carcasses along 28.8 km of highway in the west Mojave. This represents a conservative estimate of 1 tortoise killed per 3.3 km of road surveyed per year. This source of mortality primarily affects subadults and adults, although the results are partially skewed by the difficulty of finding smaller carcasses and their quicker loss to scavengers and decay. The figures cannot be extrapolated to all roads and highways to estimate total losses to road kills in the desert because mortality rate likely depends on traffic speed and volume, density and demography of surrounding tortoise population, and perhaps width and age of road. The results also cannot be applied to lightly traveled paved or dirt roads because of a four-way relationship between tortoise density, road conditions, traffic volume, and road kill rate. A tortoise depression zone exists along highway edges and extends to 0.4 km or further (Nicholson 1978, Berry and Turner 1987, Berry et al. 1990, LaRue 1993, Boarman and Sazaki 1996, von Seckendorff Hoff and Marlow 1997, cf. Baepler et al. 1994). The cause is probably primarily road kills, but illegal collections, noise, and other factors may also contribute although there are no data to evaluate their likely or relative effects.

A common mitigation for the impacts of roads and highways is a barrier fence, which has been shown to be highly effective at reducing mortality in tortoises and other vertebrates in the west Mojave (Boarman and Sazaki 1996). However, fences only increase the fragmenting effects of roads. Preliminary results of an eight-year long study indicate that culverts are used by tortoises to cross highways (Boarman et al. 1998), but it is unknown whether their use is sufficient to ameliorate the fragmenting effects of fenced highways (Boarman and Sazaki 1996).

Roads are also major attractants for common ravens, which are predators on juvenile tortoises (Knight and Kawashima 1993, Boarman 1993). Ravens, being partly scavengers, are known for cruising road edges in search of road kills (Boarman and Heinrich 1999), but risk of predation is not increased near roads (Kristan and Boarman 2001).

The flush of vegetation that grows alongside roads (Frenkel 1970, Johnson et al. 1975) as a result of rainwater runoff and collection may benefit tortoises by providing a more consistent source of food over a more extended period of time, even in relatively dry years (Boarman et al. 1997). Alternatively, the abundance of food may bring them into harms way if (1) they wander onto the road, (2) vehicles pull onto the vegetated shoulder of the road, (3) grading or mowing activities occur during times of tortoise activity, (4) herbicides are applied to control growth of weeds along the road shoulder, or (5) they are seen and caught by passers-by. Brooks (1998) found a significant positive correlation between number of alien annual plant species near roads and density of dirt roads., and the species richness and biomass of alien annuals is higher near roads than away from them (Brooks pers. comm.).

Railroads may also impact tortoise populations through train kills and perhaps by tortoises getting caught between the rails (Mount 1986). No published studies were found that looked for train-killed tortoises along extensive sections of railroad tracks. However, Ron Marlow (pers. comm.) found eight carcasses between the rails along approximately 100 km of railroad tracks in the eastern Mojave. Noise or vibration may also affect tortoises that live alongside railroads, but has not been studied (see “Noise and Vibration,” above). Railroads provide a positive benefit: tortoises regularly build burrows in railroad berms that are not covered with gravel. It is not known if train noise negatively affects the behavior, audition, or reproductive success of these tortoises.

Utility Corridors

Corridors formed by utility and energy rights-of-way cause linear impacts to populations and may have levels of impacts well beyond those of many point sources of impacts. In a retrospective evaluation of results of 234 Biological Opinions issued by USFWS in California and Nevada (LaRue and Dougherty 1999), 80% (47/59) of the tortoises reportedly killed in California and Nevada were killed along utility corridors. Most of those were along the Kern-Mojave Pipeline (Olson et al. 1993, Olson 1996). Considerable habitat destruction or alteration occurs when pipelines and transmission lines are constructed and the impacts are repeated as maintenance operations or new pipelines or power lines are placed along existing corridors. Trenches opened for laying or maintaining pipes may serve as traps for tortoises and other animals (Olson et al.

1993). Dirt roads used for maintenance-related access create dust (Wilshire 1980) and provide access to less disturbed habitat (Brum et al. 1983). The habitat conversions during early stages of post-construction succession along pipeline corridors (Vasek et al. 1975) not only may suppress regular use by tortoises, but may function to reduce dispersal across the corridor thus effectively fragmenting a previously intact population (this view is speculative).

The presence of transmission towers in areas otherwise devoid of other raven nesting substrates (e.g., Joshua trees, palo verdes, cliffs), may introduce heavy predation to an area previously immune to such predation (Boarman 1993). Most raven predation on tortoises appears to occur during the raven breeding season (April - May, pers. obs.). By one estimate, ravens probably do most (75%) of their foraging within 400 m of their nest (Sherman 1993) and raven predation pressure is notably intense near their nests (Kristan and Boarman 2001). Therefore, ravens nesting on transmission towers, where no other nesting substrate exists within about 800 m, may significantly reduce juvenile tortoise populations within 400 m of the corridor, but this effect is quite localized. However, recent unpublished data on the distribution of raven depredated juvenile tortoises suggests that not all ravens nesting within tortoise habitat actually eat tortoises (at least they do not bring the shells back to the nest; Boarman and Hamilton in press).

Data collected along paved highways indicate that road kills can substantially reduce tortoise populations within at least 0.4-0.8 km of such roads (see “Roads, Highways, and Railroads” section, above), and their impact is likely lower along newer and more lightly traveled roads (Nicholson 1978). But, there are no data on the impact of lightly traveled dirt roads (e.g., utility maintenance/access roads) on tortoise population densities.

Vandalism

Vandalism is the “purposeful killing or maiming of tortoises” (Luke et al. 1991, p. 4-61). Reports of tortoises being vandalized include shooting, crushing, running over, chopping off heads, and turning them over (Berry and Nicholson 1984a, Berry 1986a, Bury and Marlow 73). Most reports of specific incidents are anecdotal, but sometimes substantial. The most quantitative accounts are for gunshot deaths (Berry 1986a, 1990 as amended), but are mostly based on postmortem forensic analysis. Berry (1986a) found 91 tortoises carcasses (14.3% of those collected at 11 sites) showing evidence of being shot. The proportion of carcasses showing evidence of gunshots was significantly higher from west Mojave sites (20.7%) than from east Mojave (1.5%) and Colorado (2%) desert sites. Eleven of the 58 (19%) tortoise found dead on the Beaver Dam Slope, Utah, showed signs of traumatic injury. This category included individuals exhibiting gunshot wounds. These ranged from pellet wounds through .22 caliber holes to one individual exhibiting a .44 caliber bullet wound.

Wild Horses and Burros

Wild burro and tortoise ranges overlap in some places, but the overlap is quite low in the West Mojave. No published studies were found that investigated the impact burros or horses (neither of which are native to North America) have on tortoise populations. The primary effect is likely to be habitat alteration through soil compaction and vegetation change. Burro populations are probably not extensive enough in most areas to pose a major threat to tortoise populations, but this is speculative.

CUMULATIVE THREATS TO TORTOISE POPULATIONS

Human Access to Tortoise Habitat

Perhaps the most important general threat to tortoise populations relates to actual human presence in tortoise habitat and thus refers primarily to access. Many of the individual threats discussed above relate to the level of access to tortoise habitat afforded to people. For instance, law enforcement officials have documented illegal collecting of tortoises for food or cultural ceremonies on a few occasions (USFWS 1994). One study supported the intuitive impression that poaching occurs close to roads (Berry et al. 1996), but the methods employed were not very precise (counting burrows that appeared to have been dug up with shovels) making the results weak at best. Since roads likely provide access to poachers, a logical conclusion of their study is that a larger proportion of the tortoise population will be under the risk of being poached where more roads intrude on tortoise habitat.

The presence of a road poses potential harm to tortoises and their habitat and the more roads there are the greater is the proportion of the tortoise population that is under the threat of illegal off-road activity. Boarman and Sazaki (1996) demonstrated that tortoises regularly die from collisions with automobiles and Nicholson (1978) showed that the rate of mortality probably increases with traffic volume. So, road kill is probably proportionally lower on lightly traveled dirt roads, but may still exist. However, because tortoise populations are probably less depressed alongside lightly traveled roads (Nicholson 1978) and if tortoises are less inhibited from crossing narrower, dirt-covered roads (for which there are no data), we may speculate that proportionally more tortoises may cross lightly traveled roads. The possibility does exist that ORVs may crush tortoises or their burrows on or off of roads (Marlow 1974, Bury and Luckenbach 1986, Berry 1990 as amended).

Mortality on roads is not the only type of vehicle-related impact; ORVs sometimes drive off of established routes, including within 100 ft to camp and park (Bureau of Land Management 1980). One study has supported the hypothesis that off-road activity is high near dirt roads even in an area that was heavily signed (Goodlett and Goodlett 1993). For example, they counted an average of one track every 31 feet along transects walked perpendicular to authorized routes. As expected, the density of tracks decreased with distance from the road from an average of 2.1 per 20 ft near the road to 0.5 per 20 feet 250 to 300 feet away. No statistical analyses were made. Goodlett and

Goodlett (1993) also demonstrated that ORV recreationists ignored BLM signs indicating trails and roads were closed to vehicles in the Rand Mountains. An average of 11.5 new tracks was counted along 17 trails 6 to 7 days after the trails were raked. An average of 10.0 tracks was found along 20 unmarked routes (again, no statistical analyses were provided), which suggests that the signs were essentially ineffective at preventing people from riding on closed trails. The motorcycle activity occurred over Thanksgiving weekend, 1991.

Furthermore, there is ample evidence that occasional driving off of roads compacts soil and damages vegetation (Vollmer et al. 1976, Webb 1983, Adams et al. 1982a, b, see also "ORV" section, above). The greatest increase in compaction can occur after a single or very few passes by a vehicle over unimpacted soil (Webb 1983), or at least soil strength (a measure of compaction) is significantly increased after a very few passes by an SUV (Adams et al. 1982a, b). Any driving or even walking over cryptogamic crusts damages the crust (Belnap 1996). As discussed in the "ORV Activities" section, above, there are very little data to indicate how these habitat alterations might affect tortoise populations.).

Other potentially harmful activities that likely occur in greater numbers near roads include: mineral exploration, illegal dumping of garbage and toxic wastes, release of ill tortoises, vandalism, anthropogenic fire, handling and harassing of tortoises, and trailing of sheep (Berry and Nicholson 1984a). Invasive plants also proliferate near roads and where road densities are higher (Brooks 1995, 1999a). The threat posed to tortoise populations by all of these factors likely increases with increased access afforded by the proliferation of roads, even very lightly traveled ones. Furthermore, some of these individual threats may be relatively low, but their cumulative impact may be great. Berry (1990 as amended, 1992), presents data that suggests a correlation between tortoise population declines and density of roads, trails, and tracks on tortoise study plots, but the results have not been treated to statistical analysis. This important association between access and tortoise wellbeing needs further study.

Habitat Loss, Degradation, and Fragmentation

One of the most pervasive problems for desert tortoise populations is also among the most difficult to evaluate: habitat loss, degradation, and fragmentation from the myriad activities that take place in the desert. This is the cumulative result of several of the individual threats discussed above.

Habitat loss is generally quite apparent (e.g., loss of useable habitat when paved for a parking lot or plowed for agriculture), but is sometimes less than obvious (e.g., a given area may be rendered unusable by tortoises after soil is heavily compressed and vegetation is destroyed after many vehicles drive over the area). Previously useful habitat may be rendered unusable, but may appear superficially similar to useable habitat.

Habitat degradation consists of human-mediated changes in habitat characteristics that render an area less valuable to, but still potentially usable by, tortoises. The degradation may be manifested in altered soil structure, increased exotic plants, lower abundance of preferred forage plants, reduced availability of effective cover sites, or a combination of these traits. The degradation may not directly cause increased mortality in tortoise populations, but may reduce reproductive output or cause some animals to leave the area in search of less degraded habitat. Although these responses have been hypothesized, there have been no studies on tortoise habitat choice or preference patterns changing as a result of habitat changes.

Many of the impacts discussed above fit easily into the category of habitat degradation that may significantly reduce habitat quality for tortoises. A single vehicle driving over a section of ground may have little impact by itself (Adams et al. 1980a, b), but when that is added to a pile of trash nearby, compaction from grazing (Avery 1998), and reduced primary productivity of plants because of dust from a nearby dirt road (Sharifi et al. 1997), the cumulative habitat degradation may significantly reduce quantity or quality of forage for tortoises. The cumulative effects of factors leading to habitat loss and habitat degradation have been implicated as causes in the extirpation and drastic reductions in tortoise populations from the Antelope, Searles, and Indian Wells valleys, and in the vicinity of several other communities in the West Mojave (e.g., Barstow, Mojave, and Victorville; Berry and Nicholson 1984a, Feldmeth and Clements 1990, Tierra Madre Consultants 1991, USFWS 1994).

Fragmentation is the process by which solid blocks of habitat and populations depending on the habitat are broken up into smaller subunits with limited dispersal between habitat blocks (Meffe and Carroll 1997). Rivers, mountain ranges, major changes in soil or habitat type all represent natural causes of fragmentation. Highways, railroad tracks, towns, and other developments, isolated and conglomerated, are examples of anthropogenic factors that fragment desert tortoise habitat in the West Mojave Desert. Smaller populations are more susceptible to local extinctions as a result of both genetic and demographic (population) processes. A smaller population has fewer individuals available for interbreeding, which may result in genetic deterioration: inbreeding depression and loss of genetic diversity within the population (Frankham 1995). Genetic deterioration can result in the inability to adapt to short- or long-term environmental changes, which makes the population more vulnerable to extinction. Small populations are also susceptible to extinctions from random fluctuations in birth rate, death rate, age distributions, and sex ratios (Opdam 1988). Small populations suffer from the Allee Effect, the fact that it is harder to find a mate when there are fewer individuals in a population (Allee et al. 1949). Finally, smaller populations are more vulnerable to catastrophic events (e.g., disease epidemics, earthquakes, and floods) and random environmental fluctuations in such things as food resources. These processes (genetic deterioration and demographic consequences of small populations) are theoretical possibilities, but have not been documented empirically in desert tortoises populations (see USFWS 1994 for a theoretical analysis).

An additional problem associated with fragmentation is that the negative effects of habitat edges are increased considerably (Murcia 1995, Meffe and Carroll 1997). Edges, or boundaries, are problems for ecosystems because the microenvironment in the edge is different than in the interior: temperature, humidity, light, chemical inputs, etc., may all differ in edge regions. The distribution and persistence of many plant and animal species are often strongly affected by these microenvironmental conditions, so the communities are usually different along edges. Furthermore, edge conditions often facilitate the introduction, establishment, and spread of exotic species that may become predators or competitors with plants or animals in the interior (Janzen 1986, Wilcove et al. 1986). For desert tortoises, the edge effect is a theoretical possibility, but it has not been well documented in tortoise populations. Furthermore, some edge effects may only function over relatively short distances (e.g., tens of yards) or not at all (Ratti and Reese 1988, Murcia 1995).

There are little data that directly test this hypothesized cumulative effect of multiple impacts on tortoise populations. Berry and Nicholson (1984a) do cite anecdotal evidence of the loss of previously-existing populations in now heavily-populated areas of Antelope, Lucerne, and Yucca valleys. Berry et al. (1994) present correlative data showing that declines in tortoise populations in the Rand Mountains and Fremont Valleys correlate with increases in a suite of human impacts. The Desert Tortoise Recovery Plan (USFWS 1994) provides data that show significant declines occurred in populations exhibiting high rates of human-caused mortality.

Urbanization and Development

Whereas construction activity (treated as an individual threat, above) has impacts specific to the activities of building new structures (e.g., temporary compaction of vegetation and soil, fugitive dust, disturbance and possible death of tortoises), these impacts largely cease once construction has been completed (although for some impacts, such as soil compaction, there is a residual effect caused by delayed recovery, Lovich and Bainbridge 1999). The result of the construction activity is the presence of new structures, which are called here "developments," and which have its attendant impacts. These impacts include long-term or permanent loss or alteration of habitat, impacts from maintenance activities, disruption of tortoise behavior, and road kills (Berry and Nicholson 1984a, Luke et al. 1991).

Developments may be relatively isolated from each other, but “Urbanization” refers to cumulative effects of multiple and nearly contiguous developments including construction of permanent residences that cover large areas. Urbanization has several impacts associated with the presence of many people in the area, not, all of which are well documented. Urbanization results in considerable fragmentation, loss of habitat, and habitat alteration to the point of being largely useless to tortoise populations (Berry and Nicholson 1984a, Feldmeth and Clements 1990, Tierra Madre Associates 1991, section titled “Habitat Loss, Degradation, and Fragmentation”). Some recreational activities may emanate directly from urban areas. Wild dogs may be more prevalent (e.g., Bjurlin and Bissonette 2001) and collecting, handling and vandalism of tortoises could increase where there are more people. Captive tortoises, potentially infected URTD (see "Disease" section, above), are more likely to escape and help spread disease to the native population (Jacobson 1993, Berry pers. comm.). Illegal dumping is prevalent (pers. obs.), raven populations are larger (Knight et al. 1993), and exotic plants predominate

(Humphrey 1987, Brooks 1998) around urban developments. Urban areas and associated flood control channels in the desert are often the source of much fugitive dust (Wilshire 1980). Many of these impacts may be relatively minor by themselves, but their cumulative effects on nearby tortoise populations may be great.

There is some evidence that tortoise populations can persist in the presence of light industrial developments. In the 1980s 460 wind turbines and 51 electrical transformers were erected in tortoise habitat at Mesa, California. Approximately 10-20 years later, there were still tortoises living and reproducing in the same area; some burrow beneath and rest upon concrete support pads for the turbines (Lovich and Daniels 2000). Reproductive output is higher than at any other site studied to date (Lovich et al. 1999). However, there are no data available to determine if the population has increased, decreased, or remained stable since construction. Tortoises may persist in this area because of the relatively low level of actual human activity in the wind park and the high productivity in the area, which is in the ecotone between creosote scrub and coastal sage scrub habitat.

ACKNOWLEDGMENTS

Harold Avery, Bill Haigh, Ed LaRue, Jeffrey Lovich, Phil Medica, and Dave Morafka reviewed earlier drafts of this report in their entirety. Individual sections were reviewed by an army of experts including: David Bainbridge Jayne Belnap, Matt Brooks, Dan Brown, Steve Corn, David Crohn, Lesley DeFalco, Todd Esque, Gilbert Goodlett, Bruce Homer, Elliott Jacobson, Ron Marlow, Phil Medica, Kathie Meyer, Richard Minnich, Ken Nagy, Ted Owens, Phil Rundel, Sean Swezey, and Bob Webb. Emily Cohen provided editorial assistance. I apologize to those scientists whose works I may have inadvertently misrepresented or failed to include in the report.

LITERATURE CITED

Adams, J. A. and A. S. Endo. 1980a. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. Pp. 121-134, Chapt. V. *In*: The effects of disturbance on desert soils, vegetation and community process with emphasis on off road vehicles: a critical review (Rowlands, P. G., Ed.). Desert Plan Staff, Bureau of Land Management, Riverside, CA.

Adams, J. A. and A. S. Endo. 1980b. Soil impacts from off-road vehicles. Pp. 1-45, Chapt. I. *In*: The effects of disturbance on desert soils, vegetation and community process with emphasis on off road vehicles: a critical review (Rowlands, P. G., Ed.). Desert Plan Staff, Bureau of Land Management, Riverside, CA.

Adams, J.A., E.S. Endo, L.H. Stolvy, P.G. Rolands, and H.B. Johnson. 1982a. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. Journal of Applied Ecology 19:167-175.

Adams, J. A., L. H. Stolzy, A.S. Endo, P.G. Rowlands, H.B. Hyrum. 1982b. Desert soil compaction reduces annual plant cover. California Agriculture (September-October): 6-7.

Adrian, E. D., K. J. W. Craik, & R. S. Sturdy. 1938. The electrical response of the ear: vertebrates. Proc. Royal Soc. Lond. 125 : 435-455.

Ahlgren, I. F. and C. E. Ahlgren. 1966. Ecological effects of forest fires. Botan. Rev. 26:483-535.

Allee, W. C., A. E. Emerson, O. Park, T. Park, and K. P Schmidt. 1949. Principles of animal ecology. Saunders, Philadelphia.

Allen, E. B., P. E. Padgett, A. Bytnerowicz, and R. A. Minnich. 1998. Nitrogen deposition effects on coastal sage vegetation of southern California. Pages 131-140. *In* Proceedings of the International Symposium on Air Pollution and Climate Change Effects on Forest Ecosystems, Riverside, CA, February 5-9, 1996. USDA Forest Service, Pacific Southwest Research Station, PSW-GTR-166.

Allen, M. E. 1999. Cattle, dung and tortoises: symbiosis? Proc. 1997-1998 Desert Tort. Counc. Symp. 1999:99. Abstract.

Averill-Murray, R. C. 1999. Effects on growth and survival of tortoises voiding their bladders during handling. Proc. 1997-1998 Desert Tort. Counc. Symp. 1999:99-100. Abstract.

Avery, H.W. 1997. Effects of cattle grazing on the desert tortoise, *Gopherus agassizii*: nutritional and behavioral interactions. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference, pp. 13-20.

Avery, H.W. 1998. Nutritional ecology of the desert tortoise (*Gopherus agassizii*,) in relation to cattle grazing in the Mojave Desert. Ph.D. dissertation, University of California, Los Angeles.

Avery, H.W. and K.H. Berry. 1993. Upper respiratory tract disease and high adult death rates in western Mojave tortoise populations, 1989-1990. Proceedings of the 1987-1991 Symposia of the Desert Tortoise Council.

Avery, H.W. and A.G. Neibergs. 1997. Effects of cattle grazing on the desert tortoise, *Gopherus agassizii* : nutritional and behavioral Interactions. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference, pp. 13-20.

Avery, H. W., J. D. Congdon, and J. R. Spotila. 2002. Life history and demographic analysis of the desert tortoise at Fort Irwin and reference sites: study design and early findings. Desert Tortoise Council Symposium, March 22-25, 2002, Palm Springs, CA. Abstract.

Babcock and Sons, and Gallaher and Bovey, Geotechnical Consultants. 1973. A study of southeastern Mojave desert. California Division of Mines and Geology. Special Report 83.

Baepler, D. H., A. Heindl, A. K. Singh, and A. Pandley. 1994. A study of the impacts of highways on desert tortoise populations. Report to Nevada Department Transportation. Harry Reid Center for Environmental Studies, Las Vegas, NV.

Bailey, V. 1928. The desert tortoise: an example of an unusual adaptation. Nature Magazine 12:372-374.

Bailey, W. J. & G. K. Morris. 1986. Confusion of phonotaxis by masking sounds in the Bushcricket *Conocephalus brevipennis* (Tettigoniidae: Conocephalinae). Ethology 73: 9-28.

Balph, D. F. and J. C. Malecheck. 1985. Cattle trampling of crested wheatgrass under short-duration grazing. J. Range Manage. 38:226-227.

Bartolome, J. 1989. Review of Holistic Resource Management by Allan Savory. Journal of Soil and Water Conservation 44:591-592.

Baxter, G. R. And G. R. Stewart. 1990. Report of the continuing fieldwork on the desert tortoise (*Gopherus agassizii*) at the Twentynine Palms Marine Corps Base. Proc. 1986 Desert Tort. Counc. Symp. 1990:128-140.

Beatley, J. C. 1967. Effects of radioactive and non-radioactive dust upon *Larrea divaricata* Cav., Nevada Test Site. Health Physics 11:1671-1625.

Begon, M., J. L. Harper, and C. R. Townsend. 1990. Ecology: individuals, populations and communities. Blackwell Scientific Publ., Boston.

Belnap, J. 1996. Soil surface disturbances in cold deserts: effects on nitrogenase activity in cyanobacterial-lichen soil crusts. Biol. Fertil. Soils 23(4): 362-367.

Belnap, J., and J. S. Gardner. 1993. Soil microstructure in soils of the Colorado Plateau: the role of the cyanobacterium *Microcoleus vaginatus*. Great Basin Natur. 53:40-47.

Belnap, J. and K. T. Harper. 1995. Influence of cryptobiotic soil crusts on elemental content of tissue of two desert seed plants.

Bentley, H. L. 1898. Cattle ranges of the southwest: a history of the exhaustion of the pasturage and suggestions for its restoration. Farmers' Bulletin No. 72: 1-32.

Berry, K.H. 1978. Livestock grazing and the desert tortoise. 43rd North American Wildlife and Natural Resources Conference, Phoenix, Arizona.

Berry, K.H. 1985. Avian predation of the desert tortoise (*Gopherus agassizii*) in California. U.S. Department of the Interior, Bureau of Land Management. Riverside, CA.

Berry, K.H. 1986a. Incidence of gunshot deaths in desert tortoise populations in California. Wildlife Society Bulletin 14: 127-132.

Berry, K. H. 1986b. Desert tortoise (*Gopherus agassizii*) relocation: implications of social behavior and movements. Herpetologica 42:113-125.

Berry, K.H. 1990 (as amended). The status of the desert tortoise in California in 1989. U.S. Bureau of Land Management, Riverside, California; amended to include data from 1990, 1991, and 1992.

Berry, K.H. 1997. Demographic consequences of disease in two desert tortoise populations in California, USA. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference, pp. 91-99.

Berry, K. H. and M. M. Christopher. 2001. Guidelines for the field evaluation of desert tortoise health and disease. J. Wildl. Disease 37:427-450.

Berry, K. H., F. G. Hoover, and M. Walker. 1996. The effects of poaching desert tortoises in the western Mojave Desert: Evaluation of landscape and local impacts. Proc. 1996 Desert Tort. Council Symp. 1996:45.

Berry, K.H. and L.L. Nicholson. 1984a. A summary of human activities and their impacts on desert tortoise populations and habitat in California. In Berry, K.H., ed. The status of the desert tortoise (*Gopherus agassizii*) in the United States. U.S. Department of the Interior, Bureau of Land Management. Riverside, California.

Berry, K.H. and L.L. Nicholson. 1984b. Attributes of populations at twenty-seven sites in California. In Berry, K.H., ed. The status of the desert tortoise (Gopherus agassizii) in the United States. U.S. Department of the Interior, Bureau of Land Management. Riverside, California.

Berry, K.H. and L.L. Nicholson. 1984c. The distribution and density of desert tortoise populations in California in the 1970's. In Berry, K.H., ed. The status of the desert tortoise (Gopherus agassizii) in the United States. U.S. Department of the Interior, Bureau of Land Management. Riverside, California.

Berry, K. H., L. L. Nicholson, S. Juarez, A.P. Woodman. 1990. Changes in desert tortoise populations at four study sites in California. Proceedings of the 1986 Symposium of the Desert Tortoise Council. 1990:60-80.

Berry, K. H., T. Okamoto, K. Anderson, M. B. Brown, L. Wendland, and F. Origgi. 2002. Health assessments of captive and wild desert tortoises at 17 sites in the Mojave and Colorado Deserts, California. Desert Tortoise Council Symposium, March 22-25, 2002, Palm Springs, CA. Abstract.

Berry, K. H., T. Shields, A. P. Woodman, T. Campbell, J. Roberson, K. Bohuski, and A. Karl. 1986. Changes in desert tortoise populations at the Desert Tortoise Research Natural Area between 1979 and 1985. Proc. Symp. Desert Tort. Counc. 1986:100-123.

Berry, K. H. and F B. Turner. 1986. Spring activities and habitats of juvenile desert tortoises, *Gopherus agassizii*, in California. Copeia 1986:1010-1012.

Berry, K. H. and F. B. Turner. 1987. Notes on the behavior and habitat preferences of juvenile desert tortoises (*Gopherus agassizii*) in California. Proc. 1984 Desert Tortoise Council Symposium 1987:111-130.

Berry K. B., M. Weinstein, G. O. Goodlett, A. P. Woodman, and G. C. Goodlett. 1994. The distribution and abundance of desert tortoises and human uses in 1990 in the Rand Mountains, Fremont Valley, and Spangler Hills (Western Mojave Desert), California. Draft report. Bureau of Land Management, Riverside, CA.

Biggins, D. E., B. J. Miller, and T. W. Clark. 1997. Management of an endangered species: The black-footed ferret. Pp. 420-426 *In*: Principles of conservation biology (G. K. Meffe and C. R. Carroll, eds.). 2nd Ed. Sinauer Assoc., Inc. Publ., Sunderland, MA.

Bjurlin, C. D. and J. A. Bissonette. 2001. The impact of predator communities on early life history stage survival of the desert tortoise at the Marine Corps Air Ground Combat Center, Twentynine Palms, California. U. S. Dept. of the Navy Contract N68711-97-LT-70023. UCFWRU Pub. # 00-4: 1-81.

Bleeker, M. 1988. An inventory, analysis and monitoring of grazing in the east Mojave desert of California: a geographic information system approach. M.S. Thesis, University of California, Riverside. 103 pp.

Boarman, W. I. 2002. The desert tortoise. *In* Sensitive animals and plants in the western Mojave Desert (W. I. Boarman and K. Beaman, eds.).

Boarman, W. I. 1993. When a native predator becomes a pest: a case study. For: Conservation and resource management (S.K. Majumdar, et al., eds.), pp. 186-201. Penn. Acad. Sci. Easton, PA.

Boarman, W. I. In prep. Managing subsidized predator populations: reducing predation on desert tortoises by common ravens in the Mojave and Colorado Deserts.

Boarman, W. I., M. L. Beigel, Glenn C. Goodlett, and M. Sazaki. 1998. A passive integrated transponder system for tracking animal movements. Wildlife Society Bulletin 26:886-891.

Boarman, W.I., R. J. Camp, M. Hagan, W. Deal. 1995. Raven abundance at anthropogenic resources in the western Mojave Desert, California. Report to Edwards Air Force Base, CA.

Boarman, W. I., Goodlett, T., G. C. Goodlett. 1998. Review of radio transmitter attachment techniques for chelonian research and recommendations for improvement. Herpet. Rev. 29:26-33.

Boarman, W. I. and P. Hamilton. In prep. Mortality in juvenile desert tortoises caused by avian predators. U. S. Geological Survey, San Diego, CA.

Boarman, W. I. and B. Heinrich. 1999. The Common Raven. *In* A. Poole and F. Gill (eds.), The Birds of North America, No. 476. The Birds of North America, Philadelphia, PA.

Boarman, W. I. and M. Sazaki. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. Pages 169 - 173 in Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. G. Evink, D. Zeigler, P. Garrett, and J. Berry, editors. U.S. Department of Transportation, Federal Highway Administration, Washington, DC.

Boarman, W.I., M. Sazaki, and W. B. Jennings. 1997. The effect of roads, barrier fences, and culverts on desert tortoise populations in California, USA. *In* J. Van Abbema (ed.), Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles-An International Conference, pp. 54-58. New York Turtle and Tortoise Society, New York.

Bondello, M. C. 1976. The effects of high-intensity motorcycle sounds on the acoustical sensitivity of the Desert Iguana, *Dipsosaurus dorsalis*. M.A. thesis, California State Univ., Fullerton.

Borysenko, M. 1975. Cellular aspects of humoral immune responsiveness in Chelydra. Adv. Exp. Biol. Med. 64:277.

Borysenko, M. and S. Lewis. 1979. The effect of malnutrition on immunocompetence and whole body resistance to infection in *Chelydra serpentina*. Developmental and Comparative Immunology 3:89-100.

Bostick, V. 1990. The desert tortoise in relation to cattle grazing. Rangelands 12:149-151.

Bowden, L. W., J. R. Hutchinson, C.F. Johnson, C.F. 1974. Satellite photograph presents first comprehensive view of local wind: the Santa Ana. Science 134: 1077-1078.

Bowles, A. E., S. Eckert, L. Starke, E. Berg, L. Wolski, J. Matesic, Jr. 1999. Effects of flight and sonic booms on hearing, behavior, heart rate, and oxygen consumption of desert tortoises (*Gopherus agassizii*). Sea World Research Institute, San Diego, CA.

Brattstrom, B. H. 1974. The evolution of reptilian social behavior. Amer. Zool. 14 : 35-49.

Brattstrom, B. H., & M. C. Bondello. 1983. The experimental effects of off-road vehicle sounds on three species of desert vertebrates. Pp. 167-206 in Environmental effects of off-road vehicles: impacts and management in arid regions (Webb, R. H., & H. G. Wilshire, eds.). Springer-Verlag, New York.

Brooks, M. L. 1992. Ecological impact of human disturbance on the desert tortoise natural area, Kern County, California, 1978-1992. Master's thesis. Fresno, California State University**:** 51 pp.

Brooks, M. 1995. Benefits of Protective Fencing to Plant and Rodent Communities of the Western Mojave Desert. Environmental Management 19(1): 65-74.

Brooks, M. L. 1998. Ecology of a biological invasion: alien annual plants in the Mojave Desert. Ph.D. dessert. U. Calif. Riverside.

Brooks, M. L. 1999a. Habitat invasibility and dominance by alien annual plants in the western Mojave Desert. Biol. Invasions 1:325-337.

Brooks, M. L. 1999b. Alien annual grasses and fire in the Mojave Desert. Madrono 46:13-19.

Brooks, M.L. 2000. Competition between alien annual grasses and native annual plants in the Mojave Desert. American Midland Naturalist 144:92-108.

Brooks, M. L. and K. H. Berry. 1999. Ecology and management of alien annual plants in the California deserts. Calif. Exotic Pest Plant Newsl. 7(3/4):4-6.

Brown, D.E. and R.A. Minnich. 1986. Fire and changes in creosote bush scrub of the western Sonoran desert, California. American Naturalist 116(2):411-422.

Brown, M.B., I.M. Schumacher, P.A. Klein, K. Harris, T. Correll, E.R. Jacobson, 1994a. *Mycoplasma agassizii* causes upper respiratory tract disease in the desert tortoises. Infection and immunity 62(10): 4580-4586.

Brown, M., P.A. Klein, I.M. Schumacher, and K.H. Berry. 1994b. Health profiles of free ranging desert tortoises in California: results of a two year serological testing for antibody to *Mycoplasma agassizii*. University of Florida, Gainesville. Bureau of Land Management Contract No. B950-C2-0.

Brown, D. R., B. C. Crenshaw, G. S. McLaughlin, I. M. Schumacher, C. E. McKenna, P. A. Klein, E. R. Jacobson, and M. B. Brown. 1995. Taxonomic analysis of the tortoise mycoplasmas *Mycoplasma agassizii* and *Mycoplasma testudinis* by 16S rRNA gene sequence comparison. International J. Syst. Bacteriol. 45:348-350.

Brum, G. D., R. S. Boyd, and S. M. Carter. 1983. Recovery rates and rehabilitation of powerline corridors. Pp. 303-314 in Environmental effects of off-road vehicles: impacts and management in arid regions (Webb, R. H., & H. G. Wilshire, eds.). Springer-Verlag, New York.

Bureau of Land Management. 1975. 1974 Barstow-Las Vegas Motorcycle Race: Evaluation Report. Riverside, CA.

Bureau of Land Management. 1980. The California Desert Conservation Area plan. Bureau of Land management, California Desert District, CA.

Burge, B.L. and W.G. Bradley. 1976. Population density, structure and feeding habits of the desert tortoise, Gopherus agassizii, in a low desert study area in southern Nevada. Proceedings of the Desert Tortoise Council 1976 Symposium 1976:57-74.

Burge, B. L. 1986. Impact of frontier 500 off-road vehicle race on desert tortoise habitat. Proceedings of the 1983 Desert Tortoise Council Symposium 1986:27-38.

Burge, B.L. 1989. What goes up must come down. Massive balloon releases are a potential threat to tortoises and other wildlife. Tortoise Tracks 10(3):4.

Burkhardt, J.W. and D. Chamberlain. 1982. Range cattle food habits of the Mojave Desert. Report for Projects 617 to Nevada Agricultural Expt. Station. 8 pp.

Bury, R. B. (editor). 1982. North American tortoises: conservation and ecology. U. S. Dept. Interior, Fish and Wildl. Serv., Wildlife Research Rpt. 12, Washington, DC.

Bury, R.B., and P.S. Corn. 1995. Have desert tortoises undergone a long-term decline in abundance? Wildl. Soc. Bull. 18 (1): 1-7.

Bury, R. B. and D. J. Germano (editors). 1994. Biology of North American tortoises. U. S. Dept. Interior, National Biol. Surv., Fish and Wildlife Research 13, Washington, DC.

Bury, R. B. and R. A. Luckenbach. 1977. Censusing desert tortoise populations using a quadrat and grid location system. Proc. 1977 Desert Tortoise Council Symp. 1977: 169-178.

Bury, R. B. and R. A. Luckenbach. 1986. Abundance of desert tortoises (*Gopherus agassizii*) in natural and disturbed habitats. Fort Collins, CO. United States Fish and Wildlife Service.

Bury, R. B. and R. W. Marlow. 1973. The desert tortoise: Will it survive? The Environmental Journal. June: 9-12.

Camp, R.J., R.L. Knight, H.A.L. Knight, M.W. Sherman, and J.Y. Kawashima. 1993. Food habits of nesting common ravens in the eastern Mojave desert. Southwest. Natur. 38:163 165.

Campbell, T. 1983. Some natural history observations of desert tortoises and other species on and near the Desert Tortoise Natural Area, Kern County, California. Proc. 1983 Desert Tortoise Council Symp. 1983: 80-88.

Campbell, T. 1985. Hunting and other activities on and near the Desert Tortoise Natural Area, California. Proceedings of the Desert Tortoise Council 1982 Symposium 1985:90-98.

Campbell, H. W., and W. E. Evans. 1967. Sound production in two species of tortoise, *Gopherus agassizii* and *Geochelone carbonaria*. Herpetologica 23: 204-209.

Chamberlin, T. C. 1965. The method of multiple working hypotheses. Science 148:754-759 (reprinted from Science 15 [old series]:92; 1890).

Charley, J.L. and S.W. Cowling. 1968. Changes in soil nutrient status resulting from overgrazing and their consequences in plant communities of semi-arid areas. Proc. Ecol. Soc. Austral. 3:28-38.

Chaffee, M. A., K. H. Berry, and B. B. Houser. 1999. The relation between the geochemistry of surficial materials and desert tortoise mortality in selected study sites, southeastern California--a progress report. Proceedings of the 1997-1998 Desert Tortoise Council Symposia. Abstract.

Christopher, M. M. I. Wallis, K. A. Nagy, B. T. Henen, C. C. Peterson, B. Wilson, C. Meienberger, and I. Girard. 1993Laboratory health profiles of free-ranging desert tortoises in California: interpretation of physiologic and pathologic alterations. Report to Bureau of Land management, Riverside, Ca.

Christopher, M. M., R. Brigmon, and E. Jacobson. 1994. Seasonal alterations in plasma ß-hydroxybutyrate and related biochemical parameters in the desert tortoise (*Gopherus agassizii*). Comp. Biochem. Physiol. 108A:303-310.

Christopher, M. M., K. A. Nagy, I. Wallis, J. K. Klaassen, and K. H. Berry. 1997. Laboratory health profiles of desert tortoises in the Mojave Desert: a model for health status evaluation of chelonian populations. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference, pp. 76-82.

Circle Mountain Biological Consultants. 1996. Federal Biological Opinion analysis for the proposed Eagle Mountain Landfill Project. Rpt. to CH2M Hill, Santa Ana, CA. Circle Mountain Biological Consultants, Wrightwood, CA.

Cline, J. F., and W. H. Rickard. 1973. Herbage yields in relation to soil water and assimilate nitrogen. J. Range Manag. 26:296-298.

Congdon, J. D., A. E. Dunham, R.C. Van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (Emydoidea blandingii): Implications for conservation and management of long-lived organisms. Conservation Biology 7(4): 826-833.

Congdon, J. D., H. W. Avery, and J. R. Spotila. 2002. Feasible demography analyses: consequences of additional adult and juvenile mortality on a stable population of desert tortoises. Desert Tortoise Council Symposium, March 22-25, 2002, Palm Springs, CA. Abstract.

Coombs, E.M. 1979. Food habits and livestock competition with the desert tortoise on the Beaver Dam slope, Utah. Proceedings of the Desert Tortoise Council Symposium 1979:132-147.

Corn, P.S. 1994a. Recent trends of desert tortoise populations in the Mojave Desert. In Bury, R.B. and D.J. Germano. The biology of North American tortoises. Washington, D.C.: United States Department of the Interior, National Biological Service.

Corn, P.S. 1994b. Displacement of desert tortoises: Overview of a study at the Apex Heavy Industrial Zone, Clark County, Nevada. Proc. 1991 Desert Tortoise Council Symposium. 1995: 295-301.

Corn, P. S. 1997. Effects of short-distance translocations on desert tortoises. Abstract. 1997 meeting of Am. Soc. of Ichthyol. and Herpet., Seattle.

Davidson, E. and M. Fox. 1974. Effects of off-road motorcycle activity on Mojave Desert vegetation and soil. Madrono 22:381-412.

DeFalco, L. A. 1995. The influence of cryptobiotic crusts on winter annuals and foraging movements of the desert tortoise. M. S. Thesis, Colorado State University, Fort Collins, CO.

Detling, J.K. 1988. Grasslands and savannas: regulation of energy flow and nutrient cycling by herbivores. Pp. 131-148 In L. R. Pomeroy and J. J. Alberts, (eds.), Concepts in ecosystem ecology: a comparative view. Springer-Verlag, New York.

Doak, D., P. Kareiva, and B. Klepetka. 1994. Modeling population viability for the desert tortoise in the western Mojave Desert. Ecol. Applic. 4:446-460.

Dobson, A. and M. Meagher. 1996. The population dynamics of brucellosis in the Yellowstone National Park. Ecology 77:1026-1036.

Duck, T. A., T. C. Esque, and T. J. Hughes. 1995. Fighting wildfires in desert tortoise habitat: considerations for land managers. Proc. 1994 Desert Tort. Counc. Symp. 1995:58-67.

Durfee, J. A. 1988. Response of Mohave Desert communities to release from grazing pressure. M.S. Thesis. Brigham Young Univ., Orono, UT.

Eckert, R. E., Jr., F. F. Peterson, M. S. Meurisse, and J. L. Stephens. 1986. Effects of soil-surface morphology on emergence and survival of seedlings in big sagebrush communities. J. Range Manage. 39:414-420.

Eckert, R.E., F.F. Peterson, M.K. Wood, and W.H. Blackburn. 1977. Properties, Occurrence and Management of Soils with Vesicular Surface Horizons. Special Study by USDI, BLM and Nevada Agricultural Experiment Station. Contract No. 52500-CT5(N).

Edwards, SW. 1992a. Observations on the prehistory and ecology of grazing in California. Fremontia 20:3-11.

Edwards, SW. 1992b. Observations on the prehistory and ecology of grazing in California. Fremontia 20:34-35.

EG&G Energy Measurements. 1993. Yucca Mountain Biological Resources Monitoring Program: Annual Report FY92. Rpt. to U.S. Dept. of Energy. EG&G Energy Measurements, Santa Barbara Operations, Goleta, CA.

Ehret, G., & H. C. Gerhardt. 1980. Auditory masking and effects of noise on responses of the Green Treefrog (Hyla cinerea) to synthetic mating calls. J. Comp. Physiol. 141:13-18.

Eliason, S. A. and E. B. Allen. 1997. Exotic grass competition in suppressing native shrubland re-establishment. Restoration Ecology 5:245-255.

Engel, K. A., and L. S. Young. 1992. Movements and habitat use by Common Ravens from roost sites in southwestern Idaho. J. Wildl. Manage. 56: 596-602.

Ernst, C. H. J. E. Lovich, and R. Barbour. 1994. Turtles of the United State and Canada. Smithsonian Institution Press, Washington, D.C. 578 pp.

Esque, T. C. 1994. Diet and diet selection of the desert tortoise (Gopherus agassizii) in the northeast Mojave Desert. M.Sc. Thesis, Colorado State Univ. Fort Collins, CO.

Esque, T. C. and C. R. Schwalbe. In press. Alien annual plants and their relationships to fire and vegetation change in Sonoran Desertscrub. *In* Invasive organisms in the Sonoran Desert. Tellman, B. and T. R. Van Devender, eds. Arizona-Sonoran Desert Museum and University of Arizona Press, Tucson.

Esque, T. C., A. Burquez, C. R. Schwalbe, T. R. Van Devender, M. J. Nijhuis, and P. J. Anning. 2002. Effects of fire on desert tortoises and their habitats. Chapt. 10, *in* Sonoran desert tortoise: natural history, biology and conservation. Van Devender, T. R., ed. . Arizona-Sonoran Desert Museum and University of Arizona Press, Tucson.

Feldmeth, R. and R. F. Clements. 1990. City-wide survey of desert tortoise and Mojave ground squirrel: Final report. Rpt. for City of Palmdale. Ecological Research Services, Claremont, CA.

Fenn, M. E., M. A. Poth, J. D. Aber, J. S. Baron, B. T. Bormann, D. W. Johnson, A. D. Lemly, S. G. Mculyy, D. F. Ryan, and R. Stottlemyer. 1998. Nitrogen excess in North American ecosystems: predisposing factors, ecosystem responses, and management strategies. Ecol. Applic. 8:706-733.

Field, K., C. R. Tracy, P. A. Medica, R. M. Marlow, and P. S. Corn. 2000. Translocation as a tool for conservation of the desert tortoise: Can pet tortoises be repatriated? Desert Tortoise Council Symposium, April 20-23, 2000, Las Vegas, NV. Abstract.

Frankham, R. 1995. Inbreeding and extinction: a threshold effect. Conserv. Biol. 9, 792 799.

Frenkel, R. E. 1970. Ruderal vegetation along some California roadsides. Univ. Calif. Press, Berkeley.

Fusco, M.J. 1993. Influence of range condition and watering points on forage production and composition in southcentral New Mexico. Master's Thesis, New Mexico State University, Las Cruces, New Mexico.

Fusco, M.J., J. Holecheck, A. Tembo, A. Danieo and M. Cardenas. 1995. Grazing influences on watering point vegetation in the Chihuahauan desert. Journal of Range Management 48:32-38.

Gallagher, C. 1993. American ground zero: the secret nuclear war. Random House Publ.

Germano, D. J. 1988. Age and growth histories of desert tortoises using scute annuli. Copeia 1988:914-920.

Germano, D. J. 1992. Longevity and age-size relationships of populations of desert tortoises. Copeia 1992:367-374.

Gifford, G. F. and R. H. Hawkins 1978. Hydrologic impact of grazing on infiltration: a critical review. Water Resources Research 14: 303-313.

Gibbons, J. W., and J. L. Greene. 1979. X-ray photography: a technique to determine reproductive patterns of freshwater turtles. Herpetologica 35:86-89.

Gillette, D. A. and J. Adams. 1983. Accelerated wind erosion and prediction of rates. Pp. 97-109 in Environmental effects of off-road vehicles: impacts and management in arid regions (Webb, R. H., & H. G. Wilshire, eds.). Springer-Verlag, New York.

Ginn, S. E. 1990. Observations and activities of the naturalist for the Desert Tortoise Natural Area, Kern County, California, March 18-June 2, 1990., Desert Tortoise Preserve Committee, Inc. (Ridgecrest, CA) and the U.S. Bureau of Land Management, Riverside, CA.

Glenn, J. L. 1986. A note on the longevity of a captive desert tortoise (*Gopherus agassizii*). Proc. 1983 Desert Tort. Counc. Symp 1986:131-132.

Goodlett, G. O. and G. C. Goodlett. 1993. Studies of unauthorized off-highway vehicle activity in the Rand Mountains and Fremont Valley, Kern County, California. Proc. 1992 Desert Tort. Counc. Symp. 1993:163-187.

Grover, M. C. and L. A. DeFalco. 1995. Desert tortoise (*Gopherus agassizii*): status-of-knowledge outline with references. Intermountain Research Station, U.S. Forest Service, General Tech. Rpt. INT-GTR-316.

Grumbles, J. S. 1993. Proceedings of the 1993 Desert Tortoise Council Symposium. Abstract.

Hairston, N. G. 1989. Ecological experiments: purpose, design, and execution. Cambridge Univ. Press. Cambridge.

Hansen, R. M., M. K. Johnson, and T. R. Van Devender. 1976. Foods of the desert tortoise *Gopherus agassizii*, in Arizona and Utah. Herpetologica 32:247-251.

Hardy, R. 1976. The Utah population - a look in the 1970's. Proc. Desert Tort. Counc. Symp. 1976:84-88.

Hazard, L. C., D. R. Shemanski, and K. A. Nagy. 2001. Calcium and phosphorus availability in native and exotic food plants. Desert Tortoise Council Symposium, March 2001, Las Vegas, NV. Abstract.

Henen, B.T. 1997. Seasonal and annual energy budget of female desert tortoise (*Gopherus agassizii*). Ecology 76: 283-296.

Heppell, Selina S. 1998. Application of life-history theory and population model analysis to turtle conservation. Copeia 1998: 367-375.

Hereford, R. 2002. Climate variation and geomorphic processes since 1900 in the central Mojave Desert. Desert Tortoise Council Symposium, March 22-25, 2002, Palm Springs, CA. Abstract.

Hillard, S., and C. R. Tracy, C. 1997. Annual activity for juvenile desert tortoises: constraints imposed by the thermal environment. Abstracts of the Third World Congress of Herpetology, 2-10 August 1997, Prague, Czech Republic. Abstract.

Hinckley, B. S., R. M. Iverson, and B. Hallet. 1983. Accelerated water erosion in ORV-use areas. Pp. 81-96 in Environmental effects of off-road vehicles: impacts and management in arid regions (Webb, R. H., & H. G. Wilshire, eds.). Springer-Verlag, New York.

Hinton, T. G., P. D. Fledderman, J. E. Lovich, J. D. Congdon, and J. W. Gibbons. 1997, Radiographic determination of fecundity: is the technique safe for developing turtle embryos? Chelonian Cons. Biol. 2:409-414.

Hobbs, R. J. 1989. The nature and effects of disturbance relative to invasions. Pp. 389-405 In J. A. Drake et al. (eds.). Biological invasions: a global perspective. John Wiley & Sons Ltd., New York.

Hohman, J. and R.D. Ohmart. 1980. Ecology of the desert tortoise on the Beaver Dam Slope, Arizona. Arizona State University. Report for the Bureau of Land management, Arizona Strip Office, St. George, UT.

Homer, B. L., K. H. Berry, M. B. Brown, G. Ellis, E. R. Jacobson. 1998. Pathology of diseases in wild desert tortoises from California. J. Wildl. Diseases 34(3):508-523

Homer, B.L., K.H. Berry, M.M. Christopher, M.B. Brown, E.R. Jacobson. 1994. Necropsies of desert tortoises from the Mojave and Colorado Deserts of California and the Sonoran Desert of Arizona. University of Florida, Gainesville.

Homer, B.L., K.H. Berry, and E.R. Jacobson. 1996. Necropsies of eighteen desert tortoises from the Mojave and Colorado deserts of California. Final Report to the United States Department of the Interior, National Biological Service, Research Work Order No. 131, Riverside, California, 120 pp.

Hoover, F. G. 1996. An investigation of desert tortoise mortality in upland game guzzlers in the deserts of southern California. Proc. 1995 Desert Tort. Counc. Symp. 1996:36-43.

Howland, J. M. 1989. Observations and activities of the naturalist for the Desert Tortoise Natural Area, Kern County, California, March 18-June 2, 1989. Contract CA 950-CT9-44, Desert Tortoise Preserve Committee, Inc. (Ridgecrest, CA) and the U.S. Bureau of Land Management, Riverside, CA.

Humphrey, R. R. 1958. The desert grassland: a history of vegetational change and an analysis of causes. Botanical Review 24(4): 193-252.

Humphrey, R.R. 1974. Fire in the deserts and desert grassland of North America. Pp. 365-400 *In* Fire and Ecosystems (Kozlowski, T.T. and C.E. Ahlgrens, eds.). Academic Press, New York.

Humphrey, R. R. 1987. 90 years and 535 miles: vegetation changes along the Mexican border. Albuquerque, New Mexico: University of New Mexico Press.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. 54:187-211.

Iverson, R.M. 1979. Processes of accelerated erosion on desert hill-slopes modified by vehicular traffic. Submitted to Earth Surface Processes.

Jackson, L. 1985. Ecological origins of California's Mediterranean grasses. J. Biogeogr. 12:349-361.

Jacobson, E. R. 1993. Implications of infectious diseases for captive propagation and introduction programs of threatened/endangered reptiles. J. Zoo Wildl. Med. 24:245-255.

Jacobson, E. R. 1994. Causes of mortality and diseases in tortoises: a review. J. Zoo and Wildl. Med. 25:2-17.

Jacobson, E. R., M. B. Brown, P. A. Klein, I. Schumacher, D. Morafka, and R. A. Yates. 1996. Serologic survey of desert tortoises, *Gopherus agassizii*, in and around the National Training Center, Fort Irwin, California, for exposure to *Mycoplasma agassizii*, the causative agent of Upper Respiratory Tract Disease. Proc. 1996 Desert Tort. Counc. Symp. 1996:53-54. Abstract.

Jacobson, E.R., J.M. Gaskin, M.B. Brown, R.K. Harris, C.H. Gardiner, J.L. LaPointe, H.P. Adams, C. Reggiardo. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). Journal of Wildlife Diseases 27(2):296-316.

Jacobson, E.R., J. Schumacher, and K.H. Berry. 1994. Cutaneous dyskeratosis in free-ranging desert tortoises, *Gopherus agassizii*, in the Colorado desert if southern California. Journal of Zoo Wildlife Medicine 25(1):68-81.

Janzen, D. H. 1986. The eternal external threat. *In* M. E. Soule (ed.) Conservation biology: the science of scarcity and diversity, pp. 286-303. Sinauer Assoc., Sunderland, MA.

Jarchow, J. L. 1989. Report on investigation of desert tortoise mortality on the Beaver Dam Slope, Arizona and Utah. Report to Arizona Game & Fish Dept. Neglected Fauna International, Tucson, AZ.

Jennings, M. R. 1981. *Gopherus agassizii* (desert tortoise). Longevity. Herp. Review 12:81-82.

Jennings, W. B. 1993. Foraging ecology of the desert tortoise (*Gopherus agassizii*) in the western Mojave desert. Master's thesis. Arlington, University of Texas**:** 101 pp.

Jennings, W. B. 1997. Habitat use and food preferences of the desert tortoise, *Gopherus agassizii*, in the western Mojave Desert and impacts of off-road vehicles. *In* J. Van Abbema (ed.), Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles-An International Conference, pp. 42-45. New York Turtle and Tortoise Society, New York.

Johnson, A. E. Jacobson, D. J. Morafka, F. Origgi, and L. Wendland. 2002. Prevalence of URTD in captive desert tortoises on and adjacent to Fort Irwin: potential impacts to wild populations. Desert Tortoise Council Symposium, March 22-25, 2002, Palm Springs, CA. Abstract.

Johnson, H. B., F. C. Vasek, and T. Yonkers. 1975. Productivity, diversity, and stability relationships in Mojave Desert roadside vegetation. Bull. Torrey Bot. Club 102:106-115.

Kemp, P. R. and M. L. Brooks. 1998. Exotic species of California deserts. Fremontia 26:30-34.

Knight, R. L., and J. Kawashima. 1993. Responses of raven and Red-tailed Hawk populations to linear right-of-ways. J. Wildl. Manage. 57: 266-271.

Knight, R. L., H. L. Knight, and R. J. Camp. 1993. Raven populations and land-use patterns in the Mojave Desert, California. Wildl. Soc. Bull. 21: 469-471.

Knight, R. L., R. J. Camp, W. I. Boarman, and H. A. L. Knight. 1999. Predatory bird populations in the east Mojave Desert, California. Great Basin Natur. 59:331-338.

Knowles, C., C. Guntow, P. Knowles, P. Houghton.1989. Relative abundance and distribution of the common raven in the desert of southern California. Boulder, MT, FaunaWest Wildlife Consultants.

Koehler, J.H. 1977. Ground water in the Koehn Lake area, Kern County, California. U.S. Geological Survey, Water Resources Investigations 77-66.

Kristan, W.B. III, and W. I. Boarman. 2001. The spatial distribution of common ravens (*Corvus corax*) and raven depredation. *In:* W. B. Kristan, III, ed., Effects of habitat selection on avian population ecology in urbanizing landscapes. Ph.D. Dissertation, University of California, Riverside. Riverside, CA 92521.

Krzysik, A. J. 1998. Desert tortoise populations in the Mojave Desert and a half-century of military training activities. Pp. 61-73 in (J. Van Abbema, ed.) Proceedings: conservation, restoration, and management of tortoises and turtles-an international conference. NY Turtle and Tortoise Soc., NY.

Kuchling, G. 1998. How to minimize risk and optimize information gain in assessing reproductive condition and fecundity of live female Chelonians. Chelonian Cons. Biol. 3:118-123.

Lance, V. A., D. C. Rostal, J. S. Grumbles, and I. Schumacher. 1996. Effects of Upper Respiratory Tract Disease on reproduction and steroid hormone levels in male and female desert tortoises. Proc. 1995 Desert Tort. Counc. Symp. 1996:104.

Larsen, R. E., P. E. Padgett, S.N. Kee, E.B. Allen, H.W. Avery. 1997. Accomplishment Report. FY 1996-1997 DANR Competitive Grant Project #15. San Bernardino, UC Cooperative Extension**:** 17.

LaRue, E. L., Jr. 1993. Distribution of desert tortoise sign adjacent to Highway 395, San Bernardino County, California. Proceedings of the 1992 Desert Tortoise Council Symposium 1993: 190-204.

LaRue, E. and S. Dougherty. 1999. Federal Biological Opinion analysis for the Eagle Mountain Landfill project. Proc. 1997-1998 Desert Tort. Counc. Symp. 1999:52-58.

Lathrop, E. W. 1978. Plant response parameters to recreational vehicles in the California Desert Conservation Area. Final Report, Contract CA-060-CT7-2824, Desert Plan Program, Bureau of Land management, Riverside, CA.

Lathrop, E. W. 1983. Recovery of perennial vegetation in military maneuver areas. Pp. 265-277 in (R. H. Webb and H. G. Wilshire, eds) Environmental effects of off-road vehicles: impacts and management in arid regions. Springer-Verlag, NY.

Loftin, S. R. 1987. Postfire dynamics of a Sonoran Desert ecosystem. Master's Thesis. University of Arizona, Tempe. 89 pp.

Lovich, J. E. and D. Bainbridge. 1999. Anthropogenic degradation of the Southern California desert ecosystem and prospects for natural recovery and restoration. Environ. Mgmt. 24:309-326.

Lovich, J. E. and R. Daniels. 2000. Environmental characteristics of desert tortoise (*Gopherus agassizii*) burrow locations in an altered industrial landscape. Chelon. Conserv. Biol. 3:714-721.

Lovich, J., P. Medica, H. Avery, K. Meyer, G. Bowser, and A. Brown. 1999. Studies of reproductive output of the desert tortoise at Joshua Tree National Park, the Mojave National Preserve, and comparative sites. Park Science 19:22-24.

Lubchenco, J. and L. A. Real. 1991. Manipulative experiments as tests of ecological theory. Pp. 715-733 *In* Foundations of ecology: Classic papers with commentaries (L. A. Real and J. H. Brown, eds.). Univ. of Chicago Press, Chicago, IL.

Luckenbach, R. A. 1975. What the ORVs are doing to the desert? Fremontia 2(4): 3-11.

Luckenbach, R. 1982. Ecology and management of the desert tortoise (*Gopherus agassizii*) in California. *In* North American Tortoises: Conservation and Ecology. R. B. Bury. Washington, D.C., United States Department of the Interior Fish and Wildlife Service. Wildlife Research Report 12.

Luke, C., A. Karl, P. Garcia. 1991. A status review of the desert tortoise. Tiburon, California: Biosystems Analysis, Inc.

Lyon, R. H. 1973. Propagation of environmental noise. Science 179 : 1083-1090.

Mack, R. N. 1981. Invasion of *Bromus tectorum* L. into western North America: an ecological chronicle. Agro-Ecosystems 7:145-165.

Marlow, R. W. 1974. Preliminary Report on Population Dynamics in the Desert Tortoise (*Gopherus agassizii*) in the Western Mojave Desert, California. Berkeley, CA, University of California Museum of Vertebrate Zoology**:** 31.

Maryland, H. F. and T. H. McIntosh. 1966. Availability of biologically fixed atmospheric nitrogen-15 to higher plants. Nature 209:421-422.

McCullough Ecological Systems. 1995. Avian predation of juvenile desert tortoises along transmission line corridors in the Piute-Eldorado Critical Habitat Unit. McCullough Ecological Systems, Las Vegas.

McNaughton, S. J. 1985. Ecology of a grazing system: the Serengeti. Ecol. Monogr. 55:259-294.

Medica, P.A., B.R. Bury, and F.B. Turner. 1975. Growth of the desert tortoise (*Gopherus agassizii*) in Nevada. Copeia 4:639-643.

Medica, P. A., C. L. Lyons, F.B. Turner. 1982. A Comparison of 1981 Populations of Desert Tortoises (*Gopherus agassizii*) in Grazed and Ungrazed Areas in Ivanpah Valley, California. Desert Tortoise Council 1982 Symposium, Las Vegas, NV, Desert Tortoise Council.

Meffe, G. K. and C. R. Carroll. 1997. Principles of Conservation Biology. 2nd Ed. Sinauer Assoc., Inc., Publ., Sunderland, MA.

Morafka, D. J. 1994. Neonates: Missing links in the life histories of North American tortoises. Pp. 161-173 *In* Biology of North American tortoises (R. B. Bury and D. J. Germano, eds.). Fish and Wildlife Research No. 13. U. S. Dept. Interior, National Biological Survey, Wash., DC.

Mortimer, C. and P. Schneider. 1983. Population studies of the desert tortoise (*Gopherus agassizii*) in the Piute Valley study plot of southern Nevada. Report to Nevada Dept. of Wildlife.

Mount, R.H. 1986. Special Concern: Box turtle *Terrapene carolina* ssp. In Mount, R.H., ed. Vertebrate animals of Alabama in need of special attention. Alabama Agriculture Experimental Station, Auburn University.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends Ecol Evol. 10:58-62.

Nagy, K.A., B.T. Henen, and D.B. Vyas. 1998. Nutritional quality of native and introduced food plants of wild desert tortoises. J. Herpet. 32:260-267.

Nagy, K.A. and P.A. Medica. 1986. Physiological ecology of desert tortoises in southern Nevada. Herpetologica 42(1):73-92.

Nicholson, L. 1978. The effects of roads on desert tortoise populations. Proceedings of 1978 Desert Tortoise Council Symposium 1978:127-129.

Nicholson, L. and K. Humphreys 1981. Sheep grazing at the Kramer study plot, San Bernardino County, California. Proceedings of the Desert Tortoise Council 1981 Symposium

Nilsen, E. T., P. W. Rundel, and M. R. Sharifi. 1984. Productivity in native stands of *Prosopsis glandulosa*, mesquite, in the Sonoran Desert of southern California and some management implications. Pages 722-727 *in* R. E. Warner and K. M. Hendrix (eds.). California riparian systems: ecology, conservation, and productive management. Univ. Calif. Press, Berkeley.

Nussear, K. E., C. R. Tracy, P. A. Medica, R. A. Marlow, M. B. Saethre, and P. S. Corn. 2000. Translocation as a tool for conservation of the desert tortoise: Nevada studies. Desert Tortoise Council Symposium, April 20-23, 2000, Las Vegas, NV. Abstract.

O'Connor, M. P., J. S. Grumbles, R. H. George, L. C. Zimmerman, and J. R. Spotila. 1994a. Potential hematological and biochemical indicators of stress in free-ranging desert tortoises and captive tortoises exposed to a hydric stress gradient. Herpetol. Monogr. 8:5-26.

O'Connor, M. P., L. C. Zimmerman, D.E. Ruby, S.J. Bulova, J.R. Spotila. 1994b. Home range size and movements by desert tortoises, *Gopherus agassizii*, in the eastern Mojave Desert. Herpetological Monographs 8: 60-71.

Oftedal, O. 2001. Low rainfall affects the nutritive quality as well as the total quantity of food available to the desert tortoise. Desert Tortoise Council Symposium, March 16-18, 2001, Las Vegas, NV. Abstract.

O'Leary, J. F. and R. A. Minnich.1981. Postfire Recovery of Creosote Bush Scrub Vegetation in the Western Colorado Desert. Madrono 28(2): 61-66.

Oldemeyer, J. 1994. Livestock grazing and the desert tortoise in the Mojave Desert. *In* The biology of North American tortoises. R. B. Bury and D. J. Germano. Washington, D. C., United States Department of the Interior, National Biological Service**:** pp. 95-104.

Olson, T. E. 1996. Comparison of impacts and mitigation measures along three multi-state linear construction projects. Proceedings of the Desert Tortoise Council 1996 Symposium. 1996:1-9.

Olson, T. E., K. Jones, D. McCullough, and M. Tuegel. 1993. Effectiveness of mitigation for reducing impacts to desert tortoise along an interstate pipeline route. Proceedings of the 1992 Desert Tortoise Council Symposium 1993:209-219.

Olson, T. E., C. Luke, K. W. MacDonald, and H. D. Hiatt. 1992. Monitoring for desert tortoises during construction of two interstate pipelines. 1992 Transactions of the Western Section of the Wildlife Society 28:15-21.

Opdam, P. 1988. Populations in fragmented habitat. In: Schreiber, K. F. (Ed.), Connectivity in Landscape Ecology. Proceedings of the Second International Seminar of the International Association for Landscape Ecology, Munster, Germany, 1987. Munstersche Geographische Arbeiten 29, pp. 75-78.

Origgi, F., C. H. Romero, P. Klein, K. Berry, and E. Jacobson. 2002. Serological and molecular evidences of herpesvirus exposure in desert tortoises from the Mojave Desert of California. Desert Tortoise Council Symposium, March 22-25, 2002, Palm Springs, CA. Abstract.

Painter, E. L. and A. J. Belsky. 1993. Application of herbivore optimization theory to rangelands of the western United States. Ecol. Monogr. 3:2-9.

Pauli, F. 1964. Soil fertility problems in arid and semi-arid lands. Nature 204:1286-1288.

Patterson, R. G. 1971. Vocalization in the Desert Tortoise, *Gopherus agassizii*. M.A. Thesis, California State Univ., Fullerton.

Patterson, R. G. 1976. Vocalization in the desert tortoise. Proc. Desert Tortoise Council Symp. 1976: 77-83.

Patterson, R. and B. Brattstrom. 1972. Growth in captive *Gopherus agassizii*. Herpetologica 28:169-171.

Peterson, C. C. 1994a. Different rates and causes of high mortality in two populations of the threatened desert tortoise *Gopherus agassizii.* Biol. Conserv. 70:101-108.

Peterson, C. C. 1994b. Physiological ecology of the desert tortoise, *Xerobates agassizii* . pp. 213-224 in: P. R. Brown and J. W. Wright, eds., Herpetology of the North American Deserts. Proc. of a Symp.

Peterson, C.C. 1996. Ecological energetics of the desert tortoise (*Gopherus agassizii*): effects of rainfall and drought. Ecology 77:1831-1844.

Pettan-Brewer, K. C. B., M. L. Drew, E Ramsay, F. C. Mohr, J. J. Lowenstine. 1996. Herpesvirus particles associated with oral and respiratory lesions in a California desert tortoise (Gopherus agassizii). Journal of Wildlife Diseases 32: 521-526.

Platt, J. R. 1964. Strong inference. Science 146:347-353.

Prose, D.V., and S. K. Metzger. 1985. Recovery of soils and vegetation in World War II military base camps, Mojave Desert. U.S. Geological Survey Open-File Report 85-234, Reston.

Prose, D.V., S. K. Metzger, and H. G. Wilshire. 1987. Effects of substrate disturbance on secondary plant succession: Mojave Desert, California. J. Appl. Ecol. 24:305-313.

Ratti, J. T. and K. P Reese. 1988. Preliminary tests of the ecological trap hypothesis. J. Wildl. Manag. 52:484-491.

Rauzi, F. and F. M. Smith. 1973. Infiltration rates: three soils with three grazing levels in northeastern Colorado. Journal of Range Management 26(2): 126-129.

Reicosky, D.C., W.B. Voorhess, and J.K. Radke. 1979. Unsaturated water flow through a simulated wheel track. Abstract of talk presented at 1979 annual meetings of American Society of Agronomy, Fort Collins, CO.

Resnik, D. B. 1991. How-possibly explanations in Biology. Acta Biotheoretica 39:141-149.

Resource Concepts. 1996. Desert tortoise situation review. Report to Public Works Group, County of San Bernardino, CA. Resource Concepts, Inc., Carson City, NV.

Reynolds, H.G. and J.W. Bohning. 1956. Effects of burning on a desert grass-scrub range in southern Arizona. Ecology 37:769-778.

Rogers, RF. W., T. T. Lange, and D. J. D. Nichols. 1966. Nitrogen fixation by lichens of arid soil crusts. Nature 209:96-97.

Rosskopf, W. J., Jr. 1991. Protocols for handling live tortoises. Chapt. III *In* Interim techniques handbook for collecting and analyzing data on desert tortoise populations and habitats. Publ. by Arizona Game and Fish Dept.

Rostal, D. C., V. A. Lance, J. S. Grumbles, and A. C. Alberts. 1994. Seasonal reproductive cycle of the desert tortoise (*Gopherus agassizii*) in the eastern Mojave Desert. Herp. Monogr. 8:72-82.

Rowlands, P.G. 1980. Soil crusts. Pp. 46-62, Chapt. II. *In*: The effects of disturbance on desert soils, vegetation and community process with emphasis on off road vehicles: a critical review (Rowlands, P. G., Ed.). Desert Plan Staff, Bureau of Land Management, Riverside, CA.

Rowlands, P.G., J.A. Adams, H.B. Johnson, and A.S. Endo. 1980. Experiments on the effects of soil compaction on establishment, cover, and pattern of winter and summer annuals in the Mojave desert. Pp. 75-120, Chapt. VI. *In*: The effects of disturbance on desert soils, vegetation and community process with emphasis on off road vehicles: a critical review (Rowlands, P. G., Ed.). Desert Plan Staff, Bureau of Land Management, Riverside, CA.

Ruby, D. E., and H. A. Niblick. 1994. A behavioral inventory of the desert tortoise: development of an ethnogram. Herpetol. Monogr. 8:88-102.

Ruby, D. E., L. C. Zimmerman, S. J. Bulova, C. J. Salice, M. P. O'Connor, and J. R. Spotila. 1994. Behavioral responses and time allocation differences in desert tortoises exposed to environmental stress in semi-natural enclosures. Herpetological Monographs 8:27-44.

Rundel, P. W. and A. C. Gibson. 1996. Ecological communities and processes in a Mojave Desert ecosystem: Rock Valley, Nevada. Cambridge Univ. Press, Cambridge.

St. Clair, L. L., B. L. Webb, J. R. Johansen, and G. T. Nebecker. 1984. Cryptogamic soil crusts: enhancement of seedling establishment in disturbed and undisturbed areas. Reclam. Reveg. Res. 3:129-136.

Savory, A. 1989. Holistic resource management. Island Press, Washington, DC.

Schumacher, I. M., M. B. Brown, E. R. Jacobson, B. R. Collins, P. A. Klein. 1993. Detection of antibodies to a pathogenic mycoplasma in desert tortoises (*Gopherus agassizii*) with upper respiratory tract disease. Journal of Clinical Microbiology 31(6):1454-1460.

Schumacher, I. M., D. B. Hardenbrook, M. B. Brown, E. R. Jacobson, and P. A. Klein. 1997. Relationship between clinical signs of Upper Respiratory Tract Disease and antibodies to *Mycoplasma agassizii* in desert tortoises from Nevada. J. Wildl. Diseases 33:261-266.

Sharifi, M. R., A. C. Gibson, and P. W. Rundel. 1997. Surface dust impacts on gas exchange in Mojave Desert shrubs. J. Appl. Ecol. 34:837-846.

Sharifi, M. R., A. C. Gibson, and P. W. Rundel. 1999. Phenological and physiological responses of heavily dusted creosote bush (*Larrea tridentata*) to summer irrigation in the Mojave Desert. Flora 194:369-378.

Sheppard, G. P. 1981. Desert tortoise population of the Beaver Dam Slope in northwestern Arizona. Desert Tortoise Council Proceedings of the 1981 Symposium.

Sherman, M. W. 1993. Activity patterns and foraging ecology of nesting Common Ravens in the Mojave Desert, California. M. S. thesis, Colorado State Univ., Fort Collins.

Shields, T. 1994. Field sampling of small tortoises: three experiments. Proc. 1987-1991 Desert Tortoise Council Symposium. 1994:374.

Snyder, C.T., D.G. Frickel, R.F. Hadley, and R.F. Miller. 1976. Effects of off-road vehicle use on the hydrology and landscape of arid environments in central and southern California. U.S. Geological Survey Water Resources Investigations 76-99, 27 pp.

Soltero, S., F. C. Bryant, and A. Melgoza. 1989. Standing crop patterns under short duration grazing in northern Mexico. J. Range Manag. 42:20-22.

Spotila, J. R., L. C. Zimmerman, C. A. Binckley, J. S. Grumbles, D. C. Rostal, A. List, Jr., E. C. Beyer, K. M. Philips, and S. J. Kemp. 1994. Effects of incubation conditions on sex determination, hatching success, and growth of hatchling desert tortoises, *Gopherus agassizii*. Herptol. Monogr. 8:103-116.

Steiger, T.L. 1930. Structure of prairie vegetation. Ecology 11:170-217.

Stewart, G. A. 1993. Movements and survival of desert tortoises (*Gopherus agassizii*) following relocation from the Luz Solar Electric Plant at Kramer Junction. Proc. 1992 Desert Tort. Council Symp. 1992:234-261.

Stewart, G. R. and R. J. Baxter. 1987. Final report and habitat management plan for the desert tortoise (*Gopherus agassizii*) in the West and Sand Hill Training Areas of the Twentynine Palms MCAGCC. Rpt. to U.S. Dept. of Navy. Calif. State Polytech. Univ., Pomona.

Stubbs, D. 1989. *Testudo kleinmanni*. Egyptian tortoise. In Swingland, I. R. and M.W. Klemens, eds. The conservation biology of tortoises. Occasional papers of the IUCN Species Survival Commission No. 5 and the Durrell Institute of Conservation Ecology. IUCN.

Stubbs, D. 1991. Tortoise and freshwater turtles: an action plan for their conservation. IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. 2nd Ed. IUCN-The World Conservation Union, Gland, Switzerland.

Tierra Madre Consultants. 1991. Biological assessment for Lancaster City and Planning Area: Relative density surveys for desert tortoises and cumulative human impact evaluations for Mohave ground squirrel habitat. Rpt. for City of Lancaster. Tierra Madre Consultants, Riverside, CA.

Tracy, C. R. 1995. Patterns of fire incidence and implications for management of Desert Wildlife Management Areas. Proc. 1994 Desert Tort. Counc. Symp. 1995:179.

Tracy, C. R. 1996. Nutritional ecology of the desert tortoises: preliminary assessment of some impacts due to sheep grazing in the California Desert District. Report to National Biological Service. Univ. Nevada, Reno.

Tully, J. G. 1998. The important and continuing role of mycoplasmas in respiratory diseases of various animal hosts. Desert Tortoise Council Symposium, April 3-5, 1998, Tucson, AZ. Abstract.

Turner, F. B. 1975. Effects of continuous irradiation on animal populations. Pp. 83-144 in: J. T. Lett and H. Adler, eds., Advances in radiation biology, vol. 5. Academic Press, NY.

Turner, F.B., K.H. Berry, D.C. Randall, and G.C. White. 1987b. Population ecology of the desert tortoise at Goffs, California 1983-1986. Report to South. Calif. Edison. Laboratory of Biomed. and Environ. Sci., Univ. Calif, Los Angeles.

Turner, F. B., P. Hayden, B. L. Burge, and J. B. Roberson. 1986. Egg production by the desert tortoise (Gopherus agassizii) in California. Herpetologica 42:93-104.

Turner, F. B. and P. A. Medica. 1977. Sterility among female lizards (*Uta stansburiana*) exposed to continuous Y irradiation. Radiation Research 70:154-163.

Turner, F.B., P.A. Medica, and C.L. Lyons. 1981. A comparison of populations of the desert tortoise (*Gopherus agassizii*) in grazed and ungrazed areas in Ivanpah Valley, California. Proceedings of the 1981 Desert Tortoise Council Symposium.

Turner, F.B., P.A. Medica, and C.L. Lyons. 1984. Reproduction and survival of the desert tortoise (*Scaptochelys agassizii*) in Ivanpah Valley, California. Copeia 1984:811-820.

Turner, F.B., P.A. Medica, and R. B. Bury. 1987a. Age-size relationships of desert tortoises (*Gopherus agassizii*) in southern Nevada. Copeia 1987:974-979.

Turner, F. B., C. G. Thelander, D. C. Pearson, and B. L. Burge. 1985. An evaluation of the transect technique for estimating desert tortoise density at a prospective power plant site in Ivanpah Valley, California. Proceedings of the 1982 Desert Tortoise Council Symposium 1985:134-153.

U. S. Department of Energy. 1994. United States nuclear tests July 1945 through 1992. DOE/NV 209 (Rev. 14) Dec. 1994. USDOE Nevada Operations Office.

U. S. Fish and Wildlife Service. 1994. Desert tortoise (Mojave population) Recovery Plan. U.S. Fish and Wildlife Service, Portland OR.

Van Devender, T. R., R. S. Thompson, J. L. Betancourt. 1987. Vegetation history of the deserts of southwestern North America; the nature and timing of the late Wisconsin-Holocene transition. Pages 323-352 *In* W. F. Ruddiman and H. E. Wright (eds.), North America and adjacent oceans during the deglaciation. The Geological Society of America, Boulder, CO.

Vasek, F. C., H. B. Johnson, and D. H. Eslinger. 1975. Effects of pipeline construction on creosote bush scrub vegetation on the Mojave Desert. Madrono 23:1-13.

Vollmer, A.T., B.G. Maza, P.A. Medica, F.B. Turner and S.A. Bamberg. 1976. The impact of off-road vehicles on a desert ecosystem. Environmental Management. 1(2):115-129.

von Seckendorff Hoff, K., and R. Marlow. 1997. Highways and roads are population sinks for desert tortoises. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference, p. 482.

Waller, T., and P. A. Micucci. 1997. Land use and grazing in relation to the genus *Geochelone* in Argentina. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference, pp. 2-9.

Webb, R. H. 1983. Compaction of desert soils by off-road vehicles. Pp. 51-79 in Environmental effects of off-road vehicles: impacts and management in arid regions (Webb, R. H., & H. G. Wilshire, eds.). Springer-Verlag, New York.

Webb, R. H., H. C. Ragland, W. H. Godwin, and D. Jenkins. 1978. Environmental effects of soil property changes with off-road vehicle use. Environ. Management 2(3):219-233.

Webb, R. H. and S. S. Stielstra. 1979. Sheep grazing effects on Mojave Desert vegetation and soils. Environ. Manage. 3:517-529.

Weinstein, M. 1993. Health profile results from the Honda desert tortoise relocation project. Proc. 1992 Desert Tort. Counc. Symp.:58.

Weltz, M., M.K. Wood, and E.E. Parker. 1989. Flash grazing and trampling: effects on infiltration rates and sediment yield in a selected New Mexico range site. J. Arid Environ. 16:95-100.

Wilcove, D. S., C. H. McLellan, and A. P. Dobson. 1986. Habitat fragmentation in the temperate zone. . *In* M. E. Soule (ed.) Conservation biology: the science of scarcity and diversity, pp. 237-256. Sinauer Assoc., Sunderland, MA.

Willis, W.O. and W.A. Raney. 1971. Effects of compaction on content and transmission of heat in soils, pp. 165-177. *In* Compaction of Agricultural Soils. American Society of Agricultural Engineers Monograph.

Wilms, W.D., S. Smoliak, and J.F. Dormarr. 1990. Vegetation response to time-controlled grazing on mixed and fescue prairies. J. Range Manage. 43:513-517.

Wilshire, H.G. 1980. Human causes of accelerated wind erosion in California's desert. In Coates, D.R. and J.D. Vitek. Thresholds in geomorphology. London: Allen and Unwin, Limited.

Wilshire, H. G. and J. K. Nakata 1976. Off-road vehicle effects on California's Mojave desert. California Geology (June 1976): 123-132.

Wilson, D. S., C. R. Tracy, K. E. Nussear, E. T. Simandle, R. M. Marlow, P. A. Medica, and P. S. Corn. 2000. Translocation as a tool for conservation of the desert tortoise: Utah studies. Desert Tortoise Council Symposium, April 20-23, 2000, Las Vegas, NV. Abstract.

Winkel, V.K. and B.A. Roundy . 1991. Effects of cattle trampling and mechanical seedbed preparation on grass seedling emergence. J. Range Mgmt. 44:176-183.

Woodbury, A. M. and R. Hardy. 1948. Studies of the desert tortoise, Gopherus agassizii. Ecological Monographs 18: 145-200.

Woodman, A. P. 1986. Effects of Parker 400 off-road race on desert tortoise habitat in Chemehuevi Valley, CA. Proc. Desert Tortoise Council 1983: 69-79.

Woodman, A.P. and K.H. Berry. 1984. A description of carcass deterioration of the desert tortoise and a preliminary analysis of disintegration rates at two sites in the Mojave Desert, California. In Berry, K., Ed. The status of the desert tortoise (*Gopherus agassizii*) in the United States. Riverside, California: United State Department of the Interior, Bureau of Land Management.

Woodman, A.P. and S.M. Juarez. 1988. Juvenile desert tortoises utilized as primary prey of nesting common ravens near Kramer, California. Paper presented at the 13th Annual Meeting and Symposium of the Desert Tortoise Council held March 26-27, 1988, Laughlin, Nevada.

EXHIBIT 608

ELSEVIER

Journal of Arid Environments 65 (2006) 94–101

Journal of Arid Environments

www.elsevier.com/locate/jnlabr/yjare

A highway's road-effect zone for desert tortoises (*Gopherus agassizii*)

W.I. Boarman[a,*], M. Sazaki[b]

[a]*US Geological Survey, Western Ecological Research Center, 5745 Kearny Villa Road, Suite M, San Diego, CA 92123, USA*

[b]*California Energy Commission, 1516 Ninth St. Sacramento, CA 95814, USA*

Received 23 December 2004; received in revised form 29 April 2005; accepted 16 June 2005
Available online 4 January 2006

Abstract

Roads and highways can affect populations of animals directly (e.g. due to road mortality) and indirectly (e.g. due to fragmentation of habitat and proliferation of non-native or predatory species). We investigated the effect of roads on threatened desert tortoise (*Gopherus agassizii*) populations in the Mojave Desert, California, and attempted to determine the width of the road-effect zone by counting tortoise signs along transects at 0, 400, 800, and 1600 m from the edge of a highway. Mean sign count was 0.2/km at 0 m, 4.2/km at 400 m, 5.7/km at 800 m, and 5.4/km at 1600 m from the highway edge. The differences between all pairs of distances, except 800 and 1600 m, were statistically significant, suggesting that tortoise populations in our study area are depressed in a zone extending at least 400 m from roadways. We speculate that the major cause for this depression zone is road mortality.

Keywords: Mortality; Mojave desert; Desert tortoise; Road kills; Human impacts; Chelonians; Road-effect zone; Roads

*Corresponding author.
E-mail addresses: william_boarman@usgs.gov (W.I. Boarman), msazaki@energy.state.ca.us (M. Sazaki).

0140-1963/$ - see front matter © 2005 Published by Elsevier Ltd.
doi:10.1016/j.jaridenv.2005.06.020

1. Introduction

Roads and highways are ubiquitous landscape features that have a multitude of effects on surrounding animal populations. These effects can be direct, as in the case of road mortality, but they are often indirect, and, consequently, more difficult to identify. For example, road corridors fragment contiguous habitat and potentially act as barriers to dispersal and gene flow among remaining populations. This can threaten the persistence of existing species because small, isolated populations are more likely to experience inbreeding depression and have higher probabilities of extinction than large, interconnected populations (Opdam, 1988; Schonewald-Cox and Buechner, 1992; Hanski and Gyllenberg, 1993; Mills and Smouse, 1994; Frankham, 1995). The presence of roads may also lead to increased predation pressure on some species by providing travel corridors and a reliable food source (i.e. road killed animals) for predators. In addition, habitat changes along roadways may affect the viability of native animals, as invasive weeds and edge-associated species often dominate flora (Bennett, 1991; Forman and Alexander, 1998; Gelbard and Belnap, 2003).

The effects of roads and highways on animals is not limited to the immediate vicinity of a roadway because road mortality affects migrating and dispersing individuals as well as those whose home range includes the road. In addition, introduced predators and invasive plants can migrate outward from roads, affecting native animals in adjacent areas. The total area affected, or the ‘‘road-effect zone’’ (Forman, 2000; Forman and Deblinger, 2000), can be substantial for species that either travel long distance or are vulnerable to predation by species introduced along road corridors. In this study, we investigated the effect of roads on desert tortoise (*Gopherus agassizii*) populations in the Mojave Desert, California, because desert tortoises are a Federally threatened species that has suffered declines in some areas from many causes, including road mortality, disease, and predation by common ravens (*Corvus corax*; US Fish and Wildlife Service, 1994). Specifically, our study goals were to determine (1) if desert tortoises are affected by roads and (2) if present, how far from roadways does the road-effect zone extend, as measured by signs of tortoise activity or presence.

2. Material and methods

The study was conducted along California State Highway (Hwy) 58 in the western Mojave Desert, San Bernardino Co. (Fig. 1). Hwy 58 is both a two- and a divided four-lane highway with average daily traffic of 8500 vehicles (California Department of Transportation, 1993) and a posted speed limit of 105 km h^{-1}. The highway traverses relatively flat terrain with a mixture of shadscale (*Atriplex confertifolia*), spinescale (*A. spinifera*) and creosote bush (*Larrea tridentata*)–white bursage (*Ambrosia dumosa*) vegetation series (Sawyer and Keeler-Wolf, 1995) at elevations of 695–765 m. A corridor for buried pipelines, with recovering vegetation, parallels the highway for much of its length. Desert tortoise density in the general vicinity of

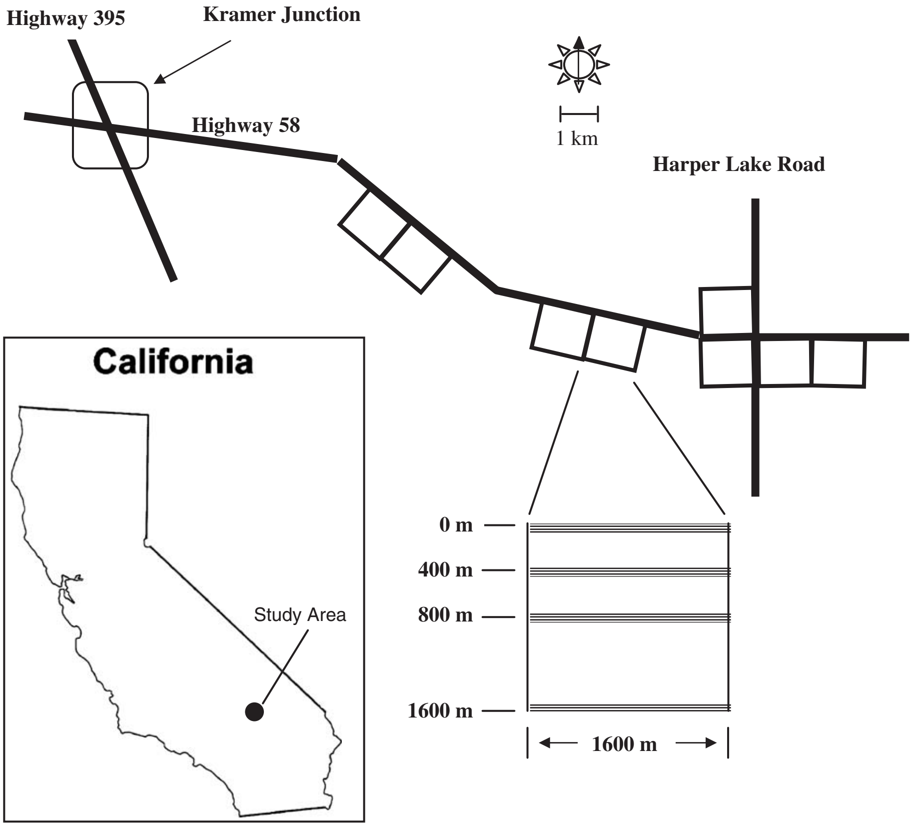


Fig. 1. Locations and configuration of 30-m wide strip transects for estimates of tortoise signs along California State Highway 58 in 1991. Inset shows location of study site in San Bernardino County, California, USA.

the study was estimated at 20 adults km^{-2} (US Fish and Wildlife Service, 1994) and average home range size was 39 ha (unpubl. data).

Between 20 and 31 March 1991, 27-m wide, 1600 m long transects were walked at four distances from and parallel to the edge of Hwy 58 (Fig. 1). The first transect abutted the fence, or desert side of a recovering pipeline right-of-way that was immediately adjacent to part of the highway. The remaining transects were centered 400, 800, and 1600 m from the fence (except for one set, which was 1200 m from the highway at the edge of a small, decommissioned landing strip). This configuration of transects was repeated at eight locations (study areas), seven along the south edge and one along the north edge of the fenced section of Hwy 58 (Fig. 1). The individual locations were chosen based on logistical considerations (accessibility, property ownership, and contiguity of relatively undisturbed habitat) and were not randomly selected. Each 30-m wide transect was searched in 10-m wide contiguous strips and totals among the three strips at each distance × location combination were entered into the analysis.

As an index of relative tortoise density, the location and characteristics of all tortoise sign (i.e. shells, tracks, scats, burrows, and pallets) and live tortoises were recorded. The data were converted to Total Corrected Sign (TCS) to eliminate bias caused by closely associated signs (e.g. scat inside a burrow were counted as one, tracks immediately behind an active tortoise were counted as one; Berry and Nicholson, 1984). Although we did not convert to tortoise density, the analysis assumes that differences in TCS correlate to differences in relative tortoise density (Berry and Nicholson, 1984; Weinstein, 1989).

To determine if there were significant differences ($a = 0.05$) among distances from the highway, the total TCS recorded at each distance per site combination were first square root transformed, then analysed using the software program SuperAnova (Gagnon et al., 1989). A randomized block design analysis of variance (ANOVA) was used, with distance as the between-groups effect and blocking for study area. Pair-wise comparisons among means were made using the Fisher's Protected Least Significant Difference test ($a = 0.05$; Gagnon et al., 1989).

3. Results

Mean ± SE TCS counts at 0, 400, 800, and 1600 m from the highway were 0.6 ± 0.32, 12.5 ± 2.42, 17.4 ± 2.76, and 16.1 ± 2.55, respectively (Fig. 2). The ANOVA of the transformed data revealed significant differences in number of tortoise signs among distances ($F_{3,21} = 62.3$, $p < 0.0001$). The post hoc analysis yielded significant differences between 0 m and all other distances and between 400 and 800 m from the highway, with TCS increasing with distance from the highway edge (Fig. 2). Although significant ($p = 0.0356$), the latter pair-wise comparison, with its relatively low p-value, should be viewed with caution given that the study sites and distances could not be selected at random.

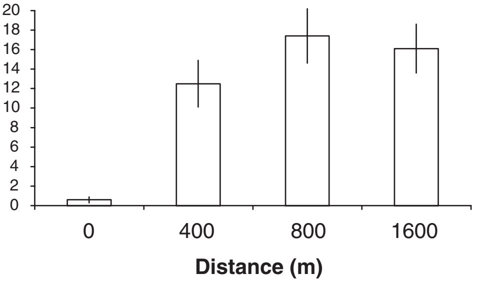


Fig. 2. Total Corrected Sign counts, an index of tortoise density, increased with distance from edge of Highway 58, San Bernardino County, California. Most differences were statistically significant (see text).

4. Discussion

One way to measure for a road-effect zone is to evaluate the density of animals with respect to a road edge. We found that TCS increased with distance from the highway (Fig. 2) and leveled off somewhere between 400 and 800 m, indicating that the road-effect zone in our study area is in this range. Our results are consistent with those of several other studies. Nicholson (1978) observed a significant increase in tortoise sign up to 1600 m from road and highway edges, with the effect magnified along older roads with greater traffic volumes. Nicholson's (1978) results may be confounded by an increase in highway mortality due to faster vehicle speeds on older, more highly traveled roads (Case, 1978; Sargeant, 1981; Osawa, 1989). Von Seckendorff Hoff and Marlow (1997) reported that tortoise populations were depressed up to 4.6 km from highways and Karl (1989) obtained similar results up to 3.2 km. Looking more intensively within 305 m of a highway edge, LaRue (1993) found a significant linear increase in tortoise sign with distance. Baepler et al. (1994) also found an increase with distance near the highway, but failed to find any increase beyond about 175 m. Field and statistical methods varied widely among these studies, sample sizes were low, and replications were rare, making tenuous any comparisons among these and our study.

Our results hinge on the assumption that changes in TCS accurately reflect differences in relative tortoise densities. Though TCS counts may vary with observer, substrate, season, and year (Turner et al., 1982; Berry and Nicholson, 1984; Weinstein, 1989), significant correlations were found between TCS and tortoise density in two studies ($r = 0.76$, $p < 0.001$, Berry et al., 1983; $r = 0.79$, $p < 0.01$, Berry and Nicholson, 1984). Our results may also be confounded by the existence of the 30-m wide pipeline right-of-way along or near the fence on the south side of the highway for most of its length. This may have had the effect of extending the low-density zone 30 m farther from the highway than may otherwise have existed. In spite of the pipeline, we believe the low tortoise presence along the 0 m transects is caused by the highway because (a) the pattern existed in 1991 on one site where there was no pipeline; (b) the pipeline was laid in place in 1989, shortly before our study; (c) the pattern was evident, although less dramatically so, along the east edge of Hwy 395, where there was no pipeline, in 1994 (Boarman, 1995); and (d) tortoises are not inhibited from crossing bare or partially bare areas (pers. obs.).

Two other human factors that could not be controlled may confound the results. The decommissioned airstrip in one of the eight study areas may have reduced the density of tortoises at the farther reaches of the site, rendering less discernable our predicted pattern of reduced tortoise sign with distance from the highway. Additionally, a lightly traveled road, Harper Lake Road, abutted the sides of three study sites, running perpendicular to the highway. This road may have increased the variance by reducing the number of tortoises, particularly at the edge distant from the highway. However, the pattern was still obtained and the result was still statistically significant in spite of the presence of the airstrip and Harper Lake Road.

In addition to roads affecting the density or distribution of desert tortoises, studies have shown that roads affect surrounding populations of other vertebrate taxa.

For instance, Rosen and Lowe (1994) report on a probable long-term reduction in snake populations along a highway in Arizona. Populations of two snake species were negatively affected by roads in Florida for up to at least 850 m from the road edges (Rudolph et al., 1999). Densities of two species of birds were depressed within 200–2000 m of a highway in the Netherlands, while a third species showed a positive response to the highway (Van der Zande et al., 1980). Wide ranging mammals are also found less often near the edges of roads (grizzly bears, *Ursus arctos*, Dood et al., 1986; Kasworm and Manley, 1990; gray wolf, *Canis lupus*, Frederick, 1991; Thurber et al., 1994; Roosevelt elk, *Cervus elaphus roosevelti*, Witmer and de Calesta, 1985). Abundance of Mojave Desert rodents did not follow this pattern; four species were not affected by proximity to a highway, and two species were more abundant near the highway (Garland and Bradley, 1984). Likewise, more species of breeding, in edge and open habitat birds were found within 100 m, but no overall difference in density was recorded within 800 m of a highway edge (Ferris, 1979).

Although our study did not attempt to determine the causes for depressed tortoise numbers in the road-effect zone, in a separate study, we found the remains of 115 road-killed tortoises along 52.8 km of this and another nearby highway with similar traffic patterns and tortoise densities (Boarman et al., in review), suggesting that road mortality is a significant factor (Berry and Nicholson, 1984). Some of the animals died while making normal home range movements, while others undoubtedly died while attempting to cross the highways during pre-breeding dispersal activity (Boarman et al., in review). To alleviate losses to road mortality, we suggest that barrier fences and culverts be used near highways in desert tortoise habitat. Fences designed to prevent crossing by tortoises resulted in 93% fewer tortoise road kills in another study (Boarman et al., in review) while culverts allow tortoises to safely travel beneath highways, perforating the barrier posed by the fences (Boarman et al., 1998). Alternatively, it has been suggested that noise from vehicular traffic may prevent tortoises from settling in the vicinity highways (Karl, 1990), and that surface disturbances near road edges reduces habitat quality for tortoises (Baepler et al., 1994). However, data are not available to support these ideas. Each of these possibilities should be the subject of future research to clarify the mechanisms that lead to reduced tortoise populations in the zone surrounding highways.

Acknowledgements

Dr. H.W. Avery, S. Barrett, Dr. K. Berry, R. Bransfield, S. Ford, Dr. J.W. Gibbons, F. Hoover, J. Kawashima (deceased), Dr. J.E. Lovich, Dr. J. Oldemeyer, Dr. J. Spotila, Dr. S. Sweet, and Dr. M. Weinstein provided ideas and suggestions for design and analysis of the project. Dr. K. Berry, D. Chamblin, S. Ford, F. Hoover, Dr. J. Oldemeyer, and Dr. M. Weinstein and two anonymous reviewers provided comments on earlier versions of the manuscript. G.C. Goodlett, G.O. Goodlett, T. Goodlett, and A.P. Woodman assisted with the field work. Dr. D. Strauss and members of his graduate course on statistical consulting provided valuable advice on statistical analyses. Funds for the project were provided by the Bureau of Land Management, California Energy Commission (Contract Nos. 700-89-007, 700-90-015, and 700-91-005 to BLM), Federal Highways Administration, US Geological Survey, and Nevada Department of Transportation.

References

Baepler, D.H., Heindl, A., Singh, A.K., Pandley, A., 1994. A study of the impacts of highways on desert tortoise populations. Report to Nevada Department Transportation. Harry Reid Center for Environmental Studies, Las Vegas, NV.

Bennett, A.F., 1991. Roads, roadsides and wildlife conservation: a review. In: Saunders, D.A., Hobbs, R.J. (Eds.), Nature Conservation 2: The Role of Corridors. Surrey Beatty & Sons, New South Wales, pp. 99–117.

Berry, K.H., Nicholson, L.L., 1984. The distribution and density of desert tortoise populations in California in the 1970s. In: Berry, K.H. (Ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the US Fish and Wildlife Service, Portland, OR, Order No. 11310-0083-81, pp. 26–60.

Berry, K.B., Woodman, A.P., Nicholson, L.L., Burge, B.L., 1983. The distribution and abundance of desert tortoises (*Gopherus agassizii*) on the Chocolate Mountains Aerial Gunnery Range. In: Proceedings of the 1993 Desert Tortoise Council Symposium, 47–65.

Boarman, W.I., 1995. Effectiveness of fences and culverts for protecting desert tortoises along California State Highway 58: 1991–1994. Report to California Energy Commission, Sacramento, CA.

Boarman, W.I., Beigel, M.L., Goodlett, G.C., Sazaki, M., 1998. A passive integrated transponder system for tracking animal movements. Wildlife Society Bulletin 26, 886–891.

Boarman, W.I., M. Sazaki, G.C. Goodlett, T. Goodlett, in review. Barrier fencing reduces vertebrate road kills. Manuscript, in review.

California Department of Transportation, 1993. 1992 Traffic Volumes on the California State Highway System. Department of Transportation, Division of Traffic Operations, Sacramento.

Case, R.M., 1978. Interstate highway road-killed animals: a data source for biologists. Wildlife Society Bulletin 6, 8–13.

Dood, A.R., Brannon, R.D., Mace, R.D., 1986. Final programmatic environmental impact statement: the grizzly bear in northwestern Montana. Montana Department of Fish Wildlife, and Parks, Helena.

Ferris, C.R., 1979. Effects of Interstate 95 on breeding birds in northern Maine. Journal of Wildlife Management 43, 421–427.

Forman, R.T.T., 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology 14, 31–35.

Forman, R.T.T., Alexander, L.E., 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29, 207–231.

Forman, R.T.T., Deblinger, R.D., 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. Conservation Biology 14, 36–46.

Frankham, R., 1995. Inbreeding and extinction: a threshold effect. Conservation Biology 9, 792–799.

Frederick, G.P., 1991. Effects of Forest Roads on Grizzly Bears, Elk, and Grey Wolves: A Literature Review. US Department of Agriculture, Forest Service Publication, Washington, DC No. R1-91-73, 53pp.

Gagnon, J., Roth, J.M., Carroll, M., Hofmann, R., Haycock, K.A., Plamondon, J., Feldman Jr., D.S., Simpson, J., 1989. SuperAnova: Accessible General Linear Modeling. Abacus Concepts, Inc., Berkeley.

Garland Jr., T., Bradley, W.G., 1984. Effects of a highway on Mojave Desert rodent populations. American Midland Naturalist 111, 47–56.

Gelbard, J.L., Belnap, J., 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. Conservation Biologist 17, 420–432.

Hanski, I., Gyllenberg, M., 1993. Two general metapopulation models and the core-satellite species hypothesis. American Naturalist 142, 17–41.

Karl, A., 1989. Investigations of the desert tortoise at the California Department of Health Services proposed low-level radioactive waste disposal facility site in Ward Valley, California. Report to US Ecology, Newport Beach, CA.

Karl, A., 1990. Research proposal for studies of the desert tortoise at the proposed site of the California Department of Health Services low-level radioactive waste disposal facility. Report to US Ecology, Newport Beach, CA.

Kasworm, W.F., Manley, T.L., 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. In: International Conference on Bear Research and Management, vol. 8, pp. 79–84.

LaRue Jr., E.L., 1993. Distribution of desert tortoise sign adjacent to Highway 395, San Bernardino County, California. In: Proceedings of the 1992 Desert Tortoise Council Symposium, 190–204.

Mills, L.S., Smouse, P.E., 1994. Demographic consequences of inbreeding in remnant populations. American Naturalist 144, 412–431.

Nicholson, L., 1978. The effects of roads on desert tortoise populations. In: Proceedings of the 1978 Desert Tortoise Council Symposium, 127–129.

Opdam, P., 1988. Populations in fragmented habitat. In: Schreiber, K.F. (Ed.), Connectivity in Landscape Ecology: Proceedings of the Second International Seminar of the International Association for Landscape Ecology, Munster, Germany, 1987. Munstersche Geographische Arbeiten 29, pp. 75–78.

Osawa, R., 1989. Road-kills of the swamp wallaby, *Wallabia bicolor*, on North Stradbroke Island, South-east Queensland. Australian Wildlife Research 16, 95–104.

Rosen, P.C., Lowe, C.H., 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation 68, 143–148.

Rudolph, D.C., Burgdorf, S.J., Conner, R.N., Schaefer, R.R., 1999. Preliminary evaluation of the impact of roads and associated vehicular traffic on snake populations in eastern Texas. In: Evink, G.L., Garrett, P., Zeigler, D. (Eds.), Proceedings of the Third International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, pp. 129–136.

Sargeant, A.B., 1981. Road casualties of prairie nesting ducks. Wildlife Society Bulletin 9, 65–69.

Sawyer, J.O., Keeler-Wolf, T., 1995. A Manual of California Vegetation. California Native Plants Society, Sacramento.

Schonewald-Cox, C., Buechner, M., 1992. Park protection and public roads. In: Fiedler, P.L., Jain, S.K. (Eds.), Conservation Biology: The Theory and Practice of Nature Conservation, Preservation, and Management. Chapman and Hall, New York, pp. 373–395.

Thurber, J.M., Peterson, R.O., Drummer, T.D., Thomasma, S.A., 1994. Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin 22, 61–68.

Turner, F.B., Thelander, C.G., Pearson, D.C., Burge, B.L., 1982. An evaluation of the transect technique for estimating desert tortoise density at a prospective power plant site in Ivanpah Valley, California. In: Proceedings of the 1982 Desert Tortoise Council Symposium, 134–153.

United States Fish and Wildlife Service, 1994. Desert tortoise (Mojave population) Recovery Plan. United States Fish and Wildlife Service, Portland 73pp.

von Seckendorff Hoff, K., Marlow, R., 1997. Highways and roads are population sinks for desert tortoises. In Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference, p. 482. Abstract.

Weinstein, M.N., 1989. Modeling desert tortoise habitat: can a useful management tool be developed from existing transect data? Unpublished Ph.D. dissertation, University of California, Los Angeles.

Witmer, G.W., de Calesta, D., 1985. Effect of forest roads on habitat use by roosevelt elk. Northwest Science 59, 122–125.

van der Zande, A.N., ter Keurs, W.J., van der Weijden, W.J., 1980. The impact of roads on the densities of four bird species in an open field habitat—evidence of a long-distance effect. Biological Conservation 18, 299–321.

EXHIBIT 609

State of California

Memorandum

DOCKET	
07-AFC-5	
DATE	OCT 27 2009
RECD	OCT 28 2009

To : Mr. John Kessler, Project Manager
Siting, Transmission & Environmental Protection Division
California Energy Commission

Date: October 27, 2009

From : **Department of Fish and Game**
Kevin Hunting, Deputy Director, Ecosystem Conservation Division

Subject: Comments on the Preliminary Staff Assessment and Recommendations for the Final Staff Assessment for the Ivanpah Solar Electric Generating System (CEC Docket # 07-AFC-5)

Dear John:

This memo and attachments convey the recommendations of the Department of Fish and Game (Department) on the Final Staff Assessment/Final Environmental Impact Statement (FSA/FEIS) and California Endangered Species Act (CESA) recommendations to the California Energy Commission (Commission) for the Ivanpah Solar Electric Generating System. Our recommendations are consistent with guidance emerging through the joint effort to implement the Governor's Executive Order S-14-08 and are consistent with the commitment among the members of the Renewable Energy Action Team (REAT) to collaborate and cooperate on project and policy guidance to facilitate achieving renewable energy targets. The Department reserves the right to adjust these recommendations, comments and mitigation conditions as appropriate to the preservation, protection, and management measures to be developed for the Desert Renewable Energy Conservation Plan (DRECP) being created in furtherance of Executive Order S-14-08.

The Department typically serves as the permitting agency with regard to projects subject to CESA. However, for energy projects that fall within the scope of the Warren-Alquist Act ("the Act"), Public Resources Code section 25000 et seq., the Commission serves as the permitting agency under California law and is responsible for ensuring compliance with the California Environmental Quality Act (CEQA), CESA and other state environmental laws. As the designated trustee agency charged with protecting, preserving, and managing California's biological resources, the Department has significant expertise in assessing project impacts to such resources and in formulating appropriate measures to mitigate those impacts. For these reasons, and to better facilitate project coordination, Commission staff has requested the Department review energy projects within the Commission's jurisdiction and make recommendations to the Commission regarding impacts and mitigation under CEQA/CESA.

The Ivanpah Solar Electric Generating System (Project) will be located in the Mojave Desert approximately fifty miles northwest of the City of Needles. When constructed, the Project will be approximately 4,060 acres and will generate approximately 400 megawatts, enough to power roughly 140,000 homes. The Project will be built in three phases, consisting of two 100 megawatt facilities and one 200 megawatt facility. With regard to CESA, the impacts of this Project relate exclusively to desert tortoise (*Gopherus agassizii*) and its habitat.

Mitigation Under CESA and ESA

The Department is providing comments and recommendations, here and via continued consultation with Commission staff, pursuant to Fish and Game Code section 2050 et seq. as it would relate to an Incidental Take Permit (ITP) for the Project. Compliance with CESA's incidental take provisions is required for any otherwise lawful activities which could result in the "take" (as defined in Section 86 of the Fish and Game Code) of any species listed under CESA. The Department is also providing comments and recommendations pursuant to its Lake and Streambed Alteration Agreement (LSAA) program under Fish and Game Code section 1600 et seq. in regard to any proposed activity that would divert, obstruct, or affect the natural flow or change the bed, channel, or bank of any waterway that could adversely affect any fish or wildlife resources. Jurisdiction under section 1600 et seq. may apply to all lands within the 100-year floodplain, including the numerous desert washes on site that will be affected by the Project, which will require LSAA permitting compliance via the FSA/FEIS. The Department continues to work with the Commission to clarify authorities and roles under Fish and Game Code section 1600 et seq. as it relates to the Warren-Alquist Act and intends to provide additional clarifying recommendations at a later date.

In regards to CESA, the FSA/FEIS must: 1) provide a full and complete analysis and disclosure of the impacts of the proposed taking; 2) provide an analysis of whether project certification will jeopardize the continued existence of desert tortoise (or any other State-listed species) for which "take" coverage is being sought; 3) provide a proposed plan for compliance and effectiveness monitoring for mitigation measures, inclusive of an adequate desert tortoise translocation/relocation plan; 4) provide measures that minimize and fully mitigate the impacts of the proposed taking; and 5) provide a description of funding source and level of funding available for implementation of the minimization and mitigation measures.

The Desert Tortoise Recovery Plan (Recovery Plan) previously had the Ivanpah Project location within the proposed Desert Wildlife Management Areas (DWMAs) in the eastern and northeastern Mojave recovery units (Figure 9 of the Recovery Plan and states, "These desert tortoises (tortoises outside of DWMAs) may be important in recovery of the Mojave population by providing a source of adult desert tortoises for repopulating extirpated populations in DWMAs once translocation techniques have been perfected. Habitat outside DWMAs may provide corridors for genetic exchange and dispersal of desert tortoises among DWMAs.") The Recovery Plan also states, "In addition, isolated populations of healthy desert tortoise found outside of DWMAs should be noted, but no active management is recommended for these populations unless it is needed to ensure their viability. These isolated populations may have a better chance of surviving the potentially catastrophic effects of URTD [upper respiratory tract disease] or other diseases than large, contiguous populations." The Department believes this known population of desert tortoise in its natural habitat within the northern portion of Ivanpah Valley, but outside of a DWMA, may be valuable to the recovery of the species for the same reasons stressed in the Recovery Plan.

The Recovery Plan also states, "The desert tortoise is also listed as a threatened species under the California Endangered Species Act of 1984. Similar to the Federal Act, this legislation requires State agencies to consult with the California Department of Fish and Game on activities that may affect a listed species. Compensation is required by the California Department of Fish and Game for projects which result in loss of desert tortoise habitat." As previously described, CESA requires full mitigation for take of endangered and threatened species. Full mitigation is based on habitat and population characteristics present at the site. This CESA mitigation standard is more restrictive than the federal Endangered Species Act (FESA) "mitigate to the maximum extent practicable" standard.

The Department, the Commission, the U.S. Bureau of Land Management (BLM), and the U.S. Fish and Wildlife Service (Service) are working toward establishing a process to provide renewable energy applicants a combined mitigation standard meeting both state and federal obligations regarding FESA/CESA. The attached letter from the BLM demonstrates the progress made among the members of REAT to closely coordinate mitigation requirements for the Ivanpah Project and signals collaboration among the agencies to this end. In the interim, we recommend the Commission require mitigation sufficient to meet both the federal and state mitigation standards outlined above.

Also, in recognition of the landscape scale of renewable energy projects across the California desert and as part of the DRECP, work continues in an effort to identify mitigation and/or enhancement projects that directly meet the unique requirements of large-scale renewable energy projects in the California desert where conservation opportunities exist on both private and public lands. The vision for a completed Natural Community Conservation Plan (NCCP) for the California desert – as contemplated in the Desert Renewable Energy Conservation Plan (DRECP) – includes processes and mechanisms for pooling biological resource conservation funds and directing funding to the actions that most effectively produce conservation and recovery of target species. Early implementation of this conservation and renewable energy balance vision is a top priority for the REAT and is manifested through several actions currently underway for RPS projects. The NCCPA offers opportunities for consideration of early implementation through an "interim process" clause that provides for some flexibility in developing and directing project-level mitigation and conservation prior to approval of the DRECP.

The Department recommends consideration of an in-lieu fee program currently under development by the REAT to facilitate the processing and directing of impact compensation and conservation funding that may be provided by the applicant for the Ivanpah Project. The conceptual in-lieu fee program being developed for the DRECP would base habitat acquisition compensation on current land prices via appropriate appraisals and assign per-acre values for the purposes of habitat acquisition. Actual acquisition, through fee title, deed restriction, easements, or other mechanism, would then be carried out by a designated third-party and directed to areas identified through the DRECP process as supporting the highest conservation values. The REAT anticipates having a fully operational program in place early in 2010 that could accommodate an in-lieu fee from the applicant.

<u>CEQA and LSAA Comments</u>

Alternatives

CEQA and NEPA require a meaningful range of alternatives to be analyzed in the FSA/FEIS. The PSA is lacking in specific information to support many of the statements regarding the limited alternatives evaluated for the Project. The conclusions in the FSA/FEIS should be supported with the best available data for impacts to desert tortoise and plant species of concern that clearly indicate a comparable or at least higher level of impact to those resources than they are being impacted by the Project. For example, Ivanpah and Broadwell Dry Lakes should be studied and fully analyzed in the FSA/FEIS regardless of existing recreational use vs. "take" of an endangered species (Ivanpah), or the reported "equal" mitigation requirement due to presence of desert tortoise when the FESA standard may not represent the state CESA requirement for the location, and a significant reduction in total combined desert tortoise compensation may apply (Broadwell).

The Department also recommends a full analysis of alternate siting locations and scenarios in relative proximity to the existing Project footprint given the fact the current Project area is excellent tortoise habitat, with a low level of disturbance and high plant species diversity, yet lower quality habitat is clearly within range to potentially reduce the overall Project impacts to endangered and sensitive species.

Biological Resources Table 1

State Regulations- Fish and Game Code section 3503.5 Birds of Prey or Eggs should be included in this table. The code states it is unlawful to take, posses, or destroy any birds in the orders Falconiformes or Strigiformes or to take possess, or destroy the nest or eggs of any such birds.

Biological Resources Table 4
Waters of the State- The mitigation includes "....implement terms and conditions of state and federal permits." This is not adequate since the Department may not be issuing a Lake & Streambed Alteration Agreement (LSAA). Thus, the FSA/FEIS must include all measures that would be required in a LSAA, including all modification to the Project scope and mitigation as required in an LSAA.

For sensitive plant species, seeds could be collected for redistribution on compensation lands or within the general area. Specific types of compensatory mitigation must be identified in the FSA/FEIS.

Banded Gila Monster- Stating "Compensatory mitigation for desert tortoise may also offset impacts to Gila monsters" is inadequate. There must be a plan in place to address impacts to Gila monster should desert tortoise mitigation be insufficient to reduce Gila monster impacts to less than significant levels.

<u>Construction Impacts and Mitigation</u>

Impacts to Special-Status Plants
Since the drainage report is not completed, rare plants adjacent to the Project site may also be indirectly impacted by the diversion of Waters of the State.

The FSA/FEIS must address the outstanding conditions (BIO-14 and BIO-17) in enough detail to determine if the impacts to the plants species will or will not be reduced to less-than-significant levels.

Migratory/Special-Status Bird Species
"...the compensatory mitigation plan could offset the significant loss of habitat for these species." This section should be updated to either show that the compensatory mitigation does offset the loss, or other measures may need to be developed that will reduce impacts to less-than-significant levels.

<u>Impacts to Special-Status Mammals</u>
American Badger (*Taxidea taxus*)
The FSA/FEIS should include what will occur if a badger is found. Performing surveys for them does not avoid or minimize the impacts to the species. The process that will occur if a badger is found should be discussed in this section.

Nelson's Bighorn Sheep (*Ovis Canadensis nelsoni*)
Historically, Nelson's Bighorn sheep utilized the site during wet seasons when foraging in this area would have been the best. Since potential impacts to the sheep are not known at this time, it would be advantageous to enlist some basic measures to minimize direct or indirect impacts to bighorn that may utilize the area; e.g. moving back the fence at the base of the mountain range, not using barbed wire fencing in this location, checking known big horn sheep springs data periodically to ensure the Project wells are not adversely impacting sheep watering locations, and ensuring invasive plants have not taken over the springs are valid minimization measures that should be evaluated.

Desert Tortoise (*Gopherus agassizii*)
The draft translocation/relocation plan developed to date is inadequate to state that the desert tortoises are going to a "safe location". Based on past experiences, translocation in itself is not a "safe" process nor is it considered minimization or avoidance for the desert tortoises, but is a measure to salvage individuals on the site. Additional survey and biological assessment data and

information must be included in regards to translocation sites and identified in the FSA/FEIS.

Indirect Effects

Raven and Other Predators

For the Raven and other predators section, coyotes should be included in the evaluation as a predator to desert tortoise. As experienced during the Ft. Irwin translocation/relocation effort, coyotes can cause significant predation to desert tortoise, especially around areas where there is human activity and translocations of desert tortoise.

Increased Risk from Roads/Traffic

Another potential measure to minimize predation in the area would to be to require road kill, or other observed dead animals to be picked up and appropriately disposed of as soon as possible.

Impacts to Waters of the State/United States

The Department would like to stress that if waters are determined to have federal jurisdiction and/or permits which require modification of the drainage plan, those changes could directly or indirectly impact the Project scope and/or description, which could impact the final LSAA compliance conditions. The final jurisdictional requirements and conditions for federal and state agencies will need to be determined and disclosed in the FSA/FEIS.

Operation Impacts and Mitigation

In this section, it might be advantageous to mention the affect of night lighting on bats in the area. The bats may currently be using the site for foraging and will on occasion utilize the insect swarms that occur under bright lights. Monitoring of impacts to bats, including mortality found on-site, should be discussed with reduction of artificial lighting proposed as a potential mitigation measure.

Cumulative Impacts

Biological Resources Table 5

The last sentence of this section states "This significant cumulative impact may be reduced to less than significant levels with appropriate levels of compensatory mitigation..." The Department believes that it is premature to determine if the levels can be reduced to a level of less than significant due to the limited information on the compensatory mitigation being implemented for this Project. Without more detailed information, the Department does not agree that this Project will reduce impacts to a level of less than significant as it pertains to biological issues.

Permits/Consultations Required

It should be noted that the Department will not be issuing an Incidental Take Permit for this Project, but will work with Commission staff to ensure all requirements and conditions for those permits will be integrated into the conditions of certification recommended in the FSA/FEIS.

Proposed Conditions for Certification

Bio-1- The PSA's description of the Designated Biologist should be more in line with the U.S. Fish and Wildlife Service (Service) definition of a desert tortoise authorized biologist. As written, the Designated Biologist is not required to have any knowledge or approval to handle or survey for desert tortoise, yet the biologist will be directing the monitors to complete those tasks. Also, the designated biologist or a monitor should have knowledge on burrowing owl, gila monsters and badgers. The Department recommends for a project this long in duration that more than one designated biologist be approved and/or there be a mechanism which states how a new designated biologist will be approved.

Bio-3 – There are usually two classes of desert tortoise biologists; authorized biologist and biological monitor(s). In this condition, the description of the "biological monitor" is one the Department would use for the "authorized biologist". Some projects prefer to have what is normally considered a biological monitor, who is allowed to perform surveys, but does not have the qualification to handle desert tortoise. In addition, all biologists and monitors must complete and submit the U.S. Fish and Wildlife Service Desert Tortoise Biologist Qualification form.

Bio-4- The PSA states: "Biological monitors shall be or any aspect of desert tortoise surveys or handling..." It is unclear what point or issue is being stated here.

Bio-5- This section gives the biological monitors the same exact level of authority as the designated biologist without the monitors having the same over all knowledge of the Project components.

Bio-6- It would be advantageous if the Worker Environmental Awareness Program (WEAP) specifically addressed the protected species in the area with pictures. Also, if applicable, this presentation may be required in a different language. The WEAP should discuss that a gila monster is venomous and should only be handled by the biological monitor(s) with specific knowledge on how to handle them for the safety and well being of the species and humans on the Project site. Finally, the WEAP should discuss that species such as snakes and reptiles should be allowed to leave the site or be relocated by the biologist/monitor instead of being killed.

The Department recommends the biological information within the WEAP be taught by a biologist so specific questions, if asked by the workers, can be correctly answered on-the-spot.

Bio-7- Number 4 states: "terms and conditions, such as those provided in the permits or agreements with the Department and RWQCB." Since the Department will not be issuing permits or agreements for this Project this information must be discussed in the FSA/FEIS and reflected in the Biological Resources Mitigation Implementation and Monitoring Plan.

Bio-8 - Number 1 states for the clearance surveys, transects will be no more than 30 feet apart, but the Service guidelines for clearance surveys state transects are to be no more then 10 feet apart.

Number 2 states the permanent tortoise exclusionary fencing shall consist of galvanized hard wire cloth l-cm mesh sunk 15 cm into the ground (USFWS 2008). The fencing would be buried approximately 6 inches. The Service's usual recommendations are that the fencing be a 1" X 2" mesh size and buried 12", but no less than 6 inches underground. In addition, this section should state the fence should be 24" above ground, but not less than 18".

Number 6 states "Any pre-activity tortoise surveys for other construction areas would be performed within 72 hours of ground disturbing activities." This should only be allowed if there is a temporary fence enclosing the area. Otherwise, surveys must be performed immediately prior to any work because desert tortoise could, in certain seasons, move into and establish pallets in an area within the 72-hour time frame.

Bio-9-This section states a translocation plan will be developed and then states at least 60 days prior to start of any Project-related ground disturbance activities a final version shall be provided. For CESA and CEQA compliance purposes, relocation site surveys and assessment should be completed and the final plan should be included in the FSA/FEIS. Although the translocation plan is considered for some measures to be a working document, the critical information requested to date for this plan is required to determine the level of impact to the species as a result of translocation/relocation, and should be disclosed in the FSA/FEIS.

Bio-10- Number 9 should have any compliance reports or incidents of tortoise injury and/or mortality submitted to the Service <u>and</u> Department. The Department also needs to be included in any discussion on the determination of the final disposition or further actions to be taken for the injured animal.

Bio-11- Number 12 should include coyotes. Coyotes will, much like ravens, be able to access the site even with fencing, so the prevention of unnatural ponding water should be done both on and offsite.

Number 15 should state that the trash containers should be removed once full and removed or repaired if the self-closing mechanism breaks. Also, the WEAP should also stress that cigarettes and cigars are trash and should not be left on the ground within or outside the site, even if buried.

Bio-14- Until a revegetation and reclamation draft plan has been developed, the Department cannot make comments and recommendations necessary for implementation of revegetation and reclamation measures, but these measures should be in the FSA/FEIS.

Bio-18- The Department will not be issuing a separate LSA Agreement or ITP for this Project. All measures and mitigation that would normally be required in such permits will need to be included in the FSA/FEIS.

Bio-19 - The Department agrees the applicant should develop a facility closure plan addressing biological resource related mitigation measures. Any seed or plant mixtures used for revegetation of the Project site prior to closure will need to be approved by the Department and Commission.

Thanks again for all the effort to coordinate with the Department and agencies for this Project. Questions or comments regarding this letter may be directed to me at (916) 653-1070.

Attachments

cc: Mr. Terry O'Brien, Commission Deputy Director
Mr. Rick York, Commission Staff Biologist
Ms. Susan Sanders, CEC Staff Biologist
Ms. Misa Milliron, Commission Staff Biologist

Mr. Bruce Kinney, Inland Deserts Region
Mr. Scott Flint, CDFG, Habitat Conservation Branch
Mr. Curt Taucher, CDFG, Inland Deserts Region
Ms. Tonya Moore, CDFG, Inland Deserts Region
Ms. Becky Jones, CDFG, Inland Deserts Region

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
California State Office
2800 Cottage Way, Suite W-1623
Sacramento CA 95825
www.blm.gov

JUL 2 3 2009

In Reply Refer To:
2800 (CA930)P
(CACA-48668)

Mr. Kevin Hunting
California Department of Fish and Game
1416 Ninth Street
Sacramento, California 95814

Subject: Coordination of Mitigation for BrightSource Solar Development

Dear Mr. Hunting:

This letter confirms agreement between the Bureau of Land Management (BLM) and the California Department of Fish and Game (DFG) regarding mitigation measures for the BrightSource Energy solar development project near Ivanpah, California (CACA-48668).

The current per acre mitigation fee established by the California State Director should be updated to reflect current land value and recent purchase prices. BLM will work with DFG and the applicant to establish the updated value.

The BLM mitigation ratio of 1 to 1 will be applied within the mitigation ratio that DFG has determined for the BrightSource project. The BLM acknowledges and accepts that BLM's mitigation requirement will primarily fund implementation of recovery actions jointly recommended by BLM, DFG and the United States Fish and Wildlife Service (FWS) biologists, while the remaining mitigation requirement will fund land acquisition.

Deed restriction language approved by the Department of Justice will be included in the deeds for lands acquired for project mitigation and donated to BLM for long-term management.

For any land enhancement actions or recovery actions implemented on existing BLM-owned lands as part of mitigation for this project, BLM will develop a Memorandum of Understanding with DFG containing provisions for notification of any proposed projects affecting those lands. The BLM agrees that future projects that may degrade or diminish the recovery value of this mitigation action will be compensated at a higher rate.

Thank you and your staff for your effort in working with the BLM and the FWS in determining a solution that meets all of our agencies' goals and missions. We look forward to continuing our collaborative efforts to promote renewable energy while protecting a healthy and functional desert ecosystem.

Sincerely,

James W. Abbott
Acting State Director

EXHIBIT 610

Mojave Desert Ecosystem Program: Central Mojave Vegetation Database

Final Report

Prepared for:

Mojave Desert Ecosystem Program

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
Western Ecological Research Center &
Southwest Biological Science Center

Mojave Desert Ecosystem Program: Central Mojave Vegetation Database

By Kathryn Thomas[1], Todd Keeler-Wolf[2], Janet Franklin[3], and Peter Stine[4]

U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER &
SOUTHWEST BIOLOGICAL SCIENCE CENTER

Final Report

Prepared for:

Mojave Desert Ecosystem Program

[1]Colorado Plateau Field Station
USGS Southwest Biological Science Center
2255 N. Gemini Drive
Flagstaff, Arizona 86001

[2]California Department of Game and Fish
Sacramento, California

[3]Department of Geography
San Diego State University
San Diego, California

[4]Pacific Southwest Research Station
U.S. Forest Service
Sacramento, California

Sacramento, California
2004

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, SECRETARY

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information, contact:

Center Director
Western Ecological Research Center
U.S. Geological Survey
7801 Folsom Blvd., Suite 101
Sacramento, CA 95826

Center Director
Southwest Biological Science Center
U.S. Geological Survey
2255 N. Gemini Drive
Flagstaff, Arizona 86001

2004

Project Team

Principal Investigators

Administrative coordination

- Peter Stine, Pacific Southwest Research Station, U.S. Forest Service, Sacramento, California

Photo-interpretation and predictive vegetation modeling

- Janet Franklin, Department of Geography, San Diego State University (SDSU), San Diego, California

Vegetation classification

- Todd Keeler-Wolf, California Department of Game and Fish, Sacramento, California

Fieldwork oversight, data management, product compilation

- Kathryn Thomas, U.S. Geological Survey (USGS), Southwest Biological Science Center, Colorado Plateau Field Station, Flagstaff, Arizona

Collaborators

Department of Defense oversight

- Clarence Everly, Mojave Desert Ecosystem Program, Barstow, California

Climate modeling

- Joel Michaelsen, University of California Santa Barbara, Santa Barbara, California

Aerial photography

- Aircraft Data Facility, National Aeronautics and Space Administration (NASA) Ames Research Center

Staff

Field crew: Jim Thorne (crew leader 1997-98), Julie Evens, Sue Weiss, Casey Stewman, Michael Marion, Cristian Singer, Ryan Roberts, Mimi Murov, Fred Sproul, Ryan Stevens, Matthew Gilkey, Matthew Barmann, Nicole Good, Bridget Paule, Keith Pohs

Data management: Jon Helleson, Ryan Stevens, Elena Deshler, Kris Estes, Gina Mullen, J. Judson Wynne, Monica Hansen, Charis Corporation

Photointerpretation and predictive vegetation modeling: David Shaari (SDSU Project Manager); Clint Garrison, Stacie Hathaway, Alexandra Hofmann, Jennifer Miller, Peter Scull, Dena Simons, Richard Sperling, Alexandra Syphard (research assistants)

Vegetation classification: Kari Lewis, Ryelle Bueller, Jennifer Baumbach, Jeanne Wirka, Craig Bailey

Map compilation: Gina Mullen, Shawn Tousley

Acknowledgements

Many people have contributed in a variety of important ways to this project, including:

Dave Mouat, Environmental Protection Agency (project support)
Mark DePoy, Bureau of Land Management
Roy Dokka, Louisiana State University (landform data)
Joe Watts, Army Corp of Engineers (landform data)
Tom Zmudka, Bureau of Land Management, California Desert District (digital data)
Bruce Bingham
Bruce Coffland NASA – (aerial photography)
Jim Andre, Sweeney Granite Mountain Reserve (technical and logistical support)
Rob Fulton and Al Prigge, Desert Studies Center, Cal State University Fullerton (technical and logistical support)
Tom Edwards, Utah State University
Richard Toth, Utah State University
Denny Grossman, The Nature Conservancy
Pat Comer, The Nature Conservancy
Frank Davis, University of California (UC) Santa Barbara
Jim Quinn, Information Center for the Environment, UC Davis
Mike McCoy, Information Center for the Environment, UC Davis
Jennifer Lucas, Information Center for the Environment, UC Davis
Dennis Schramm, Mojave National Preserve
Charles Convis, Earth Systems Research Institute (ESRI)
Anne Kinsinger, USGS
T. Pavlis
Marion Reid, NatureServe
Keith Schulz, NatureServe
Gloria Maender, USGS
Scott Jackson, USGS

Model Review Workshop

Mark Bagley, private consultant
John Sawyer, Humboldt State University
Julie Evens, Sequoia and Kings Canyon National Park
Jim Thorne, UC Davis
Dana York, Death Valley National Park
Matt Brooks, USGS, Western Ecological Research Center
Al Romspert, Desert Studies Center
Jim Andre, Sweeney Granite Mountain Reserve
Monica Hansen, USGS, Colorado Plateau Field Station

And we thank them all! A project like this would not be possible without the contributed help of numerous individuals.

Contents

List of Tables

List of Figures

Introduction

The Department of Defense (DOD) and the other desert managers are developing and organizing scientific information needed to better manage the natural resources of the Mojave Desert. Scientific, natural, and cultural resource professionals in the Mojave have agreed upon the importance of developing mechanisms by which land management decisions can be made to maintain the Mojave Desert ecosystem while supporting sustainable economies, communities, and national defense preparedness. The Desert Managers Group (DMG), a federal/state partnership of land and resource managers working in the California portion of the Mojave Desert, contains within their mission (http://mojavedata.gov/partners.html) a charge to develop and integrate databases and scientific studies needed for effective resource management and planning. The Mojave Desert Ecosystem Program (MDEP) Legacy Program, which supports critical DOD installations, collects data needed to support the DMG mission.

Detailed vegetation distribution data, incorporated into a digital map, is a crucial baseline data set needed by the DMG. In 1996, the MDEP requested the U.S. Geological Survey (USGS) Biological Resources Discipline (BRD) to create a vegetation map using current vegetation classification standards in the Mojave Desert in California. The MDEP tasked BRD with detailing the scope of work, identifying the appropriate mix of expertise to accomplish the tasks, and managing the development of the products under the guidance of the MDEP and DMG.

We initiated work in September 1996. The USGS management team spent six months working with the Science and Data Management Team of the DMG and with a large number of field staff from all DMG agencies and other field experts. At the conclusion of this extensive scoping session, we developed a project schedule, the identified the products, and assembled the project core team.

With the level of funding available, we determined that we could map approximately 60%, five million ha of the Mojave in California. The areas selected represent a majority of public lands in the Californian portion of the Mojave (Figure 1), with an emphasis on certain DOD and Department of the Interior lands, referred to as the central Mojave in this report.

Project Products

The project produced a vegetation map for this area and ancillary maps and coverages to support the development of the vegetation map. Secondly, we reviewed and revised the classification of vegetation types in the Mojave.

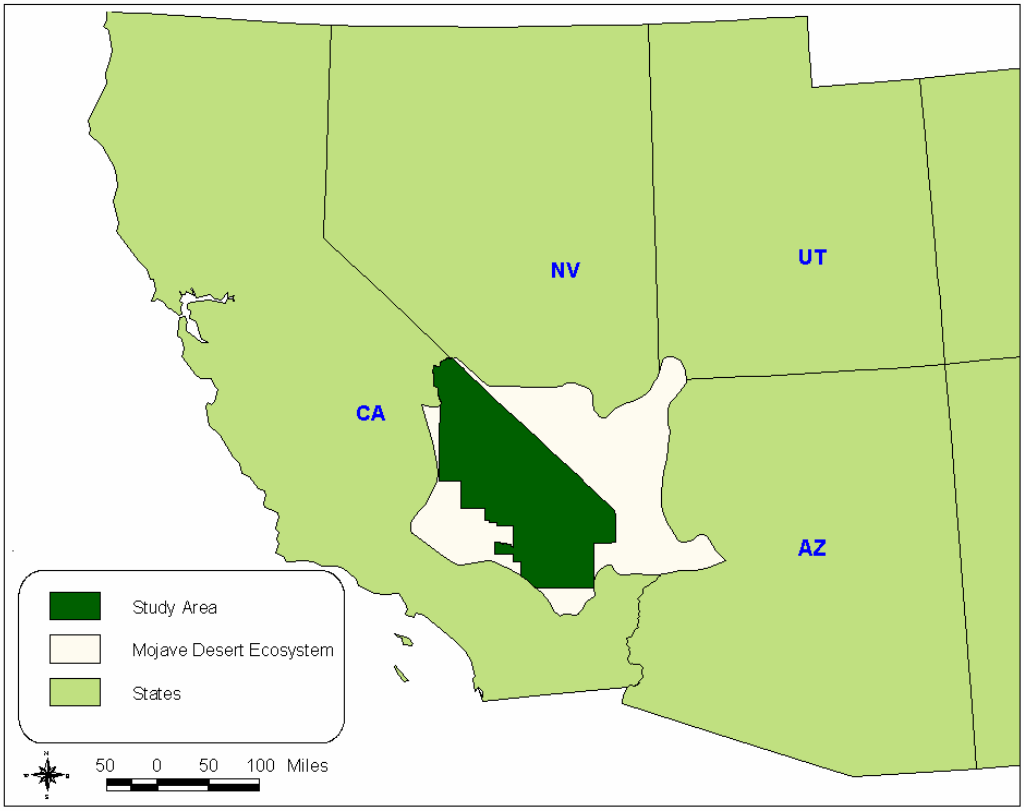


Figure 1. The project study area within the Mojave Ecosystem.

The target specifications for the vegetation map were:

Resolution:	Minimum mapping unit (MMU) is 5 ha and certain rare or localized types mapped as points
Coverage:	Estimated 60% of California Mojave
Thematic detail:	Alliance level for most vegetation types, some types are aggregated and mapped as complexes, and some alliances possibly divided into sub-units and mapped as associations if strong evidence exist for that detail
Datum:	Horizontal World Geodetic Systems of 1984 (WGS84), which is equivalent to North American Datum of 1983 (NAD83), Universal Transverse Mercator (UTM) projection Vertical - National Geodetic Vertical Datum of 1929
Accuracy:	80% thematic accuracy or confidence level

The resulting map products (four ArcInfo coverages and four grids) and associated metadata for each are compiled into the Central Mojave Vegetation Database. In addition, the compiled database includes the Access records for the classification relevés collected during this project. The Central Mojave Vegetation Database includes:

1. Central Mojave Vegetation Map: Vegetation types for the eastern Mojave Desert in California, at two levels of aggregation,
2. Central Mojave Environmental Type Grid: Environmental classes defined to stratify the study area to allocate the vegetation relevé samples,
3. Mojave Summer Precipitation Grid,
4. Mojave Winter Precipitation Grid,
5. Mojave January Average Minimum Temperature Grid,
6. Mojave July Average Maximum Temperature Grid,
7. Central Mojave Field Data Tables,
8. Central Mojave Plots Map: Locations of relevé locations measured for the project, and
9. Central Mojave Special Features Map: Potential and known locations of special vegetation features, that is rare vegetation or other features with less 5 ha extent

In this report we present a user's guide to the structure of each component of the Central Mojave Vegetation database and discuss the methods used to create it. We describe the production of the quantitatively based classification of Mojave vegetation. In the appendices is a list of currently accepted alliances in the greater Mojave Desert (Appendix A); an identification key based on floristic properties of the alliances (Appendix B) and descriptions of 70 alliances (Appendix C), 20 of which are new to the U.S. National Vegetation Classification.

The Central Mojave Vegetation Database is available on CD-ROM and as individual downloads through the web sites for the Mojave Desert Ecosystem Program or the USGS Colorado Plateau Field Station.

Vegetation Classification

Selection of the vegetation classification for a map has tremendous influence on the utility of the data for desert land managers. Quantitative, data-driven vegetation classification creates an unbiased source of information for all scientific and management applications, including map labeling. In addition, the vegetation classification is a stand-alone product that can be used with or without reference to the map.

The U.S. National Vegetation Classification, referred to as NVC in the report, (FGDC 1997, Grossman et al. 1998) is the standard classification throughout this project. The FGDC has adopted the National Vegetation Classification Standard (NVCS). It describes a hierarchical vegetation classification framework intended to encompass a uniform method of describing vegetation types across administrative boundaries and at the national level. It is important that as an agency map or inventory land cover, sufficient data are collected to accurately describe vegetation types for national reporting, aggregation, and comparisons. Adoption of the NVCS facilitates the compilation of regional and national vegetation distribution maps. NatureServe, the current managers of the NVC, have reviewed and approved the projects' classification for the Mojave at the alliance level.

The NVCS defines vegetation at several levels (Table 1). The physiognomically-based upper levels of the classification such as the formation or group are often used as a basis of broad regional or national assessments. The mid-resolution floristically based alliance is “a physiognomically uniform group of plant associations sharing one or more dominant or diagnostic species, which as a rule are found in the upper-most stratum of the vegetation" (Grossman et al. 1998). The association is the finest level of the hierarchy and is based upon additional dominant/diagnostic species. It may be used at local scales to address specific projects.

Table 1. Classification hierarchy in the U.S. National Vegetation Classification.

Class	Sub-class	Group	Formation	Alliance
I. Forest. Trees usually over 5-m tall with their crowns interlocking (generally forming 60-100% cover).	I.A. Evergreen forest. Evergreen species generally contribute > 75% of the total tree cover.	I.A.6. Temperate broad-leaf seasonal evergreen forest	I. A.6.n.b . Lowland or submontane winter-rain evergreen sclerophyllous forest	Ia.6.n.b.2 *Quercus chrysolepis* forest alliance
II. Woodland. Open stands Of trees usually over 5-m tall with crowns not usually touching (generally forming 25-60% cover)	II.A. Evergreen woodland. Evergreen species generally contribute >75% of the total tree cover	II.A.4. Temperate or sub-polar needle-leaved evergreen woodland	II.A.4.N.a . Rounded-crowned temperate or subpolar needle-leaved evergreen woodland	II.A.4.N.a.45 *Pinus monophylla* woodland alliance
III. Shrubland. Shrubs or trees usually 0.5 To 5-m tall with individuals or clumps not touching to interlocking (generally forming >25% canopy cover).	III.A. Evergreen Shrubland. Evergreen species generally contribute >75% of the total shrub and/or tree cover.	III.A.2 Temperate broad-leaved evergreen shrubland	III.A.2.N.h . Seasonally flooded temperate broad-leaved evergreen shrubland	III.A.2.N.h.2 *Pluchea sericea* seasonally flooded shrubland alliance
III. Shrubland. Shrubs or trees usually 0.5 To 5-m tall with individuals or clumps not touching to interlocking (Generally Forming >25% Canopy Cover).	III.B. Deciduous shrubland. Deciduous species generally contribute >75% of the total shrub and/or tree cover	III.A.5. Extremely xeromorphic subdesert shrubland	III.A.5.N.b . Facultatively deciduous extremely xeromorphic subdesert shrubland	III.A.5.N.b.11 *Coleogyne ramosissima* shrubland alliance
IV. Dwarf-shrubland. Low-growing shrubs and/or trees usually under 0.5-m tall, individuals or clumps not touching to interlocking (generally forming >25% cover).	IV.A. Evergreen dwarf-shrubland. Evergreen species generally contribute >75% of the total shrub and/or tree cover.	IV.A.2. Evergreen subdesert dwarf shrubland	IV.A.2.N.a . Extremely xeromorphic evergreen subdesert dwarf-shrubland	IV.A.2.N.a.6 *Ambrosia dumosa* dwarf-shrubland alliance
V. Herbaceous vegetation. Graminoids and/or forbs (including ferns) generally forming >10% cover with woody cover usually <10%.	V.A. Perennial graminoid vegetation. Graminoids over 1-m tall when inflorescences are fully developed, generally contributing to >50% of total herbaceous cover	V.A.5. Temperate or subpolar grassland	V.A.5.N.d . Medium-tall bunch temperate or subpolar grassland	V.A.5.N.d.3 *Pleuraphis rigida* herbaceous alliance

The NVC had not been extensively developed for California alliances. *The Manual of California Vegetation* (Sawyer and Keeler-Wolf 1995) was previously developed to address the need for a classification of vegetation in California. To build on the Sawyer and Keeler-Wolf descriptions of series in the Mojave, we collected and analyzed relevé data collected for this project or otherwise available and revised the classification to identify alliances compatible with the NVC, examples of which occur on Table 1.

The Central Mojave Vegetation Database

Central Mojave Vegetation Map

A total of 101 alliances have been identified as occurring within the greater Mojave Desert (see Appendix A), but not all of these alliances occurred in the study area. Alliances on the vegetation map are those that consistently occur in patches of at least five ha or more. Other alliances that we identified in the study area were not included in the map because they do not occur in patches as large as the minimum map unit. Where there is a field observation of one of these alliances, we included the observation point in the Special Features Map (see Central Mojave Special Features Map).

In the vegetation spatial database there are 31 primary vegetation type labels (label_1, label_2) consisting of alliances, alliances complexes, and land use type map labels and 12 systems consisting of groups of the primary map labels (Table 2). While the classification we produced defined alliances in the Mojave Desert, we did not find it possible to map most vegetation types directly to the alliance level. Our map labels have two levels of aggregation, fine and coarse. The finest level of mapping, "Label_1" and "Label_2", represents a single alliance or groupings of similar alliances (alliance complex) or a land use type. The coarser level of mapping, the "System", consists of “sets of alliances of mixed composition/physiognomy occurring in tight juxtaposition on the natural/semi-natural landscape” (Perlstine et al. 1998), the ecological complex in NatureServe terminology, and “sets of alliances within the same NVC class that are found in similar environments, and with similar spectral signatures. Component alliances often share species of the same genera, or at least family, in the upper-most vegetation stratum” (Perlstine et al. 1998), the compositional group in NatureServe terminology.

Structure

The Central Mojave Vegetation Map is a digital map (ArcInfo vector coverage, MojVeg.e00) with each polygon or map unit labeled with five database items:

Label_1:	Vegetation type representing an alliance, alliance complex, or land use type
Label_2:	Vegetation type representing an alliance or alliance complex that may also be found in the map unit
Source_1:	The source of information used to assign Label_1 (Table 3)

Source_2: The source of information used to assign Label_2, if present (Table 3)
System: Vegetation type representing groupings of alliances

The Central Mojave Vegetation Map is accompanied by a FGDC compliant metadata text file (MojoVeg_Metadata.txt) and embedded metadata that can be viewed with the ArcCatalog module of ArcGIS8. The citation for the coverage is:

> Thomas, K., J. Franklin, T. Keeler-Wolf and P. Stine. 2002. Central Mojave Vegetation Map. A Digital spatial database (ArcInfo). U.S. Geological Survey.

Table 2. Vegetation types in the Central Mojave Vegetation Map.

System	**Label_1, Label_2**	**Alliances, alliance complexes or land use represented**
Barren	Sparse vegetation	Less than 2% perennial vegetation
Creosote Bush Mixed Scrub	Creosote	*Larrea tridentata* Shrubland Alliance, *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance, *Larrea tridentata-Encelia farinosa* Shrubland Alliance (occasionally), *Ambrosia dumosa* Dwarf-Shrubland Alliance, *Encelia farinosa* Shrubland Alliance (occasionally)
Creosote Bush Mixed Scrub	Creosote-Brittlebush	*Larrea tridentata-Encelia farinosa* Shrubland Alliance, *Encelia farinosa* Shrubland Alliance
Creosote Bush Mixed Scrub	White Burrobush	*Ambrosia dumosa* Dwarf-Shrubland Alliance
Desert Grassland and Shrub Steppe	Galleta	*Pleuraphis jamesii* or *Pleuraphis rigida* Herbaceous Alliance
Desert Sink	Alkali Meadow/Sink	*Distichlis spicata* Intermittently Flooded Herbaceous Alliance
Desert Sink	Iodine Bush-Bush Seepweed	*Allenrolfea occidentalis* Shrubland Alliance, *Suaeda moquinii* Intermittently Flooded Shrubland Alliance
Desert Sink	Playa	Barren, around edges may find *Atriplex polycarpa*, *Atriplex confertifolia*, or *Atriplex canescens* shrubland alliances; *Allenrolfea occidentalis* Shrubland Alliance, *Suaeda moquinii* Intermittently Flooded Shrubland Alliance, *Pluchea sericea* Seasonally Flooded Shrubland Alliance, *Prosopis glandulosa* Shrubland Alliance, *Sporobolus airoides* Intermittently Flooded Herbaceous Alliance
Desert Wash System	Low Elevation Wash System	Barren, *Psorothamnus spinosus* Intermittently Flooded Shrubland Alliance, *Hymenoclea salsola* Shrubland Alliance, *Ephedra californica* Intermittently Flooded Shrubland Alliance, *Acacia greggii* Shrubland Alliance, *Chilopsis linearis*

		Intermittently Flooded Shrubland Alliance, *Encelia virginensis* Shrubland Alliance, *Ericameria nauseosa* Shrubland Alliance, *Eriogonum fasciculatum* Shrubland Alliance, *Hyptis emoryi* Intermittently Flooded Shrubland Alliance, *Lepidospartum squamatum* Intermittently Flooded Shrubland Alliance, *Prosopis glandulosa* Shrubland Alliance, *Tamarix* spp. Semi-Natural Temporarily Flooded Shrubland Alliance, *Viguiera parishii* Shrubland Alliance and occasionally more typically upland types such as *Atriplex hymenelytra* Shrubland Alliance, *Atriplex canescens* Shrubland Alliance, *Atriplex confertifolia* Shrubland Alliance or *Atriplex polycarpa* Shrubland Alliance
Desert Wash System	Mid Elevation Wash System	Barren, *Acacia greggii* Shrubland Alliance, *Prosopis glandulosa* Shrubland Alliance, *Chilopsis linearis* Intermittently Flooded Shrubland Alliance, *Ericameria paniculata* Intermittently Flooded Shrubland Alliance, *Viguiera parishii* Shrubland Alliance, *Baccharis sergiloides* Intermittently Flooded Shrubland Alliance, *Viguiera reticulata* Intermittently Flooded Shrubland Alliance, *Ephedra californica* Intermittently Flooded Shrubland Alliance, *Hymenoclea salsola* Shrubland Alliance, *Salazaria mexicana* Shrubland Alliance, *Encelia virginensis* Shrubland Alliance, *Ericameria nauseosa* Shrubland Alliance, *Eriogonum fasciculatum* Shrubland Alliance, *Lepidospartum squamatum* Intermittently Flooded Shrubland Alliance, occasionally more typically upland types such as *Atriplex hymenelytra* Shrubland Alliance and *Atriplex canescens, A. confertifolia* or *A. polycarpa* shrubland alliances
Desert Wash System	High Elevation Wash System	Sparsely Vegetated Wash, Unvegetated, *Prunus fasciculata* Shrubland Alliance, *Salazaria mexicana* Shrubland Alliance, *Hymenoclea salsola* Shrubland Alliance, *Salvia dorrii* Dwarf-Shrubland Alliance, *Viguiera reticulata* Intermittently Flooded Shrubland Alliance (occasionally), *Baccharis sergiloides* Intermittently Flooded Shrubland Alliance, occasionally more typically upland types such as *Artemisia tridentata* Shrubland Alliance
Interior Dunes	Dunes	Barren; Herbaceous Dunes Sparse Vegetation Alliance; *Panicum urvilleanum* Sparsely Vegetated Herbaceous Alliance; *Achnatherum speciosum* Herbaceous Alliance; *Pleuraphis rigida* Herbaceous

		Alliance; *Ambrosia dumosa* Dwarf-Shrubland Alliance; *Atriplex canescens, A. polycarpa* or *A. confertifolia* shrubland alliances; *Larrea tridentata* Shrubland Alliance; *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance; *Prosopis glandulosa* Shrubland Alliance, *Abronia villosa* Sparsely Vegetated Alliance
Land Use	Agriculture	Agriculture generally irrigated
Land Use	Mining	Mining pits and infrastructure
Land Use	Rural Development	Building, structures or surface development other than urban
Land Use	Urban	Towns and settlements as designated on the DeLorme Atlas (1998) and with multiple residences within the five ha mapping unit
Lava Beds	Lava Beds and Cinder Cones	Barren, *Atriplex hymenelytra* Shrubland Alliance, *Encelia farinosa* Shrubland Alliance, *Larrea tridentata-Encelia farinosa* Shrubland Alliance
Limber Pine-Bristlecone Pine Woodland	Limber Pine/Bristlecone Pine	*Pinus flexilis* Woodland Alliance, *Pinus longaeva* Woodland Alliance
Mesquite Bosque	Mesquite	*Prosopis glandulosa* Shrubland Alliance
Mid Elevation Mixed Desert Scrub	Blackbrush	*Coleogyne ramosissima* Shrubland Alliance
Mid Elevation Mixed Desert Scrub	Hopsage	*Grayia spinosa* Shrubland Alliance
Mid Elevation Mixed Desert Scrub	Joshua Tree	*Yucca brevifolia* Wooded Shrubland Alliance
Mid Elevation Mixed Desert Scrub	Menodora	*Menodora spinescens* Dwarf-Shrubland Alliance
Mid Elevation Mixed Desert Scrub	Mojave Yucca	*Yucca schidigera* Shrubland Alliance
Mid Elevation Mixed Desert Scrub	Nevada Joint-Fir	*Ephedra nevadensis* Shrubland Alliance
Pinyon Juniper Woodland	Big Sagebrush	*Artemisia tridentata* Shrubland Alliance, *Ephedra viridis- Artemisia tridentata* Shrubland Alliance
Pinyon Juniper Woodland	Juniper	*Juniperus californica* or *Juniperus osteosperma* Wooded Shrubland Alliance
Pinyon Juniper Woodland	Pinyon	*Pinus monophylla* Wooded Shrubland Alliance, *Pinus monophylla* - (*Juniperus osteosperma*)

		Woodland Alliance
Saltbush Scrub	Saltbush	*Atriplex canescens* Shrubland Alliance, *Atriplex polycarpa* Shrubland Alliance, *Atriplex confertifolia* Shrubland Alliance (when around playas)
Saltbush Scrub	Shadscale	*Atriplex confertifolia* Shrubland Alliance
Saltbush Scrub	Desert Holly	*Atriplex hymenelytra* Shrubland Alliance

Table 3. Source codes in the Central Mojave Vegetation Map

Source Code	**Source of map label information**
EXPERT1	Expert review workshop
EXPERT2	MDEP mapping team editors
FIELD1	San Diego State University photointerpretation team field observations
FIELD2	Relevé data, retrospective data, validation and editing observations
LSU	Landforms from Geomorphic Landform and Surface Composition
MOD1	First iteration predictive modeling
MOD2-100	Predictive modeling, all of polygon is predicted as a primary label
MOD2-25	Predictive modeling, 25-34% of polygon is predicted as a primary label
MOD2-35	Predictive modeling, 35-44% of polygon is predicted as a primary label
MOD2-45	Predictive modeling, 45-54% of polygon is predicted as a primary label
MOD2-55	Predictive modeling, 55-64% of polygon is predicted as a primary label
MOD2-65	Predictive modeling, 65-74% of polygon is predicted as a primary label
MOD2-75	Predictive modeling, 75-84% of polygon is predicted as a primary type
MOD2-85	Predictive modeling, 85-99% of polygon is predicted as a primary type
Photo-CPFS	Photointerpretation conducted at Colorado Plateau Field Station
Photo-SDSU	Photointerpretation conducted at San Diego State University

Methods

We assumed, based on literature review and personal observation, that floristic variation (at the alliance level) in the Mojave Desert is not strongly related to spectral reflectance as recorded in satellite imagery because vegetation cover is sparse and the substrate dominates the reflectance response. Although more details about vegetation can normally be discerned with aerial photography than with satellite imagery, many vegetation types, particularly desert types, are not identifiable, even with large-scale photography. We decided to use a hybrid approach where aerial photography was used to delineate polygons and each polygon was assigned a map label using information derived from one of five different sources of information on the vegetation types found at that location. Those sources were: 1) field observations; 2) photo-interpretation; 3) expert knowledge; 4) the Geomorphic Landform and Surface Composition GIS (GLSCGIS, http://mojavedata.gov/datasets.php?&qclass=geo), a spatial database developed by R. Dokka of Louisiana State University for the MDEP Legacy Program; or 5) predictive modeling.

We used the following steps, sometimes conducted concurrently, to develop the vegetation map:

- Delineate map polygons
- Develop map label information sources
- Assign labels to map polygons
-

Delineating Map Polygons

For this mapping effort, NASA's High Altitude Airborne Sciences Program obtained color aerial photography at approximately 1:32,000 scale between May 14 and July 24, 1997. Photo frames had a nominal overlap of 60 percent. Color diapositive transparencies were provided to us, some in 9 x 9 inch format (Wild-Heerbrugg RC30 metric mapping camera 6 inch focal length), and some in 9 x 18 inch format (Hycon HR-732 large scale mapping camera 24 inch focal length). Color positive contact prints were also developed for every other photo and provided to the vegetation sampling crew. NASA acquired photos during several missions, and using two different aircraft platforms, due to problems with cloud cover. Photos varied in quality, as a function of format and mission.

We also obtained SPOT panchromatic satellite imagery with 10-m resolution from the California Department of Fish and Game (copyright CNES/SPOT Image Corp. 1994) for the mapping area. This imagery was geocoded and terrain corrected (R. Dokka, personal comm.) and reprojected to UTM projection WGS84 datum. The imagery was provided to us in files corresponding to one half of each USGS 1:100,000 topographic map in the mapping area. As described below, we used the SPOT imagery as a base for delineated map polygons.

The aerial photography was to identify map polygons based on vegetation and land-surface characteristics. Following field reconnaissance, we determined we could delineate polygons based on tone, texture, and terrain features related to landform, soil or surface color, and sometimes plant size, tone, or density. Only large shrubs and trees could be resolved on the photos; even using magnification, small shrubs were not typically visible, especially when contrast with the substrate was poor.

We developed a classification of photo-interpreted preliminary labels with three attributes: vegetation type, landform, and vegetation cover. These preliminary labels indicated what criteria the photo-interpreter used to delineate the polygon. We used these labels to stratify the mapped area to apply the test predictive models separately to non-overlapping areas of the landscape representing subsets of the vegetation types. We included a photo-interpreted landform label because although there was a landform map available, the Geomorphic Landform and Surface Composition GIS (GLSCGIS), it was developed at a coarser scale (10 ha MMU). Our landform classification is simplified from that used in the GLSCGIS, but it was adequate for our vegetation mapping purposes and enabled us to assign landform labels to the finer-scale polygons that we delineated.

Rolls of photo transparencies were cut into frames, and placed in protective polypropylene sleeves. Polygons were drawn onto the sleeve and then visually transferred and digitized on-screen using the georeferenced SPOT image as a base map. Therefore, polygons had to be interpretable or “detectable” (their boundaries visible) in the SPOT image for them to be delineated. Interpreters first delineated landform boundaries, and then added any additional boundaries related to vegetation physiognomy (large shrubs, trees) and cover (as indicated by tone and texture).

The polygon map initially consisted of about 25,000 polygons ranging in area from approximately five ha to over 10,000 ha. While the nominal MMU was five ha and some polygons were slightly smaller, it is typical in a vegetation map for many polygons to range from 10-1000 times larger than the MMU (Franklin and Woodcock 1997). The largest polygons corresponded to undifferentiated bajadas and to dissected highlands with very sparse vegetation. Washes and small inselbergs were the finest-scale features. Washes were especially problematic to delineate because although their vegetation composition may contrast strongly with surrounding uplands, they are narrow linear features, often occurring in braided systems difficult to map at the MMU. We initially mapped a landform class that we called “Wash Systems” – a high density of small washes with the intervening areas of upland included in the polygons. During editing, we tried to separate all washes and upland while maintaining the specified MMU.

Delineated polygons do not necessarily correspond directly to vegetation alliance boundaries in many cases, but rather to those landscape units that we interpreted from the photos. We tended to delineate highlands (mountain ranges) into many small polygons corresponding to topography (slope facets) with no corresponding change in vegetation across boundaries. Conversely, we could not delineate vegetation changes that occur on one landform such as a bajada, or a highly dissected highland area, with no clear vegetation boundary visible in the air photos. A widespread example is a *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance on an upper bajada, which may be replaced by a *Larrea tridentata* Shrubland Alliance (associated with *Atriplex polycarpa* Shrubland Alliance) on finer, more alkaline soils nearer a playa or valley floor. We could not recognize this vegetation boundary in the photos, although we could commonly see it in the field. Delineation of polygons corresponding to these alliances could be achieved in the future through additional field-based mapping.

While we preserved all polygon boundaries in the final vegetation map so that the source and secondary label items are maintained for each polygon, an ArcInfo "dissolve" can be used to eliminate polygon boundaries between adjacent identical primary map labels. Alternately, the map may be viewed in ArcView with polygon boundaries eliminated for a presentation of contiguous vegetation labels without the polygon boundaries.

Map Label Information Sources

We used five main sources of information to guide labeling of the map polygons:

- Decision tree predictive modeling
- Photo interpretation
- Field observations
- Geomorphic Landform and Surface Composition GIS
- Expert knowledge

Map Labels from Modeling

An increasing number of large-area (regional to continental scale) land cover or vegetation maps are being developed, and many of them are based on satellite imagery and spectral pattern recognition. However, where floristic detail is required, some element of gradient modeling, predictive mapping based on the relationship between vegetation patterns and environmental gradients (Franklin 1995), can be incorporated. This method has been used in cases where the exclusive use of photo-interpretation or field observations of vegetation types is impractical due to the source material available (air photo quality and scale) and size of the area mapped.

Decision tree models (also known as classification or regression trees) were developed as one type of gradient modeling to predict the presence/absence of an alliance or group of alliances. Decision tree modeling is a non-parametric method of iteratively partitioning, or splitting of the data (the observed vegetation types) into increasingly homogeneous subsets or nodes with the use of decision rules based on threshold values of the independent variables (the environmental data). Breiman et al. (1984), Clark and Pregibon (1992), Austin et al. (1994), Franklin (1995, 1998), Quinlan (1993) Michaelsen et al. (1994), and Venables and Ripley (1994) discuss this modeling approach.

Decision tree modeling is essentially a multivariate, divisive, monothetic classification method. The statistical software presents an output that looks much like a dendrogram (hence, decision tree) with branches and nodes. It shows the probability of a dependent variable (in our case the alliances or groups of alliances being predicted) at a "terminal node." A terminal node is not split any further because it has reached maximum homogeneity or the number of observations in it is the minimum acceptable. Each terminal node is associated with a subset of the explanatory environmental variables used to develop the decision tree and an alliance or alliance group that the tree predicted to occur as a response of that particular subset of explanatory environmental variables. Decision tree methods can estimate the “probability” of an alliance or alliance group occurring with each subset based on its proportion of the observations at the terminal node (note that this is not a true probability as would be estimated by a logistic regression or other methods). These decision tree models can be converted into a script encoding the decision rules, which can then be used in a geographic information system (GIS) to produce a probability surface (a map of the probability of a vegetation type occurring) from maps of the environmental variables. Again, these probability maps have N discrete values where N is the number of terminal nodes, because the probability is simply estimated from the proportions of the training observations from an Alliance in a terminal node.

Decision trees can be used with continuous (regression trees) or categorical response variables (classification trees). In this study, we focus on the prediction of a dichotomous variable (vegetation type presence/absence); therefore, we used classification trees. We used the S-Plus software version 2000 for Windows (StatSci 1999) for statistical analysis. Conversion of the decision tree model into a GIS script was done with a customized C++ program.

We developed decision tree models for each of 20 training datasets, one for each alliance/alliance complex to be predicted. A training dataset consisted of a random subset of 75% of all available field observations recoded to presence/absence of each alliance or alliance group, and the value of the environmental variables at the location at which each field observation occurred (extracted from GIS maps). Each decision tree model was "cross-validated" (a S-Plus editing function) to determine a suitable number of terminal nodes that minimized unexplained deviance (remaining heterogeneity in the grouped observations) without over-fitting the model to the training data. The decision trees were "pruned" to the cross-validated size, and then "snipped" to remove nodes that were redundant. We verified the models with the test data (the other 25% of the observations). Then, we used all observations to develop the final decision tree models.

Explanatory Environmental Variables in the Decision Tree Model

We tested eight terrain, two landform and four climate variables and decided to use following terrain variables were used (Table 4):

1. Elevation - related to temperature and precipitation.
2. Slope - related to available soil moisture, soil depth.
3. Aspect - related to solar radiation, evaporative demand (water balance). This variable was “scaled” using a cosine transform to differentiate pole facing (moist), neutral, and equator-facing (dry) slope aspects. We used ((*cos*(aspect-225) +1) *100) as an index of "southwestness" (higher values are more xeric exposures).
4. Potential Solar Radiation or Topographic Solar Radiation - modeled incoming (potential) shortwave solar radiation as a function of terrain (elevation, slope, aspect, terrain-reflectance and horizon effect) assuming a clear sky (optical depth ~0.6). We calculated daily radiation for the winter solstice as an index of annual radiation.
5. Upslope Catchment Area - count of grid cells in the Digital Elevation Model (DEM) upslope from (draining into) a given grid cell (based on various flow distribution algorithms).
6. Topographic Moisture Index - Upslope Catchment Area scaled by the tangent of the slope. Related to available soil moisture as a function of drainage basin position and slope angle
7. Hillslope Position Index - surrogate for soil development, texture, moisture holding capacity. By automatically deriving streams and ridges from a DEM, Skidmore (1989) proposed that one could assign cells to hillslope position classes (ridge, upper midslope, midslope, toeslope) based on the relative distance

between the closest ridge and stream. We assigned cells a value from 1-100 based on their relative distance to the nearest stream and ridge.

8. Landscape Position Index - another measure of hillslope position. Average difference between a cell and neighbors (negative upslope, positive downslope) for a chosen search radius, *r* (4, 10 and 16 cells).

Simple (slope, aspect, and elevation) and complex (topographic solar radiation, topographic moisture index) terrain variables are related to vegetation patterns in other predictive mapping studies. Terrain variables were all derived from the pre-processed (seamless) mosaic of 1:24,000 30-m resolution USGS digital elevation models (DEM) provided for the study area by the Bureau of Land Management (BLM). Digital terrain models (30-m resolution, corresponding to 1:24,000 scale topographic quadrangles) were acquired from the USGS (http://rmmcweb.cr.usgs.gov/elevation/). The level 2 (root mean square error < ½ contour interval) quadrangles for the Mojave were made into a mosaic, and seams and other obvious errors were edited (T. Zmudka, BLM, personal comm.). We calculated slope aspect, angle, and flow accumulation (upslope catchments or contributing area) using ArcInfo functions (and the algorithms noted in Table 4).

Other variables were examined for their use. The GLSCGIS is a digital polygon coverage with three attributes: landform, surface composition and age. We used landform and surface composition as explanatory variables in the classification trees. We aggregated the surface composition classes for the decision tree modeling (Table 4) but we used the landform classes from the GLSCGIS without aggregation. We also used the four interpolated climate variables as explanatory variables in the classification trees. See the section of the report on Mojave Climate Grids for further information on the development of the climate grids. We also examined southwestness, upslope catchment area, and hillslope position index, but we did not use these variables in the predictive modeling.

Developing Labels for Wash Systems

Wash systems are a habitat characterized by hydrological process. All reference field data points designated *a priori* as alliances characteristic of washes were included in a “washplots” data subset. Upon reviewing our vegetation polygons it was determined that, because the delineated wash system polygons are large (five ha MMU), they will inevitably be composed of mixtures of wash alliances in most cases. Therefore, a set of wash system labels commensurate with the map scale comprises three groups of alliances – those occurring at low-, mid-, and high-elevations within the study area. The elevation boundaries and composition of these mixtures was determined by developing a classification tree using only elevation as a predictor variable. The result was three wash system types: “low elevation” (< 980-m), “mid elevation” (980 - 1482-m), and “high elevation” (> 1482-m).

We applied the wash system labels only to those polygons receiving “wash” photo-interpreted preliminary labels. Therefore, there is never an upland alliance label derived by predictive modeling for a photo-interpreted wash system polygon (and vice versa).

However, upland types do occur within the wash systems, and this is reflected in the definitions of the alliances expected in the map label.

Table 4. Explanatory variables examined for predictive modeling.

Used	**Terrain Variables**	**Source**	**Algorithm**	**Range of Values Used**
Yes	Elevation	USGS 7.5' DEM, 30-m grid		-85 – 3390 m
Yes	Slope	"	maximum difference (3x3 window)	0-78 °
Yes	Aspect	"	Direction of the maximum (eight classes)	0-300 °
Yes	Potential Solar Insolation	"	Clear sky, winter solstice, horizon effect, terrain reflected, Dubayah and Rich (1995)	0-383
Yes	Topographic Moisture	"	(Upslope Catchment Area)/tan(Slope), Moore et al. (1991)	0-22.6
Yes	Landscape Position	"	Average difference between a cell and neighbors (negative upslope, positive downslope), Fels and Matson (1996)	-1732 to 2311
Yes	Landform	GLSCGIS	Disaggregated classes	29 classes
Yes	Surface composition	GLSCGIS	Aggregated classes	6 classes: calcium carbonate, evaporite, igneous plutonic, igneous volcanic metamorphic, sedimentary
Yes	Winter precipitation	Mojave Winter Precipitation Grid	Interpolation using geostatistics and spatial regression	See table 7
Yes	Summer precipitation	Mojave Summer Precipitation Grid	Interpolation using geostatistics and spatial regression	See table 7
Yes	January average minimum temperature	Mojave January Average Minimum Temperature Grid	Interpolation using geostatistics and spatial regression	See table 7
Yes	July average maximum temperature	Mojave July Average Maximum Temperature Grid	Interpolation using geostatistics and spatial regression	See table 7

Developing Probability Maps

Initially, we used a modeling dataset of 2,008 point observations (relevés collected by fall of 1999 and some data from retrospective plots) to create a preliminary map of predicted alliance and alliance complex distributions. This map was field validated in the fall of 1999 using check maps of vegetation polygons overlain on satellite imagery. Based on the field validation and a review panel of Mojave vegetation experts, additional updating and editing of the map were planned based on collection of new field survey points. In the spring of 2000, we collected over 2,000 additional observation points.

A second modeling dataset with 3,819 point observations of vegetation types and their georeferenced locations (UTM northing and easting) was used for the final modeling effort. These consisted of project relevés, retrospective plots, and 1999-2000 survey observations. We selected twelve environmental variables from all the variables examined for predictive modeling (Table 4). These variables were obtained in digital format (with integer values and 30-m resolution) to cover the study area. The temperature data originally consisted of decimal values, so to reduce file size while retaining a range of variability each of the values was multiplied by 10. The four climate grids were originally one-km resolution, but we resampled them to 30-m resolution for consistency.

We created modeling datasets for training and testing for each of 20 vegetation types (Table 5), by adding a field indicating presence or absence of each type at each field point observation. For example, the dataset for *Atriplex canescens* Shrubland Alliance would contain a field named "p_a" where an entry of "p" indicates observations where this was the observed alliance and "a" indicates its absence.

The value for each environmental variable at each of the field point observations was extracted (ArcInfo "sample"). This resulted in a database containing the observed vegetation type, UTM coordinates at that site, and the value for each of 12 environmental variables at that site. We developed, pruned and snipped decision tree models predicting presence/absence of each of the 20 alliances. The resulting trees ranged in size from 12 to 41 terminal nodes. A C++ program was used to convert the classification tree rules into an AML (Arc Macro Language) script for use in ArcInfo. The AML generated consists of a series of “if-then” statements based on the threshold values of environmental variables, and the terminal node associated with those environmental criteria. We interactively edited each AML so that the terminal node number represented the proportion of observations in which the modeled alliance was present at that node, and this proportion is interpreted as a probability that the Alliance is present in the cell. When combined with grids of the environmental data, the AML generates an output grid where each grid cell meets the environmental criteria of one of the classification tree terminal nodes and has an associated probability of presence based on the observed data used to construct the model.

Table 5. Alliance and alliance complexes used in predictive modeling

Alliance	**NOTES**
Allenrolfea occidentalis Shrubland Alliance and *Suaeda moquinii* Intermittently Flooded Shrubland Alliance	Combined for predictive modeling and in map labeling.
Artemisia tridentata Shrubland Alliance and *Ephedra viridis-Artemisia tridentata* Shrubland Alliance	Combined for predictive modeling and in map labeling.
Atriplex canescens Shrubland Alliance	Combined after predictive modeling with other *Atriplex* alliances for assignment of map label.
Atriplex confertifolia Shrubland Alliance	Combined after predictive modeling with other *Atriplex* alliances for assignment of map label when located at playa edges
Atriplex hymenelytra Shrubland Alliance	
Atriplex polycarpa Shrubland Alliance	Combined after predictive modeling with other *Atriplex* alliances for assignment of map label.
Atriplex spp.	Combined after predictive modeling with other *Atriplex* alliances for assignment of map label.
Coleogyne ramosissima Shrubland Alliance	
Ephedra nevadensis Shrubland Alliance	
Pleuraphis rigida and *P. jamesii* Herbaceous Alliance	Combined for predictive modeling and in map labeling.
Grayia spinosa Shrubland Alliance	
Juniperus californica and *J. osteosperma* Wooded Shrubland Alliance	Combined for predictive modeling and in map labeling.
Larrea tridentata Shrubland Alliance	Combined with *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance and *Larrea tridentata-Encelia farinosa* Shrubland Alliance (in part) after predictive modeling for map labeling.
Larrea tridentata-Ambrosia dumosa Shrubland Alliance	Combined with *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance and *Larrea tridentata-Encelia farinosa* Shrubland Alliance (in part) after predictive modeling for map labeling.
Larrea tridentata-Encelia farinosa Shrubland Alliance	Used as a map label only where predictive modeling resulted in 85% or higher probability.
Menodora spinescens Dwarf-Shrubland Alliance	
Pinus monophylla Woodland and *Pinus monophylla* Wooded Shrubland Alliance	Combined for predictive modeling.
Salazaria mexicana Shrubland Alliance	Not included in map label set because of disturbance nature of alliance
Yucca brevifolia Wooded Shrubland Alliance	
Yucca schidigera Shrubland Alliance	

We used the AML's to generate 20 probability maps, one for each vegetation type modeled. The predicted probabilities for each vegetation type ranged from 0-100 initially and were reclassified (ArcInfo Grid "reclass") to five categories: 1 = <10% probability, 2= 11-49%, 3=50-64%, 4=65-84%, and 5=85-100% probability.

Each probability grid was clipped into "workareas" based on 1:100,000 topographic quads within the study area. In some cases, we further subdivided the probability grids for processing. We combined the 20 probability grids into a master probability grid (ArcInfo Grid "combine") for each workarea where each grid cell contained the 1-5 probability category for the 20 predicted alliances.

We extracted the database tables for the master probability grids (by workarea) into an Access database for further processing. Using these tables, we assigned one alliance to each grid cell by inspecting the probability categories for all 20 alliances for each cell and selecting the best possible prediction(s) for that grid cell. We visually inspected the probabilities in each cell to recode using a set of recoding rules described below. To develop the recoding rules, we examined the omission and commission errors for each alliance in each of the five probability categories. Based on that analysis, we used the following rules:

1. *Larrea tridentata/Ambrosia dumosa* Shrubland Alliance, *Larrea tridentata* Shrubland Alliance, and *Larrea tridentata/Encelia farinosa* Shrubland Alliance were combined into Creosote Bush Shrubland except when *Larrea tridentata/Encelia farinosa* Shrubland Alliance had a probability of five (85-100% prediction probability). The *Larrea* dominated alliances occur across gradients and are difficult to delineate except from ground-based observations.
2. The *Atriplex* alliances: *Atriplex canescens* Shrubland Alliance, *Atriplex polycarpa* Shrubland Alliance, and *Atriplex spinifera* Shrubland Alliance were combined into a Saltbush Complex. The *Atriplex* alliances occur in similar environments, often intermixing, and we generally could not delineate them as separate alliances except from the ground.
3. The recoding assigned the alliance with the highest prediction probability for that location. If a single vegetation type was predicted with a probability category of five or four (greater than 65%), we assigned the grid cell that label.
4. If more than one vegetation type had a probability category of four or five, we assigned the grid cell a combination of all the types with probability four or five.
5. If the highest predicted probability was three, two, or one, we assigned the grid cell the vegetation type with the highest probability.
6. If the Creosote Bush Shrubland was predicted with a probability equal to a non-*Larrea* dominated vegetation type, the we assigned the grid cell the non-*Larrea* dominated vegetation type. This rule was used because model performance (correct prediction of alliance presence/absence) is a function of both the probability threshold used to predict "presence" and the accuracy criteria used (omission or commission errors, or both). In particular, in models predicting a binary outcome, often a low probability threshold must be selected to minimize omission and commission, errors when the class is rare

within the sample. This is the case for most alliances except for the Creosote Bush Shrubland. In other words, if an alliance were rare within the sample, a trivial model that predicts it to be absent everywhere would have a high correct classification rate, but would have 100% omission errors.

The recoded grids were converted from raster to vector format to create check maps with preliminary map labels consisting of the assigned modeled alliance or alliance complex. We printed the check maps with ancillary information (select reference points, 1:24K topographic quad lines and names, road information from Digital Line Graphic data (DLG) to aid in georeferencing. A two-person field crew was given check maps with the directions to provide feedback on the preliminary map label assignments in specific areas. Before going to the field, the check maps were reviewed and questionable predicted map labels identified. Based on review from team members and the feedback of the field crew on the check maps, we decided that we would use the probability maps as only one of several data sources to assign final map labels to the photointerpreted polygons.

Map Labels from Photointerpretation

We delineated several land use types from the aerial photography and often cross-checked the delineation against land use in the Southern and Central California Atlas and Gazetteer (DeLorme 1998). These land use types included urban and rural development, mines, and agricultural fields.

Two vegetation alliances were labeled from photointerpretation: *Pinus monophylla* - (*Juniperus osteosperma*) Woodland Alliance could be sometimes identified on the aerial photography, as could *Prosopis glandulosa* Shrubland Alliance. The *Pinus monophylla* - (*Juniperus osteosperma*) Woodland Alliance was included in the map label "Pinyon" with *Pinus monophylla* Wooded Shrubland Alliance. The vegetation map includes Pinyon polygons labeled from the photointerpretation and from the predictive model. We labeled the Mesquite Bosque (*Prosopis glandulosa* Shrubland Alliance) polygons using photointerpretation, field observation, and expert review.

Map Labels from Field Observations

In this project, data from field relevés allocated by gradient directed sampling, retrospective data, and field observations collected extensively across the desert were used for three key purposes: 1) to develop a classification of vegetation types, 2) to develop models to predict the occurrence of alliances from environmental variables, and 3) to directly label some map polygons.

Vegetated areas with less than 2% total vegetation cover ("Sparse Vegetation") are difficult to model, and impossible to photointerpret (being virtually indistinguishable from barren). We found that sparse vegetation has some fidelity with certain landforms, occurring on dunes and playas (about 35% of the sparse vegetation relevés), and on eroded highlands (about 40%), but the remainder is divided among a variety of landforms including lava flow and montane talus/scree, and so on. In preliminary modeling, the model always predicted sparse vegetation as a mixture with other vegetation types. We chose to apply the Sparse Vegetation and Barren map label from direct field observations and from known association with landform defined habitats such as sand dunes, playas, and lava fields. The aerial photography and the GLSCGIS did not provide fine enough resolution data to distinguish sparse vegetation from desert pavement. The photointerpreted polygon coverage was updated with specified landform polygons extracted from the GLSCGIS coverage.

Map Labels from the Geomorphic Landform and Surface Composition GIS

In the Mojave, a few geomorphic units are strongly associated with the distribution of certain alliances. We have mapped habitat types that are important vegetation controllers in the Mojave – sand dunes, lava fields and volcanic cones, and playas (Table 2). Delineation of the geomorphic boundaries for these habitats was obtained from the GLSCGIS map.

Map Labels from Expert Knowledge

Nine Mojave Desert vegetation experts attended a project workshop in November 1999. The workshop attendees reviewed the first version of the vegetation map and provided information on the location of certain vegetation types that we had not been able to adequately sample. We used this information and observations made by the team mapping editors to guide polygon labeling in some cases.

Assigning Labels to Map Polygons

We labeled vegetation within polygons using the best available information for the location. Best available information was determined in the following order of priority:

1. Field observations where the observation was for an area at least the size of the minimum map unit (five ha). We obtained field observations from San Diego State University observations to support photointerpretation, photos of the relevés acquired as part of the project (1997, 1998, and 1999), and the validation assessment (2000).
2. Expert knowledge where a) the expert is known as an area authority, b) the alliance type is known to be discrete in its distribution, and/or c) the assignment could be based on the expert's use of ancillary data sources.
3. Photointerpretation for some alliances in the Pinyon system (*Pinus monophylla* - (*Juniperus osteosperma*) Woodland Alliance), Sparse Vegetation, all land use categories (Development, Mining, Agriculture, and Urban), Mesquite (*Prosopis glandulosa* Shrubland Alliance), and Limber Pine/Bristlecone Pine (*Pinus flexilis* and *Pinus longaeva* Woodland Alliances).
4. Modeling for Low Elevation, Mid Elevation, and High Elevation Wash Systems based on identification of wash alliances that occur within particular elevation

zones. We used elevation modeling of the field-collected relevé data and the descriptions of wash alliances as presented in Appendix B.

5. The GLSCGIS landform labels for Interior Dune, Lava Beds/Cinder Cones, and Playa.
6. Modeling for all other labels. We assigned model-derived map labels to photointerpreted polygons based on the area of predicted vegetation types for all grid cells within polygons (by a vector overlay of the polygon coverage on the raster recoded grids, ArcView "tabulate area"). These areas were exported to Access, and the percentage of each prediction in each polygon was calculated. Model map labels were assigned to each polygon based on the composition of predicted alliances within each polygon. The majority prediction was the first alliance assigned to each polygon. The Source item in the map coverage expresses the percent (100%, 85-99%, 65-84%, 55-64%, 45-55%, and so on) of the polygon that the model predicted as occupied by that alliance (Table 3).

Assigning Systems to Map Polygons

We derived the system labels from the map labels. Groupings of systems were designed using the systems developed by The Nature Conservancy (TNC) for their Mojave Ecoregional Planning as a guideline (Pat Comer, pers. Comm.).

Central Mojave Environmental Types Grid

The distribution of plant species and vegetation types can correlate with various physical environmental variables. We combined four climate variables and geologic substrate to create a Central Mojave Environmental Types Grid, which we also used in part to determine the locations to collect field data for the alliance classification and vegetation map. The main purpose of the Central Mojave Environmental Types Grid was to provide the first stage of stratification in a two-stage, random stratified sample of vegetation in the study area. The Central Mojave Field Data Tables section of this report describe allocating relevé locations, the field sampling methods, and results of sampling. In this section, we describe how the grid was developed. Franklin et al. (2001) also describe the development of the environmental grid and allocation of the sample of field relevé locations

Structure

The Central Mojave Environmental Types Grid is a digital map (ArcInfo grid, envtypes_grid.e00) that consists of one-square-kilometer grid cells each labeled by a combination of climatic and geologic substrate variables. The grid contains one hundred sixty-seven environmental classes (unique combinations of values of the climate and geology variables). Metadata documenting the Central Mojave Environmental Types Grid is also provided in a text file and embedded in the grid for viewing with the ArcCatalog module of ArcGIS8 (MojoEnvTypes_Metadata.txt). The citation for the coverage is:

Franklin, J. and D. Shaari. 2002. Central Mojave Environmental Types Grid. A digital spatial database (ArcInfo). U.S. Geological Survey.

Methods

The 1:750,000 scale geologic map of California (Jennings 1985) was the best available digital data on geologic substrate for the study area when the project began. This digitized map (ArcInfo grid, one-km^2 resolution) depicted about 22 categories in the study area. We aggregated these categories into eight geologic classes (Table 6) thought to best represent environmental gradients (water availability, nutrients) affecting plant species distributions.

The climate variables were derived from the four climate grids developed for this project. We inspected maps of each climate variable and histograms of their values to aggregate the variables into a small number of categories (Table 7). Regression analysis showed correlation between January average minimum temperature and elevation in the study area (r=-0.78), and so January average minimum temperature was finely divided into six categories that also reflect an elevation gradient. July average maximum temperature was divided into two categories using a threshold value of 35 °C. Winter precipitation shows a west-east gradient that was captured in three categories (Table 7). Summer precipitation shows relatively higher values in the eastern Mojave, and we captured this distinction using a threshold value of 40 mm to divide this variable into two categories.

In a GIS, we "overlayed" (intersected) the reclassified climate and geology grids to create the Central Mojave Environmental Type Grid (Franklin et al. 2001). Each one-km^2 grid cell in the map was labeled with a category for the climate variables and class from the geologic map. Overlaying the grid maps could potentially have produced 504 unique combinations or “environmental classes” (2 x 6 x 2 x 3 x 7). However, only 167 combinations occurred in the study area.

Mojave Climate Grids

We created four Mojave Climate Grids. We used them to develop the Central Mojave Environmental Types Grid described in the previous section and to provide climate data in the predictive modeling portion of the Central Mojave Vegetation Map.

Structure

Four climate grids were developed:

1. Mojave January Average Minimum Temperature (jan_tmp_grid.e00),
2. Mojave July Average Maximum Temperature (july_tmp_grid.e00),
3. Mojave Summer Precipitation (sum_ppt_grid.e00), and
4. Mojave Winter Precipitation (win_ppt_grid.e00).

Table 6. Geologic classes used to create Environmental Types Grid.

Class[1]	**Description (geologic map categories combined to form this class)**
Alluvium	Unconsolidated bajadas and alluvial fans; Quaternary, mainly Holocene marine and non-marine origin.
Older Alluvium	Old bajada and fans surfaces, consolidated into fanglomerates.
Aeolian Sand	Extensive sand deposits, sand sheets.
Playa	Quaternary playas.
Weakly lithified sedimentary rock	“Badlands” -- sedimentary rock of various ages and marine/non-marine origin.
Silicic-intermediate rock	Includes igneous plutonic, volcanic/metavolcanic, sedimentary/metasedimentary rock of various ages of silicic-intermediate composition (granite, diorite, rhyolite, andesite, gneiss).
Mafic-ultramafic rock	Includes igneous plutonic, volcanic/metavolcanic, sedimentary/metasedimentary rock of various ages of mafic-ultramafic composition (schist, basalt, gabbro).
Carbonate rock	Sedimentary/metasedimentary rock of various ages with carbonate composition (limestone, dolomite, marble).

[1] Based on aggregation of classes in the Geology Map of California, 1:750,000 scale (Jennings 1985).

Table 7. Classification of climate variables used in predictive modeling.

Climate Variable	**Mean and Range**	**Reclassified Category**	**Standard Error of Variable**
July average maximum temperature	35.5 °C (16.6 to 44.4 °C)	< 35 °C ≥ 35 °C	+/- 1.1 °C
January average minimum temperature	-0.0 °C (-11.3 to 4.8 °C)	< –7 °C, -7 to <-4.5 °C -4.5 to <–2 °C -2 to <0.5 °C 0.5 to <2 °C ≥ 2 °C	+/- 2.2 °C
Summer precipitation (May-October)	30 mm (11-146 mm)	< 40 mm ≥ 40 mm	+/- 30%
Winter precipitation (November-April)	124 mm (45-579 mm)	< 100 mm 100 to <175 mm ≥ 175 mm	+/- 30%

The grid cell size for each is approximately one-km² and each extends over the entire California Mojave. The temperature grids report monthly average maximum temperature in July and average monthly minimum temperature in January. Temperature values range from 16.6 to 44.4 °C for the July grid and –11.3 to 4.8°C for the January grid.

The precipitation grids report monthly average precipitation between the months of May to October for the summer grid and November to April for the winter grid. The values range from 11 to 146 mm in the summer grid and 45 to 579 mm for the winter grid (see Table 4).

The grid metadata are text files (MojoJanTemp_Metadata.txt, MojoJulyTemp_Metadata.txt, MojoSummerPrecip_Metadata.txt, and MojoWinterPrecip_Metadata.txt) and are embedded in each grid for viewing with the ArcCatalog module of ArcGIS8. The citations for the grids are:

> Michaelsen, J. 2002. Mojave July Average Maximum Temperature. A digital spatial database (ArcInfo). U.S. Geological Survey.
>
> Michaelsen, J. 2002. Mojave January Average Minimum Temperature. A digital spatial database (ArcInfo). U.S. Geological Survey.
>
> Michaelsen, J. 2002. Mojave Summer Precipitation. A digital spatial database (ArcInfo). U.S. Geological Survey.
>
> Michaelsen, J. 2002. Mojave Winter Precipitation. A digital spatial database (ArcInfo). U.S. Geological Survey.

Methods

Joel Michaelsen (Geography Department, University of California Santa Barbara, California) developed the climate maps by interpolating 30-year averages for the climatic variables from 104-135 climate stations over a 30 arc-sec (roughly one-km) grid. Averages were collected over a thirty-year period (1961-1990). We based the interpolations on a two-component statistical model similar to universal kriging (Bailey and Gatrell 1998; Venables and Ripley 1994). The first component consisted of multiple regressions between the climate variable of interest and latitude, longitude, and elevation. This component captured the large-scale variation, or trend, in the climatic variable. The residuals from the linear model predictions at the station locations were autocorrelated, and standard geostatistical models were fit to the variograms of the residuals. Since the presence of autocorrelated residuals violates the assumptions for ordinary least squares, the linear regression models were refit using generalized least squares with residual covariance matrices based on the spatial autocorrelation models. In addition to the model predictions, the method produces reasonable estimates of spatially varying prediction standard errors that account for uncertainties in the linear model predictions and spatial variability in the autocorrelation models. We used cross validation to diagnose any problems with misfit of either component of the climate models and flag potentially erroneous station data.

In effect, the climate model predictions were based on large-scale relationships captured by the linear regression models with adjustments made for deviations of nearby stations from the overall linear regression relationships. For much of the California portion of the Mojave, distances greater than the characteristic autocorrelation distances of 50-260 km separated stations. The primary exception was in the Antelope Valley, where stations were relatively numerous and local conditions somewhat different than in areas farther east. The standard errors of the models vary spatially, depending on the distance from the predicted location to the nearest stations.

Central Mojave Field Data Tables

The Central Mojave Field Data Tables contain the field observations made at 1,242 relevés (those located by random stratified sampling and surveyed in 1997-99). We used these data to help develop the vegetation classification and for developing the predictive modeling map labels used in the Central Mojave Vegetation Map.

Structure

The Central Mojave Field Data Tables contain five main tables and eight look-up tables (Table 8) organized in an Access file (Plot_Data.mdb). In addition to environmental and location data for the 1,242 relevés, cover, and strata data are presented for the perennial species found in the relevés.

A separate metadata file exists for the Access file. The citation is:

> Thomas, K., T. Keeler-Wolf, and J. Thorne. 2002. Central Mojave Field Data. A digital database (Access). U.S. Geological Survey.

Table 8. Central Mojave Field Data Tables.

Main Table Name	Items	Information type	Associated look-up table
GeoInfo	FinalPlotCode	Unique relevé identifier (divides the unique code into segments, which is useful for sorting)	xPlotCodes
	DSRVY	Date observations made	
	LSBoundry	Relevé within study boundary (Yes) or outside (No)	
	NPUTMX	UTM easting (NAD 27)	
	NPUTMY	UTM northing (NAD 27)	
	NPELEV	Elevation in meters	
	NSLOPE	Slope in degrees	
	NASPECT	Aspect in degrees	
Impact	FinalPlotCode	Unique relevé identifier	xPlotCodes
	CIMPACT1	Code for primary disturbance, if present	xImpact_Code

	CINTENS1	Intensity of primary disturbance	xIntensity
	CIMPACT2	Code for second level disturbance	xImpact_Code
	CINTENS2	Intensity of second level disturbance	xIntensity
	CIMPACT3	Code for third level disturbance	xImpact_Code
	CINTENS3	Intensity of third level disturbance	xIntensity
	CIMPACT4	Code for forth level disturbance	xImpact_Code
	CINTENS4	Intensity of forth level disturbance	xIntensity
	CIMPACT5	Code for fifth level disturbance	xImpact_Code
	CINTENS5	Intensity of fifth level disturbance	xIntensity
	CIMPACT6	Code for sixth level disturbance	xImpact_Code
	CINTENS6	Intensity of sixth level disturbance	xIntensity
SurfCvr	FinalPlotCode	Unique relevé identifier	xPlotCodes
	CSOILTEXTURE	Soil texture	
	CBASAL	Cover class for basal area of living plants	xCover
	CFINES	Cover class for exposed fine soil (<3 mm)	xCover
	CBEDROCK	Cover class for exposed bedrock	xCover
	CGRAVEL	Cover class for exposed gravel (>3 mm, <76mm)	xCover
	CCOBBLE	Cover class for exposed cobble (76 mm-25 cm)	xCover
	CSTONE	Cover class for exposed stone (>25-61 cm)	xCover
	CBOULDER	Cover class for exposed boulders (>61 cm)	xCover
	CLITTER	Cover class for organic matter not including living plant stems but including duff and fallen wood covering ground	xCover
VegData	FinalPlotCode	Unique relevé identifier	xPlotCodes
	Plant_Code	Code for observed plant (species, genus, or lifeform),	xPlantName
	CSPECIES	Species name	
	NVCR	Code for plant cover class, a few entries are blank because no data provided by field crew	xCover
	NPRCNT	% cover (midpoint of cover class if visual estimate not made)	
VegDes	FinalPlotCode	Unique relevé identifier	xPlotCodes
	CCOMTYPE	W=wetland, U=upland	
	CCOWSYS	Cowardin type (Cowardin et al 1979)	
	CSUBSYS	Cowardin subsystem (Cowardin et al 1979)	
	CCLASS	Cowardin class (Cowardin et al 1979)	
	CCHANNEL	Channel type	
	CLEAFPHEN	Code for leaf phenology	xLeafphen
	CLEAFTYPE	Code for leaf type	xLeaftype
	CPHYSCLASS	Code for leaf physiology	xPhysclass

	NS_MOSLICH	Cover class for moss	xCover
	NS_0CM25CM	Cover class for 0-25 cm strata	xCover
	NS_25CM50M	Cover class 25-50 cm strata	xCover
	NS_50CM1M	Cover class .5-1m strata	xCover
	NS_1M3M	Cover class 1-3m strata	xCover
	NS_3M5M	Cover class 3-5m strata	xCover
	NS_5M10M	Cover class 5-10m strata	xCover
	NS_10M20M	Cover class 10-20m strata	xCover
	NS_20M30M	Cover class 21-30m strata	xCover
	NS_30M	Cover class >30m strata	xCover
	CTOT_VEG	Total vegetation cover (class)	xCover
	CTOT_PRCNT	Total vegetation cover (%)	
	CTOT_TREE	Total tree cover (class)	xCover
	CPRCNT_TREE	Total tree cover (%)	
	CTOT_SHRUB	Total shrub cover (class)	xCover
	CPRCNT_SHR	Total shrub cover (%)	
	CTOT_GRND	Total ground layer cover (class)	xCover
	CPRCNT_GND	Total ground layer cover (%)	
	CTOT_EXOTI	Total non-native cover (class)	xCover
	CPRCNT_EXO	Total non-native cover (%)	

Methods

Gradient Directed Sample Allocation

We adapted the gradient-directed sampling protocol described by Austin and Heyligers (1989) with some minor modifications. Allocation of relevé locations was accomplished with two-stage stratification (see Franklin et al. 2001).

In the first stage stratification we:

1. Identified environmental variables influencing plant distributions in the study area,
2. Choose best available data (digital maps) for environmental stratification, and
3. Stratified the area for sampling by reclassifying the maps of selected environmental variables and combining them.

We identified climate and geologic substrate to represent the broad-scale environmental gradients affecting species distribution. We developed climate grids as part of the project (see Mojave Climate Grids section). Geologic substrate was the best available coarse scale digital data to represent nutrient and water availability gradients as influenced by substrate that was available when the sampling design was developed. We combined the climate grids and an existing geology map to create the Central Mojave Environmental Type Grid to direct the first stage stratification; the development of that grid is described in another section of the report, Central Mojave Environmental Type Grid.

For the second stage of stratification, we:

1. Identified variables to be used, and data depicting them, for a second stage of stratification at the local scale, and
2. Decided on the effort allocated for sampling the rare environmental types versus adding more replicates to common strata.

Topographic position, based on a simple classification of some digital terrain variables (Table 4), was selected for a second stage of stratification at the local scale because terrain (hill slope position, slope angle, slope aspect) exerts a strong influence on plant distributions at a finer spatial scale than bioclimatic gradients. This is important in the Mojave, where vegetation composition can change dramatically over short distances as a function of terrain position.

The terrain was classified into six categories for second stage sampling based on slope aspect and upslope catchment area (Table 9): drainage (areas of high flow accumulation, corresponding to washes and streams); flat terrain; gentle slopes (corresponding to most bajada surfaces); and steeper slopes, divided into three aspect classes corresponding to higher (southwest), lower (northeast) and intermediate values of insolation (southeast, northwest). This simple scheme captured first-order effects of terrain on vegetation, nested within the climate-geology stratification, in this desert landscape. Those effects are the influence of slope angle and drainage basin position on soil texture and moisture and the influence of slope aspect on solar insolation and evapotranspiration.

Table 9. Terrain classification for second-stage sampling.

Class	**Description (hierarchical decision rules)**
Drainage	Upslope catchment area greater than threshold value of 100 cells (9 ha)
Flat (<1% slope)	Slope less than 1%
Gentle Slope (1-10% slope)	Slope less than 10%
Northeast Aspect	Slope ≥ 10% and aspect 0 to <90°
Southwest Aspect	Slope ≥ 10% and aspect 180 to <270°
Neutral Aspect	Slope ≥ 10% and aspect 90 to <180° or 270 to <360°

Assignment of Relevé Locations

Field sampling was restricted to public lands. One hundred and sixty of the environmental classes identified for first-stage sampling occurred on public lands (seven very small classes occurred only on private lands). We estimated that resources were available to survey 1,000-2,000 vegetation relevés. The vegetation relevé locations were allocated among the environmental type classes based on weighting of the total area of the environmental class within the study area. The rarest environmental classes (≤ 7 km^2) were not sampled, but those environmental classes with less than 1,000 km^2 generally received more relevés per area and the most common environmental classes received fewer relevés per area (Table 10).

Table 10. Allocation of relevés in environmental cells.

Total area of environmental class	**Number of relevés assigned per class**
≤ 7 km²	0
8-10 km²	1
>11 km²	1
11-100 km²	1-2 each
100-1,000 km²	2-9
1,000-5,000 km²	10-15

A computer program randomly selected cells from the one-km^2 Environmental Types Grid up to at least 15 grid cells per environmental class (establishing both sample and alternate grid cells). Each of the 1,100 (33x33) 30-m terrain grid cells falling within the one-km^2 cells selected for sampling was then classified using the decision rules outlined in Table 10. We used the same computer program to allocate the second-stage sample – the actual relevé locations within the environmental cell. At least two locations were selected per terrain class from the terrain grid within each one-km^2 cell in the sample (again providing an alternate location). Terrain classes were only allocated a relevé location if they comprised at least 5% of the one-km^2 cells.

Field Collection of Data

The UTM coordinates of target sample locations were provided to the field crew. They developed travel routes and work plans to minimize travel time and arrange alternate transportation in roadless and wilderness areas. The crew navigated to the sample location using global positioning systems (GPS) with 5-10-m precision. Field crews were able to adjust their location by up to 90-m so that they did not locate a relevé on a boundary between distinctive vegetation stands. Actual coordinates of the field relevé were acquired in the field using UTM zone 11, NAD 27 so that the field crew could better determine their actual location using USGS 1:24,000 topographic maps (also in UTM zone 11, NAD 27).

The field crew identified all perennial plant species and estimated their cover in a 1,000 m^2 circular relevé. Cover was estimated to the nearest percent for each species and for each strata class (ground, shrub, and tree). All exotic species were noted. Annual species were also noted, but if the species was unidentifiable, it was noted as an unknown annual. In most cases, the field crew took a picture of the field relevé for later reference. Species data for each relevé were standardized to a common nomenclature using the USDA Plants Database (NRCS 1999).

The field crew assessed disturbance at each relevé site. They used a list of pre-determined stressors to indicate what was the primary disturbance type, if any, and the intensity of the impact. Additional disturbance types up to six levels were noted, if present.

Environmental data collected included elevation, slope, aspect, soil, landform, and geologic substrate. Elevation was determined using a military-grade GPS or, in a few cases, a 1:24,000 topographic map. Aspect was determined by aligning a compass to the direction that water would be expected to flow from the relevé and measured as the degrees from north. Slope was measured in that same direction using a clinometer. Aspects and slope measurements were made over a slope distance of approximately 90 m.

The field crew visually assessed landform and geological substrate categories. A preliminary classification of landforms and geology developed for the GLSCGIS was used in the field. The categories were aggregated into fewer types subsequent to field data collection. The seven aggregated landform categories are 1) rocky highland, 2) arroyo, 3) upland alluvial deposits, 4) wash, 5) fluvial floodplain, 6) playa, and 7) dunes and sand sheets. The five composition categories are 1) igneous 2) metamorphic, 3) calcareous carbonate, 4) evaporite, and 5) sedimentary. The six-person field crew received orientation to recognizing landform and composition categories, but they were not specifically trained in geomorphology or geology. The landform and geological substrate composition determinations by the field crew are not included in the relevé database, because an analysis showed the field determinations were not consistent among the field crew members (Thomas et al. 2002).

A quick characterization of soil texture was made by simply feeling the soil texture. The percentage of surface covered by living plants, litter, fine soil, and different sizes of rock particles was estimated in very broad categories. Finally, the field crew recorded the Cowardin hydrologic class (Cowardin et al 1979) for the site.

Sawyer and Keeler-Wolf (1995) describe additional details on field protocols.

Central Mojave Plots Map

Field-collected reference data used in this project consisted of relevés collected (described in the previous section), retrospective plots from other field-based projects conducted in the Mojave, and observations made for map development and validation, a total of 4,297 points. The location and alliance assignment for the reference data are included in the Central Mojave Plots Map. Additional relevés that were labeled with an alliance type that typically has localized occurrence (in an area less than five ha) are not included on the Central Mojave Plots Map but are included on the Central Mojave Special Features Map.

Structure

The Central Mojave Plots Map is a digital map (ArcInfo point coverage, plots.e00) that shows the occurrence of 4,297 relevés, plots, and observations. The coverage contains four unique items:

Plot_Num: The number assigned to the field observation in this project. The prefix of each plot number indicates the source of the data (Table 11). The last three digits in the plot number do not show on Table 11; each plot prefix ends with a unique sequential number assigned to that particular plot. All plots with the prefix CA-MDEP1 were relevés conducted during the course of the project and have associated field data (see Central Mojave Field Data Tables).

UTM_Y: The UTM northing for the plot location expressed in UTM Zone 11 NAD83 datum.

UTM_X: The UTM easting for the plot location expressed in UTM Zone 11 NAD83.

Label: The alliance, alliance complex, or land use assigned to that plot location (land use, alliance, or alliance group) (Table 2).

Metadata documenting the Central Mojave Plots Map is in a text file (MojoPlots_Metadata.txt) and embedded for viewing with the ArcCatalog module of ArcGIS8. The citation for the coverage is:

Thomas, K. 2002. Central Mojave Plots Map. A digital spatial database (ArcInfo). U.S. Geological Survey.

Table 11. Source of data in Central Mojave Plots Map[1].

Prefix	**Number of plots**	**Data source**
CA-MDEP1-xxx	1,242	1997, 1998, 1998 relevés obtained by project
CA-MDEP3-01-xxx	41	Existing data, Novak (1998)
CA-MDEP3-04-xxx	136	Existing data, Evens (2000)
CA-MDEP3-05-xxx	300	Existing data, Novak (1996)
CA-MDEP3-06-xxx	108	Existing data, Watts (1996)
CA-MDEP3-07-xxx	122	Existing data, Thomas (1997)
CA-MDEP3-08-xxx	152	Existing data, Root (1978)
CA-MDEP3-09-xxx	40	Existing data, Silverman (1996)
CA-MDEP4-xxx	2,197[2]	Spring 2000 observation points
CA-MDEP5-xxx		Fall 1999 observation points
TOTAL	4,297	

[1] CA-MDEP2, CA-MDEP3-02, and CA-MDEP3-03 were unassigned; [2] Fall 1999 and spring 2000 observation points are combined.

Methods

Project Relevé Data

The project team collected relevé data at 1,242 locations (see Central Mojave Field Data Tables) in the fall of 1997, winter and spring of 1998, and spring of 1999. We assigned each relevé an alliance label using an alliance key (Appendix C). The key was based on classification rules developed for this project (see Vegetation Classification section). The data for all 1,242 relevés from this project (the CA-MDEP1 series) are in the Central Mojave Field Data Tables.

Observation Data

Additional observations were made in the fall of 1999 and spring of 2000 (2,197 observation points) to support the predictive modeling and verification of the vegetation map. Field crews made extensive observations on the occurrence of alliances by driving any accessible road and making an observation every mile or every time the vegetation type changed. They used the alliance key to apply an alliance label at the time of the observation. Based on the field crew's comments, we edited and revised the alliance key.

Retrospective Field Data

A survey was conducted to identify existing (retrospective) vegetation studies in the Mojave Desert that had included collection of field plot data. We identified thirty-four different retrospective studies. We evaluated each study's methodology for collection of data to determine if the collection met the following criteria for inclusion in the reference dataset:

- A complete survey was made of perennial species including an estimation of cover for each species;
- Plots were taken within homogeneous stands;
- The study had a minimum of 20 samples; and
- Location of the plot was described with an expected 100-m accuracy.

Seven data sets existed that were used to validate the Central Mojave Vegetation Map (Table 12). We also used some of these datasets for vegetation classification. An additional five data sets were not sufficiently georeferenced for use in the reference dataset, but could be used for classification. Permission was obtained from the initial data developers to use plot data that passed inclusion criteria. We used plot data that met all inclusion criteria except for the positional requirement for vegetation classification and description only (Table 12).

Table 12. Summary of retrospective data accepted for reference and for classification.

Source	Geographic area	Purpose	Methods	N plots	Use[1]
Evens (2000)	Eastern Mojave Preserve	Thesis study	1,000-m^2 relevés	136	C,R
Johnson (1978A)	Eastern Mojave Scenic Area	Unit Resources Inventory for Desert Plan	100-pace toe-point within representative pre-delineated polygons	751	C
Johnson (1978B)	Saline Valley Area	Unit Resources Inventory for Desert Plan	100-pace toe-point within representative pre-delineated polygons	106	C
Long (1997)	Joshua Tree National Park	Preliminary vegetation mapping data	Relevés averaging 2,100 m^2 in representative stands	72	C
Novak (1998)	Marine Corp Air Ground Command Center	Base-wide Soil/Vegetation Survey	5-10 parallel 100-ft line intercepts per plot	41	C,R
Novak (1996)	Fort Irwin	Base-wide Soil/Vegetation Survey	5-10 parallel 100-ft line intercepts per plot	300	R
Prigge (1995)	Fort Irwin/Goldstone Military Reservation and Training Center	Pilot sampling strategy for proposed vegetation map	Belt transects 6-m wide and 100-200 m long	113	C
Root (1978)	Death Valley National Park	Ground truthing NASA-NPS Landsat Mapping	100 ft x 100 ft orthogonal transects from a central point	152	C,R
Schramm (1977)	Black Mountains, Death Valley National Park	Thesis research	Belt transect 100 yd x 6 yard, Line intercept two parallel 33-m lines	82	C
Silverman (1996)	China Lake	Ground truthing associated with separate China Lake mapping effort	Unknown	40	R
Thomas (1997)	Death Valley NP	Relevé for mapping project later included into this project	1,000-m^2 relevés	122	R
Watts (1996)	Fort Irwin	Preliminary data from vegetation mapping of Malapai Hill quad	100-m^2 plots with average size of all shrubs estimated for cover	108	C,R

[1] C = used in classification, R = used in map reference dataset (modeling, special features, and map validation).

We assigned alliance labels for the Root (1978) and Evens (2000) datasets by analysis of the species composition of each plot followed by correlation with the classification results of all the 1997-1999 project relevé data. The Novak (1996), Watts (1996), Novak (1998), Thomas (1997), and Silverman (1996) datasets were assigned alliance labels using a floristically based alliance key that summarized the rules developed to classify the field data (Appendix C).

Central Mojave Special Features Map

The Central Mojave Special Features Map shows known or potential point locations of alliances and unique stands that typically occur with less than five-ha extent. The Central Mojave Special Features Map is incomplete in its representation of all special feature vegetation stands. However, it is important to note the known or potential location of these alliances and unique stands where known as a starting place for future mapping at finer resolution. The Central Mojave Special Features Map serves as a template for more comprehensive development of a database describing rare or localized vegetation types, habitats, or plant species.

Structure

The Central Mojave Special Features Map is a digital map (ArcInfo point coverage, spec_feat.e00) with point locations. We obtained the point locations from existing digital maps, from hard-copy maps or literature descriptions, or from fieldwork conducted by this project or other Mojave field projects. The attribute table documents each point with these items:

Feature:	The type of feature at this point. The point can indicate a landform type expected to have co-occurring alliances or it can indicate a known or potential alliance.
Map_Label:	The name of vegetation type occurring at that point, if known. Types can be unique stands or defined alliances (Table 13).
Label_Type:	The physiognomic type of Map_Label.
Data_Source:	The source of information for the point.
Georef:	The manner in which the point was identified: 1) digital data where points were extracted from existing maps, 2) literature data sources where points were estimated based on descriptions in literature or hard copy maps, or 3) measured with a GPS in the field.
Plot_Num:	The plot number for data collected by this project either as field relevés or from other Mojave field projects. This can be used to access the full relevé data in the Central Mojave Field Data Tables.

Metadata documenting the Central Mojave Special Features Map is in a text file (MojoSpecFeat_Metadata) and embedded for viewing with the ArcCatalog module of ArcGIS8. The citation of the coverage is:

Mullen, G. and K. Thomas. 2002. Central Mojave Special Features Map. A digital spatial database (ArcInfo). U.S. Geological Survey.

The Central Mojave Special Features Map contains 1,414 point locations for 33 alliances and six unique stands (Table 13). Unique stands are populations of species that the NVC does not recognize as an alliance, yet are botanically and/or ecologically of interest.

Table 13. Central Mojave Special Features Map.

Label_Type (Physiognomic type)	**Map_Label (Alliance or Unique stand)**
Unique Stand	*Abies concolor* Unique Stand
Shrubland Alliance	*Acacia greggii* Shrubland Alliance
Unique Stand	*Amphipappus fremontii* Unique Stand
Shrubland Alliance	*Artemisia nova* Dwarf-Shrubland Alliance
Shrubland Alliance	*Baccharis sergiloides* Intermittently Flooded Shrubland Alliance
Unique Stand	*Bebbia juncea* Unique Stand
Unique Stand	Carothers Canyon Unique Stand
Unique Stand	*Castela emoryi* Unique Stand
Shrubland Alliance	*Chilopsis linearis* Intermittently Flooded Shrubland Alliance
Herbaceous Alliance	*Distichlis spicata* Intermittently Flooded Herbaceous Alliance
Shrubland Alliance	*Ephedra viridis* Shrubland Alliance
Shrubland Alliance	*Ephedra californica* Intermittently Flooded Shrubland Alliance
Sparse Vegetation Alliance	*Ephedra funerea* Sparse Vegetation Alliance
Shrubland Alliance	*Eriogonum fasciculatum* Shrubland Alliance
Shrubland Alliance	*Ericameria nauseosa* Shrubland Alliance
Shrubland Alliance	*Ericameria parryi* Intermittently Flooded Shrubland Alliance
Shrubland Alliance	*Ericameria teretifolia* Shrubland Alliance
Unique Stand	*Hecastocleis shockleyi* Unique Stand
Shrubland Alliance	*Hymenoclea salsola* Shrubland Alliance
Unique Stand	Keystone Canyon Unique Stand
Shrubland Alliance	*Krascheninnikovia lanata* Dwarf-Shrubland Alliance
Unique Stand	Live Oak Unique Stand
Shrubland Alliance	*Menodora spinescens* Dwarf-Shrubland Alliance
Unique Stand	*Mortonia utahensis* Unique Stand
Shrubland Alliance	*Nolina parryi* Shrubland Alliance
Herbaceous Alliance	*Phragmites australis* Semipermanently Flooded Herbaceous Alliance
Woodland Alliance	*Pinus flexilis* Woodland Alliance

Woodland Alliance	*Pinus longaeva* Woodland Alliance
Woodland Alliance	*Populus fremonitii* Seasonally Flooded Woodland Alliance
Shrubland Alliance	*Pluchea sericea* Seasonally Flooded Shrubland Alliance
Shrubland Alliance	*Prunus fasciculata* Shrubland Alliance
Shrubland Alliance	*Psorothamnus spinosus* Intermittently Flooded Shrubland Alliance
Shrubland Alliance	*Purshia mexicana* Shrubland Alliance
Shrubland Alliance	*Purshia tridentata* Shrubland Alliance
Forest Alliance	*Quercus chrysolepis* Forest Alliance
Shrubland Alliance	*Salix exigua* Temporarily Flooded Shrubland Alliance
Shrubland Alliance	*Salazaria mexicana* Shrubland Alliance
Unique Stand	*Simmondsia chinensis* Unique Stand
Unique Stand	*Swallenia alexandrae* Unique Stand
Shrubland Alliance	*Tamarix spp.* Semi-Natural Flooded Shrubland Alliance
Shrubland Alliance	*Viguiera parishii* Shrubland Alliance
Shrubland Alliance	*Viguiera reticulata* Intermittently Flooded Shrubland Alliance
Wetland Habitat	Unknown, no alliance or unique stand known, but identified as a location in the Feature item

Springs in the Mojave Desert often support vegetation alliances that occur at less than the five ha MMU. Locations of springs were added to the Central Mojave Special Features Map using USGS springs 1:24,000 (7 ½ minute) and 1:100,000 (15 minute) scale DLG's (see Tables 14 and 15). Polygon features were not included in the map. Not all points identified as springs, such as wells or windmills were deleted. We jointed the resulting quads of spring locations to form a single spring location coverage containing 640 spring locations.

The Death Valley National Park Resource Management supplied the National Wetlands Inventory (1986) map of riparian and wetland features for portions of Death Valley. We did not include point features for areas known to be devoid of vascular vegetation; for example, salt flats.

Maps developed by the BLM in association with the North and East Colorado Desert planning effort (BLM 1997 and BLM 1998) provided point locations of crucifixion thorn (*Castela emoryi*).

Point locations of relevés obtained during the 1997-99 project field work (see Central Mojave Field Data Tables) that we identified as alliances with localized distribution were included in the Central Mojave Special Features Map.

Table 14. 7.5-Minute DLG's used to determine spring locations.

Alvord Mtn. West	Anvil Spring Canyon West	Avawatz Pass
Baker	Ballarat	Bitter Spring
Blackwater Well	Cima Dome	Clark Mtn.
Copper Queen Canyon	Cow Cove	Coyote Lake
Cuddeback Lake	Crescent Peak	Crucero Hill
Deadman Pass	Death Valley Junction	Desert
Dunn	East of Echo Canyon	East of Ryan
Echo Canyon	Emigrant Pass	Epaulet Peak
Franklin Well	Gold Valley	Goldstone
Greenwater Canyon	Harris Hill	Hart Peak
Hopps Well	Ibex Spring	Ivanpah Lake
Jackass Canyon	Jail Canyon	Langford Well
Leach Lake	Manly Fall	Manly Peak
Maturango Peak NE	Mescal Range	Mineral Hill
Nelson Range	Old Ibex Pass	Pachalka Spring
Panamint	Paradise Range	Quail Spring
Red Pass Lake NE	Resting Spring	Saddle Peak Hills
Salsberry Peak	Shenandoah Peak	Shore Line Butte
Shoshone Soda	Soda Lake North	Soda Lake South
Sourdough Spring	Stump Spring	Tecopa
Tecopa Pass	Telescope Peak	Valjean Hills
Valley Wells	West of Baker	West of Nelson Lake
West of Shenandoah Peak	West of Soda Lake	Wildrose Peak

Table 15. 15-Minute DLG's used to determine spring locations.

Amboy East	Amboy West	Beatty West
Big Bear Lake East	Cuddeback East	Darwin Hills East
Darwin Hills West	Davis Dam West	Death Valley Junction East
Death Valley Junction West	Ivanpah East	Ivanpah West
Las Vegas West	Last Chance East	Last Chance West
Mesquite Lake East	Mesquite Lake West	Needles West
Newberry Springs East	Newberry Springs West	Owlshead Mountains East
Owlshead Mountains West	Ridgecrest East	Ridgecrest West
Saline Valley East	Saline Valley West	Sheep Hole Mts. East
Sheep Hole Mts. West	Soda Mountains East	Soda Mountains West

Literature data sources

During the summer of 1998, we undertook an extensive review of published descriptions of vegetation types with localized distribution. We reviewed the Mojave Desert Ecosystem Program Spatially Referenced Bibliography (http://www.mojavedata.gov/Home/Catalog/ Spatialy_referenced_bibligraph/spatialy_referenced_bibligraph.html) and two survey trips were made to agency offices in the Mojave to identify existing literature and database sources that could contribute to the Central Mojave Special Features Map.

The locations of potential special-feature locations come from the literature (Table 16). In most cases, the UTM location of the point for the feature is from written descriptions and only approximates the location of the feature.

Table 16. Literature sources for alliance locations

Data source	**Information**	**Location determination**
Stone (1983)	Location of calcicolous taxa (potentially *Mortonia utahensis, Artemisia nova, Nolina parryi, Cercocarpus intricatus)*	UTM determined from 7 ½' topographic map based on place name and location description
Hendrickson and Prigge (1975)	Location of *Abies concolor*	UTM determined from 7 ½ ' topographic map based on descriptions found in the literature
BLM (1986)	Location of a rupicola assemblage (*Quercus chrysolepis*)	UTM determined from 7 ½' topographic map based on descriptions found in the plan
Prigge (1979)	Location of *Abies concolor* in the Clark Mountain Range	UTM determined from 7 ½ ' topographic map based on location description

Field collected data Sources

Point locations of alliances recorded in the field but used to develop the Central Mojave Vegetation Map were also included in the Central Mojave Special Features Map. These field efforts include work overseen by Root (1978) in Death Valley, thesis work conducted by Evens (2000) in the Mojave National Preserve, Novak (1996) in Ft. Irwin, Novak (1998) at Marine Corp Air Ground Command Center (29-Palms), and by this project in 1997 through 2000.

Each data source was inspected for its potential use in the predictive modeling phase of the project. We classified these field data into alliances using the alliance key. Alliances that were not part of the predictive modeling data set were included in the Central

Mojave Special Features Map. The locations of the alliances were determined from the raw field data sheets provided by the data developer and converted to UTM zone 11 NAD83 datum, where conversion was needed.

Mojave Vegetation Classification

Quantitative classification of vegetation for the Mojave Desert has never been previously attempted. Before Sawyer and Keeler-Wolf (1995), all previous classifications (Munz and Keck 1950, Thorne 1976, Cheatham and Haller 1975, Holland 1986, Mayer and Laudenslayer 1988) derived from anecdotal habitat-based descriptions of vegetation types and lacked a systematic and synoptic view of the region. Sawyer and Keeler-Wolf (1995) reviewed all published analyses of desert vegetation. However, their classification was in many cases speculative and without quantitative data for several series they describe. Several major quantitative efforts have been undertaken in the ecoregion but have never been analyzed comparatively or comprehensively (Root 1978; Johnson 1978a, 1978b; Prigge 1995). Most of these have dealt with relatively circumscribed sub-regions of the Mojave.

Structure

This part of the project resulted in modifications to the NVC for the Mojave. With the contribution of 20 new alliances to the NVC by this project, 101 alliances are recognized in the greater Mojave Desert (Appendix A) with another six proposed. Fifty-one of these alliances are mapped either individually or in alliance complexes in either the Central Mojave Vegetation Map or the Central Mojave Special Features Map. Appendix B provides descirpitons and photographs of 70 of the 101 Mojave alliances. Appendix C provides a key to alliances found in the study area.

Methods

Developing a standardized, quantitative classification of the vegetation for the Mojave Desert involved several steps. In brief, the steps are as follows:

1. Accumulate existing literature and combine into preliminary classification,
2. Accumulate and analyze all vegetation data available for a preliminary data-driven classification based on retrospective data,
3. Use field sampling conducted during this project to capture all bio-environments in the study area and fill in the gaps in the existing classification,
4. Analyze these new relevés to develop quantitative classification rules,
5. Standardize the classification with the NVC,
6. Combine the retrospective and the new data into a completed classification, and
7. Develop keys and descriptions to all the alliances of the mapping area.

Existing Literature Review

Beginning in the fall of 1997, we made a literature search for existing information on vegetation classification of the Mojave. Information from Sawyer and Keeler-Wolf (1995), Bourgeron and Engelking (1994), TNC and NatureServe regional ecologists (P. Bourgeron personal com., R. Crawford personal com., P. Comer personal com., M. Reid, personal com., K. Schulz, personal com.) were synthesized to obtain the most current view of the NVC for the mapping area. Much of the information that went into the existing Mojave classification was collected outside of the mapping area in Nevada, Utah, or Arizona. Although some quantitative studies were available, these studies were typically of small subsets of the vegetation and were not necessarily developed directly for the purpose of classification.

This information was synthesized into a preliminary classification for the Mojave at the alliance level. Because the spatial resolution of the alliance units of vegetation classification is highly variable, notes were also made on the "mapability" of each of the alliances thought to occur in the area. Mapability is defined by visual distinctiveness, that is, contrast, tone, texture, and context in photointerpretation, and size of a typical stand relative to some standard (the project's five ha MMU). A preliminary classification of Mojave Desert Alliances nested within associated formations, and a set of notes about how alliances might need to be aggregated for mapping, was produced following initial literature review and was used to direct work at the beginning of the Central Mojave Vegetation Mapping Project.

The literature review described 80 alliances within the mapping area, a geographical subset of the greater Mojave Desert, several of which might need to be aggregated with other adjacent alliances because they did not meet the criteria for mapping in this project. Some of these alliances, such as several California chaparral alliances, were included because of the uncertain boundaries of the project in its initial stages. We eventually eliminated these when the project boundaries became more constrained.

Retrospective Field Data for Classification

The second phase of the classification involved investigating the various sources of existing vegetation data. We assembled potential data sources into a table with salient characteristics noted. These data sources represented unpublished field data for several studies with various purposes. The team assessed each each of these sources for vegetation classification. Some were deemed inappropriate for various reasons such as sampling methodology, non-systematic approach, or small sample size. There were also datasets that we could make available. Between the summer of 1997 and 1998, we assembled all usable and available data. The majority of these data had never been analyzed or assembled beyond the stored original field data sheets. Table 12 lists the existing data sources used in the classification, their locations, the number of samples, and the methodology for each of the data sets.

The field data in these studies consisted of location, environmental characteristic, species composition, and cover data. The most consistent and important part of these data was species composition and cover information. In our review of these data, we evaluated the dataset's location information to determine if it was specific enough to be usable in the modeling. We also evlauted the nvironmental data provided bu in general it was variable in resolution and not specific enough or systematically complete to provide adequate ecological characterizations for the vegetation. Long (1997), Johnson (1978a, 1978b), Watts (1996), Evens (2000), Thomas (1997), and Schramm (1977) data were entered into a spreadsheet (plots in rows, species abundances in columns) while others such as Root (1978) were entered into Cornell Condensed Format (Gauch 1982).

Due to the various methods and purposes of data collection, we analyzed all data sets individually. The intent was to compare results from each data set and assemble it into a systematic “existing classification.”

The most extensive and consistently collected of the existing data sets is the Johnson data (1978a, 1978b). It consisted of a data set from the eastern Mojave area and the Saline data set from the northwestern Mojave. This effort was a unit resource inventory for the BLM’s California Desert Plan. For all three sub-sets, initial vegetation polygons were drawn from 1:130,000-scale aerial photography within selected portions of the Mojave. Within each of the polygons, one or more representative 100-pace toe-point transects were taken. The inventory collected data on elevation, slope direction, slope steepness, landforms, soil surface characteristics, cover of perennial plants, and presence of annuals. Thus, the inventory collected from the three focus areas about 870 vegetation samples using the same methodology. Other data sets were less extensive and more localized and consisted of 72 to 152 individual plots.

Analysis of Retrospective Classification Data

The analysis of existing data was conducted with the PC-Ord software suite of ordination and classification tools (McCune and Mefford 1997). PC-Ord allows the use of disparate types of data in classification programs such as TWINSPAN (Hill 1979) or Cluster Analysis (McCune and Mefford 1997), whether entered in various spreadsheet, database, or condensed formats.

The classification analysis for all existing data followed a standard process. First, all sample-by-species information was subjected to two basic TWINSPAN runs. The first used presence/absence of species with no additional cover data considered. This provided a general impression of the relationships between all the groups based solely on species membership. The second used a standard default run, where cover values are converted to five different classes including:

Class I	merely present to 2%
Class II	>2-5%
Class III	>5-10%
Class IV	>10-20%, and
Class V	>20% cover

These cover values are reasonable for the typically light cover of most desert vegetation. The first three cover classes compose the majority of the species values. This second run demonstrated the modifications of cover values can make on the group memberships. Depending on the size of the data set, the default runs were modified to show from 6 to 12 divisions (the largest data sets were subdivided more than the smaller data sets). A minimum group size of three observations was specified for all runs. The intent was to display the natural divisions at the finest level of classification (the association) rather than the alliance level.

Following each of these runs, we identified and compared consistent groupings. After identifying natural groups in TWINSPAN, Cluster Analysis using Ward's scaling method and Euclidean Distance (McCune and Mefford 1997) measure was employed for an agglomerative view of grouping as opposed to the divisive grouping in the TWINSPAN algorithm. The congruence of groupings between TWINSPAN and Cluster Analysis was generally close. Disparities were resolved by reviewing the species composition of individual samples. Most of these uncertain plots either represented transitional forms of vegetation that are either borderline misclassified plots or outliers with no similar samples in the data set.

For each of the data sets, we developed a list of groupings based on the combination of TWINSPAN and cluster analysis runs. These lists were developed into a preliminary classification of 37 alliances for the existing data.

Analysis of Project Field Data

Following the 1997-98 sampling effort (see Central Mojave Field Data Tables), 1,242 vegetation relevés were available for analysis. The process of analysis of the new data was similar to the existing data analysis with some modifications. This was the largest uniform set of data collected throughout the mapping area based on a random stratified sample and was used as the principal means of defining the alliance composition throughout the mapping area. As a result, we employed careful scrutiny of the membership of each defined grouping to establish membership rules for all existing relevé data and to set the standard for the definition of the alliances.

The process of defining vegetation alliances and assigning relevés to alliances generally followed these steps:

1. Identify the most distantly related relevés using PC-ORD outlier analysis. These relevés usually are vegetation types at either ends of an environmental gradient, such as alliances associated with alkali sinks or high-elevation pinyon or bristlecone pine alliances.
2. Determine the general arrangement of species along the first axis of a detrended correspondence analysis (DCA) using TWINSPAN. The general gradient was of *Allenrolfea occidentalis* Shrubland Alliance and *Prosopis glandulosa* Shrubland

Alliance relevés at low end and *Pinus monophylla* Woodland Alliance relevés at other end.

3. Examine the general variation in arrangement of samples by running different permutations of TWINSPAN. Generally the samples held together well throughout the different permutations, and the main gradient did not vary.
4. Determine the final representative TWINSPAN run to use in the preliminary labeling.
5. Assign alliance and association (when possible) labels to each of the relevés.
6. Identify the major break points (main divisions) in TWINSPAN of the full data set and do individual TWINSPAN runs on major subsets of data (upper elevation scrub, *Larrea tridentata-Ambrosia dumosa* relevés, *Encelia farinosa -Atriplex hymenelytra* data, pinyon and juniper relevés).
7. Run cluster analysis (Ward's method) to test congruence with the subsets of TWINSPAN groupings.
8. Determine consistency of alliances (number and indicator values of other species associated with the selected proposed indicator species) using indicator species analysis.
9. Develop decision rules for each alliance, reflecting most conservative group membership possibilities based on review of species cover on a relevé-by-relevé basis.
10. Apply final alliance labels to each relevé and arrange in spreadsheet with location data for use in predictive modeling and map editing.
11. Apply decision rules developed for the field relevé data to assign alliance names to all retrospective data.
12. Review of new alliance designations by NatureServe for inclusion into the NVC.

Classification of the retrospective data included several additional steps:

1. Define membership and fidelity of select relevés to certain alliances using indicator species analysis (as provided in PC-Ord).
2. Reanalyze subsets of TWINSPAN data. Initial TWINSPAN runs subdivided the dataset because of its size. These subsets were re-analyzed using TWINSPAN and cluster analysis. This process is progressive fragmentation (Bridgewater 1989).
3. Reevaluate each relevé within the context of the cluster it had been assigned following cluster and TWINSPAN analysis to quantitatively define the membership rules for each alliance. These membership rules are defined by species constancy and species cover values and are translated into the floristic key.

Indicator species analysis was a useful tool in defining the alliances. This analysis (Dufrene and Legendre 1997) uses Monte Carlo simulation to test the likelihood of certain species as good indicators for groups of relevés. Thus, it provides a quantitative means to confirm or deny the definition of an alliance based on the presence of a given species.

Despite the strong influence of outlier relevés (relevés that did not fit neatly into analysis groupings) on the arrangement of the main body of vegetation data, we chose not to remove them from the data. Because the sampling scheme tended to under-represent the rare types, based on their rare bio-environments, we considered these relatively unique samples important. They were often the only representatives of rare alliances defined from areas beyond the boundary of the study area. In some cases, they represented unusual species groupings here-to-fore undescribed, and therefore provided insights into unusual vegetation types that would deserve further sampling at some future date. To adjust for the skewing effects of outliers, we removed them from subset analysis, but retained them in the final analysis and classification.

The NVC Classification for the Mojave Classification

Quantitative floristic data derived from field relevés are the building blocks of the NVC. However, because of the abrupt shift from the floristic units of the association and alliance to the physiognomic units of formation, group, and class in the NVC (Table 1), additional groupings in the classification must be made to accommodate significant physical differences in the vegetation. These may not strictly reflect the floristic affinities of the relevés.

Although the rules of aggregation for associations and alliances use a flexible set of decisions based on a combination of constancy and cover of characteristic species (Grossman et al. 1998), the rules for membership in the physiognomic upper units of the classification are more rigorous. For example, the classification criteria for woodland with a shrub understory of greater than 10% are that trees should compose on average at least 25% total cover and generally not more than 60% cover. For cases where the tree species is less than 25% cover, the placement of the assemblage within a woodland alliance or a shrubland alliance is not as clear, and we developed criteria on a case-by-case basis. Placing an assemblage with the same species composition as a woodland type in a shrubland type based on cover of the species would require applying cover criteria to a range of canopy covers (including trees, shrubs, and grasses as canopy). The NVC recognizes the “modal” representation of cover as important. Therefore, a single *Pinus monophylla* relevé with extremely high cover (>60%) would not constitute a reason to define a *Pinus monophylla* forest alliance, if the preponderance of the relevé data showed that the modal cover for such vegetation in an area was in the woodland range (25-60% cover).

Several such examples exist in the Mojave Desert. As an example, TWINSPAN and Cluster Analysis group any relevés with pinyon pine greater than 2% cover into a discrete unit. However, the cover values suggest that relevés with *Pinus monophylla* (pinyon pine) >25% cover are a *Pinus monophylla* Woodland Alliance, while relevés with pinyon pine <25% cover could be considered a shrubland with a sparse tree cover. What does remain constant is that the pinyon pine is stillthe characteristic unifying tree species. However, where pinyon pine is < 25% cover, shrubs and/or herbaceous species are usually a more significant component of the overall community structure. Thus, in this example, the first is a *Pinus monophylla* Woodland Alliance, while the second is a *Pinus monophylla*

Wooded Shrubland Alliance. This NVC naming convention allows maintenance of information on both the structural and floristic components of the vegetation type.

For purposes of modeling the alliances without distinctive photo signatures, it was typically necessary to aggregate floristically related alliances, for example, *Pinus monophylla* Woodland and *Pinus monophylla* Wooded Shrubland, into compositional groups. However, for the purposes of the classification, we adhered to the NVC naming convention.

Accuracy Assessment Protocol for Vegetation Map

Any type of mapping effort will unavoidably involve some degree of error. Maps constructed using satellite imagery, aerial photography, or even ground surveys will contain both thematic and positional error. This is not to suggest that all error in maps can or should be eliminated, but rather that map users should be made aware of the nature of errors contained within the map. We must have some means of judging the reliability or the product that others will use. An accuracy assessment is an essential component of any land cover mapping exercise and the product is unverified before a systematic accuracy assessment. Accuracy assessment is important because quantitative estimates of thematic and positional errors in the data will allow users of the data to assess data suitability for any particular application (ESRI, NCGIA, and TNC 1994). Accuracy assessments are usually only conducted after the map developer believes that the map is near the target accuracy. An accuracy assessment should be distinguished from map validation, defined in this report as a process used in map development to refine and update a preliminary map. Validation is a step that map developers use to achieve the target accuracy but it does not confirm the final accuracy – that is the role of the accuracy assessment. The generally accepted goal for a vegetation map is 80% or higher accuracy for each map class (alliance or ecological system). If accuracy assessment determines a map class to have less than 80% accuracy, additional update may be performed before finalizing the map.

An accuracy assessment is a laborious and relatively expensive task. It has been estimated that the cost of an accuracy assessment is 25%-100% the cost of the mapping effort for this type of map. At the initial development of the Central Mojave Vegetation Map, we asked the Desert Manager's Group and their science Committee if we should incorporate such a task into our workplan, recognizing that this would require a significant proportion of the financial resources available to this project. In light of the fact that we knew at the outset there were insufficient resources to complete the vegetation map for the California portion of the Mojave, we agreed that we should devote all the available resources to development of the Mojave Vegetation Database, including a version of the Central Mojave Vegetation Map, that has not been accuracy assessed. This was not to discount the value and importance of an accuracy assessment. Resources and land management agencies could execute an accuracy assessment in a collaborative effort, with direction from a project coordinating team.

As the Central Mojave Vegetation Map is not accuracy assessed, it is unverified until all mapped areas have a statistically valid accuracy assessment. Until then, it will exist in unassessed form.

We recommend that a statistically valid accuracy assessment be conducted on the map using methods described for accuracy assessment of land cover maps in the USGS/NPS Vegetation Mapping Program (http://biology.usgs.gov/npsveg/aa/toc.html), the National Gap Analysis Program (http://www.gap.uidaho.edu/handbook/ LandCoverAssessment/default.htm), Congalton (1991) and Edwards et al. (1998).

In addition, we recommend that:

1. The accuracy assessment must be independent from the mapping process itself. Since the Mojave Vegetation Map for the entire ecoregion may be compiled as a series of within-region projects (Central Section, Western Section, Ward Valley Section, Joshua Tree National Park, and the Mojave regions of the Southwest Gap Analysis), a separate accuracy assessment should be conducted either for each sub-project or for the entire map when compiled. We recommend a single accuracy assessment.
2. The accuracy assessment be based on an observational unit equivalent or larger than the MMU.
3. The recommended number of samples per class reflects the abundance of each class within the project area. Rare classes should be sampled based on how certain we are about their accuracy, not based on their rarity alone. In many cases, the rare ones can never have enough samples to statistically satisfy their accuracy, unless you sample all of them. Most scientists suggest a minimum number of samples for even the most rare classes; 30, 50, or 100. However, using the recommended formula, as few as 20 samples could be used.
4. Thematic accuracy be expressed using contingency matrices, and overall accuracy should be reported both as a simple proportion correctly classified and as map accuracy adjusted for chance agreement with a Kappa index. It is recommended to report users' and producers' accuracy for each class. These accuracies should be expressed as a percentage with a 90% confidence interval. The users should be provided with the actual accuracy estimates rather than stating whether or not the product meets a specific accuracy standard.
5. Ideally, accuracy assessment should capture all components of uncertainty associated with vegetation mapping. Recognizing that operationally this may not be feasible, we nevertheless recommend testing of experimental methods measuring, for example, within polygon variation, or the uncertainty in the position of polygon boundaries.
6. Before implementing any of the accuracy assessment procedures, they should be tested operationally during the preliminary phase of the project. We anticipate that the methodology will need to be refined because of this testing.
7. The number of samples per class should reflect, as much as possible, the importance of each class and the relative abundance of each class within the project area. Statistically the number of samples has nothing to do with the area of

the map covered by the specified type. Rather, it addresses the certainty of mapping a particular type and the desired level of significance from the deviation of the actual accuracy from the estimated accuracy. Thus, the more certain one is about the identity of a mapped type, the fewer samples one needs to collect. However, the more certain one wants to be that the estimated accuracy is actually close to the real accuracy, the more samples one would need to gather. For widespread types, a large number of samples may not be needed, but they need to be distributed in a well stratified, random selection.

Use and Update of the Mojave Vegetation Map

This project is a first step in developing an up-to-date continuous vegetation map for the entire ecoregion. The detail and accuracy of the Mojave Vegetation Map can be developed and improved in subsequent efforts. The goal of the Mojave Desert Ecosystem Program is to have a seamless vegetation map for the entire Mojave Desert. The Central Mojave Vegetation Mapping Project has initiated this project. The MDEP expressed that the completed Mojave Vegetation Database will ultimately contain vegetation coverage and associated relevé database for the entire ecoregion.

The Mojave Vegetation Database consists of several digital maps and their associated relational databases. Because we developed the digital maps in a GIS environment, they can be continually updated as a dynamic product. Before the advent of software to manage map information, maps were restricted to hard copy format. They were static products, published at one time, with one scale of representation. The data displayed were all the data in the map. The GIS environment allows a map to be periodically updated, to be represented at multiple scales of representation (although the resolution of representation does not change), and to contain selected multiple data items in a relational database.

Implementation of a dynamic map database requires that the methods and procedures for development and update of database are explicit. Updates to the database should include the cartographic history of the map. Users of the map need to be aware that the map is not static. Users need to be aware of which version of the map they are using and should review accompanying metadata to understand how the content of the database edition in use is different from previous versions. A dynamic database may be updated at any time, but the updates should not be distributed until the map is published. Publication for the Mojave Vegetation Database could be posted through the Mojave Desert Ecosystem Program website. FGDC compliant metadata should document each publication and a referencing citation that refers to that version of the map and or database.

Update of the Mojave Vegetation Map

The first phase of the Central Mojave Vegetation Mapping Project encompassed a 5.5-million ha area in the central section of the Mojave Desert. Three other sections must be addressed to complete mapping for the entire Mojave Desert: 1) the west Mojave, 2) the south Mojave, 3) and the east Mojave. Two other currently ongoing mapping projects, the

USGS/NPS Park Mapping Program in Joshua Tree National Park and the Southwest Regional Gap Analysis Program will potentially provide suitable mapping for the southern Mojave and portions of the eastern Mojave (those portions in Arizona, Nevada, and Utah). Additional areas in the eastern Mojave are the sections in the Mojave not included in this project: Ward Valley and portions of the Colorado River Corridor.

The points of consideration for inclusion of additional mapping into the Mojave Vegetation Database are:

- Consistency of classification standards
- Consistency of mapping resolution
- Consistency of polygon delineation

Consistency of classification standards

We developed an alliance-level classification and key of the study area for this stage of the Mojave Vegetation Mapping project. Additional alliances, not yet described or with preliminary description, will be found in the western Mojave or eastern California Mojave. Additions to the classification should use the NVC framework and quantitative analysis of relevé data. We described earlier procedures for quantitative analysis earlier in the Vegetation Classification section. Inclusion of any alliance into the key must be verified by a minimum number of observations supporting that alliance (we suggest five). The accepted process, at the time of consideration, for inclusion of an alliance into the NVC Mojave classification should adopted. Currently, inclusion into the NVC relies on review by NatureServe. The Ecological Society of America is developing guidelines for documentation of alliances within the scientific community. Eventually, all alliances need to be documented in peer-reviewed literature using guidelines that are being established.

Consistency of mapping resolution

The target MMU for the Mojave Vegetation Database is five ha. It is known that numerous alliances occur in the Mojave typically at a resolution less than five ha, for example, *Salix exigua* Woodland or *Prosopis glandulosa* Woodland Alliances. In addition, alliances that may occur commonly with greater than five ha extent may also occur as inclusions within a more expansive alliance; for example, 1 hectare of *Salazaria mexicana* Shrubland occurring within a larger expanse of *Larrea tridentata* Shrubland. Three strategies exist to deal with these situations: 1) ignore all alliance occurrences less than five ha in size, 2) gather information on these alliances when encountered but maintain the information separately from the Mojave Vegetation Map, or 3) gather information on these alliances and actively incorporate the data into the Mojave Vegetation Map. The first option is the one usually adopted by mapping projects, but it does not fulfill the intention of a dynamic database. We established the framework for the second option with the Special Features Map. The third option would result in a map with mixed minimum mapping units. We do not recommend this option unless pursued in a systematic manner.

Consistency of polygon delineation

We based polygon delineation, as described in the Central Section, on photointerpretation of 1:32,000 true color aerial photography. The polygons in most instances represent primarily integrated land units, subjectively determined, rather than discrete vegetation units. Delineation of exact vegetation units cannot be implemented without higher resolution imagery. The development of Digital Ortho Photoquads (DOQQ's) for the Mojave Desert provides an additional affordable image database that may allow further polygon delineation.

The existing polygons in the vegetation map can be further refined using finer resolution imagery, such as the DOQQ's, or from direct field mapping. Whenever polygons are refined, the changes should be made from a georeferenced base map, such as a DOQQ and/or 1:24,000 topographic quad.

Mapping being conducted in Joshua Tree National Park and for the SW Regional Gap Analysis is using different methods to delineate map units. Compilation of these various map sources into a regional database will potentially result in a map with some inconsistencies in map unit representation. The compiler will need to determine if the inconsistencies are too large to allow effective use of a compiled map. Annotation of each map unit with its original and clear documentation of the methods of original will help make such a compilation more users friendly.

The history of edits should be included either in the ArcInfo database or in a linked relational database. This cartographic history should include:

- Type of edit such as polygon edit or map label change
- Date of edit
- Source of information for edit

We recommended that one entity act as the clearinghouse for any edits made to the Mojave Vegetation Map. Periodic edits to the map should include updates of the accompanying metadata.

Availability and Use of the Mojave Vegetation Map

All coverages, grids, and the tabular database are documented with Federal Geographic Data Committee (FGDC)/Tri-Services compliant metadata for all digital maps. The spatial products are available through the MDEP (http://www.mojavedata.gov/ datasets.php?&qclass=veg) and the USGS Southwest Biological Science Center's Colorado Plateau Field Station website (http://www.usgs.nau.edu/).

Mapping of vegetation alliances with a five-ha MMU will provide the base information for a variety of management and basic research needs. Following is a list of potential uses of a Mojave Vegetation Map:

Inventory

- Baseline of existing vegetation types
- Distribution of vegetation types
- Diversity of vegetation types

Landscape analysis

- Evaluate existing vegetation conditions
- Determine desired vegetation conditions
- Conduct biodiversity analysis
- Baseline for wildlife habitat modeling
- Baseline for threatened and endangered species modeling

Collaboration

- Provides common platform for all agencies
- Planning and implementation of ground level actions done with common baseline

Management

- Facilitates management activities at a variety of scales (monitoring impacts such as fire and weed invasion, development, and so on)
- Facilitates implementation of land use plans

References Cited

Annable, C. R. 1985. Vegetation and flora of the Funeral Mountains, Death Valley National Monument. California-Nevada Cooperative National Park Resources Studies Unit, National Park Service/University of Nevada Contribution 016/07. Las Vegas, Nev. 188 p.

Arno, S. F., and A.E. Wilson. 1986. Dating past fires in curlleaf mountain-mahogany communities. Journal of Range Management 39(3):241-243.

Austin, M.P., and P.C. Heyligers. 1989. Vegetation survey design for conservation: gradsect sampling of forests in northeastern New South Wales. Biological Conservation 50:13-32.

Austin, M. P., J. A. Meyers, and M. D. Doherty. 1994. Predictive models for landscape patterns and processes, Sub-project 2, Modeling of landscape patterns and processes using biological data. Division of Wildlife and Ecology, Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra, ACT, Australia.

Axelrod, D.I. 1978. The origin of coastal sage vegetation, Alta and Baja California. American Journal of Botany 65:1117-1131.

Bagley, M. 1986. Baseline data for a sensitive plant monitoring study of the Eureka Dunes in Inyo County, California. Unpublished report. USDI, Bureau of Land Management, Sacramento, Calif.

Bahre, C.J., and T.H. Whitlow. 1982. Floristic and Vegetational Patterns in a California Dredge Field. Journal of Biogeography, 9(1):79-90.

Bailey, T.C., and A.C. Gatrell. 1998. Interactive spatial data analysis. Longman, Harlow, England.

Ball, J.T. 1976. Ecological survey Last Chance Meadow candidate Research Natural Area, Mount Whitney Ranger District, Inyo National Forest. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Barbour, M.G. 1988. Californian upland forests and woodlands. Pages 131-164 in M.G. Barbour and W.D. Billings, editors. North American Terrestrial Vegetation. Cambridge University Press, New York, New York.

Barbour, M.G., and J. Wirka. 1997. Alluvial scrub vegetation in Southern California: A case study using the vegetation classification of the California Native Plant Society. Contract #FG5638-R-5, U.S. Fish and Wildlife Service Section 6 Program to California Department of Fish and Game. Report on File at California Natural Diversity Database, Sacramento, Calif.

Barbour, M.G. 1994. Coastal sage shrub – SRM 205. Page 15 in T.N. Shiflet, editor. Rangeland Cover Types of the United States. Society for Range Management, Denver, Colo.

Barney, C.W. 1980. Limber pine. Pages 98-99 in F.H. Eyre, editor. Forest Cover Types of the United States and Canada. Society of American Foresters, Washington, D.C.

Barry, W. J. 1989a. A hierarchical vegetation classification system with emphasis on California plant communities. State of California, The Resources Agency, Department of Parks and Recreation, Sacramento, Calif.

Barry, W. J. 1989b. The classification and analysis of natural vegetation with emphasis on California vegetation. Unpublished report. State of California, The Resources Agency, Department of Parks and Recreation, Sacramento, Calif.

Bates, R.C. 1984. The role and use of fire in black brush communities in California. Master's Thesis. University of California, Davis, CA

Beasley, R.S., and J.O. Klemmedson. 1980. Ecological relationships of bristlecone pine. American Midland Naturalist 104:242-252.

Beatley, J. C. 1976. Vascular plants of the Nevada Test Site and central-southern Nevada: Ecological and geographic distributions. Technical Information Center, Energy Research and Development Administration TID-26881. Prepared for the Division of Biomedical and Environmental Research, Energy Research and Development Administration. 297 p.

Beauchamp, R.M. 1977. Survey of sensitive plants of the Algodones Dunes. Unpublished report. Bureau of Land Management, Riverside, Calif.

Beauchamp, R.M. 1986. A flora of San Diego County, California. Sweetwater Press. National City, Calif.

Billings, W.D., and J.H. Thompson. 1957. Composition of a stand of old bristlecone pines in the White Mountains of California. Ecology 38:158-160.

Bittman, R. 1985. National natural landmark evaluation, Phases I, II, and III. Unpublished report. State of California, The Resources Agency, Department of Fish and Game, Natural Heritage Section, Natural Diversity Data Base, Sacramento, Calif.

BLM [Bureau of Land Management]. 1986. New York Mountain Resource Management Plan. Final Report. California Desert District, Needles Resource Area, Calif.

BLM [Bureau of Land Management]. 1997. Unpublished digital dataset compiled by N. Pratini. Bureau of Land Management, California Desert District Office, Riverside, Calif.

BLM [Bureau of Land Management]. 1998. Unpublished digital dataset compiled by M. Daniels. Bureau of Land Management, California Desert District Office, Riverside, Calif.

BLM [Bureau of Land Management]. 2001. Draft Northern and Eastern Colorado Desert Coordinated Management Plan and Environmental Impact Statement. Bureau of Land Management, California Desert District Office, Riverside, Calif.

Borchert, M., and M. Hibberd. 1984. Gradient analysis of a north slope montane forest in the western Transverse Ranges of southern California. Madroño 31:129-139.

Bougeron, P.S., and L.D. Engelking, editors. 1994. A preliminary vegetation classification of the western U.S. Monograph. The Nature Conservancy, Boulder, Colo.

Bowler, P.A. 1989. Riparian woodlands: an endangered habitat in Southern California. Pages 80-97 in A.A. Schoenherr, editor. Endangered Plant Communities of Southern California. Southern California Botanists, California State University, Fullerton, Calif.

Bowns, J.E., and N.E. West. 1976. Blackbrush (*Coleogyne ramosissima* Torr.) on southwestern Utah rangelands. Research Report 27. Utah State University, Utah Agricultural Experiment Station. Logan, Utah. 27 p.

Boyd, S.D. 1983. A flora of the Gavilan Hills, western Riverside County, California. Master's thesis, University of California, Riverside, Calif.

Bradley, W.G. 1970. The vegetation of Saratoga Springs, Death Valley National Monument. Southwest Naturalist 15:111-129.

Brayshaw, T.C. 1976. Catkin bearing plants (*Amentiferae*) of British Columbia. British Columbia Provincial Museum, Victoria, B.C.

Breiman, L., J. Friedman, R. Olshen, and C. Stone. 1984. Classification and regression trees. Wadsworth, Belmont, Calif.

Bridgewater, P.B. 1989. Syntaxonomy of the Australian mangal refined through iterative ordinations. Vegetatio 81:159-169

Brown, D.E. 1982. Great Basin conifer woodland. Desert Plants 4:52-57.

Brown, D.E., C.H. Lowe, and C.P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. Journal of the Arizona-Nevada Academy of Science 14(Suppl.1):1-16.

Brown, D. E., and R.A. Minnich. 1986. Fire and changes in creosote bush scrub of the western Sonoran Desert, California. American Midland Naturalist 116(2):411-422.

Burk, J.H. 1977. Sonoran Desert vegetation. Pages 869-889 in M.G. Barbour and J.

Major, editors. Terrestrial vegetation of California. Wiley–Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Burkart, A. 1976. A monograph of the genus *Prosopis* (*Leguminosae* subfamily *Mimosoideae*). Journal of the Arnold Arboretum 57:450-530.

Calflora. 2000. The CalFloraDatabase: An online database of California's 8,363 vascular plants. http://www.calflora.org/

Capelli, M.H., and S.J. Stanley. 1984. Preserving riparian vegetation along California's south central coast. Pages 673-686 in R.E. Warner and K.M. Hendrix, editors. California Riparian Systems: Ecology, Conservation and Productive Management. University of California Press, Berkeley, Calif.

Cheatham, N.H., and J.R.Haller. 1975. An annotated list of California habitat types. Unpublished report. University of California, Berkeley, Calif.

Clark, L. A., and D. Pregibon. 1992. Tree-based models. Pages 377-419 in J. Chambers and T. J. Hastie, editors. Statistical models in S. Wadsworth and Brooks/Cole Advanced Books and Software, Pacific Grove, Calif.

Comer, P., and K. Schultz. 2002. Ecological classification, biophysical models and land cover mapping. Nature Serve. 6 p.

Conard, S.G., and R.F. Robichaux. 1980. Ecological survey of the proposed Soda Ridge Research Natural Area, Lassen National Forest, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Congalton, R.G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing of the Environment 37:35-46.

Cooper, W.S. 1922. The broad-sclerophyll vegetation of California. Publication 319. Carnegie Institution of Washington, Washington, D.C.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. FWS/OBS 79/31. U.S. Government Printing Office. Washington, D.C.

Davidson, E., and M. Fox. 1974. Effects of off-road motorcycle activity on Mojave Desert vegetation and soil. Madroño 22:381-412.

Davis, J.N. 1994a. Curlleaf mountain-mahogany – SRM 415. Page 54 in T.N. Shiflet, editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

Davis, J.N. 1994b. Littleleaf mountain-mahogany – SRM 417. Page 56 in T.N. Shiflet, editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

DeDecker, M. 1979. Can BLM protect the dunes? Fremontia 7:6-8.

DeDecker, M. 1984. Flora of the northern Mojave Desert, California. California Native Plant Society, Sacramento, Calif.

DeLorme. 1998. Southern and Central California Atlas and Gazetteer. 4th Edition. Yarmouth, Maine.

Derby, J.A., and R.C. Wilson. 1978. Floristics of pavement plains of the San Bernardino Mountains. Aliso 9:374-378.

Derby, J.A., and R.C. Wilson. 1979. Phytosociology of pavement plains of the San Bernardino Mountains. Aliso 9:463-474.

Desert Workshop. 1/27/00. (Notes on the comments of participants in the Jan 27, 2000 workshop on the revision of the Manual of California Vegetation. Held at Black Rock Nature Center, Joshua Tree National Park, Calif.

DeSimone, S.A., and J.H. Burk. 1992. Local variation in floristics and distributional factors in California coastal sage scrub. Madroño 39:170-188.

Dubayah, R., and P. M. Rich. 1995. Topographic solar radiation for GIS. International Journal of Geographic Information Systems 9:405-419.

Dufrene, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345-366.

Edwards T.C., Jr., G.G. Moisen, and D.R. Cutler. 1998 Assessing map uncertainty in remotely-sensed, ecoregion-scale cover maps. Remote Sensing of Environment 63:73-83.

Erdman, J. A. 1970. Pinyon-juniper succession after natural fires on residual soils of Mesa Verde, Colorado. Brigham Young University Science Bulletin, Biological Series 11(2):1-26.

ESRI, NCGIA, and TNC. 1994. Final Draft: Accuracy Assessment Procedures. USGS/NPS Park Mapping Program. http://biology.usgs.gov/npsveg/aa/aa.html.

Evens, J.M. 2000. Water course vegetation on granitic and calcareous substrates in the eastern Mojave Desert, California. Master's Thesis Humboldt State University, Arcata, Calif. 169 p.

Faber, P.M., E. Keller, A. Sands, and B.M. Massey. 1989. The ecology of riparian habitats of the southern California coastal region: a community profile. Biological Report 85(7.27). USDI, Fish and Wildlife Service, Washington, D.C.

FEIS. 2001. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2002, January). Fire Effects Information System, http://www.fs.fed.us/database/feis/.

Fels, J. E., and K. C. Matson. 1996. A cognitively-based approach for hydrogeomorphic land classification using digital terrain models. Pages http://bbq.ncgia.ucsb.edu:80/ conf/SANTA FE CD-ROM/sf papers/felsjohn/ in M. F. Goodchild, editor. Proceedings Third International Workshop Integrating GIS and Environmental Modeling, Santa Fe, New Mexico, Jan 21-25, 1996. NCGIA, Santa Barbara, Calif.

Ferren, W.R. and F.W. Davis. 1991. Biotic inventory and ecosystem characterization* California Department of Fish and Game, Sacramento, Calif.

FGDC [Federal Geographic Data Committee]. 1997. Vegetation classification standard, FGDC-STD-005. http://www.fgdc.gov/Standards/Documents/Standards/Vegetation.

Franklin, J. 1995. Predictive vegetation mapping: geographic modeling of biospatial patterns in relation to environmental gradients. Progress in Physical Geography 19:474-499.

Franklin, J. 1998. Predicting the distribution of shrub species in southern California from climate and terrain-derived variables. Journal of Vegetation Science 9:733-748.

Franklin, J., and C.E.Woodcock. 1997. Multiscale vegetation data for the mountains of Southern California: spatial and categorical resolution, Pages 141-168 in D.A. Quattrochi and M.F. Goodchild, editors. Scale in Remote Sensing and GIS. CRC/Lewis Publishers Inc., Boca Raton, Fla.

Franklin, J., T. Keeler-Wolf, K. Thomas, D. Shaari, P.Stine, J. Michaelsen, and J. Miller. 2001. Stratified sampling for field survey of environmental gradients in the Mojave Desert Ecoregion. Pages 229-253 in Millington, M., S. Walsh and P. Osborne, editors. GIS and remote sensing applications in biogeography and ecology. Kluwer Academic Publishers.

Franklin, J.F., and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. General Technical Report PNW-8. USDA, Forest Service, Pacific Northwest Research Station, Portland, Ore.

Fritts, H.C. 1969. Bristlecone pine in the White Mountains of California. Growth and ring width characteristics, Paper No. 4. University of Arizona, Laboratory of Tree Ring Research, Tucson, Ariz.

Gauch H. G., Jr. 1982. Multivariate analysis in community ecology. Cambridge University Press, New York.

Gordon, H.J. and T.C. White. 1994. Ecological guide to southern California chaparral plant series. Technical Publication R5-ECOL-TP-005. USDA, Forest Service, Pacific Southwest Region, San Francisco, Calif.

Gray, J.T. 1978. The vegetation of two California mountain slopes. Madroño 25:177-185.

Gray, M.V. and J.M. Greaves. 1984. Riparian forest as habitat for the least Bell's vireo. Pages 605-611 in R.E. Warner and K.M. Hendrix, editors. California Riparian Systems: Ecology, Conservation and Productive Management. University of California Press, Berkeley, Calif.

Griffin, J.R., and W.B. Critchfield. 1972. The distribution of forest trees in California. Research Paper PSW-82. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Griggs, F.T. 1980. Valley saltbush scrub element protection plan. Unpublished report. The Nature Conservancy, San Francisco, Calif.

Griggs, F.T., and J. Zaninovich. 1984. Definitions of Tulare Basin plant associations. Unpublished report. The Nature Conservancy, San Francisco, Calif.

Grossman, D.H., D. Faber-Langendoen, A.S.Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Gooding, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: Terrestrial vegetation of the United States. Volume I: The National Vegetation Classification Standard. The Nature Conservancy, Arlington, Va.

Gudmonds, K.N., and M.G. Barbour. 1987. Mixed evergreen forest stands in the northern Sierra Nevada. Pages 32-37 in T.R. Plumb and N.H. Pillsbury, editors. Multiple-use management of California's hardwood resources. General Technical Report, PSW 100. USDA, Forest Service, Pacific southwest Research Station.

Hanes, T.L. 1976. Vegetation types of the San Gabriel Mountains. Pages 65-76 in J. Latting, editor. Plant communities of Southern California. California Native Plant Society, Sacramento, Calif.

Hanes, T.L., R.D. Friesen, and K. Keane. 1989. Alluvial scrub vegetation in coastal southern California. General Technical Report PSW-110. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Hawksworth, F.G., and D.K. Bailey. 1980. Bristlecone pine. Pages 89-90 in F.H. Eyre, editor. Forest cover types of the United States and Canada. Society of American Foresters, Washington, D.C.

Heady, H.F. 1977. Valley grassland. Pages 491-514 in M.G. Barbour and J. Major, editors. Terrestrial vegetation of California. Wiley–Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Hendrickson, J., and B. Prigge. 1975. White fir in the mountains of eastern Mojave Desert of California. Madroño 23:164-168.

Henry, M.A. 1979. A rare grass on the Eureka Dunes. Fremontia 7:3-6.

Hickman, J.C. 1993. The Jepson manual: Higher plants of California. University of California Press, Berkeley, Calif.

Hill, M.O. 1979. DECORANA – A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell University Ithaca, New York.

Hilu, K.W., S. Boyd, and P. Felker. 1982. Morphological diversity and taxonomy of California mesquites (*Prosopis,* Leguminosae). Madroño 29:237-254.

Hogan R.E. 1977. The Joshua Tree (*Yucca brevifolia*): Vegetation and population dynamics in Joshua Tree National Monument. Master's Thesis University of California, Los Angeles, Calif.

Holland, R.F. 1986. Preliminary descriptions of the terrestrial natural communities of California. Unpublished report. State of California, The Resources Agency, Department of Fish and Game, Natural Heritage Division, Sacramento, Calif.

Holstein, G. 1984. California riparian forests: deciduous islands in an evergreen sea. Pages 2-22 in R.E. Warner and K.M. Hendrix, editors. California riparian systems: ecology, conservation and productive management. University of California Press, Berkeley, Calif.

Holzman, B. 1994. Creosote bush scrub – SRM 211. Page 20 in T.N. Shiflet, editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

Humphrey, R. R. 1974. Fire in the deserts and desert grassland of North America. Pages 365-400 in T. T. Kozlowski and C. E. Ahlgren, editors, Fire and Ecosystems. Academic Press, New York.

Hunt, C.B. 1966. Plant ecology of Death Valley, California. Professional paper 509. USDI, Geological Survey, Washington, D.C.

Jennings. C.W. 1985. An explanatory text to accompany the 1:750,000 scale fault and geologic maps of California. California Department of Mines and Geology Bulletin 201. California Department of Conservation, Division of Mines and Geology, Sacramento, Calif.

Jensen, D.B. and K.A. Schierenbeck. 1990. An ecological survey of the proposed Raider Creek Research Natural Area, Modoc National Forest, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Johnson, H.B. 1976. Vegetation and plant communities of southern California deserts. Pages 125-162 in J. Latting, editor. Plant communities of southern California. California Native Plant Society, Sacramento, Calif.

Johnson, H. 1978a. Unpublished dataset from the East Mojave Scenic Area, Calif.

Johnson, H. 1978b. Unpublished dataset from Saline Valley, Calif.

Johnson, S. 1987. Can tamarisk be controlled? Fremontia 15:19-20.

Keeler-Wolf, T. 1987. An ecological survey of the proposed Crater Creek Research Natural Area, Klamath National Forest, Siskiyou County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T. 1988. Establishment report for Hall Canyon Research Natural Area within San Bernardino National Forest, Riverside, County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T. 1989. Establishment record for the Whippoorwill Flat Research Natural Area within the Inyo National Forest, Inyo County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T. 1990a. An ecological survey of the proposed Long Canyon Research Natural Area, Sequoia National Forest, Kern County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T. 1990b. Ecological surveys of forest service research natural areas in California. General Technical Report PSW-125. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T. 1991. Ecological survey of the proposed Big Pine Mountain Research Natural Area, Los Padres national Forest, Santa Barbara County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T. 1992. Ecological survey of the Graham Pinery candidate Research Natural Area, Lassen National Forest, Californian. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T. and V. Keeler-Wolf. 1976. A survey of the scientific values of the proposed Whippoorwill Flat Research Natural Area, Inyo National Forest, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Keeler-Wolf, T., C. Roye, and K. Lewis. 1998. Vegetation mapping and classification of the Anza-Borrego Desert State Park, California. Unpublished report on file at California Dept Fish and Game, Natural Diversity Database, Sacramento, Calif.

Keeley, J.E., and S.C. Keeley. 1988. Chaparral. Pages 165-207 in M.G. Barbour and W.D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, New York.

Kirkpatrick, J.B., and C.F. Hutchinson. 1977. The community composition of Californian coastal sage scrub. Vegetatio 35:21-33.

Krantz, T. 1983. The pebble plains of Baldwin Lake. Fremontia 10:9-13.

Krantz, T. 1988. Limestone endemics of Big Bear Valley. Fremontia 16:20-21.

Lanner, R.M. 1984. Bristlecone pine and Clark's nutcracker: probable interaction in the White Mountains, California. Great Basin Naturalist 44:357-360.

Lloyd, R.M., and R.S. Mitchell. 1973. A flora of the White Mountains, California and Nevada. University of California Press, Berkeley, Calif.

Long, J. 1997. Unpublished dataset for Joshua Tree National Park, California.

MacMahon, J.A. 1988. Warm deserts. Pages 231-264 in M.G. Barbour and W.D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, New York.

MacMahon, J.A., and F.H.Wagner. 1985. The Mojave, Sonoran and Chihuahuan deserts of North America. Pg. 139-174 in M.Evenari, I.Noy-Meir, and D.W. Goodall, editors. Ecosystems of the world 12A: hot deserts and arid shrublands. Elsevier Scientific Publishing Company, New York.

Magney, D.L. 1992. Descriptions of three new southern California vegetation types: southern cactus scrub, southern coastal needlegrass grassland, and scale-broom scrub. Crossosoma 18:1-9.

Major, J., and D.W. Taylor. 1977. Alpine. Pages 601- 675 in M.G. Barbour and J. Major, editors. Terrestrial vegetation of California. Wiley–Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Malanson, G.P. 1984. Fire history and patterns of Venturan subassociation of Californian coastal sage scrub. Vegetatio 57:121-128.

Mallory, J.I. 1980. Canyon live oak. Pages 125-126 in F.H. Eyre, editor. Forest cover types of the United States and Canada. Society of American Foresters, Washington, D.C.

Marchand, D.E. 1973. Edaphic control of plant distribution in the White Mountains, eastern California. Ecology 54:233-250.

Marks, M., B. Lapin, and J. Randall. 1994. *Phragmites australis* (*P. communis*): threats, management, and monitoring. Natural Areas Journal 14:285-294.

Martin, R.E. 1980. Western juniper. Pages 115-116 in F.H. Eyre, editor. Forest cover types of the United States and Canada. Society of American Foresters, Washington, D.C.

Martin, R.E. 1994. Blackbush – SRM 212. Page 21 in T.N. Shiflet, editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

Matyas, W.J., and I. Parker. 1980. CALVEG: Mosaic of existing vegetation of California. Regional Ecology Group, U.S. Forest Service. Department of Agriculture, San Fransciso, Calif.

Mayer, K.E., and W.F. Laudenslayer, Jr. Editors. 1988. A Guide to Wildlife Habitats of California. State of California, Resources Agency, Department of Fish and Game, Sacramento, Calif. 166 p.

McAuliffe, J. R. 1988. Markovian dynamics of simple and complex desert plant communities. The American Naturalist 131(4):459-490.

McBride, J.R. 1994. Riparian woodland – SRM 203. Page 13 in T.N. Shiflet, editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

McCune. B., and M.J. Mefford. 1997. PC-ORD. Multivariate analysis of ecological data, Version 3.0. MjM Software Design, Gleneden Beach, Ore.

McDonald, P.M., D. Minore, and T. Atzet. 1983. Southwestern Oregon – northern California hardwoods. Pages 29-32 in R.M. Burns, technical compiler. Silviculture systems for the major forest types of the United States. Agriculture Handbook No. 445. USDA, Forest Service, Washington, D.C.

McHargue, L.T. 1973. A vegetational analysis of the Coachella Valley, California. Dissertation, University of California, Irvine, Calif.

McMinn, H.E. 1953. An Illustrated manual of California shrubs. University of California Press, Berkeley, Calif.

Meeuwig, R.O., and R.L. Bassett. 1983. Pinyon–juniper. Pages 84-86 in R.M. Burns, technical compiler. Silviculture systems for the major forest types of the United States. Agriculture Handbook No. 445. USDA, Forest Service, Washington, D.C.

Meeuwig, R.O., J.D. Budy, and R.L. Everett. 1990. *Pinus monophylla*-singleleaf pinyon. Pgs. 380-384 in R.M. Burns and B.H. Honkala, technical coordinators. Silvics of North America, Vol. 1. Conifers. Agriculture Handbook 654. USDA, Forest Service, Washington, D.C.

Meier, L. 1979. A vegetative survey of the Fern Canyon Research Natural Area, San Dimas Experimental Forest. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Michaelsen, J., D. Schimel, M. Friedl, F. W. Davis, and R. C. Dubayah. 1994. Regression tree analysis of satellite and terrain data to guide vegetation sampling and surveys. Journal of Vegetation Science 5:673-686.

Miles, S.R., and C.B Goudy. 1997. Ecological subregions of California. USDA Forest Service, Pacific Southwest Region, R5-EM-JP-005.

Minckley, W.L., and D.E. Brown. 1982. Part 6. Wetlands. Page 342 in F.S. Crosswhite, editor. Biotic communities of the American Southwest – United States and Mexico. The University of Arizona Press, Tucson, Ariz.

Minnich, R.A. 1976. Vegetation of the San Bernardino mountains. Pages 99-125 in J. Latting, editor. Plant communities of Southern California. California Native Plant Society, Sacramento, Calif.

Minnich, R.A. 1980. Wildfire and the geographic relationships between canyon live oak, Coulter pine, and bigcone Douglas-fir forests. Pages 55-61 in T.R. Plumb, editor. Ecology, management, and utilization of California oaks. General Technical Report PSW-44. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Minnich, R.A., A. Sanders, S. Wood, K. Barrows, and J. Lyman. 1993. Natural resources management plan, Marine Corps Air-Ground Combat Center, Twentynine Palms, California. Unpublished report. University of California, Riverside, Calif.

Mooney, H.A. 1973. Plant communities and vegetation. Pages *. In R.M. Lloyd and R.S. Mitchell, editors. A flora of the White Mountains, California and Nevada. University of California Press, Berkeley, Calif.

Mooney, H.A. 1977. Southern coastal scrub. Pages 471-489 in M.G. Barbour and J. Major, editors. Terrestrial vegetation of California. Wiley–Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Mooney, H.A., G. St. Andre, and R.D. Wright. 1962. Alpine and subalpine vegetation patterns in the White Mountains of California. American Midland Naturalist 68:257-273.

Moore, I. D., R. B. Grayson, and A. R. Ladson. 1991. Digital terrain modeling: a review of hydrological, geomorphologic and biological applications. Hydrological Processes 5:3-30.

Munz, P.A. and D. Keck 1950. California plant communities. El Aliso2:87-105.

Munz, P.A. 1974. A flora of southern California. University of California Press, Berkeley, Calif.

Myatt, R.C. 1980. Canyon live oak vegetation in the Sierra Nevada. Pages 86-91 in T.R. Plumb, editor. Ecology, management and utilization of California oaks. General Technical Report PSW-44. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

National Wetlands Inventory. 1986. Death Valley National Park National Wetland Inventory Maps. U.S. Fish and Wildlife Service.

Neal, D.L. 1994. Bitterbrush – SRM 210. Page 19 in T.N. Shiflet, editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

Neill, W.M. 1985. Status reports on invasive weeds: tamarisk. Fremontia 12:22.

Nord, E.C. 1965. Autecology of bitterbrush in California. Ecological Monographs 35(3):307-334.

Novak, P. 1996. Unpublished dataset from Ft. Irwin, Calif.

Novak, P. 1998. Unpublished dataset from Marine Corp Air Ground Command Center, Calif.

NRCS [Natural Resources Conservation Service]. 1999. The PLANTS Database. http//plants.usda.gov.

Odion, D.C., R.M. Callaway, W.R. Ferren, and F.W. Davis. 1992. Vegetation of Fish Slough, an Owens Valley wetland ecosystem. Pages 171-196 in C.A. Hall and B. Widawski, editors. The History of Water: Eastern Sierra Nevada, Owens Valley, White-Inyo Mountains. White Mountains Research Station Symposium 4. University of California, White Mountain Research Station, Los Angeles, Calif.

Ohmart, R.D, W.O. Deason, and C. Burke. 1977. A riparian case history: the Colorado River. Pages 35-47 *in* R.R. Johnson and D.A. Jones, tech. coords. Importance, Preservation and Management of Riparian Habitat; a Symp. USDA For. Serv. Gen. Tech. Rep. RM-43.

O'Leary, J.F. 1989. Californian coastal sage scrub: general characteristics and considerations for biological conservation. Pages 24-41 in A.A. Schoenherr, editor.

Endangered plant communities of southern California. Southern California Botanists, California State University, Fullerton, Calif.

O'Leary, J.F., and R.A. Minnich. 1981. Postfire recovery of creosote bush scrub vegetation in the western Colorado Desert. Madroño 28:61-66.

Parikh, A. 1993. Ecological survey report, San Emigdio Mesa candidate Research Natural Area, Los Padres National Forest, Mount Pinos Ranger District, Ventura County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Pase, C.P., and D.E. Brown. 1982. Californian coastal scrub. Desert Plants 4:86-90.

Pavlik, B.M. 1985. Sand dune flora of the Great Basin and Mojave Deserts of California, Nevada, and Oregon. Madroño 32:197-213.

Pavlik, B.M., P.C. Muick, S.G. Johnson, and M. Popper. 1991. Oaks of California. Cachuma Press, Inc., Los Olivos, Calif.

Paysen, T.E., J.A. Derby, H. Black, V.C. Bleich, and J.W. Mincks. 1980. A vegetation classification system applied to southern California. General Technical Report PSW-45. USDA, Forest Service, Pacific South-west Research Station, Berkeley, Calif.

Pearlstine, L., A. McKerrow, M. Pyne, S. Williams, and S. McNulty. 1998. Compositional groups and ecological complexes: A method for alliance based vegetation mapping. Pages 16-17 in E. Brackney and M. Jennings, editors. Gap Analysis Bulletin No. 7, U.S. Geological Survey, Biological Resources Division, Moscow, Idaho.

Peterson, P.M. 1984. Flora and physiognomy of the Cottonwood Mountains, Death Valley National Monument, California. University of Nevada Cooperative National Park Resources Studies Unit Report CPSU/UNLV 022/06. Las Vegas, Nev.

Phillips and McMahon. 1981. Competition and spacing patterns in desert shrubs. Ecology 69:97-115.

Phillips, E.A., K.K. Page, and S.D. Knapp. 1980. Vegetational characteristics of two stands of Joshua tree woodland. Madroño 27:43-47.

Prigge. B.A. 1979. A checklist of vascular plants, Caruthers Canyon, New York Mountains, Mojave Desert. Report to BLM in fulfillment of contract no. CA_60_CT7_2430.

Prigge, B. 1995. Vegetation classification of transect monitoring data on Fort Irwin, San Bernardino County, Calif. Unpublished report to Department of Defense.

Quinlan, J. R. 1993. C4.5: programs for machine learning. Morgan Kaufmann Publishers, Inc., San Mateo, Calif.

Randall, D.C. 1972. An analysis of some desert shrub vegetation of Saline Valley, California. Dissertation, University of California, Davis, Calif.

Reed, P.B. 1988. National list of plant species that occur in wetlands: California (Region 0). Biological Report 88(26.10). USDI, Fish and Wildlife Service, Washington, D.C.

Reid, M. S., KA. Schulz, P J. Comer, M H. Schindel, D R. Culver, D A. Sarr, M C. Damm. 1999. An alliance level classification of vegetation of the coterminous western United States. The Nature Conservancy, Western Conservation Science Department Boulder, Colorado. A report to the University of Idaho Cooperative Fish and Wildlife Research Unit and National Gap Analysis Program.

Root, R. 1978. Unpublished dataset from Death Valley National Park, California.

Rowlands, P.G. 1978. The vegetation dynamics of the Joshua tree (*Yucca brevifolia* Engelm.) in the southwestern United States of America. Dissertation, University of California, Riverside, Calif.

Sands, A. 1980. Riparian forests in California. Publication No. 15. University of California, Institute of Ecology, Davis, Calif.

Sawyer, J. O., and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento, Calif. 471 p.

Sawyer, J.O., and K.T. Stillman. 1977. An ecological survey of the proposed Specimen Creek Research Natural Area, Siskiyou County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Sawyer, J.O., and K.T. Stillman. 1978. An ecological survey of the proposed William's Point Research Natural Area, Siskiyou County, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Sawyer, J.O., D.A. Thornburgh, and J.R. Griffin. 1977. Mixed evergreen forest. Pages 359-381 in M.G. Barbour and J. Major, editors. Terrestrial Vegetation of California. Wiley–Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Schramm, D. R. 1977. Unpublished dataset from the Black Mountains, Death Valley National Monument, California.

Schramm, D. R. 1982. Floristics and vegetation of the Black Mountains, Death Valley National Monument. Unpublished report prepared for the University of Nevada, Las Vegas, Nev.

Schulman, E. 1954. Longevity under adversity in conifers. Science 119:395-399.

Schultz, B. W., R.J. Tausch, and P.T. Tueller. 1991. Size, age, and density relationships in curlleaf mahogany (*Cercocarpus ledifolius*) populations in western & central Nevada: competitive implications. Great Basin Naturalist 51(2):183-191.

Sharf, M.R., E.T. Nilsen, and P.W. Rundel. 1982. Biomass and net primary production of *Prosopis glandulosa* (Fagaceae) in the Sonoran Desert of California. American Journal of Botany 69:760-767.

Shiflet, T.N. editor. 1994. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

Shreve, F. 1927. The vegetation of a coastal mountain range. Ecology 8:27-44.

Silverman, D. 1996. Unpublished dataset from China Lake Naval Weapons Center, California.

Skidmore, A. K. 1989. A comparison of techniques for calculating gradient and aspect from a gridded digital elevation model. International Journal of Geographic Information Systems 3:323-334.

Skinner, M.W., and B.M. Pavlik. 1994. California Native Plant Society's inventory of rare and endangered vascular plants of California. Fifth edition. California Native Plant Society, Sacramento, Calif.

Smith, R.L. 1980. Alluvial scrub vegetation of the San Gabriel River floodplain, California. Madroño 27:126- 138

Spolsky, A.M. 1979. An overview of the plant communities of Anza-Borrego Desert State Park. Unpublished report. State of California, The Resources Agency, Department of Parks and Recreation, Anza- Borrego Desert State Park, Borrego Springs, Calif.

StatSci. 1999. S-Plus 2000 modern statistics and advanced graphics: user's guide. MathSoft, Inc., Cambridge, Mass.

Stebbins, G.L., and J. Major. 1965. Endemism and speciation in the California flora. Ecological Mongraphs 35:1-35.

Stoddart, L.A., A.D. Smith, and T.W. Box. 1975. Range management. McGraw-Hill, New York, NY.

Stone, R.D., and V.A. Sumida. 1983. The Kingston range of California: a resource survey. Publication No. 10. University of California, Environmental Field Program, Santa Cruz, Calif.

Talley, S.N. 1978. An ecological summary of the Sentinel Meadow candidate Research Natural Area on the Inyo National Forest, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Taylor, D.W. 1976. Disjunction of Great Basin plants in the northern Sierra Nevada. Madroño 23:301-364.

Taylor, D.W. 1979. Ecological survey of the vegetation of White Mountain Natural Area, Inyo National Forest, California. Unpublished report. USDA, Forest Service, pacific Southwest Research Station, Berkeley, Calif.

Taylor, D.W., 1980. Ecological survey of the vegetation of Indiana Summit Research Natural Area, Inyo National Forest, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Taylor, D.W., and D.C. Randall. 1977. Ecological survey of the vegetation of the proposed Peavine Research Natural Area, El Dorado National Forest, California. Unpublished report. USDA, Forest Service, Pacific Southwest Research Station, Berkeley, Calif.

Thomas, K.A. 1996. Vegetation and floristic diversity in the Mojave Desert of California: A regional conservation evaluation. Dissertation. University of California, Santa Barbara. Santa Barbara, Calif. 191 p.

Thomas, K. 1997. Unpublished dataset from Death Valley National Park, Calif.

Thomas, K., T. Keeler-Wolf, and J. Franklin. In Press. In J.M. Scott and P Heglund, editors. Comparison of fine and coarse resolution environmental variables toward predicting vegetation distribution in the Mojave Desert. Predicting Species Occurrences. Island Press.

Thornburgh, D.A. 1990. *Quercus chrysolepis* – canyon live oak. Pages 618-624 in R.M. Burns and B.H. Honkala, technical coordinators. Silvics of North America, Volume 2. Hardwoods. Agriculture Handbook 654. USDA, Forest Service, Washington, D.C.

Thorne, R.F. 1976. The vascular plant communities of California. Pages 1-31 in J.Latting, editor. Plant communities of southern California. California Native Plant Society, Sacramento, Calif.

Thorne, R.F. 1982. The desert and other transmontane plant communities of southern California. Aliso 10:219-257.

Tisdale, E.W. 1994. Basin big sagebrush – SRM 401. Page 40 in T.N. Shiflet, editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

Tratz, W.M. 1978. Postfire vegetational recovery, productivity, and herbivore utilization of a chaparral-desert ecotone. Master's Thesis. California State University, Los Angeles, Calif. 133 p.

Tueller, P.T., C.D. Beeson, R.J. Tausch, N. E. West, and K.H. Rea. 1979. Pinyon–juniper woodlands of the Great Basin. General Technical Report. USDA, Forest Service, Intermountain Research Station, Ogden, Utah.

Turner, R.M. 1982a. Great Basin desertscrub. Desert Plants 4:145-155.

Turner, R.M. 1982b. Mohave desertscrub. Desert Plants 4:157-168.

Turner, R.M. and D.E. Brown. 1982. Sonoran Desert scrub. Desert Plants 4:181-221.

Vale, T.R. 1975. Invasion of big sagebrush (*Artemisia tridentata*) by white fir (*Abies concolor*) on the southeastern slopes of the Warner Mountains, California. Great Basin Naturalist 35:319-324.

Vasek, F.C. 1980. Creosote bush: long-lived clones in the Mojave Desert. American Journal of Botany 67:246-255.

Vasek, F.C., and M.G. Barbour. 1977. Mojave Desert scrub vegetation. Pages 835-867 in M.G. Barbour and J. Major, editors. Terrestrial Vegetation of California. Wiley–Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Vasek, F.C., and R.F. Thorne. 1977. Transmontane coniferous vegetation. Pages 797-832 in M.G. Barbour and J. Major, editors. Terrestrial vegetation of California. Wiley–Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Vasek, F.C., H.B. Johnson, and D.H. Eslinger. 1975. Effects of pipeline construction on creosote bush scrub vegetation of the Mojave Desert. Madroño 23:1-13.

Venables, W. M., and B. D. Ripley. 1994. Modern applied statistics with S-Plus. Springer-Verlag, New York.

Vogl, R.J., and L.T. McHargue. 1966. Vegetation of California fan palm oases on the San Andreas fault. Ecology 47:532-540.

Waananen, G.R., and H. Crippen. 1977. Streamflow records from California stream gages. California Department of Water Resources Bull. 102. Sacramento Calif.

Watts, J. 1996. Unpublished dataset from Ft. Irwin, Calif.

Webb, R.H., J.W. Steiger, E.B. Newman. 1988. The response of vegetation to disturbance in Death Valley National Monument, California. U.S. Geological Survey Bulletin 1793. U.S. Gov Printing Office 103p.

Went, F.W. 1948. Ecology of desert plants I. Observations of germination in the Joshua Tree National Monument, California. Ecology 29:242-253

Went, F.W. 1949. Ecology of desert plants II. The effect of rain and temperature on germination and growth. Ecology 30:1-13.

Werschkull, G.D., F.T. Griggs, and J.M. Zaninovich. 1984. Tulare Basin protection plan. Report 103. The Nature Conservancy, San Francisco, Calif.

West, N.E. 1988. Intermountain deserts, shrub steppes, and woodlands. Pages 209-230 in M.G. Barbour and W.D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, New York.

West, N.E. 1994. Juniper-pinyon woodland - SRM 412. Pg. 51 in T.N. Shiflet, Editor. Rangeland cover types of the United States. Society for Range Management, Denver, Colo.

Westman, W.E. 1983. Xeric Mediterranean-type shrubland associations of Alta and Baja California and the community/continuum debate. Vegetatio 52:3-19.

White, S.D. 1994. Coastal sage scrub classification for western Riverside County, California. Unpublished report. Tierra Madre Consultants Inc., Riverside, Calif.

White, S.D., and J.O. Sawyer. 1995. *Quercus wislizenii* forest and shrubland in the San Bernardino Mountains, California. Madroño 41:302-315.

Wieslander, A.E. 1935. A vegetation type map of California. Madroño 3:140-144.

Wolfram, H.W., and M.A. Martin. 1965. Big sagebrush in Fresno County, California. Journal of Range Management 18:285-286.

Wood Y., and S.G. Wells. 1996. Characterizing the habitat of slender-horned spineflower (*Dodecahema leptoceras*); Geomorphic analysis. Report to Region 5 of Department of Fish and Game, Long Beach Calif.

Wright, R.D., and H.A. Mooney. 1965. Substrate- oriented distribution of bristlecone pine in the White Mountains of California. American Midland Naturalist 73:257-284.

Yoder, V. 1983. Vegetation of the Alabama Hills region, Inyo County, California. Madroño 30:2(118-126)

Young, J.A., and C.G. Young. 1986. Collecting, processing, and germinating seeds of wildland plants. Timber Press, Portland Ore. 236p.

Young, J.A., R.A. Evans, and J. Major. 1977. Sagebrush steppe. Pages 763-796 in M.G. Barbour and J. Major, editors. Terrestrial vegetation of California. Wiley– Interscience, reprinted by the California Native Plant Society 1988, Sacramento, Calif.

Zembal, R. 1989. Riparian habitat and breeding birds along the Santa Margarita and Santa Ana rivers of southern California. Pgs. 98-113 in A.A. Schoenherr, editor. Endangered plant communities of southern California. Southern California Botanists, California State University, Fullerton, Calif.

Appendix A. Vegetation Alliances in the Mojave Desert

This appendix lists 101 vegetation alliances known to occur in the Mojave Desert (not just the study area) based on the current listing of alliances as maintained by NatureServe, formerly the Association for Biodiversity Information, (Ecology Group ABI 2000). NatureServe uses a hierarchical code to identify each alliance registered in the National Vegetation Classification as of November 2001. Where the alliance hierarchical code is not yet completely assigned, we use 'x' to indicate the incomplete portion.

NatureServe reviewed and accepted 20 alliances proposed by this study into the National Vegetation Classification (NVC); we used bold text to indicate these alliances in the list following. The data for classification of new alliances consisted of the relevé data collected for this project augmented with other data from select Mojave Desert field samples (see Products: Vegetation Classification, this volume). We indicate the sample sizes for newly described alliances in parenthesis. Usually NatureServe requires four or more plot descriptions to propose an alliance for new listing into the NVC.

Some vegetation types appear to have repeatable consistency across the landscape, but lack sufficient samples for inclusion yet into the NVC. We present these vegetation types as probable alliances pending confirmation with additional sampling in the Mojave Desert.

For the most current information on the accepted alliances in the Mojave Desert, view the NatureServe website, http://www.natureserve.org/.

I. Forest

Trees usually over 5 m tall with their crowns interlocking (generally forming 60-100% cover).

I.A. Evergreen Forest

I.A.6.N.b.2 *Quercus chrysolepis* Forest Alliance

I.B. Deciduous Forest

I.B.2.N.d.38 *Populus fremontii* Temporarily Flooded Forest Alliance

II. Woodland

Open stands of trees usually over 5 m tall with crowns not usually touching (generally forming 25-60% cover).

II.A. Evergreen Woodland

II.A.2.N.b.1.	*Washingtonia filifera* Seasonally Flooded Woodland Alliance
II.A.4.N.a.20	*Pinus longaeva* Woodland Alliance
II.A.4.N.a.27	*Pinus sabiniana* Woodland Alliance
II.A.4.N.a.38	*Juniperus osteosperma* Woodland Alliance
II.a.4.N.a.42	*Pinus flexilis* Woodland Alliance
II.A.4.N.a.45	*Pinus monophylla* - (*Juniperus osteosperma*) Woodland Alliance

II.B. Deciduous woodland

II.B.2.N.b.2	*Platanus racemosa* Temporarily Flooded Woodland Alliance
II.B.2.N.b.12	*Populus fremontii* Temporarily Flooded Woodland Alliance
II.B.2.N.c.7	*Populus fremontii* Seasonally Flooded Woodland Alliance
II.B.3.N.a.2	*Prosopis (glandulosa, velutina)* Woodland Alliance

III. Shrubland

Shrubs or trees usually 0.5 to 5 m tall with individuals or clumps not touching to interlocking (generally forming > 25% canopy cover)

III.A. Evergreen Shrubland

III.A.2.N.c.13	*Ceanothus greggii - Fremontodendron californicum* Shrubland Alliance
III.A.2.N.c.40	*Quercus turbinella* Shrubland Alliance
III.A.2.N.c.400	*Quercus cornelius-mulleri* Shrubland Alliance
III.A.2.N.h.2	*Pluchea sericea* Seasonally Flooded Shrubland Alliance
III.A.4.N.a.1	*Artemisia californica - Eriogonum fasciculatum* Shrubland Alliance
III.A.4.N.a.6	*Ericameria parryi* Shrubland Alliance (aka *Chrysothamnus parryi*)
III.A.4.N.a.7	*Cleome isomeris - Ephedra californica - Ericameria linearifolia* Shrubland Alliance
III.A.4.N.a.13	*Purshia tridentata* Shrubland Alliance
III.A.4.N.a.16	*Cercocarpus ledifolius* Shrubland Alliance
III.A.4.N.a.17	*Artemisia tridentata* Shrubland Alliance
III.A.4.N.a.21	*Purshia stansburiana* Shrubland Alliance
III.A.4.N.a.23	*Ericameria nauseosa* Shrubland Alliance
III.A.4.N.b.	***Baccharis sergiloides* Intermittently Flooded Shrubland Alliance (n=21)**
III.A.4.N.b.1	*Lepidospartum squamatum* Intermittently Flooded Shrubland Alliance

III.A.4.N.c.1	*Tamarix* spp. Semi-Natural Temporarily Flooded Shrubland Alliance
III.A.5.N.a.	***Larrea tridentata - Ambrosia dumosa* Shrubland Alliance**
III.A.5.N.a.5	*Larrea tridentata* Shrubland Alliance
III.A.5.N.a.9	*Ephedra viridis - Artemisia tridentata* Shrubland Alliance
III.A.5.N.a.10	*Ephedra nevadensis - Ephedra viridis* Shrubland Alliance
III.A.5.N.a. 11	*Ephedra nevadensis* Shrubland Alliance
III.A.5.N.a.12	*Ephedra viridis* Shrubland Alliance
III.A.5.N.a.14	*Encelia virginensis* Shrubland Alliance
III.A.5.N.b.x	***Larrea tridentata - Encelia farinosa* Shrubland Alliance (n=87)**
III.A.5.N.b.1	*Atriplex (lentiformis, polycarpa)* Shrubland Alliance
III.A.5.N.b.2	*Atriplex spinifera* Shrubland Alliance
III.A.5.N.b.3	*Allenrolfea occidentalis* Shrubland Alliance
III.A.5.N.b.4	*Encelia farinosa* Shrubland Alliance
III.A.5.N.b.5	*Eriogonum fasciculatum* Shrubland Alliance
III.A.5.N.b.6	*Atriplex canescens* Shrubland Alliance
III.A.5.N.b.7	*Atriplex confertifolia* Shrubland Alliance
III.A.5.N.b.9	*Atriplex hymenelytra* Shrubland Alliance
III.A.5.N.b.10	*Atriplex polycarpa* Shrubland Alliance
III.A.5.N.b.11	*Coleogyne ramosissima* Shrubland Alliance
III.A.5.N.b.x	***Viguiera parishii* Shrubland Alliance (n=16)**
III.A.5.N.c.x	***Nolina parryi* Shrubland Alliance (n=5)**
III.A.5.N.c.3	*Opuntia bigelovii* Shrubland Alliance
III.A.5.N.c.7	*Yucca schidigera* Shrubland Alliance
III.A.5.N.e.x	***Pinus monophylla* Wooded Shrubland Alliance**
III.A.5.N.e.1	*Yucca brevifolia* Wooded Shrubland Alliance

III.B. Deciduous Shrubland

III.B.2.N.c.10	*Suaeda moquinii* Intermittently Flooded Shrubland Alliance
III.B.2.N.d.6	*Salix (exigua, interior)* Temporarily Flooded Shrubland Alliance
III.B.2.N.d.28	*Forestiera pubescens* Temporarily Flooded Shrubland
III.B.2.N.d.36	*Salix lasiolepis* Temporarily Flooded Shrubland Alliance
III.B.3.N.a.x	***Salazaria mexicana* Shrubland Alliance (n=14)**
III.B.3.N.a.4	*Prosopis glandulosa* Shrubland Alliance
III.B.3.N.a.9	*Acacia greggii* Shrubland Alliance
III.B.3.N.a.11	*Grayia spinosa* Shrubland Alliance
III.B.3.N.a.14	*Sarcobatus vermiculatus* Shrubland Alliance
III.B.3.N.a.15	*Prosopis pubescens* Shrubland Alliance
III.B.3.N.a.x	***Hymenoclea salsola* Shrubland Alliance (n=70)**
III.B.3.N.b.x	***Ephedra californica* Intermittently Flooded Shrubland Alliance (n=50)**
III.B.3.N.b.x	***Viguiera reticulata* Intermittently Flooded Shrubland Alliance (n=6)**

III.B.3.N.b.x	***Hyptis emoryi* Intermittently Flooded Shrubland Alliance (n=1)**
III.B.3.N.b.x	***Ericameria paniculata* Intermittently Flooded Shrubland Alliance (n=23)**
III.B.3.N.b.x	***Prunus fasciculata* Intermittently Flooded Shrubland Alliance (n=28)**
III.B.3.N.b.x	***Psorothamnus spinosus* Intermittently Flooded Shrubland Alliance (n=7)**
III.B.3.N.b.1	*Chilopsis linearis* Intermittently Flooded Shrubland Alliance
III.B.3.N.b.2	*Grayia spinosa* Intermittently Flooded Shrubland Alliance
III.B.3.N.b.3	*Sarcobatus vermiculatus* Intermittently Flooded Shrubland Alliance

III.C. Mixed evergreen-deciduous shrubland

III.C.3.N.c.x	***Ericameria teretifolia* Shrubland Alliance (n=5)**
III.C.x.x.x.x	***Juniperus californica* Wooded Shrubland Alliance (n=30)**
III.C.x.x.x.x	***Juniperus osteosperma* Wooded Shrubland Alliance (n=71)**

IV. Dwarf-shrubland

Low-growing shrubs and/or trees usually under 0.5 m tall, individuals or clumps not touching to interlocking (generally forming > 25% cover).

IV.A.2.N.a.6	*Ambrosia dumosa* Dwarf-shrubland Alliance
IV.A.2.N.a.9	*Artemisia nova* Dwarf-shrubland Alliance
IV.A.2.N.a.8	*Krascheninnikovia lanata* Dwarf-shrubland Alliance
IV.B.3.N.a.4	*Salvia dorrii* Dwarf-shrubland Alliance
IV.B.3.N.a.x	***Menodora spinescens* Dwarf-shrubland Alliance (n=4)**

V. Herbaceous Vegetation

Graminoids and/or forbs (including ferns) generally forming > 10% cover with woody cover usually < 10%.

V.A.5.N.d.3	*Pleuraphis rigida* Herbaceous Alliance (aka *Hilaria rigida*)
V.A.5.N.d.19	*Achnatherum hymenoides* Herbaceous Alliance (aka *Oryzopsis hymenoides*)
V.A.5.N.e.14	*Pleuraphis jamesii* Herbaceous Alliance
V.A.5.N.f.2	*Achnatherum speciosum* Herbaceous Alliance (aka *Stipa speciosa*)
V.A.5.N.i.5	*Distichlis spicata* Intermittently Flooded Herbaceous Alliance
V.A.5.N.i.4	*Sporobolus airoides* Intermittently Flooded Herbaceous Alliance
V.A.5.N.k.x	***Juncus cooperi* Seasonally Flooded Herbaceous Alliance**

V.A.5.N.l.4	*Phragmites australis* Semipermanently Flooded Herbaceous Alliance
V.A.5.N.l.5	*Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance
V.A.5.N.1.16	*Schoenoplectus acutus - (Schoenoplectus tabernaemontani)* Semipermanently Flooded Herbaceous Alliance
V.A.7.N.e.4	*Chrysothamnus viscidiflorus* Shrub Herbaceous Alliance
V.A.7.N.e.9	*Pleuraphis rigida/Gutierrezia sarothrae* Shrub Herbaceous Alliance
V.A.7.N.h.1	*Pleuraphis rigida* Shrub Herbaceous Alliance (aka *Hilaria rigida*)
V.A.7.N.m.2	*Achnatherum speciosum* Shrub Herbaceous Alliance
VII.C.1.N.a.x	***Panicum urvilleanum* Sparsely Vegetated Herbaceous Alliance (n=3)**

VII. Sparse Vegetation

VII.A.1.N.a.x	Rock Outcrop Sparse Vegetation Alliance
VII.A.1.N.a.x	Rock Outcrop/Butte Sparse Vegetation Alliance
VII.A.2.N.a.4	Open Pavement Sparse Vegetation Alliance
VII.B.2.N.b.x	Gravel Wash Sparse Vegetation Alliance
VII.C.1.N.a.x	Herbaceous Dunes Sparse Vegetation Alliance
VII.C.1.N.a.1	*Abronia villosa* Sparsely Vegetated Alliance
VII.A.2.N.a.x	***Ephedra funerea* Sparse Vegetation Alliance (n=3)**

Probable

III.A.4.N.a.6.	*Ericameria parryi* Shrubland Alliance
III.A.2.N.c.401	*Quercus john-tuckeri* Shrubland Alliance
III.B.3.N.b.x	*Bebbia juncea* Intermittently Flooded Shrubland Alliance
V.A.5.N.k.10	*Eleocharis (montevidensis, palustris, quinqueflora)* Seasonally Flooded Herbaceous Alliance
V.A.5.N.k.13	*Juncus balticus* Seasonally Flooded Herbaceous Alliance
V.A.5.N.l.9	*Typha (angustifolia, latifolia) – (Schoenoplectus* spp.) Semipermanently Flooded Herbaceous Alliance

Appendix B. Alliance Key

We developed this key to aid in field identification of alliances and unique stands in the study area. It does not include all alliances in the Mojave Desert. It was field-tested during extensive collection of reference data in the spring of 2000 by six observers.

IA Total perennial plant cover ≤ 2% or no perennial species with ≥ 1% cover. Go to 100A.
IB Go to IIA.

IIA Tree species are present. Trees are defined as woody perennials that are regularly > 3 m in height; including shrub species often taller than 3 m such as *Chilopsis linearis*, *Cercocarpus ledifolius*, *Yucca brevifolia, Tamarix spp.* and *Juniperus osteosperma* or *californica*. The tree layer is visibly uniform in the stand although it may be low in cover. Go to II.1.

II.1 Tree species generally ≥ 25% cover. If total cover < 25%, tree species cover is greater than either herbaceous or shrub cover. Go to 200A.
II.2 *Yucca brevifolia, Pinus monophylla, Juniperus californica*, and/or *Juniperus osteosperma* ≥ 1% cover. Go to 250A.
II.3 Go to IIIA.

IIB Tree species not present. Go to IIIA.

IIIA Perennial herbaceous vegetation present (≥ 2% cover), and woody shrubs generally < 2% cover. Go to 300A.
IIIB Go to IVA.

IVA Shrubs present (≥ 2%); go to 400A.
IVB Perennial vegetation less than 2% or absent; go to 100A.

SPARSE AND UNVEGETATED ALLIANCES

100A Perennial plants present but less than 2%; depending upon substrate alliance may be: Rock Outcrop Sparse Vegetation Alliance, Rock Outcrop/Butte Sparse Vegetation Alliance, Open Pavement Sparse Vegetation Alliance, Gravel Wash Sparse Vegetation Alliance, Herbaceous Dunes Sparse Vegetation Alliance
100B Go to 101A.

101A Perennial vegetation absent. May be dominated seasonally by annual herbs and grasses. ***Unvegetated.***

TREE DOMINATED ALLIANCES

200A *Pinus monophylla* ≥ 25% cover or total cover greater than either shrubs or herbaceous cover. No other tree species approaches or exceeds it in cover. *Juniperus osteosperma* may be present. Restricted to cooler, moister sites than

Pinus monophylla Wooded Shrubland alliance, ***Pinus monophylla* - *(Juniperus osteosperma)* Woodland Alliance**.

200B Go to 201A.

201A *Pinus longaeva* ≥ 25% cover or total cover greater than either shrubs or herbaceous. Found only in the highest portions of the Inyo and Panamint Mountains. When occurring with *Pinus flexilis,* as on the upper east facing slopes of Waucoba Mtn. (Inyo Mountains.) the latter species may equal *Pinus longaeva* in cover, ***Pinus longaeva* Woodland Alliance.**

201B Go to 202A.

202A *Pinus* flexilis is the major tree species (> 55% relative cover and > 25% absolute cover). Typically occurs on more gently sloping, northerly exposures than *Pinus longaeva*, only on highest portion of Inyo and Panamint Mountains, ***Pinus flexilis* Woodland Alliance.**

202B Go to 203A.

203A *Abies concolor* co-dominates with *Pinus monophylla*. Stands are restricted to ravines and north-facing slopes in three mountain ranges in the eastern part of the study area (Clark Mtn., Kingston Range, and New York Mountains.), ***Abies concolor* Unique Stand.**

203B Go to 204A.

204A *Prosopis glandulosa* ≥ 2% cover. No other species with greater or equal cover. Trees and/or large shrubs of washes, dunes or riparian stands, ***Prosopis (glandulosa/velutina)* Woodland Alliance or *Prosopis glandulosa* Shrubland Alliance**.

204B Go to 205A.

205A *Populus fremontii* dominates stands (> 50% relative cover in tree layer), ***Populus fremontii* Seasonally Flooded Woodland Alliance or *Populus fremontii* Temporarily Flooded Woodland Alliance** (depending upon hydrology).

205B Go to 206A.

206A *Salix exigua* dominates stands (> 50% relative cover in tree layer), ***Salix exigua* Temporarily Flooded Shrubland Alliance.**

206B Go to 207A.

207A *Salix lasiolepis* dominates stands dominated (> 50% relative cover in tree layer), *Salix lasiolepis* **Woodland Alliance**.

207B Go to 208A.

208A Vegetation characterized by the relative dominance of *Quercus chrysolepis* (Canyon Live Oak) in the tree layer. Represented in the study area only by the rare canyon bottom stands of in the higher eastern Mojave Desert (Caruthers Canyon and other similar areas of eastern Mojave mountains), *Quercus* ***chrysolepis*** **Woodland Alliance**.

208B Go to 209A.

209A Vegetation characterized by the relative dominance of the shrubby tree *Cercocarpus ledifolius*. Stands occur in dry, rocky, and usually very well drained exposures in the highest portions of the Inyo, Panamint, and other tall ranges of the northern Mojave Desert, ***Cercocarpus ledifolius* Shrubland Alliance.**

209B Not treated in key.

250A *Yucca brevifolia* ≥ 1% cover, *Juniperus spp.* and/or *Pinus spp.* absent. Dominant understory species are shrub species such as *Coleogyne ramosissima, Opuntia ramosissima* or the perennial grass *Pleuraphis rigida*. Common in shallow upland soils throughout the Mojave Desert, ***Yucca brevifolia* Wooded Shrubland Alliance**.

250B Go to 251A.

251A *Juniperus californica, Juniperus osteosperma* and/or *Pinus monophylla* ≥ 1% cover. *Yucca brevifolia* absent. Go to 251.1.

- 251.1 *Juniperus californica* or *Juniperus osteosperma* ≥ 1%, *Pinus monophylla* not present (< 1% cover), and dominant understory species is a shrub. Due to taxonomic uncertainty of *Juniperus*, both species are lumped in this classification. However, in general *Juniperus californica* is largely found in the southwestern portion of the study area and *Juniperus osteosperma* in the northern and eastern portion, *Juniperus spp*. **Wooded Shrubland Alliance.**
- 251.2 *Pinus monophylla* ≥ 1% but less than 25% cover. *Juniperus osteosperma or californica* may be present. *Pinus monophylla* occurs over a sparse to relatively dense cover of shrubs, widespread in all of the higher mountains of mapping area. ***Pinus monophylla* Wooded Shrubland Alliance.**

251B Go to 252A.

252A Stands characterized (1% or higher cover) by *Chilopsis linearis* (desert willow) no other tree-size or tall shrub species equals or exceeds *Chilopsis linearis* cover, ***Chilopsis linearis* Intermittently Flooded Shrubland Alliance.**

252B Go to 254A.

254A Vegetation dominated by tall shrubby invasive *Tamarix* spp. (either *T. ramosissima, T. chinensis*, or other similar species, not including the less invasive, taller T. *aphylla*). *Tamarix* spp. should strongly dominate (> 60% relative cover) over native tall shrubs and/or low trees to be considered as alliance, ***Tamarix* spp. Semi-Natural Flooded Shrubland Alliance.**

254B Not considered in key.

HERBACEOUS DOMINATED ALLIANCES

300A *Pleuraphis jamesii* ≥ 2%. This species occurs in upper-elevation mid-Mojave Desert, often associated with *Yucca brevifolia*, *Opuntia acanthocarpa* and

Gutierrezia spp. May be easily confused with *Pleuraphis rigida*. ***Pleuraphis jamesii*** **Herbaceous Alliance.**

300B Go to 301A.

301A *Pleuraphis rigida* ≥ 2%. This species occur in low sandy areas and occasionally uplands at mid elevations, often with emergent shrubs such as *Yucca schidigera* and *Ephedra nevadensis*. As an alliance in the Mojave Desert, it is generally uncommon in upland areas and more common in low sandy areas. ***Pleuraphis rigida*** **Herbaceous Alliance.**

301B Go to 302A.

302A *Distichlis spicata* ≥ 2%. Usually associated with alkali basin wetlands, but small stands may occur along stream margins. ***Distichlis spicata*** **Intermittently Flooded Herbaceous Alliance.**

302B Go to 303A.

303A *Phragmites australis* ≥ 2%. Usually associated with alkali wetlands adjacent to playas, alkali springs, and meadows; may also occur in freshwater wetlands. ***Phragmites australis*** **Semipermanently Flooded Herbaceous Alliance.**

303B Go to 304A.

304A Vegetation characterized by the medium height bunch grass *Achnatherum hymenoides* (Indian Rice grass). Rare in the Mojave Desert. Usually a sparsely vegetated alliance with the grass as the major native perennial species. Sandy areas such as dune apron east of Eureka Dunes. ***Achnatherum hymenoides*** **Herbaceous Alliance.**

304B Go to 305A.

305A Vegetation characterized by the dominance of the bunch grass *Achnatherum speciosum* (desert needlegrass). Rare in mapping area, usually in small enclaves surrounded by more extensive upland vegetation of mid-to-upper Mojave Desert such as *Coleogyne ramosissima* Shrubland. ***Achnatherum speciosum*** **Herbaceous Alliance.**

305B Go to 306A.

306A Vegetation characterized by the presence of *Panicum urvilleanum* (dune panic grass). Usually a sparse rhizomatous grassland of open dune areas typically < 10% cover. Rare in Mojave Desert, associated with deep dune deposits at Kelso Dunes and Devils Playground. ***Panicum urvilleanum*** **Sparsely Vegetated Herbaceous Alliance**.

306B Go to 307A.

307A Vegetation characterized by the presence of *Swallenia alexandrae* (Eureka Dune Grass). Occurs only on sand dunes and sand sheets of the Eureka Valley, ***Swallenia Alexandrae*** **Unique Stands.**

307B Go to 308A.

308A Vegetation characterized by the canopy dominance of the bunchgrass *Sporobolus airoides*. Usually of margins of alkali springs and in alkali meadows as at Tecopa, Shoshone, and other sites along the Amargosa River. Most stands well below 5 ha in extent. ***Sporobolus airoides* Intermittently Flooded Herbaceous Alliance.**

308B Go to 309A.

309A Vegetation characterized by the relative dominance of *Schoenoplectus americanus* (three-square or American bulrush). Generally in permanently moist alkali springs, meadows, or streamsides. Most stands less than 5 ha in extent. ***Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance.**

309B Go to 310A.

310A Vegetation characterized by the relative dominance of *Juncus cooperi*. Usually small stands associated with other species of low-lying alkali seeps or meadows in such areas as Zzyzx, Tecopa, Shoshone, and Death Valley. ***Juncus cooperi* Intermittently Flooded Herbaceous Alliance.**

310B Not treated in key.

SHRUB CHARACTERIZED ALLIANCES

400A Either *Hymenoclea salsola*, *Bebbia juncea, Eriogonum fasciculatum, Salazaria mexicana,* or *Senna armata*, are > 1%. Other shrubs, if present, are each less than half of the above species with the exceptions of *Hyptis emoryi* or *Salvia dorrii*, which may have higher cover. Go 400.1.

- 400.1 *Bebbia juncea* > 1% other shrubs. May be present in small stands in the Mojave Desert. ***Bebbia juncea* Intermittently Flooded Shrubland Alliance.**
- 400.2 *Hymenoclea salsola* > 1% other shrubs. Found in wash environments or disturbed environments. ***Hymenoclea salsola* Shrubland Alliance.**
- 400.3 *Eriogonum fasciculatum* ≥ 2%. Usually in disturbed shallow soils on slopes and pediments at mid and upper elevation. ***Eriogonum fasciculatum* Shrubland Alliance.**
- 400.4 *Salazaria mexicana* ≥ 2% cover**.** Usually of washes, but may occur on burns or in other disturbed uplands. ***Salazaria mexicana* Shrubland Alliance.**
- 400.5 *Senna armata* > 1% other shrubs. ***Senna armata* Unique Stand.**

400B Go to 401A.

401A *Yucca schidigera* ≥ 2% cover. Understory dominant species is a shrub. ***Yucca schidigera* Shrubland Alliance.**

401B Go to 402A.

402A Creosote Bush < 1% cover; go to 410A.

402B Go to 403A.

403A No shrub with cover greater than *Larrea tridentata,* with the following exceptions: *Ambrosia dumosa*, *Encelia farinosa, Krameria spp. Bebbia juncea, Ericameria teretifolia* or *Acamptopappus spherocephalus*. *Ephedra nevadensis* or *Opuntia acanthocarpa* may have higher cover, but no more than three times. Go to 401.1.

401.1 *Ambrosia dumosa* present (≥ 1% cover) may have higher cover than *Larrea tridentata*. If *Encelia farinosa is* present, go to 401.2. Widespread on all but the hottest and most rocky, sandy or most alkaline areas of the low Mojave Desert. ***Larrea tridentata-Ambrosia dumosa* Shrubland Alliance.**

401.2 *Encelia farinosa* present (≥ 1% cover), may have higher cover than *Larrea tridentata. Ambrosia dumosa* may be present. Widespread on hot (southerly exposure) mountain slopes and upper bajadas. ***Larrea tridentata-Encelia farinosa* Shrubland Alliance.**

401.3 Associate shrubs other than *Ambrosia dumosa* or *Encelia farinosa* may be present or absent. Except for shrubs listed above, associate shrub cover is less than Larrea tridentata. ***Larrea tridentata* Shrubland Alliance**.

403B Go to 420A.

410A *Ambrosia dumosa* > 1% cover and no other species with equal or higher cover. ***Ambrosia dumosa* Dwarf Shrubland Alliance**.

410B Go to 411A.

411A *Encelia farinosa* > 1% and no other species with equal or higher cover. ***Encelia farinosa* Shrubland Alliance.**

411B Go to 420A.

420A *Atriplex* spp. with ≥ half of all cover. Go to 420.1.

420.1 *Atriplex confertifolia* with highest shrub cover. May occur in alkaline valleys or playas and in upper mid-elevation Mojave Desert on rolling hills and slopes, particularly common in the northern portion of the mapping area, ***Atriplex confertifolia* Shrubland Alliance.**

420.2 *Atriplex canescens* with highest shrub cover. Typically of low-lying playa edges, dune aprons, or edges of alkaline wetlands from low- to mid-elevation. ***Atriplex canescens* Shrubland Alliance.**

420.3 *Atriplex polycarpa* with highest shrub cover. May occur on playa edges, in washes through alkaline areas, or occasionally uplands with alkaline substrate, ***Atriplex polycarpa* Shrubland Alliance.**

400.4 *Atriplex hymenelytra* > 1% cover and no other species with equal or higher cover. May occur on hot rocky slopes, dry bajadas, or alkaline badlands and playa edges. ***Atriplex hymenelytra* Shrubland Alliance.**

400.5 *Atriplex spinifera* with highest shrub cover. Largely restricted to the Western portion of the mapping area around edges of playas and other alkaline situations. ***Atriplex spinifera* Shrubland Alliance.**

400.6 Vegetation characterized by the relative dominance of *Atriplex lentiformis* (quailbush). Localized in study area along upper Amargosa River and east shore of Owens Lake. ***Atriplex lentiformis* Shrubland Alliance.**

420B Go to 421A.

421A *Acacia greggii* ≥ 2% cover. No other single tall shrub species with greater cover but *Prunus fasciculata* or *Hyptis emoryi* may be equal or slightly greater cover than *Acacia.* Smaller shrubs such as *Ericameria paniculata* or *Hymenoclea salsola* can have higher cover but no more than twice the cover of *Acacia greggii.* Occurs in washes, arroyos, as well as upland valleys and bouldery slopes**. *Acacia greggii* Shrubland Alliance.**

421B Go to 422A.

422A *Amphipappus fremontii* ≥ 2% cover. No other species with greater or equal cover. Occurs in washes and on slopes in limestone. ***Amphipappus fremontii* Unique Stand.**

422B Go to 423A.

423A *Allenrolfea occidentalis* ≥ 2% cover, no other single species with greater cover. Vegetation typically occupying strongly alkaline playas usually with distinct salt deposits in soil surface. ***Allenrolfea occidentalis* Shrubland Alliance.**

423B Go to 424A.

424A *Artemisia nova* ≥ 2% cover. No other single species with greater cover. This is typically an alliance of the limestone mountains and may occur at mid-elevation Mojave Desert or well up into the higher mountains. Other limestone shrubs such as *Mortonia utahensis* may be common. May also mix with lesser amounts of widespread species such as *Atriplex confertifolia*. ***Artemisia nova* Dwarf-Shrubland Alliance.**

424B Go to 425A.

425A *Atriplex confertifolia* ≥ 2% cover. No other single species with greater cover with the exception of woody subshrubs such as *Krameria spp*. ***Atriplex confertifolia* Shrubland Alliance.**

425B Go to 426A.

426A *Artemisia tridentata* ≥ 2% cover, no other single species with greater cover. Go to 426.1.

426.1 *Ephedra viridis* < 1% cover. ***Artemisia tridentata* Shrubland Alliance.**

426.2 *Ephedra viridis* ≥ 1% cover. Upper elevation scrubs on well drained rocky to gravelly soil usually adjacent to stands of *Pinus monophylla* and or *Juniperus osteosperma*. Other seral shrub species e.g. *Ericameria* spp. may equal these two in cover. ***Ephedra viridis-Artemisia tridentata* Shrubland Alliance.**

426B Go to 427A.

427A *Baccharis sergiloides* dominant. Typically of intermittent springs and washes in mid-elevation Mojave Desert. ***Baccharis sergiloides*** **Intermittently Flooded Shrubland Alliance**.
427B Go to 428A.

428A *Cercocarpus intricatus* the clear dominant (> 55% relative cover in tall shrub layer) on limestone outcrops in northern portion of Mojave Desert as at Last Chance Range, northern Inyo Mountains, Panamint Mountains. (Aguerreberry Point), ***Cercocarpus intricatus*** **Shrubland Alliance.**
428B Go to 429A.

429A *Coleogyne ramosissima* ≥ 2% cover. *Ephedra nevadensis*, and or *Krameria grayi* can have up to twice the cover of *Coleogyne ramosissima*. Typically dominates stands, but may be exceeded by species of disturbance (*Hymenoclea salsola, Salazaria mexicana, Ericameria* spp., *Eriogonum fasciculatum*), A widespread type of shallow rocky soils on upper bajadas, pediments and hill slopes. ***Coleogyne ramosissima*** **Shrubland Alliance.**
429B Go to 430A.

430A *Encelia virginensis* (including the subspecies *Encelia virginensis actonii*) ≥ 2% cover. No other species with greater or equal cover. Typically of washes or other disturbed areas in the eastern Mojave Desert. ***Encelia virginensis*** **Shrubland Alliance.**
430B Go to 431A.

431A Vegetation either dominated or co-dominated by *Ephedra californica,* typically of broad, active washes of mid to upper bajadas and fans. Ranging somewhat locally throughout the southwestern, central and eastern portions of the area. ***Ephedra californica*** **Intermittently Flooded Shrubland Alliance.**
431B Go to 432A.

432A Vegetation strongly dominated by *Ephedra funerea* with no other indicator species present. An uncertain alliance of limestone mountains in the northeastern Mojave Desert, represented by little data. ***Ephedra funerea*** **Sparse Vegetation Alliance**.
432B Go to 433A.

433A *Ephedra nevadensis* ≥ 2% cover. No other species with greater cover with the exceptions of *Acamptopappus sphaerocephalus* or *Chrysothamnus viscidiflorus*. ***Ephedra nevadensis*** **Shrubland Alliance.**
433B Go to 434A.

434A *Ericameria nauseosa* ≥ 2%. *Ericameria nauseosa* must have 25% or greater relative cover. Mid- and upper-elevation elevations, usually in areas with fire, flood or grazing history. ***Ericameria nauseosa*** **Shrubland Alliance.**
434B Go to 435A.

435A *Chrysothamnus viscidiflorus* ≥ 2%. *Chrysothamnus viscidiflorus* must have 25% or greater of all cover. ***Chrysothamnus viscidiflorus* Shrubland Alliance.**
435B Go to 436A.

436A *Ericameria paniculata* ≥ 2%. *Ericameria paniculata* must be ≥ 25% of all cover. Widespread throughout broad elevation range in much of the mapping area in relatively large, recently active washes. ***Ericameria paniculata* Intermittently Flooded Shrubland Alliance.**
436B Go to 437A.

437A *Ericameria teretifolia* ≥ 2% cover. No other species with greater or equal cover. Usually of disturbed uplands**,** mid elevation**. *Ericameria teretifolia* Shrubland Alliance.**
437B Go to 438A.

438A *Grayia spinosa* ≥ 2% cover; no other species with greater cover except *Ericameria cooperi* or *Lycium andersonii. Lycium andersonii* must dominate in some circumstances. ***Grayia spinosa* Shrubland Alliance.**
438B Go to 439A.

439A Vegetation characterized by the tall aromatic shrub *Hyptis emoryi* (desert lavender). Local in rocky washes of upper bajadas and canyons in the southern portion of the Mojave Desert. ***Hyptis emoryi* Intermittently Flooded Shrubland Alliance.**
439B Go to 440A.

440A Vegetation usually of mid- to upper- elevation flats and small basins dominated strongly by the low shrub *Krascheninnikovia lanata* (winter-fat), without any other species in higher cover. Uncommon in mapping area. ***Krascheninnikovia lanata* Shrubland Alliance.**
440B Go to 441A.

441A Vegetation characterized by the broom-like *Lepidospartum squamatum* (scale-broom). Stands concentrated along washes on eastern base of the San Bernardino Mountains in the extreme southwest portion of the mapping area. Other smaller stands occur at mid-elevations throughout the desert. ***Lepidospartum squamatum* Shrubland Alliance.**
441B Go to 442A.

442A *Menodora spinescens* ≥ 2% cover, no other single species with greater cover although many other species may be present. Represented by a few localized stands in well-defined, shallow rocky soils characteristically just above *Larrea tridentata-Ambrosia dumosa.* ***Menodora spinescens* Shrubland Alliance.**
442B Go to 443A.

443A *Mortonia utahensis* ≥ 2% cover. No other species with greater or equal cover. An open scrub of limestone slopes at mid-elevation in the east Mojave Desert mid-elevation. ***Mortonia utahensis* Unique Stand.**
443B Go to 444A.

445A *Nolina parryi* > 3% cover. Uncommon, scattered in extreme southwest of study area and in Kingston Range. ***Nolina parryi* Shrubland Alliance.**
445B Go to 446A.

446A *Pluchea sericea* ≥ 2% cover. No other species with greater or equal cover. Occurs as narrow stringers at alkaline springs and seeps and as rare extensive stands on alkaline flats such as Devil's Golfcourse and Saline Valley. ***Pluchea sericea* Seasonally Flooded Shrubland Alliance.**
446B Go to 447A.

447A *Prunus fasciculata* ≥ 2% cover. Must be 25% or more of total cover. *Gutierrezia sarothrae* may have higher cover. If *Prunus fasciculata* co-occurs with other tall shrubs such as *Acacia greggii*, it must have 2x the cover of other species to make alliance definition. Typically of washes, but may occur on wash terraces and valleys, ***Prunus fasciculata* Shrubland Alliance.**
447B Go to 448A.

448A *Psorothamnus spinosus* ≥ 2% cover. No other species with greater or equal cover. Of low elevation washes in southern and central portion of mapping area ***Psorothamnus spinosus* Intermittently Flooded Shrubland Alliance.**
448B Go to 449A.

449A *Purshia stansburiana* ≥ 2% cover, no other single species with greater cover. Tends to occur in eastern Mojave Desert limestone mountains in washes in the pinyon and juniper belt. ***Purshia stansburiana* Shrubland Alliance.**
449B Go to 450A.

450A *Purshia tridentata* ≥ 2% cover, If *Artemisia tridentata* or *Ephedra viridis* are present they have less than 1% cover. A local type in high eastern and northern portions of mapping area***.*** ***Purshia tridentata* Shrubland Alliance**.
450B Go to 451A.

451A Vegetation characterized by the scrub oak *Quercus turbinella*. Occurs in New York Mountains and perhaps Clark Mtn. ***Quercus turbinella* Shrubland Alliance**
451B Go to 452A.

452A *Sarcobatus vermiculatus* (Greasewood) ≥ 2%. *Sarcobatus* is the relative dominant and may have *Suaeda moquinii* and *Atriplex* spp. associated in lesser cover. Only known in study area from the alkali dunes and flats above the east shore of Owens Lake. ***Sarcobatus vermiculatus* Shrubland Alliance.**
452B Go to 453A.

453A *Suaeda moquinii* ≥ 2% cover. No other species with greater or equal cover. Typically occupying strongly alkaline playas usually with distinct salt deposits in soil surface, but may occur in upland areas adjacent to playas (Owens Lake) where wind-blown salts are deposited. ***Suaeda moquinii* Intermittently Flooded Shrubland Alliance.**

453B Go to 454A.

454A *Viguiera parishii* ≥ 2% cover. No other species with greater or equal cover. On northerly slopes of the Mojave Desert characteristically just above *Larrea tridentata-Ambrosia dumosa* , or in washes in east Mojave Desert. ***Viguiera parishii* Shrubland Alliance.**

454B Go to 455A.

455A *Viguiera reticulata* ≥ 2% cover. No other species with greater or equal cover. Of calcareous (mostly limestone) washes and arroyos in mountains in the mid- or upper-elevation in the eastern Mojave Desert. ***Viguiera reticulata* Intermittently Flooded Shrubland Alliance.**

455B Not Treated in the Key.

Appendix C. Alliance Descriptions

This appendix provides descriptions for 70 alliances occurring within the map project study area as identified on the vegetation map or special features map. Todd Keller-Wolf and Julie Evens provided photographs.

The descriptions follow a standard format:

- National Vegetation Classification alliance name,
- Habitat: Common upland landforms in which alliance occurs. Common hydrologic regimes in which alliance occurs. Common soil types in which alliance occurs,
- Distribution: Distribution of alliance by ecological section within California (see below) and by state and country for areas outside of California,
- Elevation: Elevation range for the alliance,
- NDDB Rank: The California Natural Diversity Database (http://www.dfg.ca.gov/endangered/ranks.html) ranking of an alliance or the closest alliance synonym. The system consists of global ranks and state ranks. Global Ranks are the worldwide statues of a full species and are indicated with these ratings:
    1. G1 = extremely endangered: < 6 viable occurrences (EO's) or < 1,000 individuals, or < 2,000 acres of occupied habitat
    2. G2 = endangered: about 6-20 EO's, or 1,000 - 3,000 individuals, or 2,000 to 10,000 acres of occupied habitat
    3. G3 = restricted range, rare: about 21-100 EO's, or 3,000-10,000 individuals, or 10,000-50,000 acres of occupied habitat
    4. G4 = apparently secure: some factors exist to cause some concern such as narrow habitat or continuing threats
    5. G5 = demonstrably secure: commonly found throughout its historic range

  State Ranks are the statewide status of a *full species or a subspecies* and are indicated by S1 to S5. S1 to S5 have the same general definitions as global ranks, but just for the range of the taxa within California,
- Synonyms: Labels applied to the alliance in existing classification systems, including: Barry (1989a,b), CALVEG (Matyas and Parker 1980), Cheatam and Haller (1975), Holland (1986), Munz and Keck (1950), PSW-45 (Paysen et al 1980), Thorne (1976) and WHR (Mayer & Laudenslayer 1988), Stone and Sumida (1983), Sawyer and Keeler-Wolf (1995), Rangeland (Shiflet 1994), and Brown, Lowe and Pase (1979),
- References: Additional information on alliance including references to plot-based descriptions that describe and classifies the alliance other than in the Mojave Desert,
- Membership Rules: Criteria to recognize and define the alliance,
- Comments: Notes on the classification of the alliance, vegetation dynamics of the alliance, biology of the dominant species and effects of disturbance,

- Regional Status: Status of the alliance within the Mojave Desert and Southeast Great Basin, the two ecological sections in which parts of the mapping area occur, and
- Management Considerations: Notes on issues of management concern regarding the alliance.

Miles and Goudy (1997) describe one standard for geographic classification of ecological regions. This is a hierarchical system used by several federal agencies to provide a uniform framework of ecosystem classification and mapping throughout the United States. The portion of the hierarchy referred to in this report includes the Ecological Sections and Subsections. Nineteen ecological sections are found in California (Table A1).

Table A1. Ecological Sections in California

Ecological Section Name
Central California Coast
Southern California Coast
Great Valley
Northern California Coast
Klamath Mountains
Northern California Coast Range
Northern California Interior Coast Ranges
Southern Cascades
Sierra Nevada
Sierra Nevada Foothills
Modoc Plateau
Central California Coast Ranges
Southern California Mountains and Valleys
Mojave Desert
Sonoran Desert
Colorado Desert
Mono
Southeastern Great Basin
Northwestern Basin and Range

Acacia greggii Shrubland Alliance

Figure A1. *Acacia greggii* Shrubland Alliance, Granite Cove, Granite Mountains

Acacia greggii is the sole, dominant, or important tall shrub or small tree in canopy. *Chilopsis linearis, Parkinsonia florida, Juniperus californica, Juniperus osteosperma, Olneya tesota,* or *Psorothamnus spinosus* may be present as emergent trees over the shrub canopy. *Bebbia juncea, Ephedra californica, Encelia virginensis, Ericameria teretifolia, Eriogonum fasciculatum, Hymenoclea salsola, Hyptis emoryi, Larrea tridentata, Opuntia acanthocarpa, Phoradendron californicum, Prunus fasciculata, Rhus ovata, Salazaria mexicana, Senna armata, Viguiera parishii,* or *Yucca schidigera* may be present. Trees < 5 m, scattered; shrubs < 3 m, intermittent or open. Ground layer sparse, annual herbs or grasses seasonally present.

Habitat: Rocky slopes, valleys, and bajadas. Washes, intermittent channels, arroyos intermittently flooded riverine or palustrine. Soils coarse, well drained and moderately acidic to slightly saline.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, and Southern California Mountains and Valleys, south Nevada, west Arizona, Baja California.

Elevation: 10 to 1500 m

NDDB Rank: G5 S4

Synonyms:
Holland: Mojave wash scrub (34250), Mojave desert wash scrub (63700)
Barry: G7411124
Cheatham and Haller: Desert dry wash woodland
PSW-45: Catclaw series
CALVEG: Catclaw series
Thorne: Desert microphyll woodland
WHR: Desert wash
Munz: Creosote bush, Shadscale scrubs, Joshua tree woodland

References: Johnson (1976), MacMahon (1988), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Turner and Brown (1982), Vasek and Barbour (1977); plot-based descriptions include Vasek and Barbour (1977), Barbour and Wirka (1997), Keeler-Wolf et al.1998.

Membership Rules: *Acacia greggii* ≥ 2% cover up to 25% cover. No other single tall shrub species with greater cover but *Prunus fasciculata* or *Hyptis emoryi* may be equal or slightly greater cover than *Acacia.* Smaller shrubs such as *Ericameria paniculata* or *Hymenoclea salsola* can have higher cover but no more than twice the cover of *Acacia greggii.* Occurs in washes, arroyos, as well as upland valleys and bouldery slopes. Evens (2000) states variable cover (1-< 6%) of *Acacia greggii*, but mentions it is always the dominant canopy shrub.

Comments: In washes**,** *Acacia greggii* Shrubland Alliance occupies habitat similar to other leguminous microphyll alliances in the Colorado and Sonoran deserts. The *Acacia greggii* Shrubland Alliance extends farther north into the Mojave Desert than these microphyll alliances. Because it is relatively frost-tolerant, it also ascends into the desert mountains and the adjacent desert transition of the Peninsular Ranges. It is a warm-season rain species and does not occur in the western Mojave Desert (T. Keeler-Wolf personal communication, Desert Workshop 2000). Although commonly of washes, arroyos, and lower canyons, *Acacia greggii* Shrubland Alliance may also occupy rocky slopes and valleys away from fluvial disturbance (Reid et al.1999). In Anza-Borrego Desert State Park, it occurs in upland valleys up to 1,200 m and on south-facing rocky granite slopes up to 1,400 m (Keeler-Wolf et al.1998). Evens (2000) sampled 55 plots in the eastern Mojave Desert and described six associations. She indicates that of the six associations she describes as occurring in washes and arroyos only one occurs in lower elevation canyons.

Acacia greggii is a large shrub or small tree of the southwest deserts. It is tied to fluvial disturbance in much of its range, lining small to relatively large active washes and arroyos. It is a vigorous sprouter, following flood damage, heavy browsing, or fire, and may be long-lived (FEIS 2001). It is cold-deciduous and requires greater concentrations of water than available in the modal desert landscape. It thus occupies washes, valley bottoms and in some cases, slopes where outcrops and boulders channel surface water to roots. Stands are typically uneven in age. *Acacia* seeds are nutritious and often cached and dispersed by small mammals. Seeds require scarification for germination either by passing through herbivore digestive systems or by abrasion of the seed coat (Young and Young 1986). Recruitment is sporadic. Little information exists on variation in flood frequencies in the wash associations. Fire was not likely to be an important disturbance before the advent of Eurasian annual grasses in portions of its upland distribution. However, in stands with *Pleuraphis rigida* understory, fire may have played a natural disturbance role. *Acacia greggii* individuals are notoriously difficult to kill once they are established (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Flooding intensities along washes are highly variable; however, relatively low discharges (< 20 cu ft./second) are sufficient in small concentrated channels to initiate seed germination and dispersal. *Acacia greggii* may be tolerant of grazing and may be an increaser (Granite Cove, Sweeney Granite Mountains Reserve, Cima Dome area). Fire may enhance the stands due to resprouting following fires spread by fine fuels such as *Bromus madritensis*. Upland stands occur on south-facing slopes as high as 1,300-1,400 m (as in the Granite Mountains and Mid Hills in eastern Mojave Desert). As a result of the resprouting response, *Acacia greggii* stands tend to replace *Larrea tridentata-Ambrosia dumosa, Yucca schidigera, Coleogyne ramosissima* and other related upland alliances following prolonged browsing pressure and/or fire in upland settings. Wash and arroyo stands are relatively persistent, though patchy, and are interspersed with other wash alliances (see *Ericameria paniculata, Hymenoclea salsola, Psorothamnus spinosus, Salazaria mexicana, Eriogonum fasciculatum, Encelia virginensis, Prunus fasciculata, Hyptis emoryi* dominated shrublands). The five Mojave Desert associations defined reflect the range in elevation distribution from the lower and hotter elevations (with *Psorothamnus spinosus* and *Hyptis emoryi* dominated shrublands) through the mid elevations (with *Viguiera parishii* and *Encelia virginensis* dominated alliances) to the cooler, upper elevations (with *Prunus fasciculata* and *Salvia dorrii* dominated shrublands). We expect additional associations to exist in the upland environments.

Regional Status:
Mojave Desert: Stands occur in the southern and eastern Mojave Desert north to the southern end of Death Valley National Park.
Sonoran Desert: Stands occur throughout the Sonoran Desert in California. Flooding intensities have similar effects as in the Mojave Desert portion of its range. *Acacia greggii* alliance appears more restricted to washes in the region due to the excessively dry and relatively low elevations compared to other portions of its California range. Fire and grazing are not as significant an influence as in the Mojave Desert or Peninsular Ranges.

Management Considerations: Natural flooding regimes in most wash and riparian settings are adequate for perpetuating the alliance range-wide. Some evidence points to an increase relative to less disturbance-resistant desert alliances in upland stands. It is likely that continued high fire frequency in the upper desert stands with non-native grasses will benefit *Acacia greggii* Shrubland Alliance to the detriment of stands of other non-fire tolerant alliances.

Achnatherum speciosum Herbaceous Alliance

Figure A2. *Achnatherum speciosum* Herbaceous Alliance, Aguerreberry Point, Panamint Mountains

Achnatherum speciosum is the sole, dominant, or important grass in ground layer. *Achnatherum hymenoides, Elymus elymoides, Nassella cernua*, and/or *Poa secunda* may be present. Emergent shrubs such as *Coleogyne ramosissima, Ericameria cooperi, Grayia spinosa, Hymenoclea salsola*, and *Krascheninnikovia lanata* may be present. Emergent *Yucca brevifolia* may be present (< 1% cover). Grass < 1 m; cover open to intermittent. Annual herbs may be seasonally present.

Habitat: Flat ridges, lower slopes, hills, and swales. Soils sandy, rocky, alluvial

Distribution: Mojave Desert, Southeastern Great Basin.

Elevation: 600 to 1,800 m

NDDB Rank: G1 S1.2

Synonyms
Holland: Valley needlegrass grassland (42110 *in part*)
Cheatham and Haller: Creosote bush scrub
Thorne: Creosote bush scrub
WHR: Desert Scrub
Munz: Creosote bush scrub

References: Holland (1986), Reid et al. (1999), Sawyer and Keeler-Wolf (1995); plot descriptions occur in the California NDDB.

Membership Rules: Vegetation is characterized by the dominance of the bunch grass *Achnatherum speciosum* (desert needlegrass). Rare in mapping area, usually in small enclaves surrounded by more extensive upland vegetation of mid-to-upper elevation Mojave Desert such as *Coleogyne ramosissima* Shrubland.

Comments: The species *Achnatherum speciosum* occurs throughout much of the Mojave Desert and Southern Great Basin. However, the *Achnatherum speciosum* Herbaceous Alliance is rare, only known from a few stands in the Mojave Desert and the adjacent Southeastern Great Basin. Its rarity is likely a function of the natural disturbance regimes necessary for its development (see below). However, it is also likely to be a function of the invasion of non-native annual grasses and altered fire frequencies in the California deserts.

Achnatherum speciosum will resprout after relatively cool, rapidly spreading fire (Humphrey 1974). Stands of *Achnatherum speciosum* are likely to be associated with past fires. Fires probably occurred most often in late summer or fall. Stands of *Achnatherum speciosum* occupy portions of the desert where fire frequencies are relatively high, such as the borderland between the chaparral and the desert shrublands (Tehachapi Mountains and Antelope Valley). This alliance is likely to be the natural post-fire state of many stands of *Coleogyne ramosissima, Grayia spinosa,* and other fire-susceptible desert shrublands. However, because of the invasion of *Bromus madritensis, Schismus* spp. and other non-native herbaceous species, the increased fire frequencies and rapid invasive qualities of these species have imposed a decline on the importance of native grasses in these desert ecosystems. The successful re-establishment of stands following fire relies on the relatively high stocking of individuals within the pre-fire shrubland. *Achnatherum speciosum* individuals that survive the fire re-sprout rapidly, set seed, and colonize the burned shrubland more rapidly than the formerly dominant woody species. However, shrubland will likely re-invade with the low fire frequencies in most parts of the desert. Fire intervals of 50 years or less are probably necessary to maintain *Achnatherum speciosum* stands. *Achnatherum speciosum* has been seen to invade old cleared agricultural lands in the Antelope Valley of the Mojave Desert (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Regional Status:
Mojave Desert: Currently stands occur only in the western Mojave Desert, the adjacent Tehachapi Mountains, the eastern Mojave Desert, and Panamint Mountains. These stands are in the upper desert adjacent to stands of *Coleogyne ramosissima, Ericameria teretifolia* or *Grayia Spinosa* Shrublands and *Juniperus californica* or *Yucca* Wooded Shrublands. The Antelope Valley stands are generally small (< 30 ha) and are interspersed among larger stands of *Juniperus californicus, Yucca brevifolia,* and *Ericameria linearifolia*. Stands are generally open and, in good years, may have well developed annual native wildflowers carpeting the bare ground between clumps. The surrounding vegetation is generally well stocked with individuals of *Achnatherum speciosum*, suggesting that with appropriate fire intensity and frequency the stands could increase.

Southeastern Great Basin: The only known stands occur in the Panamint Mountains adjacent to stands of *Coleogyne ramosissima* and *Artemisia tridentata*. The irregular shapes of the stands suggest the burn caused the current extent of the stand. Stands are generally < 50 ha.

Management Considerations: This rare alliance may have been more common before the invasion of non-native grasses in the deserts of California. In its natural state, it probably represented a relatively short-lived, but important seral community associated with small irregularly occurring fires in the mid-to-upper elevation desert scrubs of the Mojave Desert and the Southeastern Great Basin. All stands should be considered natural resources and should be monitored. Stands of associated shrublands with a significant component of *Achnatherum speciosum* should be identified and post-fire response should be monitored for a better understanding of the shrub/grassland seral relationships and perpetuation of this phase of the natural desert temporal systems. Intensive sheep grazing in the late 1800s and early 1900s may have reduced the range of this alliance. Old rangeland records in the western Mojave Desert on *Achnatherum speciosum* suggest that this species was once more common and widespread (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Achnatherum hymenoides Herbaceous Alliance

Figure A3. *Achnatherum hymenoides* Herbaceous Alliance, Eureka Dunes

Achnatherum hymenoides (aka *Oryzopsis hymenoides*) is the sole or dominant grass in ground layer. *Bromus tectorum*, *Elymus elymoides*, *Pascopyrum smithii*, *Koeleria* *macrantha, Poa secunda,* or *Stipa comata* may be present. Emergent shrubs may be present. Grass < 1.5 m tall; cover open.

Habitat: All topographic locations. Soils sandy.

Distribution: Sierra Nevada, Mojave Desert, Mono, Southeastern Great Basin, Northwestern Basin and Range, western and central U.S.

Elevation: 0 to 3,400 m

NDDB Rank: G4 S1.2

Synonyms
Holland: Mojave mixed steppe
Barry: G7411331 BORHY00
Brown, Lowe and Pase: 142.231
Cheatham and Haller: Great Basin native grassland
PSW-45: Ricegrass series
Thorne: Great Basin sagebrush scrub
WHR: Perennial grass
Munz: Sagebrush scrub

References: Heady (1977), Paysen et al. (1980), Stoddart et al. (1975), Turner and Brown (1982); plot descriptions include California NDDB, Major and Taylor (1977).

Membership Rules: Vegetation characterized by the medium height bunch grass *Achnatherum hymenoides* (Indian Rice grass). Rare in the Mojave Desert. Usually a sparsely vegetated alliance, with the grass as the major native perennial species. Sandy areas such as dune apron east of Eureka Dunes.

Comments: The dominant species, *Achnatherum hymenoides,* is a component of many transmontane California alliances but it rarely dominates stands. In California, most stands where it dominates are small and form fine mosaics with alliances (see *Artemisia tridentata, Abronia villosa, Purshia tridentata* dominated alliances). The ecological literature may refer to *Achnatherum hymenoides* also as *Oryzopsis hymenoides*. *The Jepson Manual* (Hickman 1993) places it in the genus *Achnatherum*; other manuals place it in the genus *Stipa.*

Achnatherum hymenoides is a perennial bunchgrass that tolerances low nutrient and water levels. It is commonly found in sandy soils, but individuals may also occur on rocky substrates (including limestone). Seedling establishment is high under moist conditions. Culms are green in the fall and begin growing when spring temperatures become favorable. Plants continue growing into early summer, with more carbohydrates becoming stored in the crowns than in the roots at the end of the growing season. *Achnatherum hymenoides* is good forage for livestock, but heavy early spring grazing easily depletes it. Plants tolerate fire well. Their open crowns burn with little damage to the basal buds. Seedlings establish after fire from off-site seed sources. *Achnatherum hymenoides* may dominate the site within 4 years (Erdman 1970). In some cases, *Achnatherum hymenoides* may locally dominate degraded *Atriplex confertifolia* Shrubland. Such stands are more likely a brief transitional stage between growth cycles of *Atriplex confertifolia* stands. Such a stand occurs along the Death Valley Highway at the junction with Darwin Road. All stands of this alliance in California are known from sandy substrates.

Regional Status:
Southeastern Great Basin: The alliance occurs at the Eureka Dunes.

Management Considerations: This alliance is very rare in California. All stands should be inventoried and monitored.

Allenrolfea occidentalis Shrubland Alliance

Figure A4. *Allenrolfea occidentalis* Shrubland Alliance, Salt Creek

Allenrolfea occidentalis is the sole or dominant shrub in canopy. *Suaeda moquinii, Sarcobatus vermiculatus, Atriplex canescens, Distichlis spicata*, *Sporobolus airoides, Frankenia salina* or *Kochia californica* may be present. Shrubs < 2 m tall; canopy continuous to open. Ground layer variable.

Habitat: Wetlands intermittently flooded, saturated. Water chemistry: hypersaline. Dry lakebed margins, hummocks, lagoon bars, old lakebeds perched above current drainages, and seeps. Cowardin class: palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Allenrolfea occidentalis* as a Facultative Wetland species.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Mono, Southeastern Great Basin, Northwestern Basin and Range, Great Valley, Central California Coast Ranges, southwest U.S., Mexico.

Elevation: -80 to 1,800 m

NDDB Rank: G3 S2.2 (Great Valley associations are very rare)

Synonyms:
Holland: Desert sink scrub (36120 *in part*), Desert greasewood scrub (36130 *in part*), Valley sink scrub (36210 *in part*)
Barry: G7412321
Brown, Lowe and Pase: 153.171
Cheatham and Haller: Alkali sink scrub, saltbush scrub
PSW-45: Iodine bush series
Thorne: Alkali sink scrub
WHR: Alkali sink
Munz: Alkali sink scrub
CALVEG: Iodine bush series

References: Bittman (1985), Burk (1977), Griggs (1980), MacMahon (1988), McMahon and Wagner (1985), Payson et al. (1980), Sawyer and Keeler-Wolf (1995), Thorne (1982), Vasek and Barbour (1977), Werschskull et al. (1984), Young et al. (1977): plot descriptions include Odion et al. (1992), McHargue (1973), Keeler-Wolf et al. (1998).

Membership Rules: *Allenrolfea occidentalis* ≥ 2% cover, no other single species with greater cover. Occupies strongly alkaline playas usually with distinct salt deposits in soil surface.

Comments: This is one of several alliances (see *Atriplex canescens, Suaeda moquinii,* and *Sarcobatus vermiculatus* dominated shrubland alliances) included in alkali sink or scrub vegetation. These alliances commonly occur on and around margins of dry and wet alkaline lakebeds or other bottomlands. Whether a given stand is classed as a member of these alliances or not depends on which species dominates. *Allenrolfea occidentalis* tolerates high salt concentrations. It is typically found in distinctly saline or alkaline situations, often as the only species growing on salt-laden evaporite deposits. Compared to the *Suaeda moquinii* Shrubland Alliance it is more restricted to intermittently saturated substrates and is not found on uplands. Compared to several *Atriplex* dominated shrubland alliances it is more tolerant of high concentrations of salinity and inundation. Stands of these alliances can form a fine mosaic in response to microtopography. *Allenrolfea occidentalis* is less common than these other alliances because of its highly stressful and localized environment. *Allenrolfea occidentalis* occurs at seasonally moist or flooded sites where evaporation concentrates transported salts, leaving visible mineral crusts at the soil surface. *Allenrolfea occidentalis* is tolerant of extreme salinities and heavy soils, which tend to exclude other species, and usually forms the lowest ring of perennial vegetation around desert salt flats. The species tends to tap permanent moisture from relatively long roots and is thus found on playas and other settings where the water table is accessible to the plant's root system.

The *Allenrolfea occidentalis* Shrubland Alliance is restricted to alkaline/saline substrates in desert or semi-desert. Little is known about dispersal and seed viability. Birds are presumably the principal agents of dispersal. These communities are maintained by intra- or inter-annual cycles of flooding followed by extended drought, which favor accumulation of transported salts. The moisture supporting these intermittently flooded wetlands is usually derived off-site, and they are dependent upon natural watershed function for persistence (Reid et al. 1999). *Allenrolfea occidentalis* has a varied morphology depending on the conditions of moisture, salinity, and age of the stand. In general, many Mojave and Colorado desert stands are made up of small, low, and widely spaced shrubs or sub-shrubs, while San Joaquin Valley stands may be composed of shrubs that are up to 2 m in height and width. Based on the substantial woody base of older shrubs, maximum ages of *Allenrolfea occidentalis* may be greater than other shrubs of similar environments such as *Suaeda moquinii*, though little is known about growth rate. Stand density is variable (2-80%). Due to the harsh environment and succulent nature of the plants, fire is unlikely in all but the densest and driest conditions. Disturbance in some areas comes from shifts in the water table beneath the playas.

Regional Status:
Mojave Desert: *Allenrolfea occidentalis* occurs in all of the Mojave Desert, but is restricted to low-lying alkaline playas and basins. Disturbance patterns are as described generally above. Groundwater pumping seems to have affected some stands in Mesquite Valley dry lake. Bradley (1970) defines two associations in Death Valley National Park (Mojave Desert).
Sonoran Desert: *Allenrolfea occidentalis* occurs around some playas.
Colorado Desert: *Allenrolfea occidentalis* occurs around playas and in basins. In Anza-Borrego, it occupies playa borders and adjacent lower bajadas as well as alkaline terraces above washes. It mixes with *Suaeda moquinii-*, *Atriplex polycarpa-* and *Atriplex canescens*-dominated shrubland alliances in these locations.

Management Considerations: *Allenrolfea occidentalis* Shrubland Alliance is simple floristically and structurally. Management concerns include direct alteration and disturbance such as evaporite mining and scraping and blading for road construction. Groundwater pumping also appears to reduce vigor of the plants. In the stands with high cover, response to fire needs to be researched.

Ambrosia dumosa Dwarf-shrubland Alliance

Figure A5. *Ambrosia dumosa* Dwarf-shrubland Alliance, Panamint Mountain

Ambrosia dumosa is the sole or dominant shrub in canopy. *Acamptopappus spherocephalus, Atriplex canescens, Atriplex confertifolia, Atriplex hymenelytra, Echinocactus polycephalus, Ephedra funerea, Encelia farinosa, Larrea tridentata, Opuntia acanthocarpa*, *O. basilaris, O. bigelovii. O. ramosissima,* or *Pleuraphis rigida* may be present. Shrubs in dominant layer < 1 m tall. Emergent *Larrea tridentata* and *Fouquieria splendens* may be present. Tall emergent shrubs < 3 m tall. Emergent trees < 5 m tall. Ground layer is open. Annuals seasonally present.

Habitat: Alluvial fans, bajadas, rocky hills, partially stabilized, stabilized sand fields, upland slopes, older wash and river terraces. Soils well drained, may have pavement surface, may be sandy, clay rich, and/or calcareous.
Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, and Southeastern Great Basin.

Elevation: 0 to 1,700 m

NDDB Rank: G5 S4

Synonyms:
Sawyer and Keeler-Wolf: Brittlebush-white bursage (*in part*)
Holland: Sonoran creosote bush scrub (33100 *in part*), Mojave creosote bush scrub (34100 *in part*)
Brown, Lowe and Pase: 154.113

Cheatham and Haller: Mojave creosote bush scrub, Sonoran creosote bush scrub
Thorne: Desert dune sand plant community
WHR: Desert scrub
Munz: Creosote bush scrub
CALVEG: White bur-sage series

References: Burk (1977), Hunt (1966), MacMahon (1988), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Turner (1982b), Turner and Brown (1982), Vasek and Barbour (1977); plot-based descriptions are Keeler-Wolf et al. (1998).

Membership Rules: *Larrea tridentata* < 1% cover; *Ambrosia dumosa* > 1% cover and no other species with equal or higher cover. In Keeler-Wolf et al. (1998) described as *Ambrosia dumosa* the major shrub or subshrub with only scattered emergent shrubs (no species > 1%), at least twice greater cover *than Larrea tridentata*, and exceeds cover of any other subshrubs such as *Encelia farinosa.*

Comments: This is part of creosote bush scrub. In this alliance *Ambrosia dumosa* dominates or shares dominance with other low shrubs (see *Larrea tridentata-Ambrosia dumosa, Larrea tridentata-Encelia farinosa, Encelia farinosa,* and *Larrea tridentata* alliance descriptions). Shrub density varies, as does diversity. Further sampling throughout much of the California desert over the past several years has refined the description. It is now considered partly disturbance-related, ecologically close to *Larrea tridentata-Ambrosia dumosa, Larrea tridentata-Encelia farinosa, Encelia farinosa,* and *Atriplex hymenelytra* Shrublands and extending from low elevations to over 1,700 m, where it is related to *Atriplex confertifolia* Shrubland and *Juniperus osteosperma* Wooded Shrubland Alliances. The brittlebush-white bursage series of Sawyer and Keeler-Wolf (1995) has been subsumed partially by this alliance, which now includes all stands where *Ambrosia dumosa* dominates or shares dominance with *Encelia farinosa* (≥ 50% relative cover).

Ambrosia dumosa is a short-lived shrub living generally < 50 years, although it does have limited cloning abilities. It has relatively shallow and restricted roots. It colonizes sites that have had vegetation removed mechanically more quickly than *Larrea tridentata* (Vasek 1980). *Ambrosia dumosa*, with its high recruitment and mortality rates, dominates in the colonizing stage in many locally disturbed *Larrea tridentata-Ambrosia* stands in the Mojave and Sonoran deserts. *Ambrosia dumosa* is poorly adapted to fire because of its limited sprouting ability (FEIS 2001). Despite its adaptation to early seral transition states, *Ambrosia dumosa* stands often seem to be more defined by substrate than by a higher disturbance frequency than the modal *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance. As a dominant indicator, *Ambrosia dumosa* occurs on sandy substrates (dune aprons, shallow blow sand, wash terraces), rocky hills (of calcareous, igneous, or sedimentary rock), or alluvial fans, particularly older ones with a developed caliche or clay layer. It tends to replace *Larrea tridentata* on soils with high clay content. *Ambrosia dumosa* is a species tolerant of harsh substrates (limestone) and of local site disturbance (excellent recolonizing abilities from seed in adjacent seed sources). It is also removed from areas subjected to long-term, moderate-to-intense grazing, where the palatable foliage is selected over less palatable and more browse-resistant *Larrea tridentata* and other large species.

Regional Status:
Mojave Desert: *Ambrosia dumosa* Dwarf-shrubland Alliance is scattered throughout the Mojave Desert, found in various settings throughout the region. Its sandy substrate forms such as the *Ambrosia dumosa-Pleuraphis rigida* association occur on linear dunes and sand sheets. Its calcareous rock forms occur in limestone ranges (*Ambrosia dumosa-Ephedra funerea* association), and it may occur as low-diversity, often monospecific stands, in recently disturbed areas adjacent to roads, powerlines, off-highway-vehicle (OHV) areas.
Southeastern Great Basin: The Southeastern Great Basin marks the northernmost occurrences of the alliance in California. Here it may co-occur as local disturbance-related stands within larger stands of *Atriplex confertifolia* Shrubland and *Juniperus osteosperma* Wooded Shrubland Alliances at elevations up to 1,500 m. It also occupies limestone outcrops.

Management Considerations: Sensitivity to fire carried by non-native annual grasses and to over-grazing, makes the absence of *Ambrosia dumosa* a good indicator of these types of unnatural disturbances. Fire and long-term intensive grazing should be excluded from *Ambrosia dumosa* stands. Typical small-scale disturbance patterns that initiate small stands of *Ambrosia dumosa* (blading, excavation, spot fires) are not a normal part of the processes in the hot deserts of California. Natural stands of *Ambrosia dumosa* Dwarf-shrubland Alliance are more related to particular substrate preferences.

Artemisia nova Dwarf-shrubland Alliance
No photograph is available.

Artemisia nova is the sole dominant or important shrub in canopy. *Arenaria macradenia, Atriplex confertifolia, Chrysothamnus viscidiflorus, Echinocactus polycephalus, Ephedra funerea, Ephedra viridis, Eriogonum heermannii, Lycium andersonii, Menodora spinescens, Mortonia utahensis*, or *Krascheninnikovia lanata* may be present. Emergent *Pinus jeffreyi, Pinus monophylla,* or *Juniperus osteosperma* may be present. Shrub < 0.5 m tall; canopy continuous to open. Ground layer sparse or grassy.

Habitat: The alliance occurs on flats, depressions, slopes, and ridges. Parent material limestone or other calcareous substrates. Soils are poorly drained to rocky.

Distribution: Mojave Desert, Southeastern Great Basin, Southern California Mountains and Valleys, Utah, Nevada, Arizona.

Elevation: 1,000 to 2,300 m

NDDB Rank: G4 S3.2

Synonyms:
Holland: Subalpine sagebrush scrub (in part), Pebble plain scrub (in part).
Barry: G7411211 CARNO00
Brown, Lowe and Pase: 152.113
PSW-45: Sagebrush series
Rangeland: SRM 405
Stone and Sumida: Calcareous community
Thorne: Great Basin sagebrush scrub
WHR: Low sagebrush

References: Derby and Wilson (1978, 1979), Krantz (1983, 1988), Paysen et al. (1980), Tisdale (1994), Turner (1982a), Young et al. (1977), West (1988), Reid et al. (1999); plot-based descriptions are found in California NDDB

Membership Rules: *Artemisia nova* ≥2% cover. No other single species with greater cover. This is typically an alliance of the limestone mountains and may occur at mid-elevation Mojave Desert or well up into the higher mountains. Other limestone shrubs such as *Mortonia utahensis* may be common. May also mix with lesser amounts of widespread species such as *Atriplex confertifolia*.

Comments: In California, *Artemisia nova* is generally restricted to substrates with some calcareous component. This includes harsh rocky desert mountain slopes and canyons, as well as flats with clay-rich soil derived from surrounding calcareous rock. The pebble plain community of the Big Bear Lake area of the San Bernardino Mountains (Krantz 1988; Holland 1986) has *Artemisia nova* alliance stands in deep alluvial soils in small basins adjacent to intermittent lakes and vernally moist valley bottoms. These stands often contain *Thelypodium stenopetalum* or other rare species. They may occur adjacent to stands of *Artemisia tridentata* and *Chrysothamnus viscidiflorus* shrubland alliance or to the true pebble plains stands that are dominated by several rare, low mat-forming perennial herbs such as *Eriogonum kennedyi* var. *austromontanum*. In the mountains of the Mojave Desert and Southeastern Great Basin, stands of *Artemisia nova* are often associated with other calcophile alliances dominated by *Ephedra funerea*, *Purshia stansburiana*, or *Viguiera reticulata*. .

Artemisia nova is a fire-sensitive species (FEIS 2001) and does not resprout. However, fire is not a regular component of the disturbance regime of this alliance. Some stands in the San Bernardino Mountains may receive sufficient moisture in some springs to be flooded and thus disturbed. Most desert stands are open and are in rocky or otherwise open stands.

Regional Status:
Mojave Desert: Stands are known from calcareous alluvium in the Clark Mountains.
Southeastern Great Basin: Stands are known from the Last Chance Range, the Cottonwood Mountains, the Funeral Range, and the Panamint Mountains; all drain into Death Valley. Stands are also known from the White and Inyo Mountains**.** Seven stands were sampled in the Southeastern Great Basin as part of this project.

Management Considerations: In the San Bernardino Mountains, stands containing rare species are protected from trampling and grazing by the U.S. Forest Service.

Artemisia tridentata Shrubland Alliance

Figure A6. *Artemisia tridentata* Shrubland Alliance, Mid Hills

Artemisia tridentata is the sole or dominant shrub in canopy. *Ericameria nauseosa, Chrysothamnus viscidiflorus, Ephedra viridis, Purshia tridentata*, *Ribes velutinum*, or *Tetradymia canescens* may be present. Emergent trees may be present. Shrubs < 3 m tall; cover continuous, intermittent, or open. Ground layer sparse or grassy.

Habitat: Bajadas, pediments, alluvium, valleys, dry washes. Soils well-drained, gravelly.

Distribution: Southern Cascades, Sierra Nevada, Sierra Nevada Foothills, Modoc Plateau, Great Valley, Southern California Mountains and Valleys, Mojave Desert, Mono, Southeastern Great Basin, Northwestern Basin and Range, Intermountain West, Baja California.
Elevation: 300 to 3,000 m

NDDB Rank: unknown

Synonyms:
Holland: Big sagebrush, Great Basin mixed scrub, Sagebrush steppe
Barry: G7411211 CARTR20

Brown, Lowe and Pase: 142.213, 142.222, 152.111, and 152.112
Cheatham and Haller: Great Basin sagebrush
PSW-45: Sagebrush series
Rangeland: SRM 401, SRM 403
Thorne: Great Basin sagebrush scrub
WHR: Sagebrush
Munz: Sagebrush scrub

References: Paysen et al. (1980), Taylor (1976), Tisdale (1994), Vale (1975), West (1988), Wolfram and Martin (1965), Young et al. (1977); plot-based descriptions include Taylor (1980), Keeler-Wolf (1990b), Ferren and Davis (1991), Franklin and Dyrness (1973), Gordon and White (1994), Spolsky (1979), and Keeler-Wolf et al. (1998)

Membership Rules: *Artemisia tridentata* ≥ 2% cover, no other single species with greater cover, and *Ephedra viridis* < 1% cover.

Comments: Stands of the *Artemisia tridentata* Shrubland Alliance are extensive and varied in the Great Plains, Pacific Northwest, Great Basin, and Southwest. Some stands of this alliance have scattered juniper, pine, or *Yucca brevifolia* trees. *Artemisia tridentata* occurs as an important understory shrub in stands of woodland and forest alliances (see *Pinus monophylla-Juniperus osteosperma*, *Pinus washoensis, Pinus jeffreyi* Woodlands and *Juniperus occidentalis* and *Yucca brevifolia* Wooded Shrublands). Where *Artemisia tridentata* shrubs are infrequent, the stand is placed within an herbaceous alliance.

In California *Artemisia tridentata* includes four subspecies. In Intermountain West vegetation classifications, subspecies define different alliances. In California, the subspecies have overlapping ranges, and two subspecies are uncommon (*Artemisia tridentata* ssp. *parishii,* and *Artemisia tridentata* ssp. *wyomingensis*). *Artemisia tridentata* ssp. *vaseyana,* with narrow inflorescences, tends to grow on slopes at higher elevations than *Artemisia tridentata* ssp. *tridentata,* which inhabits valley bottoms.

Young et al. (1977) list 11 species as important grasses in describing regional variation in the alliance. Keeler-Wolf (1990b) qualitatively describes a ridgetop stand at Mud Lake Resource Natural Area in Plumas Co., at Cahuilla Mountain RNA in Riverside Co.; at Whippoorwill Flat RNA in Inyo Co.; Hanes (1976) describes vegetation types in the San Gabriel Mountains including the *Artemisia tridentata* Shrubland Alliance.

Artemisia tridentata ecology varies among subspecies, and their differences are mainly known for areas outside the state. *Artemisia tridentata* ssp. *tridentata* grows in deep, fertile soils, so much of its habitat has been claimed for pasture and agriculture. It is less palatable to livestock and wildlife than *Artemisia tridentata* ssp. *vaseyana* and grows on the foothills and mountain slopes in shallow, well-drained, rocky soils. It is an important browse for livestock and wildlife, especially in the winter. Much of the lands dominated by big sagebrush are over-grazed.

Big sagebrush plants are easily killed by fire. Seeds from this shrub are prolific and have high germination rate, which allows for rapid establishment of seedlings following fire. Seed are available from surviving plants and from a bank of seeds that are viable up to 5 years. Seed dispersal is less than 4 m. It takes about a decade for seedlings to grow to dominate the site. Shrubs live to 50 years. Severe fires that burn the banked seeds and mycorrhizal spores are slow to regenerate.

Regional Status:
Mojave Desert: Locally present stands had higher elevations in the northeastern part
Southeastern Great Basin: Common.

Management Considerations: No additional information is available.

Atriplex hymenelytra Shrubland Alliance

Figure A7. *Atriplex hymenelytra* Shrubland Alliance, Death Valley

Atriplex hymenelytra is the sole or conspicuous shrub in canopy. *Encelia farinosa, Ambrosia dumosa, Atriplex confertifolia, Suaeda moquinii, Larrea tridentata, Tidestromia oblongifolia, Dalea mollossima,* or *Peucephyllum schottii* may be present. Shrubs < 1 m tall; canopy open. Ground layer sparse; annuals seasonally present.

Habitat: Alluvial fans, along washes, steep colluvium, recent lava flows, cinder cones. Soils are derived from alluvium, colluvium, and residuum from metamorphic, igneous, and other sedimentary rocks and may be carbonate, alkaline, or salt-rich. Also, wetland habitats such as intermittently flooded wash bottoms. Cowardin Class: riverine.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, and Southeastern Great Basin.

Elevation: -75 to 1,400 m

NDDB Rank: G5 S4

Synonyms:
Holland: Desert saltbush scrub (36110 *in part*)
Barry: G7411221
Cheatham and Haller: Creosote bush scrub
PSW-45: Saltbush series
Thorne: Creosote bush scrub
WHR: Desert scrub
Munz: Creosote bush scrub
CALVEG: Desert holly series

References: Brown (1982), Hunt (1966), Johnson (1976), MacMahon (1988), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982); plot-based descriptions include Annable (1985) and Schramm (1982)

Membership Rules: *Atriplex hymenelytra* > 1% cover and no other species with equal or higher cover. May occur on hot rocky slopes, dry bajadas, or alkaline badlands and playa edges.

Comments: This alliance is part of either creosote bush scrub or saltbush scrubs ecological system, which is a collection of alliances. This alliance shares species with the *Larrea tridentata, Larrea tridentata-Ambrosia dumosa,* and *Larrea tridentata-Encelia farinosa* Shrublands. It commonly occurs along drainages that dissect the west-facing bajadas and on western and southern slopes of very dry mountains. It also occurs on desert pavement with very sparse vegetation. It may occupy rough lava and limestone deposits with skeletal soil and heavy alkaline sea floor and lake sediments (mud hills). The density of shrubs is usually very low. This is the most xeric shrub alliance in the Mojave Desert. It persists in extremely hot, dry locations where almost no other perennial shrub is able to flourish.

In its rarified environment, *Atriplex hymenelytra* alliance has relatively simple seral relationships. *Atriplex hymenelytra* can be both an invader and a long-lived stable component of the landscape. Studies at the Zzyzx Desert Studies Center (A. Romspert, personal communication) indicate individuals are long-lived and may undergo sex change based on age and environmental conditions. Recruitment at Trona Pinnacles is episodic; the last major event was 21 years ago, suggesting long-viable seeds in soil (G. Harris, personal communication). Natural disturbance in the harsh upland environments comes mostly as shifts in moisture availability. A series of wetter years will shift the *Atriplex hymenelytra* toward other desert alliances such as *Larrea tridentata, Larrea tridentata-Ambrosia dumosa* or *Larrea tridentata-Encelia farinosa* Shrublands. A series of drier years will eliminate individual *Atriplex hymenelytra* and other component species and leave only annual ephemeral herb species, such *Geraea canescens* and *Chorizanthe rigida*, in the seed bank. Where *Atriplex hymenelytra* occurs in washes it generally occupies the rocky, gravelly bottoms that have little or no organic build up in the substrate. These washes may not receive water for several successive years. Surrounding upland vegetation may include *Larrea tridentata-Ambrosia dumosa* or *Larrea tridentata-Encelia farinosa* Shrublands or desert annuals. Tolerance of bare mineral substrate with low nutritional value, and no apparent mycorrhizal associations confer an advantage for *Atriplex hymenelytra* in colonizing low-elevation washes as well as roadcuts and other unnatural disturbances. *Tidestromia oblongifolia*, one of the most common associates of this alliance, is commonly found in disturbed sites (OHV areas, roadsides). It is possible that severe degradation of upland *Atriplex hymenelytra* stands can result in *Tidestromia oblongifolia* alliance, but this has not yet been described.

Regional Status:
Mojave Desert: *Atriplex hymenelytra* occurs in all parts of the Mojave Desert, but is more common in the northern Mojave Desert. There it may form large stands hundreds of hectares in size, on lower bajadas, rocky slopes, and alkaline mud hills. Disturbance patterns are as described generally above.
Southeastern Great Basin: This alliance occurs in large stands on lava, cinder fields and other volcanic substrate in the Cottonwood Mountains. It also occurs in smaller stands in the Inyo, Grapevine, Coso/Argus and Panamint Ranges. At Owens Lake it may intermingle with *Suaeda moquinii* and *Atriplex confertifolia* dominated alliances on wind-blown alkaline deposits on the lower bajadas of the Inyo Mountains.

Management Considerations: *Atriplex hymenelytra* Shrubland Alliance is simple floristically and structurally. It occurs in such harsh environments that it is rarely impacted by human-mediated disturbance, except by OHV activity in some areas (e.g., Trona Pinnacles). As with other shrubby *Atriplex* species, *Atriplex hymenelytra* is likely to be palatable to livestock. Management concerns are minimal except where mining, OHV, and grazing activity are present.

Atriplex polycarpa Shrubland Alliance

Figure A8. *Atriplex polycarpa* Shrubland Alliance, Emigrant Canyon

Atriplex polycarpa is the sole or dominant shrub in canopy. *Ambrosia dumosa, Atriplex canescens, Bromus madritensis, Chamaesyce polycarpa, Distichlis spicata, Hymenoclea salsola, Isocoma acradenia, Larrea tridentata* or *Schismus barbatus* may be present. Emergent *Prosopis glandulosa* may be present. Shrubs < 3 m tall; canopy continuous to open. Ground layer variable, including native annuals.

Habitat: Soil of old beach, lake deposits; dissected alluvial fans, alluvial terraces, rolling hills. Soils may be carbonate-rich, alkaline, sandy, sandy clay loams. Washes, playa lakebeds and shores. Water chemistry: mixohaline. Cowardin class: palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Atriplex polycarpa* as a Facultative Upland species.

Distribution: Mojave Desert, Colorado Desert, Sonoran Desert, Great Valley, Central California Coast Ranges, Southern California Mountains and Valleys, Sierra Nevada Foothills, Southeastern Great Basin, Nevada, Arizona, New Mexico, Mexico

Elevation: -75 to 1,500 m

NDDB Rank: G5 S4 some associations are rare in Great Valley (S2, S1)

Synonyms:
Holland: Relictual interior dunes (23200), Desert saltbush scrub (36110 *in part*), Valley saltbush scrub, (36220 *in part*), Sierra-Tehachapi saltbush scrub (36310), Interior coast range saltbush scrub (36320)
Barry: G7411221 CATPO00
Cheatham and Haller: Saltbush scrub
PSW-45: Saltbush series
Thorne: Shadscale scrub
WHR: Alkali sink
Munz: Creosote bush scrub, shadscale scrub
CALVEG: Allscale series

References: Bittman (1985), Burk (1977), Griggs (1980), Griggs and Zanovitch (1984), Johnson (1976), MacMahon (1988), MacMahon and Wagner (1985), McHargue (1973), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995).
Vasek and Barbour (1977), Werschkull et al. (1984); plot-based descriptions include Keeler-Wolf et al. (1998).

Membership Rules: *Atriplex* > 2% absolute and > 50% relative canopy cover. *Atriplex polycarpa* with highest shrub cover. May occur on playa edges, in washes through alkaline areas, or occasionally uplands with alkaline substrate.

Comments: This alliance is part of the saltbush scrub ecological system. One or more perennial species of *Atriplex* spp. dominate most alliances within the saltbush scrub collection of alliances (see also *Atriplex canescens, Atriplex spinifera, Atriplex hymenelytra, Atriplex confertifolia* Shrublands). *Atriplex polycarpa* Shrubland is the most widespread and common of the saltbush scrub in the Mojave Desert and the foothills surrounding the southern San Joaquin Valley. It occupies large areas of the central and western Mojave Desert, either adjacent to playas or in large spreading basins. It also covers many of the low hills of the Inner Coast Ranges, the southern Sierra and Tehachapi foothills. It is more narrowly distributed, mostly in alkaline basins and along washes and stream channels, in portions of the Sonoran and Colorado deserts and the Southeastern Great Basin. *Atriplex polycarpa* is a facultative phreatophyte and occurs in moderately saline (< 2%) conditions, just above the water table or xeric non-saline upland sites (Vasek and Barbour 1977). It has limited salt tolerance and is very drought-tolerant (Vasek and Barbour1977). These two factors interact to control water stress in plants and define habitat boundaries. In California, *Atriplex spinifera* and *Atriplex canescens* are more tolerant of finer textured soils and higher alkalinity (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Atriplex polycarpa produces abundant seed, which is banked in the soil. Following some disturbance events, such as heavy grazing, and with sufficient winter rain, *Atriplex polycarpa* produces abundant seedlings (T. Keeler-Wolf personal communication, Desert Workshop 2000). Many North American species of *Atriplex* are highly tolerant of fire. If top-killed, they sprout prolifically (FEIS 2001). However, *Atriplex polycarpa* is only a weak root-sprouter (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Managers in some parts of its range are concerned about the alliance, because human caused fires have burned the matrix of annual grassland and *Atriplex polycarpa*, diminishing its extent. Due to the arid climate and typically low elevation of stands in much of its range, fire was not likely to have been a significant natural disturbance agent. *Atriplex polycarpa* as with other *Atriplex* spp. may be more sensitive to fire, depending on the time of year, with late spring and summer fires more destructive. However, in some areas of upper elevations, fire is a natural component of disturbance. Most natural fires were relatively small and had long intervals (T. Keeler-Wolf personal communication, Desert Workshop 2000). Because it produces abundant, wind-dispersed seed, *Atriplex polycarpa* probably also establishes on burned sites from off-site seed. The natural disturbance cycle in much of its range also includes flooding events. In deserts, this alliance commonly occupies the terraces and edges of large, low gradient washes. Flood frequencies are not as high as in adjacent wash bottom alliances such as *Ericameria paniculata, Hymenoclea salsola, Psorothamnus spinosus,* or *Bebbia juncea* dominated shrublands, but are higher in frequency than in *Larrea tridentata-Ambrosia dumosa* Shrubland and other surrounding upland alliances.

Regional Status:
Mojave Desert: *Atriplex polycarpa* occurs throughout all of the Mojave Desert, but is more common in the western Mojave Desert. There it may form large stands thousands of hectares in size (as between Red Mountain and Kramer Junction), in slightly alkaline plains and basins. In these areas *Atriplex polycarpa* gives way to *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance on rocky hills. Some of these stands have colorful and diverse annual flower displays on years with high rain (*Coreopsis bigelovii, Lasthenia californica, Phacelia distans,* etc.) Other stands have very high cover of non-native grasses (*Bromus madritensis* and *Schismus* sp.). Disturbance patterns are generally as described above. *Atriplex spinifera* Shrubland Alliance stands tend to be on finer-textured soils compared to *Atriplex polycarpa*. At Red Rock Canyon State Park, some resprouting has been noted after light blading of shrubs by bulldozers.

Management Considerations: *Atriplex polycarpa,* as with other shrubby *Atriplex* species, is palatable to livestock. Reduction in extent due to grazing and fire needs to be investigated. Losses due to intensive agriculture and development have occurred in the Great Valley and surrounding foothills. Fire has increased greatly since the spread of non-native annual grasses in the understory of many stands. Protection of stands from fire may become necessary in the western Mojave Desert and the San Joaquin Valley and surrounding foothills.

Atriplex spinifera Shrubland Alliance
No photograph is available.

Atriplex spinifera is the sole or dominant shrub in canopy. *Atriplex polycarpa*, *Frankenia salina, Ephedra californica, Hymenoclea salsola,* and/or *Distichlis spicata* may be present. Shrubs < 2 m tall; canopy open. Ground layer variable. Annuals seasonally present.

Habitat: Alluvial fans; old lakebeds perched above current drainages. Soils may be carbonate-rich. Wetland habitats intermittently flooded, saturated. Water chemistry: mixosaline. Dry lakebeds, plains. Cowardin class: palustrine shrub-scrub wetland. The national list of wetland plants lists *Atriplex spinifera* as a Facultative species.

Distribution: Central California Coast Ranges, Great Valley, and Mojave Desert

Elevation: 50 to 800 m

NDDB Rank: G2 S2.2 stands in the southern Great Valley may be very rare (S1.1)

Synonyms:
Holland: Desert saltbush scrub (36110 *in part*), Valley saltbush scrub, (36220 *in part*), Sierra-Tehachapi saltbush scrub (36310), Interior coast range saltbush scrub (36320)
Barry: G7411221 CATPO00
Cheatham and Haller: Saltbush scrub
PSW-45: Saltbush series
Thorne: Shadscale scrub
WHR: Alkali sink
Munz: Creosote bush scrub, shadscale scrub
CALVEG: Allscale series

References: Bittman (1985), Burk (1977), Griggs (1980), Griggs and Zanovitch (1984), Johnson (1976), MacMahon (1988), MacMahon and Wagner (1985), McHargue (1973), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Vasek and Barbour (1977), Werschkull et al. (1984); plot-based descriptions include Phillips and MacMahon (1981) in MacMahon (1988).

Membership Rules: *Atriplex spinifera* with highest shrub cover. Largely restricted to the Western portion of the mapping area around edges of playas and other alkaline situations.

Comments: This alliance is part of saltbush scrub ecological system, which is a collection of alliances dominated by saltbush species as *Atriplex canescens, Atriplex hymenelytra,* and/or *Atriplex confertifolia*. *Atriplex spinifera* Shrubland is the most restricted of the *Atriplex*-dominated alliances in the Mojave Desert and the foothills surrounding the southern San Joaquin Valley. It occupies small areas of the central and western Mojave Desert, either adjacent to playas or in large spreading basins. It is frequently associated with *Atriplex polycarpa* alliance stands, but often occurs more immediately adjacent to playas, while *Atriplex polycarpa* may occur farther away from the lakebeds. Similarly, in the southern San Joaquin Valley, *Atriplex spinifera* stands are often associated with alkaline soils of basins and occur adjacent to stands of *Allenrolfea occidentalis,* while *Atriplex polycarpa* stands are more commonly found on uplands.

Atriplex spinifera, as with the related *Atriplex polycarpa* and *Atriplex confertifolia* Shrublands, probably produces abundant seed, which is banked in the soil. However, little specific information is available. Fire is not likely to be a strong natural impact to the stands of this alliance but it may be a negative impact in areas where annual grass cover is high.

Regional Status:
Mojave Desert: Stands of *Atriplex spinifera* are largely restricted to the western Mojave Desert, where they occur adjacent to alkaline playas usually in combination with *Atriplex polycarpa* or *Atriplex canescens*.

Management Considerations: Stands in the San Joaquin Valley are considered rare and threatened due to the fragmented habitat and threats from fire carried by non-native annual grasses.

Atriplex canescens Shrubland Alliance

Figure A9. *Atriplex canescens* Shrubland Alliance, Stovepipe Wells

Atriplex canescens is the sole or dominant shrub in canopy. *Ambrosia dumosa, Atriplex confertifolia, Atriplex polycarpa, Chrysothamnus viscidiflorus, Ephedra viridis, Grayia spinosa, Hymenoclea salsola, Isomeris acradenia, Larrea tridentata,* or *Suaeda moquinii,* may be present. Emergent *Prosopis glandulosa* may be present. Shrubs < 3 m tall, canopy open or intermittent. Trees < 5 m tall, scattered distribution. Ground layer variable, seasonally present including annual herbs and non-native grasses.

Habitat: Soil of old beach, lake deposits; dissected alluvial fans, rolling hills. Soils may be carbonate-rich, alkaline, sandy, sandy clay loams. Wetland habitats such as washes, playa lakebeds and shores. Water chemistry: mixohaline. Cowardin class: palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Atriplex canescens* as a Facultative Upland species.

Distribution: Mojave Desert, Colorado Desert, Sonoran Desert, Great Valley, Central California Coast Ranges, Southern California Mountains and Valleys, Southeastern Great Basin, Intermountain West.

Elevation: -75 to 1,500 m

NDDB Rank: G5 S4, some associations are rare in Central California Coast Ranges

Synonyms:
Holland: Relictual interior dunes (23200), Desert saltbush scrub (36110 *in part*), Valley saltbush scrub, (36220 *in part*), Sierra-Tehachapi saltbush scrub (36310), Interior coast range saltbush scrub (36320)
Barry: G7411221 CATPO00
Cheatham and Haller: Saltbush scrub
Rangeland: SRM 414
PSW-45: Saltbush series
Thorne: Alkali sink scrub
WHR: Alkali sink
Munz: Creosote bush scrub, shadscale scrub, alkali sink
CALVEG: Allscale series

References: Bittman (1985), Burk (1977), Griggs (1980), Griggs and Zanovitch (1984), Johnson (1976), MacMahon (1988), MacMahon and Wagner (1985), McHargue (1973), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Vasek and Barbour (1977), Werschkull et al. (1984); plot-based descriptions include Keeler-Wolf et al. (1998).

Membership Rules: *Atriplex canescens* with highest shrub cover. Typically of low-lying playa edges, dune aprons, or edges of alkaline wetlands from low- to mid- elevation Mojave Desert.

Comments: This alliance is part of the saltbush scrub ecological system, which is a collection of alliances dominated by *Atriplex polycarpa, Atriplex spinescens, Atriplex lentiformis, Atriplex hymenelytra,* or *Atriplex confertifolia* species. In California, *Atriplex canescens* Shrubland occurs in the low hills of the Inner South Coast Range.

In California, ecological settings for the alliance are variable. They include sandy dune aprons and low dunes, as in Death Valley and Saline Valley, and moderately alkaline playas such as Silver Dry Lake and Superior Dry Lake. In the hot deserts of California, *Atriplex canescens* appears to have more of an affinity for windblown sand than other *Atriplex* shrubs and frequently forms part of the dune margin matrix with stands of *Prosopis glandulosa, Pleuraphis rigida,* and *Larrea tridentata-Ambrosia* Shrublands. *Atriplex canescens* also mixes regularly with other species of *Atriplex* to form mixed stands in washes (*Atriplex canescens-Atriplex polycarpa*), and on playa and playa edges (*Atriplex canescens-Atriplex confertifolia*). Associated alliances range from wetland types such as *Schoenoplectus americanus, Distichlis spicata, Pluchea sericea,* and *Juncus balticus*- dominated alliances to playa types dominated by *Suaeda moquinii, Allenrolfea occidentalis,* and *Atriplex polycarpa* to upland types dominated by *Atriplex confertifolia, Grayia spinosa,* and *Coleogyne ramosissima.* Chromosomal differences in populations explain, at least partially, the wide variety of ecological settings in which the alliance occurs.

Different ploidy levels of *Atriplex canescens* appear to occupy different ecoregions. These include hot desert and cold desert ecotypes (FEIS 2001). The species is one of the most rapidly evolving shrubs in North America (FEIS 2001). In California, *Atriplex canescens* occurs in 34 counties (CalFlora 2000), including ssp. *linearis* and ssp. *canescens* as treated in *The Jepson Manual* (Hickman 1993), but the alliance is largely restricted to the deserts and the San Joaquin Valley and surrounding foothills.

Atriplex canescens is a very widespread species throughout the western United States. The species has been used extensively for rehabilitation of mine excavations in Wyoming and Montana. It colonizes readily from seed and does not appear to require mycorrhizal associations to grow vigorously. Tolerant of grazing, the species is also resistant to fire because of moist and non-volatile leaf composition. If top-killed, it sprouts prolifically (FEIS 2001). Natural disturbance processes probably did not involve fire to any great degree in most California stands except in the cismontane region. Fire may be more important currently because of invasion of *Bromus* spp. in understory and increased ignitions caused by people.

Regional Status:
Mojave Desert: *Atriplex canescens* occurs throughout the Mojave Desert. It occurs less commonly in large stands than *Atriplex polycarpa,* and small stands may occur within a matrix of *Prosopis glandulosa* Shrubland along streams and washes or at edges of dunes. It is more restricted to alkaline areas than *Atriplex polycarpa* Shrubland and does not occur on rocky uplands, as does *Atriplex confertifolia* or *Atriplex hymenelytra* Shrubland Alliances. It commonly associates with *Suaeda moquinii* Intermittently Flooded Shrubland Alliance at edges of playas.
Southeastern Great Basin: Occupies edges of playas, valleys, and flats with clay soil (northern Panamint Range). Stands at higher elevations than elsewhere in the state (up to 1,600 m) may indicate different ecotype and ploidy levels than in hot deserts of California.

Management Considerations: In general, this alliance is in good shape throughout its range. Its ability to tolerate alkaline soils, grazing, fire, and other disturbance bodes well for its persistence. Investigations are needed on the alliance's sensitivity to high levels of grazing and fire at certain times of the year (FEIS 2001). This may be particularly important in the cismontane distribution of the species.

Atriplex confertifolia Shrubland Alliance

Figure A10. *Atriplex confertifolia* Shrubland Alliance, Amargosa Desert

Atriplex confertifolia is the sole or dominant shrub in canopy. *Ambrosia dumosa, Artemisia spinescens, Atriplex polycarpa, Atriplex spinescens, Chrysothamnus viscidiflorus, Encelia actonii, Coleogyne ramosissima, Ephedra nevadensis, Eriogonum heermannii, Grayia spinosa, Gutierrezia microcephala, Krascheninnikovia lanata, Larrea tridentata, Lycium andersonii, Sarcobatus vermiculatus,* or *Tetradymia axillaris* may be present. Shrubs < 1 m tall; canopy continuous, intermittent, or open. Emergent taller shrubs may be present. Ground layer sparse.

Habitat: Bajadas, flats, edges of playas, lower slopes, rocky hills, valleys, and minor rills and washes. Soils variable; may be carbonate-rich, clay-rich, may have high sand content, may have desert pavement. Wetland habitats such as ashes, playa lakebeds and shores. Water chemistry: mixohaline. Cowardin class: palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Atriplex confertifolia* as a Facultative Upland species.

Distribution: Northwestern Basin and Range, Mono, Southeastern Great Basin, Mojave Desert, Modoc Plateau, Intermountain West

Elevation: 450 to 2,500 m

NDDB Rank: G4 S3.2

Synonyms:
Holland: Shadscale scrub (36140)

Cheatham and Haller: Shadscale scrub
PSW-45: Saltbush series
Rangeland: SRM 414, SRM 501
Thorne: Shadscale scrub
WHR: Alkali sink
Munz: Shadscale scrub
CALVEG: Shadscale series

References: Beatley (1976), Burk (1977), MacMahon (1988), MacMahon and Wagner (1985), McHargue (1973), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Turner (1982b), Vasek and Barbour (1977), Young et al. (1977).

Membership Rules: *Atriplex confertifolia* ≥ 2% cover. No other single species with greater cover with the exception of woody subshrubs such as *Krameria* spp. May occur in alkaline valleys or playas and in upper mid-elevation Mojave Desert on rolling hills and slopes, particularly common in the northern portion of the mapping area.

Comments: *Atriplex confertifolia* Shrubland is one of the major regional vegetation types of the Great Basin Province. It exists in many associations from low alkali basins across extensive intermountain flats and on rocky upland soils. It ranges widely south and west into the Mojave Desert. The species continues westward across the Tehachapi Mountains into the southern San Joaquin Valley and to the Carrizo Plain of San Luis Obispo Co. Chromosomal variation enables, at least in part, the variety of ecological settings occupied by *Atriplex confertifolia*. Diploid individuals typically occur in rocky uplands. Tetraploids typically occur in basins at lower elevations in extensive, nearly pure stands. Octaploid and decaploid races also grow in extensive, pure stands in lower elevation basins, or with *Artemisia tridentata* or *Sarcobatus vermiculatus* (FEIS 2001). Male *Atriplex confertifolia* plants are much more common on harsher sites than are female plants (FEIS 2001). *Atriplex confertifolia* Shrubland occurs adjacent to *Larrea tridentata-Ambrosia* Shrubland in the Mojave Desert and ranges up into the *Artemisia tridentata* Shrubland and the edge of the *Juniperus osteosperma* and *Pinus monophylla* Woodland.

Atriplex confertifolia Shrubland is disturbance-related at least in part. In many parts of its range, it tolerates moderate or even heavy grazing (FEIS 2001). It also has increased its range relative to other alliances such as *Artemisia tridentata*, *Artemisia nova*, and *Krascheninnikovia lanata* Shrublands because of grazing and mechanical disturbance. *Atriplex confertifolia* reestablishes readily following mechanical treatments. For example, it can replace cleared stands of *Artemisia tridentata* and dominate sites in less than 10 years (FEIS 2001). *Atriplex confertifolia* is sensitive to certain types of disturbance. Grazing in the fall tends to decrease stands (FEIS 2001). Prolonged drought tends to kill most mature shrubs in a stand, and shrubs are not typically long lived. Thus, stands tend to increase and diminish due to the irregular, desert precipitation patterns.

The effects of fire on *Atriplex confertifolia* Shrubland are not well understood. Fire does not typically affect the open stands of most *Atriplex confertifolia. Bromus tectorum* and other non-native annual exotics are likely to carry fire readily through many stands. It is likely that *Atriplex confertifolia* is resistant to fire because of its low volatilization rates. However, resistance may be related to timing and intensity of the fire. Also, in most stands fire is not a factor due to the relative openness of the stand. The species apparently does not resprout. Although most stands tend to consist of relatively short-lived shrubs, individuals of *Atriplex confertifolia* have been estimated to live over 100 years, as seen from historical photography matching (Robert Webb, personal communication).

Regional Status:
Mojave Desert: Stands include both upland and basin types. In Owens Valley, the Funeral Mountains, Greenwater Valley, the Owlshead Mountains, Searles Valley, and Granite Mountains upland stands occur on rocky hills mixed with stands of *Ephedra nevadensis, Menodora spinescens, Larrea tridentata-Ambrosia dumosa, Yucca schidigera,* and *Yucca brevifolia*-dominated alliances. In the Owens Valley, Pahrump Valley, and central Mojave Desert valleys, stands also occur in valleys and flats surrounding and within playas and alkali basins. Most stands in the southern portion of the range of the alliance are in valleys surrounding *Atriplex polycarpa* Shrubland and below upland stands of *Larrea tridentata-Ambrosia* Shrubland (e.g., Superior Dry Lake, Coolgardie Mesa).
Southeastern Great Basin: Upland stands are extensive in the Cottonwood Mountains and Coso, Argus and Panamint ranges, where they may intermix with *Yucca brevifolia, Grayia spinosa, Artemisia tridentata* and *Larrea tridentata-Ambrosia dumosa* Shrublands. Several upland stands in the Cottonwood Mountains show recent demise of many shrubs and are currently occupied by species of sandy substrates including *Achnatherum hymenoides.*

Management Considerations: *Atriplex confertifolia* Shrublands occupy a broad spectrum of environmental situations in the Southeastern Great Basin and Mojave Desert. It may occur as a seral and invasive alliance; it may be short-lived or site-persistent. We need further information in California to understand the natural and disturbance-related contexts for this alliance. Since the species increases under browsing, its presence in certain areas may be due to response to grazing. However, some stands in all ecological settings may be natural. Response to fire and invasion of *Bromus* and *Schismus* spp. needs to be investigated.

Baccharis sergiloides Intermittently Flooded Shrubland Alliance

Figure A11. *Baccharis sergiloides* Intermittently Flooded Shrubland Alliance

Baccharis sergiloides is the sole or dominant shrub in canopy. *Eriogonum fasciculatum Gutierrezia microcephala, Lotus rigidus, Yucca schidigera, Ericameria linearifolia, Sphaeralcea ambigua, Acacia greggii, Opuntia acanthocarpa Artemisia ludoviciana, Prunus fasciculata,* or *Rhus trilobata* may be present. Emergent *Populus fremontii* and *Salix* species may be present. Shrubs < 5 m tall; canopy open to continuous. Understory is sparse to intermittent.

Habitat: Washes, arroyos and canyon bottoms. Streams and seeps, intermittently flooded. Soils seasonally saturated, gravelly to sandy to medium fine sandy loam. Cowardin class: intermittently flooded riverine or palustrine.

Distribution: Mojave Desert, Southern California Mountains and Valleys, Nevada, Arizona, north Mexico.

Elevation: 1,000 to 1,800 m

NDDB Rank: G4 S3.2

Synonyms:
Holland: Mojave wash scrub (34250), Mojave desert wash Scrub (63700)
Barry: G7411124
Cheatham and Haller: Desert dry wash woodland

WHR: Desert wash
Munz: Pinyon-juniper woodland, Joshua Tree woodland

References: Beatley (1976), Evens (2000); plot-based descriptions found in Evens (2000)

Membership Rules: *Baccharis sergiloides* dominant. Typically of intermittent springs and washes in mid-elevation Mojave Desert**.**

Comments: *Baccharis sergiloides* is a common shrub of moist canyon bottoms, seeps, and springs in the mountains of the Mojave Desert. It occurs in similar habitats in the desert-facing Peninsular and Transverse ranges of California. Stands are typically small and occur in relatively moist, intermittently flooded stretches of canyon bottoms, or borders and tails of springs and seeps. Boulders and bedrock typically break up the stands, although rooting substrate is typically relatively fine sand. Evens (2000) found this alliance only on granitic substrates in the narrower canyons of the eastern Mojave Desert mountains. She describes variation in this association based on associated species and microtopography ranging from flat sandy stretches, bouldery ravines > 10% slope, to vertical waterfalls on bedrock. In comparison to other canyon alliances in the eastern Mojave Desert, *Baccharis sergiloides* Intermittently Flooded Shrubland has an ecological overlap with the *Salix exigua* Temporarily Flooded Shrubland, suggesting relatively high subsurface moisture requirements.

As with other members of the genus, *Baccharis sergiloides* produces abundant seed that is easily dispersed on the wind with the assistance of substantial pappus bristles. Little specific information exists on the autecology of the species. Its longevity and relationship to fire and mechanical disturbance are not treated in FEIS (2001). However, as with other similar species (e.g., *Baccharis sarothroides* and *Baccharis pilularis*), it probably does resprout following disturbance and does not attain great age.

Regional Status:
Mojave Desert: Stands are known from most of the eastern Mojave Desert mountains on granite.
Southeastern Great Basin: Stands occur in the Panamint, Inyo, and Coso Mountains in similar settings to other parts of its range.

Management Considerations: No additional information is available.

Cercocarpus ledifolius Shrubland Alliance

No photograph is available.

Cercocarpus ledifolius or *Cercocarpus intricatus* is the sole or dominant in shrub or tree canopy. Emergent trees such *Juniperus occidentalis* ssp. *australis, Juniperus occidentalis* ssp. *occidentalis, Pinus albicaulis, P. balfouriana, P. contorta* ssp. *murrayana, P. jeffreyi* and *P. monophylla* may occur or emergent shrubs such as *Amelanchier alnifolia, Arctostaphylos patula, Artemisia tridentata, Prunus virginiana,* or *Purshia tridentata* may occur. Trees < 10 m tall; canopy continuous or scattered. Shrubs are common or infrequent. Ground layer sparse or grassy.

Habitat: Ridges, upper slopes. Soils sedimentary, ultramafic, volcanic-derived and shallow.

Distribution: Klamath Mountains (subalpine), montane Northern California Coast Ranges (montane), Southern Cascades (montane and subalpine), Modoc Plateau, Southern California Mountains and Valleys, Mojave Desert (ranges), Mono, Southeastern Great Basin, Northwestern Basin and Range, western U.S., Mexico.

Elevation: 1,200 to 3,000 m

NDDB Rank: unknown

Synonyms:
Holland: Broadleaved upland forests.
Barry: G74 G7411214.
Cheatham and Haller: High desert scrub.
PSW-45: Mountain mahogany series.
Rangeland: SRM 415, SRM 417.
Thorne: Desert rupicolous scrub, Mountain juniper woodland.
WHR: Sagebrush.
Munz: Sagebrush scrub.

References: Davis (1994a, 1994b), Paysen et al. (1980), West (1988), Young et al. (1977); plot-based descriptions are found in Keeler-Wolf (1987), Keeler-Wolf (1990b), Jensen and Schierenbeck (1990), Keeler-Wolf et al. (1998), and Young et al. (1977)

Membership Rules: Vegetation characterized by the relative dominance of the shrubby tree *Cercocarpus ledifolius*. Stands occur in dry, rocky and usually very well drained exposures in the highest portions of the Inyo, Panamint, and other tall ranges of the northern Mojave Desert.

Comments: *The Jepson Manual* (Hickman 1993) recognizes two varieties of *Cercocarpus ledifolius*. *Cercocarpus ledifolius* var. *ledifolius* is uncommon in comparison to *Cercocarpus ledifolius* var. *intermontanus*. *Cercocarpus intricatus* may dominate on rock outcrops in Mojave Desert and Southeastern Great Basin. *Cercocarpus intricatus* stands are included in the *Cercocarpus ledifolius* Shrubland Alliance at this time.

Cercocarpus ledifolius has a wide range in California. On rocky ridges and steep slopes with thin soil, this plant can be the sole tall shrub or small tree. Other trees may be present in these areas as well. Trees, if present, also occur in other alliances of the region. The degree of canopy development varies as *Cercocarpus ledifolius* can occur in other alliances as a secondary component.

Cercocarpus ledifolius is a long-lived, small tree or shrub characteristic of nutrient and water-deficient environments, especially on ridges, rock outcrops, and steep slopes. It mainly reproduces by seed, and it is a sporadic producer. The wind-dispersed seeds germinate best on well-lighted, mineral soil, but seedling mortality is high as they are readily browsed. Higher survivorship is afforded seedlings under the protection of older plants. Mature plants are important browse for livestock and wildlife. It is easily killed by fire, after which it is a feeble respouter.

Stands of *Cercocarpus ledifolius* alliance are typically on sites that inhibit conifer establishment. *Cercocarpus ledifolius* also occurs in woodland and forest alliances, where it plays a seral role, and may be maintained within them by fire.

Regional Status:
Mojave Desert: Found in the northern ranges.
Southeastern Great Basin: Found in the ranges.

Management Considerations: No additional information is available.

Chilopsis linearis Intermittently Flooded Shrubland Alliance

Figure A12. *Chilopsis linearis* Intermittently Flooded Shrubland Alliance

Chilopsis linearis is the sole, dominant, or important tall shrub or small tree in canopy; *Acacia greggii, Olneya tesota, Prosopis glandulosa, Psorothamnus spinosus*, or *Yucca brevifolia* may be present. Emergent trees may be present over a shrub canopy. *Atriplex polycarpa, Bebbia juncea, Ephedra californica, Encelia virginensis, Ericameria paniculata, Eriogonum fasciculatum, Hymenoclea salsola, Hyptis emoryi, Larrea tridentata, Lepidospartum squamatum, Opuntia acanthocarpa, Petalonyx thurberi, Prunus fasciculata, Senecio flaccidus, Viguiera parishii,* or *Yucca schidigera,* may be present. Trees < 6 m tall; canopy intermittent or open. Shrubs < 3 m tall; intermittent or open. Ground layer sparse, annual herbs or grasses seasonally present.

Habitat: Washes, intermittent channels, arroyos, lower canyons; intermittently flooded riverine or palustrine. Soils coarse, well drained, moderately acidic to slightly alkaline, including granitic and calcareous substrates.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, and Southern California Mountains and Valleys, south Nevada, west Arizona, New Mexico, Texas, Baja California, Mexico.

Elevation: 100 to 1,500 m

NDDB Rank: G4 S3.2

Synonyms:
Holland: Mojave wash scrub (34250), Mojave Desert Wash Scrub (63700)
Barry: G7411124
Cheatham and Haller: Desert dry wash woodland
PSW-45: Desert willow series
CALVEG: Desert wash woodland
Thorne: Desert microphyll woodland
WHR: Desert wash
Munz: Creosote bush scrub

References: Johnson (1976), MacMahon (1988), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Turner and Brown (1982), Vasek and Barbour (1977); plot-based descriptions are found in Keeler-Wolf et al. (1998) and Evens (2000)

Membership Rules: Keeler-Wolf et al. 1998 suggest trees and/or large shrubs of *Chilopsis linearis* at least 2% cover, with no other large shrubs equaling or exceeding it in cover. Other smaller shrubs (e.g., *Hymenoclea salsola, Hyptis emoryi, Ericameria paniculata, Atriplex* spp.) may be higher in cover in understory than emergent trees. Evens (2000) reports similar limits of 1-2% minimum cover over a variable short- to tall-shrub understory for her six associations.

Comments: *Chilopsis linearis* Intermittently Flooded Shrubland Alliance occurs strictly in washes and arroyos in the southern Mojave, Colorado, and sporadically in the Sonoran deserts of California. Arid climate restricts stands to washes, riparian arroyos, and adjacent flood plains. Although the alliance is widely distributed, stands are local and do not occur in many of the washes that would seem suitable. It tends to occupy sandy or gravelly washes where wash energy is dissipated across a relatively wide flood path. It does not range up into mountain valleys and narrow arroyos as much as the *Acacia greggii* or *Prunus fasciculata* Shrublands, and does not tend to occupy the most active wash centers such as do *Psorothamnus spinosus, Ericameria paniculata,* or *Hymenoclea salsola* Shrublands. Evens (2000) reports five out of the six associations she describes as occurring in washes and arroyos surrounded by alluvial deposits and only one in lower canyons.

Chilopsis linearis can become a large (5-6 m), relatively long-lived tree, and some of the best mature stands of this alliance occur along wash terraces where flooding has been infrequent, but where subterranean water is available. Many stands occur where runoff is forced to near surface as in washes across pediments, and in natural “narrows” in valleys. This alliance often occurs as a matrix with other wash alliances such as *Ericameria paniculata, Acacia greggii, Psorothamnus spinosus, Ephedra californica, Lepidospartum squamatum, Prunus fasciculata* and *Hymenoclea salsola* dominated alliances. Sawyer and Keeler-Wolf (1995) include this alliance within *Acacia greggii* Shrubland Alliance. Reid et al. (1999) recognizes it from other parts of the southwest United States. It is a “warm season” rain species and thus does not occur in the western Mojave Desert. It is reported to be sensitive to salinity and alkalinity (T. Keeler-Wolf personal communication, Desert Workshop 2000). *Chilopsis linearis* is a partially facultative, winter-deciduous species that may opportunistically delay its leaf output until water is available. This alliance is dependent on the intermittent flows/flooding of the channel to supplement soil moisture. The plants become large, and are likely to become fairly old (> 100 yrs) if established in relatively sheltered locations. Seeds are shed in the winter. Seedling establishment is sporadic, with occasional good recruitment, but many stands show none to few seedlings even after good flooding events. Seeds are not dormant, but inundation in wet sand will speed germination (Young and Young 1986). Most stands tend to be represented by multiple age classes. However, they are often strongly dominated by individuals of a single size class. It is likely that moderate flooding in combination with abnormally wet years provide the most favorable conditions to establish seedlings.

Flood frequencies and intensity levels are highly variable (Waananen and Crippen 1977); but compared to *Ericameria paniculata* and *Hymenoclea salsola* Shrublands, flooding frequencies are probably lower. Most large-stature stands are on small terraces above the most active wash channels. The understory of many of the Mojave Desert stands for this alliance is composed of the shrubs that are dominates in other alliances. Thus, flooding frequencies are probably within the low range of these shorter structured shrub alliances. Most stands probably receive sheet flooding at least every 10-20 years. No information on stand replacement and persistence is available.

Other disturbance effects include some competition from exotic *Tamarix* spp. Although most *Chilopsis* stands are not prone to invasion by *Tamarix* due to less than optimum moisture availability for *Tamarix* spp. establishment. Resprouting is well developed (FEIS 2001) although response to fire is not documented.

Regional Status:
Mojave Desert: Stands occur in the southern and eastern Mojave Desert north to the vicinity of Alvord, Avawatz and Clark Mountains, and west to Daggett Wash. Stands are widely scattered with more in the south and the eastern portions of the ecoregion.

Management Considerations: Because *Chilopsis linearis* is likely to be an alliance of longer disturbance intervals, it is less likely to be capable of frequent regeneration. Stands are relatively uncommon and typically small. They may be thought of as distinct resources requiring relatively low frequency flooding events, coupled with an abnormally wet seedling establishment period for stand maintenance. Some stands show partial senescence. The die-off is usually of individual trees that have likely reached their maximum age. Conservation planning for long-range maintenance of this alliance should include large drainages with several stands of different age classes.

Coleogyne ramosissima Shrubland Alliance

Figure A13. *Coleogyne ramosissima* Shrubland Alliance, Homewood Canyon

Coleogyne ramosissima is the sole or dominant shrub in canopy. *Artemisia spinescens, Atriplex confertifolia, Eriogonum fasciculatum, Ephedra nevadensis, Grayia spinosa, Krascheninnikovia lanata, Menodora spinescens, Salazaria mexicana,* or *Thamnosma montana* may be present. Emergent trees such as *Juniperus californica, Juniperus osteosperma, Pinus monophylla, Yucca schidigera,* or *Yucca brevifolia* may be present. Shrubs < 1 m tall; canopy intermittent to continuous. Ground layer sparse.

Habitat: Alluvial slopes, bajadas, and rocky highlands. Soil shallow, may have calcareous cemented duripans.

Distribution: Mojave Desert, Southeastern Great Basin, Sierra Nevada, Southern California Mountains and Valleys, south Nevada, north Arizona, south Utah, southwest Colorado.

Elevation: 1,200 to 1,800 m

NDDB Rank: G4 S4

Synonyms:
Holland: Black bush scrub (34300)
Barry: G7411222 BCORA00

Brown, Lowe and Pase: 153.121
PSW-45: Black bush series
Rangeland: SRM 212
Stone and Sumida: Black bush scrub
Thorne: Black bush scrub
WHR: Sagebrush
CALVEG: Black bush
Munz: Sagebrush Scrub

References: Bates (1984), FEIS (2001), Bown and West (1976), McMahon (1988), Martin (1994), Paysen et al. (1980), Reid et al. (1999), Stebbins et al. (1965), Thorne (1982), Turner (1982b), Vasek and Barbour (1977), Webb et al. (1988); plot-based descriptions are found in Keeler-Wolf et al. (1998).

Membership Rules: *Coleogyne ramosissima* ≥ 2% cover. *Ephedra nevadensis*, and or *Krameria grayi* can have up to twice the cover of *Coleogyne ramosissima*. Typically dominates stands, but may be exceeded by species of disturbance (*Hymenoclea salsola, Salazaria mexicana, Ericameria* spp., *Eriogonum fasciculatum*). A widespread type of shallow rocky soils on upper bajadas, pediments and hill slopes.

Comments: *Coleogyne ramosissima,* or Blackbrush, is in a monotypic genus restricted to the arid southwestern U.S. Stebbins and Major (1965) considers it a paleoendemic. This alliance occurs at transitional elevations between the Mojave Desert and the Southeastern Great Basin. Over the past few years plot data have confirmed the intermediate relationship between the two deserts. Elements of the lower, hotter Mojavean flora may be mixed with *Coleogyne ramosissima* Shrubland including *Larrea tridentata-Ambrosia dumosa, Yucca schidigera*, and *Yucca brevifolia* Shrublands. Upper elevation stands may mix with alliances dominated by *Artemisia tridentata, Atriplex confertifolia, Ephedra nevadensis, Juniperus californica, Juniperus osteosperma,* and/or *Pinus monophylla*. Blackbrush is also found in the peninsular ranges as far south as Anza-Borrego Desert State Park, where it forms intermittent stands between *Yucca schidigera* Shrubland Alliance stands and stands dominated by *Juniperus californica* or *Pinus monophylla*.

Coleogyne ramosissima is a long-lived shrub, up to 400 years (Webb et al. 1988) that is quite susceptible to fire. It is typically killed outright by fire, and as most stands are relatively dense and strongly dominated by *Coleogyne ramosissima,* even low frequency fire can destroy significant portions of stands for long periods. Recovery from fire is slow. Growth rates for the species are very slow (Webb et al. 1988). According to Bowns and West (1976), *Coleogyne ramosissima* is a relict species that may be on its way to extinction.

Individual plants produce relatively few seeds, which are relatively large and less mobile than other shorter-lived species in genera such as *Ericameria, Atriplex*, and *Artemisia*. Brown and West (1976) report that while some *Coleogyne ramosissima* seeds germinate on the surface, seedlings often emerge from rodent caches. Seedling survival is poor, with most not surviving beyond cotyledon stage. *Coleogyne* stands are notably depauperate in seedlings and young plants, suggesting that pulse establishment after favorable weather conditions are rare. Sinuous sharp transitions between remnant stands of *Coleogyne ramosissima* and adjacent stands that may have been burned over 50 years ago are frequently obvious. For a fire to carry through a *Coleogyne ramosissima* stand, not only does the stand need to be relatively dense but climatic conditions also need to be favorable (strong winds and dry conditions). Fire frequency is not high in these stands, as they occur in relatively low-lightning-frequency areas. In much of its range, the blackbrush-dominated alliance may be succeeded post-fire by several phases of vegetation, including an *Achnatherum speciosum* dominated phase, an *Eriogonum fasciculatum* dominated phase, an *Ericameria teretifolia* dominated phase, or a *Salazaria mexicana* dominated phase.

Regional Status:
Mojave Desert: Common above 1,000 m in mountains and on pediments. Fire has negatively affected its distribution and recruitment (M. Brooks, personal communication 2000).
Southeastern Great Basin: Stands are common in the Panamint, Last Chance, Grapevine, and Coso-Argus ranges, where they are adjacent to *Grayia spinosa, Larrea tridentata-Ambrosia dumosa, Yucca brevifolia, Menodora spinescens,* and *Artemisia tridentata* Shrublands.

Management Considerations: Increased fire frequency in the California deserts is an adverse impact on this alliance. The presence of non-native annual grasses such as *Bromus madritensis* and *Bromus tectorum* can contribute to carrying fire into and through blackbrush stands. Although relatively widespread in California, the alliance is sporadically distributed particularly towards the south of its range. Some parts of the desert (e.g., Anza Borrego) have very spotty distributions of this alliance. Extralimital and isolated stands should be protected from fire.

Encelia farinosa Shrubland Alliance

Figure A14. *Encelia farinosa* Shrubland Alliance

Encelia farinosa is the sole or dominant shrub in canopy. *Ambrosia dumosa, Artemisia californica, Eriodictyon crassifolium, Eriogonum fasciculatum, Agave deserti, Ferocactus cylindraceus, Opuntia bigelovii, Echinocactus engelmannii, Salvia apiana,* or *Yucca whipplei* may be present. Emergent *Fouquieria splendens* may be present. Shrubs <2 m tall; open to intermittent single-layered. Trees < 5 m tall scattered. Ground layer open; annuals seasonally present.

Habitat: Alluvial fans, bajadas, colluvium, upland slopes, small washes, and rills. Soils well-drained, rocky, may have desert pavement surface, often derived from granitic or volcanic rock.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Southern California Mountains and Valleys, Arizona, Nevada, Utah, Mexico.

Elevation: -75 to 1,400 m
NDDB Rank: G5 S4

Synonyms:
Sawyer and Keeler-Wolf (1995): Brittlebush series (in part),
Holland: Mojave creosote bush scrub *in part* (34100), Sonoran creosote bush scrub *in part* (33100), Riversidean Desert Scrub (32730 *in part*), Riversidean sage scrub (32700 *in part*)
Barry: G7411221

Brown, Lowe and Pase: 154.126
Cheatham and Haller: Creosote bush scrub, Coastal sage scrub
PSW-45: Encelia series
CALVEG: Encelia series
WHR: Desert scrub, Coastal scrub
Munz: Creosote bush scrub, Coastal sage scrub

References: Barbour (1994), Burk (1977), Hunt (1966), MacMahon (1988), Pase and Brown (1982), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Vasek and Barbour (1977); plot-based descriptions are found in Kirkpatrick and Hutchinson (1977), White (1994) and Keeler-Wolf et al. (1998).

Membership Rules: *Encelia farinosa* > 1% and no other species with equal or higher cover.

Comments: Many of the stands formerly considered part of the *Encelia farinosa* series and *Larrea tridentata* series (Sawyer and Keeler-Wolf 1995) are actually composed of a mixture of both species (see *Larrea tridentata-Encelia farinosa* alliance). However, this alliance lacks the overstory of taller *Larrea*. It is related to the *Larrea tridentata-Encelia farinosa, Ambrosia dumosa,* and *Larrea tridentata-Ambrosia dumosa* Shrublands. The *Encelia farinosa* Shrubland represents a drought-tolerant extension of the *Larrea tridentata* Shrubland, which is less cold-hearty and more heat-tolerant extension of the *Larrea tridentata-Ambrosia dumosa* Shrubland. The alliance also does not tolerate sandy or clay-rich soils as well as *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance. The virtual absence of creosote bush in the overstory may be due to the disturbance history of the stand (see below). It may also be due to the steep, rocky nature of the stand. Cover is variable with many steep rocky stands averaging less than 10% total vegetation cover, while disturbance-related stands may approach 50% cover.

Encelia farinosa is, like *Ambrosia dumosa*, a short-lived sub-shrub that forms an open to intermittent sub-shrub canopy. However, it is even more tolerant of hot, dry conditions and is more of an aggressive colonizer than *Ambrosia dumosa.* Leafing and flowering is opportunistic whenever moisture is available. *Encelia farinosa* rapidly colonizes burns and other disturbance; both in the south coastal scrub and desert vegetation (FEIS 2001). *Encelia farinosa* is short lived with maximum reported age 32 yrs (FEIS 2001). It reproduces entirely by seed and resprouts weakly from damaged stems. It is frost sensitive, limiting the elevation it extends to and geographic range. It grows poorly on clay soils, but survives on coarse, steep, and very rocky soils better than *Ambrosia dumosa*. It may replace longer-lived perennials after fire and, once established, may persist for decades. It is alleopathic to several winter annuals (FEIS 2001), suggesting that biodiversity is reduced if it replaces other vegetation. *Encelia farinosa* is fire sensitive and intolerant of heat from fire, as resprouting is weak or non-existent. However, it recolonizes from off-site seed readily. Recurrent desert fire selects for *Encelia farinosa* over longer-lived shrubs. Despite the colonizing properties of *Encelia farinosa*, some stands of the *Encelia farinosa* Shrubland Alliance are generally stable and occupy rocky sites too harsh for the *Larrea tridentata-Encelia farinosa* Shrubland

Alliance. Seral stages following fire or other unnatural disturbance are likely to involve a state dominated by *Encelia farinosa* for several years before *Larrea tridentata* and other long-lived shrubs re-establish. If *Larrea tridentata* reestablishes, then the stands convert to *Larrea tridentata-Encelia farinosa*-dominated alliance. Stands in the Southern California Mountains and Valleys may replace more diverse stands of *Artemisia californica, Salvia apiana* and *Eriogonum fasciculatum* Shrubland alliances following high-frequency fires.

Regional Status:
Mojave Desert: This alliance is much less common than the *Larrea tridentata-Encelia farinosa* Shrubland Alliance. However, it likely occurs in all the Mojave Desert except the northernmost and westernmost. In most parts of the Mojave Desert it is a disturbance related alliance of rocky substrates including roadsides, wash margins, and recently burned slopes. It may occupy limestone and other calcareous, as well as granitic and volcanic substrates. The northernmost stands occur on volcanic substrate on roadsides near Panamint on the boundary of the Southeastern Great Basin.

Management Considerations: This is another alliance where coincidence of non-native annual grass invasion and human-related fires have conspired to threaten the structure and diversity of the vegetation. In the deserts, fires should be excluded at all times of the year, and core areas should be identified where grass cover is low and thus stands are defensible. Unlike the *Larrea tridentata-Ambrosia dumosa* alliance, the rocky, extremely xeric nature of many of the stands preclude the establishment of dense cover of *Bromus madritensis,* and thus the resistance of this alliance to non-natural fire and weed invasion is relatively high. It is likely that this alliance is increasing relative to *Larrea tridentata-Encelia farinosa* or *Larrea tridentata-Ambrosia dumosa* in less rocky/steep parts of the desert where fires are relatively frequent. Similarly, in the inner coastal scrub, the *Encelia farinosa* alliance is often a degraded scrub resulting from high fire frequency. Fire frequencies in this area may be as high as once every 10 years.

Encelia virginensis Shrubland Alliance

Figure A15. *Encelia virginensis* Shrubland Alliance, Last Chance Range

Encelia virginensis is the important or dominant canopy shrub. *Ericameria nauseosa, Ephedra nevadensis, Gutierrezia microcephala, Hymenoclea salsola, Psorothamnus arborescens, Salvia dorrii, Salazaria mexicana, Stephanomeria pauciflora, Viguiera reticulata, Yucca baccata* or *Aristida purpurea* may be present. Emergent *Acacia greggii* may occur. Canopy intermittent short shrubs < 2 m tall. Ground layer is intermittent.

Habitat: Intermittently flooded arroyos, canyons and washes in desert mountains and on adjacent alluvial fans. Soils alluvial, gravel, or cobble, derived from calcareous, other metamorphic, or volcanic substrates; texture medium sand.

Distribution: Mojave Desert, Southeastern Great Basin, Nevada, Arizona
Elevation: 300 to 1,900 m

NDDB Rank: G4 S3.2

Synonyms:
Holland: Mojave wash scrub (34250), Mojave creosote bush scrub (34100), Sonoran creosote bush scrub (33100)
Munz: Creosote bush scrub, Shadscale scrub, Pinyon-Juniper woodland

References: Reid et al. (1999), Peterson (1984), Evens (2000); plot-based descriptions are found in Evens (2000)

Membership Rules: *Encelia virginensis* (including the subspecies *Encelia virginensis actonii*) ≥ 2% cover. No other species with greater or equal cover. Typically of washes or other disturbed areas in the eastern Mojave Desert (Evens 2000) *Encelia virginensis* over 2% cover may have *Salvia dorrii* at greater cover (> 5%).

Comments: *Encelia virginensis* and its subspecies *Encelia virginensis* spp. *actonii* occur commonly throughout the middle and upper elevations of the Mojave Desert and adjacent Colorado Desert and Southeast Great Basin. The species occurs commonly on slopes and in several vegetation alliances including those dominated by *Coleogyne ramosissima, Menodora spinescens, Larrea tridentata-Ambrosia dumosa, Larrea tridentata, Eriogonum fasciculatum,* and *Grayia spinosa*. However, *Encelia virginensis* only forms its own alliance in washes. Such stands are particularly well developed in the northeastern Mojave Desert and adjacent Southeastern Great Basin in such areas as the Cottonwood, Saline, Panamint, and Last Chance ranges of Death Valley National Park. In late spring in a good year these stands show spectacularly in full golden flower, lining the washes emanate from these mountains. Evens (2000) notes that *Encelia virginensis* Shrubland Alliance occupies washes with slopes of 4-5% with banks > 3 m high, settings which equate to her definition of upper washes and arroyos.

The *Encelia virginensis* Shrubland Alliance is locally common in washes where irregular flooding occurs. Not a great deal is known about the species' life history. It is likely not a prolific resprouter and probably does not live for long periods. It seeds well after wet years and occupies recently on disturbed ground whether in washes, roadcuts, or other recently disturbed substrate.

Regional Status:
Mojave Desert Stands occurs in calcareous alluvium in the Clark Mountains.
Southeastern Great Basin: Stands are common on the east side of the Last Chance Range, the Cottonwood Mountains, the Funeral Range, and the Panamint Mountains, all of which drain into Death Valley.

Management Considerations: No additional information is available.

Ephedra californica Intermittently Flooded Shrubland Alliance

No photograph is available.

Ephedra californica and *Hymenoclea salsola* are important canopy shrubs. *Adenophyllum cooperi, Ambrosia dumosa, Larrea tridentata, Lycium andersonii, Isomeris arborea, Opuntia ramosissima,* and *Senecio flaccidus* may be present. Perennial grasses *Pleuraphis rigida, Achnatherum hymenoides,* and *Achnatherum speciosum* may be present. Shrubs < 2 m tall; intermittent canopy over sparse ground layer with annual or perennial herbs and grasses.

Habitat: Intermittently flooded arroyos, and washes in desert mountains and on adjacent alluvial fans. Soils alluvial, derived from granitic substrates; texture is coarse to medium, sand.

Distribution: Mojave Desert, Colorado Desert

Elevation: 200 to 1,200 m

NDDB Rank: G3 S2.3. The coast range association defined as Monvero residual dunes is rare and threatened (G1 S1.2). Other coast range associations yet undefined may also be rare.

Synonyms:
Sawyer and Keeler-Wolf (1995): Bladderpod-California Ephedra-Narrowleaf goldenbush (in part)
Holland: Mojave wash scrub (34250), Mojave creosote bush scrub (34100), Monvero residual Dunes (23300), Sonoran creosote bush scrub (33100),
Munz: Creosote bush scrub, Shadscale scrub

References: Evens (2000), McHargue (1973), Sawyer and Keeler-Wolf (1995); plot-based descriptions are found in Evens (2000)

Membership Rules: Vegetation either dominated or co-dominated by *Ephedra californica,* typically of broad, active washes of mid to upper bajadas and fans. Ranging somewhat locally throughout the southwestern, central, and eastern portions of the area.

Comments: *Ephedra californica* is a widespread shrub of the Mojave and Sonoran deserts of California, ranging up the Central Coast ranges to Merced County (CalFlora 2000). It is a component of several alliances including those dominated by: *Psorothamnus spinosus, Larrea tridentata-Ambrosia dumosa, Atriplex canescens, Atriplex polycarpa, Fouquieria splendens,* and *Yucca schidigera.* Stands of *Ephedra californica* Shrubland Alliance are scattered throughout the Mojave, Sonoran, and Colorado deserts of California. Such stands are most commonly associated with washes. These stands are usually of low diversity, associated with the active portions of washes. In washes, the *Ephedra californica* Shrubland Alliance occupies a similar habitat to *Hymenoclea salsola* Shrubland Alliance, but is often found in slightly less disturbed micro sites as along low terraces and banks of washes (Evens 2000 and personal observation). Some stands are associated with sand sheets, dunes, and other sandy substrates. On these non-alluvial substrates, the stands often associate with perennial grasses such as *Pleuraphis rigida, Achnatherum hymenoides,* and *Achnatherum speciosum*. The isolated stands of *Ephedra californica-Isomeris arborea-Ericameria linearifolia* found in the inner coast range called Monvero Dunes community by Holland (1986) are found on ancient stabilized diatomaceous dunes. It is interesting to note that *Isomeris arborea* is often a characteristic species with this alliance, from the isolated coast range stands to the eastern Mojave Desert wash stands (Sawyer and Keeler-Wolf 1995, Evens 2000).

The *Ephedra californica* Shrubland Alliance is indicative of low gradient wash sites within the mid and lower elevations of the Mojave Desert. It occurs along washes ranging from 10 to 100 m in width and with variable slope aspect. Large, continuous stands are found along some washes in the eastern Mojave Desert, but many are small stands less than 100 square meters. Stands on sand sheets tend to stabilize and form mounds. *Ephedra californica* is a clonal species and may spread by underground rhizomes, making it well adapted to shifting sand and alluvial substrates.

Regional Status:
Mojave Desert: This alliance occurs throughout the Mojave Desert. In all parts of the Mojave Desert it is a disturbance related alliance of washes and is restricted to alluvial fans derived from non-calcareous substrate.

Management Considerations: No additional information is available.

Ephedra funerea Sparse Vegetation Alliance

Figure A16. *Ephedra funerea* Sparse Vegetation Alliance

Ephedra funerea is the dominant or important shrub in the canopy. *Amphipappus fremontii, Achnatherum speciosum, Encelia farinosa, Encelia virginensis, Ferocactus cylindraceus, Echinocactus polycephalus, Eucnide urens, Gutierrezia microcephala, Larrea tridentata, Salazaria mexicana,* or *Yucca schidigera* may be present. Shrubs < 1 m tall; canopy open. Ground layer sparse.

Habitat: Rocky highlands. Soils shallow, skeletal and calcareous.

Distribution: Mojave Desert, Southeastern Great Basin, and perhaps Nevada

Elevation: 800 to 1,600 m

NDDB Rank: G3 S2.3 (locally distributed on limestone and other carbonates, mostly in Death Valley NP and BLM wilderness areas)

Synonyms:
Holland: Black bush scrub (34300)
Barry: G7411222 BCORA00
Brown, Lowe and Pase: 153.121
PSW-45: Black bush series
Rangeland: SRM 212
Stone and Sumida: Black bush scrub
Thorne: Black bush scrub
WHR: Sagebrush
CALVEG: Black bush
Munz: Sagebrush Scrub

References: Beatley (1976)

Membership Rules: Vegetation strongly dominated by *Ephedra funerea* with no other indicator species present. An uncertain alliance of limestone mountains in the northeastern Mojave Desert, represented by little data.

Comments: *Ephedra funereal,* as a species, is endemic to the northern Mojave Desert and southern Great Basin of western Nevada and adjacent eastern California. It is a regular component of *Coleogyne ramosissima, Larrea tridentata-Ambrosia dumosa* and *Larrea tridentata-Encelia farinosa* dominated shrubland alliance stands on calcareous mountains. On relatively steep, rocky slopes, *Ephedra funerea* Sparse Vegetation occasionally forms open stands of low cover (usually 5-10% total vegetation) where the soil is too rocky for *Larrea tridentata, Encelia farinosa* or *Coleogyne ramosissima* to attain high cover. Slopes may be east or west/southwest facing.

The *Ephedra funerea* Sparse Vegetation Alliance occupies very open and rugged slopes and ridges where vegetation cover is usually no greater than 10%. Thus, fire is not a disturbance factor. As with other *Ephedra* species *Ephedra funerea* is probably relatively long-lived and can persist through long droughts. It may be able to resprout, and thus damage from rockfalls and other mechanical disturbance may initiate resprouting. Most shrubs are small in this alliance.

Regional Status:
Mojave Desert: The alliance appears to be relatively common in parts of the Nopah, Mesquite and Kingston Ranges.
Southeastern Great Basin: Stands occur in the Panamint Mountains.

Management Considerations: Little is known about this alliance. More sampling is needed to clarify relationships with other alliances and to its understand seral trends. Because the species is endemic to a relatively small area the alliance's ecological relationships and range should be further assessed.

Ephedra nevadensis Shrubland Alliance

Figure A17. *Ephedra nevadensis* Shrubland Alliance

Ephedra nevadensis is the sole, dominant or important shrub in canopy. *Artemisia tridentata, Atriplex confertifolia, Coleogyne ramosissima, Ericameria cooperi, Eriogonum fasciculatum, Grayia spinosa*, *Lycium andersonii, Menodora spinescens, Salazaria mexicana* or *Yucca schidigera* may be present. Shrubs < 2 m; open to intermittent cover. Ground layer open may include the bunchgrass *Achnatherum speciosum, Oryzopsis hymenoides, Elymus elymoides*, *Poa secunda* or *Pleuraphis jamesii. A*nnuals seasonally present. Emergent *Yucca brevifolia* may be present.

Habitat: Dry, open slopes, ridges, breaks with southern exposures, canyons, floodplains, Arroyos, and washes. Soils well drained, with gravel or rock, may be alkaline or saline**.**

Distribution: Mojave Desert, Southeastern Great Basin, Mono, Nevada, Utah

Elevation: 1,000 to 1,800 m

NDDB Rank: G3 S3.3

Synonyms:

Holland: Mojave mixed woody scrub (34210 *in part*), Sagebrush scrub (35200 *in part*), Blackbrush scrub (34300 *in part*)
Cheatham and Haller: Blackbrush scrub
Munz: Shadscale scrub, Creosote bush scrub
WHR: Desert scrub

References: FEIS (2001)**,** Reid et al. (1999) Yoder (1983); plot-based descriptions are found in Yoder (1983)

Membership Rules: *Ephedra nevadensis* ≥ 2% cover; no other species with greater cover with the following exceptions: *Acamptopappus spherocephalus* or *Chrysothamnus viscidiflorus*. Examine other alliance assignment if another species has equal cover. Note*:* *Ephedra nevadensis* may have high cover in *Coleogyne ramosissima, Larrea tridentata-Ambrosia dumosa* and *Larrea tridentata* Shrublands. For a stand to be a member of *Ephedra nevadensis* Shrubland, *Ephedra nevadensis* must have greater than twice the cover of the nominate species in these alliances.

Comments: *Ephedra nevadensis* is a common and widespread shrub of the transition between the Mojave Desert and Southeastern Great Basin (FEIS 2001). It is a component of many alliances including those dominated by: *Atriplex confertifolia*, *Coleogyne ramosissima*, *Larrea tridentata-Ambrosia dumosa, Juniperus osteosperma, Grayia spinosa, Lycium andersonii, Menodora spinescens, Pleuraphis jamesii, Yucca brevifolia,* and *Yucca schidigera.* Stands of *Ephedra nevadensis* Shrubland Alliance are common but generally widely scattered throughout the Mojave Desert and Southeastern Great Basin of California. Such stands may be in part related to fire, grazing, or other mechanical disturbance (see below). These stands are often composed of a diversity of perennial species and may include up to 35 species of shrubs (Reid et al. 1999). It occupies a similar climatic zone to *Grayia spinosa* Shrubland Alliance, but appears to segregate from it primarily based on soil depth, as *Grayia spinosa* Shrubland Alliance tends to prefer deeper alluvial soils than *Ephedra nevadensis* Shrubland Alliance*.*

The *Ephedra nevadensis* Shrubland Alliance is indicative of relatively disturbed sites within the mid-to-upper Mojave Desert and the lower-mid elevation Southeastern Great Basin. Yoder (1983) suggests it is the result of heavy use by livestock in the *Coleogyne ramosissima* and *Artemisia tridentata* Shrubland Alliances. *Ephedra nevadensis* is the most palatable and sought out by livestock of all the *Ephedra* species (FEIS 2001). Unlike most other dominant indicators of alliances within the same climatic zone (with the exception of *Grayia spinosa), Ephedra nevadensis* resprouts readily following browsing and light to moderate fire. Its seed set is variable, prolific in some years but low in others, probably due to precipitation (FEIS 2001). Despite its tolerance of fire and grazing, it is a relatively slow-growing shrub. It may slowly spread and replicate itself clonally. Seed viability is short (most < 5 years), although seeds do germinate from rodent caches with favorable moisture (FEIS 2001). Observations in Nevada, Utah, and Arizona (R. Webb personal communication) suggest that the species flowers infrequently, survives for long periods (15% of shrubs monitored are > 100 years old), and tend to establish in disturbed sites, such as ghost towns, after the first wave of colonizers represented by the *Hymenoclea salsola* Shrubland Alliance (Webb et al. 1988). New plants commonly develop from the roots or "stolons" of older clones in the absence of disturbance. Seedlings are very tolerant of drought and generally establish well following fall or winter plantings. *Ephedra nevadensis* generally sprouts from the root or crown after fire; however, under certain circumstances (e.g., severe June fire) hot fires may eliminate regenerative structures (FEIS 2001). *Ephedra nevadensis* may also reoccupy disturbed sites through seed. Periods of above-normal precipitation can contribute to increased stand flammability by promoting the growth of annuals such as *Bromus tectorum* and *Bromus madritensis.*

Regional Status:
Mojave Desert: Stands are widespread but local throughout most of the region except in the western Mojave Desert. It is commonly associated with *Coleogyne ramosissima, Atriplex confertifolia* and *Eriogonum fasciculatum* Shrublands.
Southeastern Great Basin: Upland stands probably occur throughout this region. These generally occur adjacent to stands dominated by *Artemisia tridentata, Coleogyne ramosissima* or *Atriplex confertifolia*.

Management Considerations: The current extent of this alliance is not well known. However, stands should be monitored and disturbance effects quantified throughout its range. It is not likely to have been an extensive type and may have increased as a result of more frequent and extensive fires and livestock use over the last 100 years or so. The high diversity of shrub species in some stands should be investigated more closely. Diversity may be related to the disturbance regime and if so it brings into focus the role of disturbance for maintaining floristic diversity in the desert.

Ephedra viridis - Artemisia tridentata Shrubland Alliance

No photograph is available.

Ephedra viridis and *Artemisia tridentata* are co-dominant, dominant, or important shrubs in canopy. *Pinus monophylla, Juniperus osteosperma, Juniperus californica* may be present. Emergent trees may be present over a shrub canopy. *Eriogonum heermannii, Opuntia erinacea, Ericameria nauseosa, Chrysothamnus viscidiflorus, Gutierrezia microcephala, Purshia mexicana* or *Purshia glandulosa* may be present. In the herbaceous layer *Elymus elymoides* and *Poa secunda* and herbs may be present. Trees < 6 m tall; scattered cover. Shrubs 1-3m tall; open to continuous cover. Ground layer < 1.5 m tall; canopy sparse to continuous.

Habitat: Ridges, slopes, Soils bedrock, colluvium, or alluvium derived.

Distribution: Mono, Southeastern Great Basin, Mojave Desert, Nevada, northern Arizona

Elevation: 1,500 to 2,300 m

NDDB Rank: G4 S4

Synonyms:
Holland: Great Basin mixed scrub (35100), big sagebrush (35210), Sagebrush steppe (35300)
Barry: G7411211 CARTR20
Brown, Lowe and Pase: 142.213, 142.222, 152.111
Cheatham and Haller: Great Basin sagebrush
PSW-45: Sagebrush series
Thorne: Great Basin sagebrush scrub
WHR: Sagebrush
CALVEG: Great Basin sagebrush
Munz: Sagebrush scrub

References: Reid et al. (1999), Peterson (1984); plot-based descriptions are found in Peterson (1984)

Membership Rules: *Ephedra viridis* ≥ 1% cover. Upper elevation scrubs on well drained rocky to gravelly soil usually adjacent to stands of *Pinus monophylla* and or *Juniperus osteosperma*. Other seral shrub species (e.g., *Ericameria* spp.) may equal these two in cover.

Comments: This alliance is considered part of the Great Basin sagebrush scrubs, or big sage scrubs by other authors. It typically occurs on shallow soils and relatively steep sites in the upper elevations of the north and east Mojave Desert. Variation in cover of both species is great. In some cases *Artemisia tridentata* dominates and in others *Ephedra viridis* dominates. The presence of both species in a stand at notable levels (see below) is sufficient for definition. Compared to the *Artemisia tridentata* Shrubland Alliance in the same regions, it is usually found on shallow, rocky, and not-deep residual or alluvial soils. *Ephedra viridis* tends to become more abundant on steeper rocky soils.

Ephedra viridis and *Artemisia tridentata* are both widespread shrubs of the Great Basin. They mix in stands in the high mountains of the northern and eastern Mojave Desert and the mid-elevations of the Great Basin. *Ephedra viridis* will resprout after fire or mechanical disturbance. *Ephedra viridis* also may germinate from seed following fire. *Artemisia tridentata* does not resprout (FEIS 2001); however, *Artemisia tridentata* seeds germinate in soil after moderate fire. Thus, a stand of *Ephedra viridis-Artemisia tridentata* may recover to previous composition and structure 15-20 years following a moderate fire event and up to 30 years after more severe burns (FEIS 2001). Fire is the principal natural disturbance affecting this alliance. Due to typically steep and rocky-slope exposures, rock falls and avalanche may occasionally impact stands. Heavy grazing is likely to affect some stands of the alliance. Grazing reduces understory grasses and herbaceous cover and creates understories susceptible to weed invasion. Natural fire frequency is related to lightning strikes from infrequent summer thunderstorms. Stand cover is generally lower than the *Artemisia tridentata* Shrubland Alliance (mean=17%, n=10). Thus, fires were likely to have been infrequent and small prior to the occurrence of invasive non-native grasses.

Regional Status:
Mojave Desert: This alliance occurs above 1,300 m in Providence, Kingston, and Funeral mountains. Little specific information on disturbance effects exists in the Mojave Desert**.**
Southeastern Great Basin: This alliance occurs above 1,200 m in the Inyo, Cottonwood, Grapevine, Coso and Argus mountains. It may occur as large stands on open slopes, but more typically occurs as smaller stands interspersed with *Pinus monophylla* Wooded Shrubland (cooler, less-exposed sites), and *Artemisia tridentata* Shrubland (deeper soil, less-steep sites).

Management Considerations: Although fire is a natural component of this alliance, large, high-frequency fires are detrimental.

Ericameria nauseosa Shrubland Alliance

Figure A18. *Ericameria nauseosa* Shrubland Alliance, Wildrose Canyon

Ericameria nauseosa is the sole or dominant shrub in canopy. *Artemisia tridentata, Chrysothamnus viscidiflorus, Ephedra* species or *Purshia tridentata* may be present. Emergent junipers or pines may be present, or emergent shrubs may occur over a ground layer of grass. Trees scattered, if present. Shrubs < 3 m tall; canopy continuous, intermittent, or open. Ground layer sparse or grassy.

Habitat: All topographic settings. Soils well-drained, sandy, gravelly.

Distribution: Central California Coast Ranges, Northern California Interior Coast Ranges, Southern Cascades, Sierra Nevada, Modoc Plateau, Southern California

Mountains and Valleys, Mojave Desert, Mono, Southeastern Great Basin, Northwestern Basin and Range, Intermountain West.

Elevation: 50 to 3,300 m

NDDB Rank: G5 S4

Synonyms:
Holland: Rabbitbrush scrub
Barry: G7411221 BCHNA20
Brown, Lowe and Pase: 142.141
Cheatham and Haller: Great Basin sagebrush
PSW-45: Rabbitbrush series
Thorne: Great Basin sagebrush scrub
WHR: Sagebrush

References: Paysen et al. (1980), West (1988), Young et al. (1977); plot-based descriptions are found in Ferren and Davis (1991).

Membership Rules: *Ericameria nauseosa* ≥ 2%. *Ericameria nauseosa* must have 25% or greater relative cover. Mid- and upper-elevation Mojave Desert, usually in areas with fire, flood or grazing history.

Comments: California stands are dominated by any of eight subspecies of *Ericameria nauseosa*. Some subspecies are local, while others have extensive ranges. It is not known which subspecies are sufficiently common to characterize California vegetation, since few ecologists make determinations of them. The species was previously in the genus *Chrysothamnus. Jepson* (Hickman 1993) redesignated it to be in the genus *Ericameria;* however, it often is still cited as *Chrysothamnus.*

Ericameria nauseosa is a fast growing shrub in the composite family that characteristically dominates in areas after disturbance. It blooms in the late summer and fruits in the fall. The wind-dispersed seeds do not require stratification and seeds germinate in the early spring. Plants grow about 10 years. In the Southeastern Great Basin *Ericameria nauseosa* is replaced over time by *Artemisia tridentata* if the stand is not disturbed.

Ericameria nauseosa is variable browse for livestock and wildlife, depending on subspecies and ecotype. Its resinous foliage burns readily even with high moisture content. It may resprout after fire, and wind-dispersed seeds readily colonize areas after fire from neighboring plants.

Regional Status:
Mojave Desert: Along watercourses in the eastern Mojave Desert**.** In the western Mojave Desert, stands occupy fallow agricultural fields

Management Considerations: This alliance is indicative of recent disturbance including fire, flood, and mechanical clearing. The existence of large areas of this alliance in an area suggests a level of disturbance greater than the norm.

Ericameria paniculata Intermittently Flooded Shrubland Alliance

Figure A19. *Ericameria paniculata* Intermittently Flooded Shrubland Alliance; Emigrant Canyon, Panmint Mountains

Ericameria paniculata is the sole or dominant shrub in canopy. *Ambrosia eriocentra, Brickellia incana, Encelia farinosa, Encelia virginensis, Ephedra nevadensis, Ephedra californica, Eriogonum fasciculatum, Hymenoclea salsola, Salvia dorrii* or *Stephanomeria pauciflora* may be present. Emergent *Acacia greggii* and *Chilopsis linearis* may be present. Trees < 5 m tall; scattered cover. Shrubs < 3 m tall; intermittent or open cover. Ground layer sparse. Annual herbs or grasses seasonally present.

Habitat: Washes, intermittent channels, arroyos intermittently flooded riverine or palustrine. Soils coarse, well-drained moderately acidic to slightly saline. The national list of wetland plants (Reed 1988) lists *Ericameria paniculata* as a Facultative Upland species.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Southeastern Great Basin.

Elevation: 100 to 1,100 m

NDDB Rank: unknown

Synonyms:
Holland: Mojave wash scrub (34250), Mojave Desert wash scrub (63700)
Barry: G7411221
Cheatham and Haller: Desert dry wash woodland
WHR: Desert wash
Munz: Creosote bush scrub, Shadscale scrub, Joshua tree woodland

References: FEIS (2001), Johnson (1976), Vasek and Barbour (1977),

Membership Rules: *Ericameria paniculata* ≥ 2%. *Ericameria paniculata* must be ≥ 25% of all cover. Widespread throughout broad elevation range in much of the mapping area in relatively large, recently active washes. Evens (2000) indicates *Ericameria paniculata* as the dominant canopy shrub with cover > 5%.

Comments: *Ericameria paniculata* Intermittently Flooded Shrubland Alliance is widespread, though localized, in washes and other fluvial channels throughout the hot deserts of California and adjacent Arizona, Nevada and Utah. Its center of distribution is in the Mojave Desert, where it occupies active washes and adjacent terraces on gently sloping bajadas and alluvial fans. It is commonly known as black-stemmed rabbitbrush, from fungal rust that causes distinct black bands around the young stems. As with other "rabbitbrush" species, it is relatively short-lived and well adapted to disturbance. However, it is not typically found in upland stands, as is *Ericameria nauseosa*, or *Chrysothamnus viscidiflorus*; *Ericameria paniculata* Intermittently Flooded Shrubland Alliance is largely limited to fluvial disturbance.

Many stands are monospecific and may be relatively dense with little or no understory. Most stands are found in medium-to-large washes where flooding events are regular (at least some water flows every few years). Stands typically occupy wash bottoms in broad, braided-channel washes and terraces in narrower, higher-energy washes, suggesting high rates of scour and flooding intensities are not conducive to high-density establishment. Seeding is prolific in the fall (September-November). The wind-blown seed will lodge in gravel and irregularities in the wash bottoms, and are further dispersed and germination activated when flooding comes. *Ericameria paniculata* grows quickly in favorable sites and may reach 4 m in height. However, shrub life span is relatively short.

Some resprouting may occur following minor damages from flood or fire, but moderate to severe fire likely kills shrubs (FEIS 2001). Fire is not likely to be an important agent of disturbance in this alliance due to its characteristic habitat. Large flooding events may destroy and eliminate all shrubs in the main watercourse, but seedling recruitment from adjacent individuals in protected microsites may be rapid. *Ericameria paniculata* does not occur at high elevations or further north in the Great Basin as do several other *Ericameria* spp. It may be relatively frost-sensitive.

Regional Status:
Mojave Desert: Stands occur in washes throughout the Californian Mojave Desert. In the west Mojave Desert, it occupies a similar niche to *Lepidospartum squamatum* Intermittently Flooded Shrubland Alliance (as at Red Rock Canyon State Park). It may also overlap with *Atriplex polycarpa, Atriplex hymenelytra, Hymenoclea salsola, Psorothamnus spinosus,* and *Larrea tridentata* or *Larrea tridentata-Ambrosia dumosa* Shrublands. In the Black Mountains and other mountains of Death Valley, it may occur with *Encelia virginensis* Shrubland Alliance. It mixes with these alliances and with open wash woodlands of *Chilopsis linearis* and *Acacia greggii*-dominated alliances. On terraces where such trees occur, *Ericameria paniculata* may succeed to the tree-dominated alliances, following long periods of no disturbance.
Southeastern Great Basin *Ericameria paniculata* Intermittently Flooded Shrubland occurs along washes in the Saline Valley and Cottonwood, Grapevine, Coso, Argus, and Panamint Ranges. Occupies washes with *Hymenoclea salsola* and *Encelia virginensis* Shrublands.

Management Considerations: Short-lived communities such as these are relatively unscathed by human interactions except for off-highway vehicle impacts and gravel mining within the wash environment.

Ericameria teretifolia Shrubland Alliance

No photograph is available.

Ericameria teretifolia is the dominant or important plant in the shrub layer. *Artemisia ludoviciana, Ephedra viridis, Eriogonum fasciculatum, Grayia spinosa, Gutierrezia microcephala, Opuntia acanthocarpa, Prunus fasciculata, Salazaria mexicana, Salvia dorrii, Sphaeralcea ambigua,* or *Stephanomeria pauciflora* along with other shrubs may be present in the overstory. *Muhlenbergia porteri, Poa secunda, Pleuraphis rigida, Pleuraphis jamesii,* or *Achnatherum speciosum* may form a scattered grass understory. Shrubs 0.5-2 m tall; intermittent to open cover. Grasses 0.5-1.5m tall; intermittent to open cover.

Habitat: Ridges, slopes, valleys. Soils bedrock or alluvium-derived.

Distribution: Mojave Desert, Southern California Mountains and Valleys, Southeastern Great Basin.

Elevation: 800 to 1,700 m

NDDB Rank: G4 S4

Synonyms:
Holland: Mojavean juniper woodland and scrub (72220), Peninsular juniper woodland and scrub (72320), Mojave mixed woody scrub (34210), Mojave mixed woody and succulent scrub (34240), Blackbrush scrub (34300)
Barry: G74G7411112BJUCA00

Cheatham and Haller: Mojavean pinyon juniper woodland
PSW-45: Juniper series
Thorne: Pinyon juniper woodland
WHR: Juniper
CALVEG: Pinyon-Juniper
Munz: Pinyon-juniper woodland, Shadscale scrub

References: Thorne (1982), Vasek and Thorne (1977), Keeler-Wolf et al.1998; plot-based descriptions are found in Keeler-Wolf et al.1998.

Membership Rules: *Ericameria teretifolia* ≥ 2% cover. No other species with greater cover but can share dominance with *Eriogonum fasciculatum, Gutierrezia sarothrae,* or O*puntia chlorotica.* Usually of disturbed uplands**,** mid-elevation Mojave Desert.

Comments: In the Mojave Desert and Peninsular Range/Colorado Desert borderland, the *Ericameria teretifolia* Shrubland Alliance is one of several mid-elevation xeromorphic upland scrub alliances above the broad belt of *Larrea tridentata-Ambrosia dumosa,* but below the high-elevation shrublands with *Artemisia tridentata* and the *Pinus monophylla*. It occurs in disturbed areas, including burns, washes, and heavily grazed sites. *Ericameria teretifolia* nearly always shares the short-shrub canopy with other shrub species. As with other members of its genus, *Ericameria teretifolia* is a relatively short-lived shrub, which may seed and germinate abundantly after disturbance. In Anza-Borrego Desert State Park, there is evidence that this alliance replaces *Juniperus californica* Wooded Shrubland Alliance following fire.

Ericameria teretifolia is a common shrub of the mid-elevation of the Mojave Desert and the Southeastern Great Basin. In the Mojave Desert, this alliance occupies similar environments to *Grayia spinosa, Eriogonum fasciculatum, Salazaria mexicana, Pleuraphis* spp. and *Juniperus osteosperma*-dominated alliances. Stands of this alliance share several other species with other relatively high-frequency disturbance alliances. In the Peninsular Ranges, the alliance occupies former stands of *Juniperus californica* following fire events as old as 25 years. This alliance is a seral type that replaces other long-persistent alliances following fire or perhaps other disturbance such as intensive grazing or mechanical soil disturbance. It occurs adjacent to *Juniperus osteosperma*, *Juniperus californica*, *Atriplex confertifolia*, *Coleogyne ramosissima,* and *Grayia spinosa*-dominated alliances. It likely replaces those types for undetermined periods following disturbance.

Regional Status:
Mojave Desert: This is a disturbance-following type with relatively few large stands. It generally occurs below the pinyon belt and is frequently found in the shadscale and juniper zones in the eastern and northern parts of the Mojave Desert. No specific disturbance information is available.
Southeastern Great Basin: It occurs in habitats similar to the Mojave Desert (see above) and has colonized road cuts in upper elevation portions of Death Valley National Park.

Management Considerations: This alliance is a seral type and should be considered part of the natural matrix of mid-to-upper desert vegetation. Large stands are indicative of some more-extensive, often anthropogenic, disturbance processes.

Eriogonum fasciculatum Shrubland Alliance

No photograph is available.

Eriogonum fasciculatum is the sole, dominant, or important shrub. In the Mojave Desert, emergent shrubs such as *Ambrosia dumosa, Coleogyne ramosissima, Ephedra nevadensis, Ericameria teretifolia, Hymenoclea salsola, Larrea tridentata, Pleuraphis jamesii, Salazaria mexicana, or Viguiera parishii* and emergent trees of *Juniperus californica, Juniperus osteosperma,* or *Yucca schidigera* may be present. Shrubs < 1 m tall; canopy continuous or intermittent. Ground layer variable, may be grassy.

Habitat: Slopes, rarely flooded low-gradient deposits. Soils shallow and rocky. Also in wetland habitats such as washes, intermittent channels, arroyos intermittently flooded riverine or palustrine. Soils are coarse, well drained, and moderately acidic to slightly saline.

Distribution: Southern California Coast, Southern Central California Coast Ranges, Southern California Mountains and Valleys, Mojave Desert, western Colorado Desert, Baja California.

Elevation: 0 to 1,200 m

NDDB Rank: unknown

Synonyms:
Holland: Alluvial fan chaparral; Central Lucian coastal, Diablan sage, Diegan coastal sage scrub, Riversidean sage scrub, Southern coastal bluff, Venturan coastal sages
Barry: G7411211 CERFA00
Cheatham and Haller: Central coastal, Coastal sage scrubs
PSW-45: California buckwheat series
Rangeland: SRM 205
Thorne: Southern coastal scrub
WHR: Coastal scrub
Munz: Coastal sage scrub

References: Axelrod (1978), Barbour (1994), DeSimone and Burk (1992), Keeley and Keeley (1988), Kirkpatrick and Hutchinson (1977), Malanson (1984), Mooney (1977), O'Leary (1989), Paysen et al. (1980), Pase and Brown (1982), Vasek and Barbour (1977), Westman (1983); plot-based descriptions are found in Hanes et al. (1989), Kirkpatrick and Hutchinson (1977), Gordon and White (1994), White (1994), and Keeler-Wolf et al. (1998)

Membership Rules: *Eriogonum fasciculatum* $\geq 2\%$. Usually in disturbed shallow soils on slopes and pediments near interface with mid- and upper-elevation Mojave Desert. Other shrubs, if present, are each less than half cover, with the exceptions of *Hyptis emoryi* or *Salvia dorrii*, which may have higher cover.

Comments: *Eriogonum fasciculatum* is a semi-woody, many-branching shrub often occurring on coarse-textured soils that may be moderately saline. It produces conspicuous flowers over much of the year with low seed set. Seed germination requires stratification and does not require a fire-related stimulus. In coastal areas, this alliance is part of the coastal scrub ecological system. Associated species vary depending upon the geographic section in which the alliance occurs (see below).

It establishes after disturbance by fire, flood, or livestock. It rarely resprouts after disturbance and can be replaced by longer-living species in areas with long periods between disturbances.

Regional Status:
Mojave Desert: Local at mid and upper elevations in areas in the eastern Mojave Desert disturbed by fire, grazing, and water (in washes).

Management Considerations: No additional information is available.

Forestiera pubescens Temporarily Flooded Shrubland Alliance

Figure A20. *Forestiera pubescens* Temporarily Flooded Shrubland Alliance, Willow Spring

Forestiera pubescens is the dominant or important shrub in the canopy. *Salix exigua, Salix laevigata, Atriplex canescens, Vitis girdiana, Baccharis sergiloides, Baccharis emoryi, Phragmites australis,* or *Rhus trilobata* may be present. Canopy intermittent to continuous. Shrubs < 5 m tall.

Habitat: Soils intermittently flooded, saturated. Water chemistry: fresh. Floodplains, stream banks, springs, river terraces or washes. Soils gravelly to fine sandy. The national list of wetland plants (Reed 1988) lists *Forestiera pubescens* as a NI (not enough information) for California.

Distribution: Mojave Desert, Southeastern Basin and Range, Colorado

Elevation: 800 to 1,800m

NDDB Rank: G3 S2.2 Multiple associations may be represented; some may be very rare.

Synonyms:
Cheatham and Haller: Desert dry wash woodland, Southern alluvial woodland
Thorne: Desert riparian woodland
WHR: Desert riparian

References: Reid et al. (1999)

Membership Rules: None developed.

Comments: The *Forestiera pubescens* Temporarily Flooded Shrubland Alliance occurs in widely scattered, small stands throughout the mountains of the Mojave Desert and adjacent Southeastern Great Basin. Stands are never common and usually occur locally around permanent water or subsurface moisture. Typical settings are springs in hilly or mountainous terrain, or narrows in canyon bottoms where moisture is forced to the surface. These stands are often associated with other wetland alliance stands dominated by *Salix exigua, Tamarix* spp., *Populus fremontii* and *Baccharis sergiloides*. The highest density of stands apparently occurs in the Argus and Coso Mountains area of the Southeastern Great Basin. There, many of the springs in the canyons on the east side of the Argus Range support stands, some of which are foraging habitat for the endemic Inyo race of the California towhee (M. Bagley, personal communication). Compared to the *Salix exigua* and *Populus fremontii*-dominated alliance, *Forestiera pubescens* Intermittently Flooded Shrubland appears to prefer slightly drier conditions as upslope from flowing water. Stands are usually dense with sparse understory.

Forestiera pubescens is a desert wetland species**.** Its fruits are drupes and are probably bird dispersed. It appears to form clonal thickets perhaps because of stem damage. No information is available from FEIS (2001) on disturbance ecology.

Regional Status:
Mojave Desert: Stands occur in the eastern Mojave Desert mountains around springs and in canyons.
Southeastern Great Basin: Stands occur in Inyo, Argus, and Coso Mountains.

Management Considerations: This wetland alliance could be very sensitive to invasion by *Tamarix* spp. It is rare and localized throughout its known range in California.

Grayia spinosa Shrubland Alliance

Figure A21. *Grayia spinosa* Shrubland Alliance, Inyo Mountains

Grayia spinosa is the dominant or important shrub in canopy. *Acamptopappus spherocephalus, Achnatherum speciosum, Ambrosia dumosa, Artemisia spinescens, Atriplex confertifolia, Chrysothamnus viscidiflorus, Larrea tridentata, Krascheninnikovia lanata, Lycium andersonii,* or *Tetradymia spp.* may be present. Emergent *Yucca brevifolia* may be present. Shrubs < 1 m tall; canopy continuous, intermittent, or open. *Bromus tectorum, Eriogonum ovalifolium*, or *Poa secunda* may be present. Ground layer sparse to intermittent.

Habitat: Basins, valleys, lower mountain slopes. Soils alluvial-derived, ranging from gravelly, sandy loams to dry heavy clays, but is typically found on highly calcareous, alkaline soils. It prefers sandy soils that are free of salt and hardpans (FEIS 2001).

Distribution: Northwestern Basin and Range, Mono, Southeastern Great Basin, Mojave Desert, Modoc Plateau, Intermountain West

Elevation: 500 to 1,900 m

NDDB Rank: G5 S3.3 (some associations may be rarer)

Synonyms:
Holland: Shadscale scrub (36140)
Cheatham and Haller: Shadscale scrub
PSW-45: Saltbush series
Rangeland: SRM 414, SRM 501

Thorne: Shadscale scrub
WHR: Alkali sink
Munz: Shadscale scrub
CALVEG: Shadscale series

References: Beatley (1976), Webb et al 1988, FEIS (2001)

Membership Rules: *Grayia spinosa* ≥ 2% cover; no other species with greater cover except *Ericameria cooperi* or *Lycium andersonii. Lycium andersonii* must dominate in some circumstances.

Comments: *Grayia spinosa* Shrubland is widespread in the Mojave Desert and Southeast Great Basin. It occupies a distinct and relatively narrow portion of the environmental gradient above the *Larrea tridentata-Ambrosia* Shrubland and below stands of *Artemisia tridentata* Shrubland and upland stands of *Atriplex confertifolia* Shrubland. According to Beatley (1976), it is the most characteristic plant community of the transition between the Mojave Desert and the Southeastern Great Basin in south-central Nevada. It often occupies deep, well-drained soils in valleys and bajadas. It typically occurs adjacent to *Coleogyne ramosissima* (shallower, rocky soils), *Atriplex confertifolia* (more alkaline or shallow calcareous soils), or upper-elevation stands of *Larrea tridentata* and *Larrea tridentata-Ambrosia dumosa* Shrublands. It grows well on limey soils, but is not as well adapted to salty soils as *Atriplex confertifolia, Atriplex polycarpa, Atriplex canescens,* or *Sarcobatus vermiculatus*. *Grayia spinosa* commonly occurs in nearly pure stands and is most commonly associated with *Lycium andersonii* in the Southeastern Great Basin and the Mojave Desert. The NVC differentiates stands with an intermittent flooding regime as *Grayia spinosa* Intermittently Flooded Shrubland Alliance and stands mixed with the evergreen shrub *Ephedra viridis* as members of another alliance, *Grayia spinosa-Ephedra viridis* Shrubland Alliance. Although suspected in California, these alliances have not been identified yet.

Grayia spinosa is considered to be intermediately-lived (mostly < 100 years), and can colonize soon after, but not immediately following mechanical disturbance (Webb et al. 1988). It is reported to sprout readily after mechanical disturbance such as trampling and/or light burning. However, deep plowing easily kills *Grayia spinosa* (FEIS 2001). It tolerates browsing and may be an important range feed for livestock in the Great Basin (FEIS 2001), but because of its spines, *Grayia spinosa* is not considered of high forage value (FEIS 2001). Response to fire is not well quantified. Plants are known to re-sprout from the base following fire (FEIS 2001). However, participants in the Desert Workshop (T. Keeler-Wolf personal communication, Desert Workshop 2000) considered it to generally be a weak sprouter. As it is an intermediately-lived shrub, it is indicative of stable conditions in many areas. Living shrubs of *Grayia spinosa* have been successfully transplanted in roadside re-vegetation projects in eastern California (FEIS 2001). Little is known about the seral stages and natural disturbance patterns of this alliance. Reproduction by seed is periodic and relatively uncommon (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Regional Status:
Mojave Desert: Stands occur in Owens, Greenwater, Searles, and Mojave valleys. Upland stands occur on rocky hills mixed with stands of *Ephedra nevadensis, Atriplex confertifolia, Menodora spinescens, Larrea tridentata-Ambrosia dumosa, Yucca schidigera,* and *Yucca brevifolia* Shrublands. Stands are known as far south as Lucerne and Johnson valleys. It ranges west into the western Mojave Desert where it commonly co-occurs in stands with *Krascheninnikovia lanata* Dwarf-shrubland. Most stands in the southern portion of the range of the alliance are in valleys surrounding *Atriplex polycarpa* Shrubland and below other upland stands of *Larrea tridentata-Ambrosia dumosa.* Stands with a high level of cattle browsing in the Ord Mountains are mixed with *Hymenoclea salsola* and *Acamptopappus spherocephalus.*
Southeastern Great Basin: Upland stands are extensive in the Cottonwood and Grapevine Mountains and Coso, Argus and Panamint Ranges. These may form a mosaic with *Coleogyne ramosissima, Yucca brevifolia, Atriplex confertifolia, Artemisia tridentata, Ephedra nevadensis,* and *Larrea tridentata-Ambrosia dumosa* Shrublands. Stands occur in alluvial valley bottoms and on gradual slopes. In the Panamint Mountains this alliance transitions gradually at lower elevations into the *Larrea tridentata-Ambrosia* Shrubland and upwards into the *Coleogyne ramosissima* Shrubland.

Management Considerations: A further understanding of fire history and other disturbance response is needed. In some areas, the alliance seems compatible with a high level of livestock browsing. It also characterizes the preferred habitat of the endangered Mojave ground squirrel (M. Bagley, personal communication).

Herbaceous Dunes Sparse Vegetation Alliance
No photograph is available.

This alliance is characterized by its occurrence on stabilized sand sheets and dunes rather than by any one dominant species. Scattered forbs and grasses in the ground canopy. *Abronia villosa, Cleome sparsifolia, Croton californicus, Dicoria canescens, Geraea canescens, Oenothera deltoides, Oryzopsis hymenoides, Panicum urvilleanum, Pleuraphis rigida, Rumex hymenosepalus,* or *Swallenia alexandrae* may be present. Individual emergent shrubs may be present such as *Ambrosia dumosa, Atriplex canescens, Eriogonum deserticola*, or *Larrea tridentata.* Shrubs < 3 m tall. Ground layer open. Annuals seasonally present.

Habitat: Sand bodies. Active, partially stabilized, and stabilized dunes; or partially stabilized and stabilized sand fields.

Distribution: Southern California Mountains and Valleys, Mojave Desert, Sonoran Desert, Colorado Desert, Mono Co. and Southeastern Great Basin.

Elevation: -10 to 1,200 m

NDDB Rank: G3 S2.2

Synonyms:
Sawyer and Keeler-Wolf (1995): *Abronia villosa* series (in part)
Holland: Active desert dunes, stabilized and partially stabilized dunes, stabilized and partially stabilized desert sand fields
Barry: G7411323
Cheatham and Haller: Partially stabilized desert dunes, stabilized desert dunes.
PSW-45: Croton series
Stone and Sumida: Sand plant community.
Thorne: Desert dune sand plant
WHR: Desert scrub

References: Henry (1979), Thorne (1982), Paysen et al. (1980), Vasek and Barbour (1977); plot-based descriptions include Bagley (1986), DeDecker (1979), Spolsky (1979); plot-based descriptions are available for individual dunes: Algodones dunes (Beauchamp 1977), Ballarat dunes (Pavlik 1985), Borrego dunes (Beauchamp 1986), Cadiz dunes, Chuckwalla Valley dunes, Death Valley dunes (DeDecker 1979, 1984), Deep Springs dunes (Pavlik 1985), Dumont dunes, Eureka dunes (DeDecker 1984), Mono dunes (Pavlik 1985), Olancha dunes (Pavlik 1985), Panamint Valley dunes, Rice Valley dunes, Saline Valley dunes (DeDecker 1984), Saratoga dunes (Pavlik 1985).

Membership Rules: Perennial plants present but less than 2%; characteristized by sand dunes and sand flats. Perennial species can include scattered grasses such as *Achnatherum hymenoides, Panicum urvilleanum, Pleuraphis jamesii, Pleuraphis rigida* and *Swallenia alexandrae*; shrubs such as *Atriplex canescens, Larrea tridentata,* and *Ambrosia dumosa*; and forbs such as *Dicoria canescens, Abronia villosa,* and *Oenothera deltoids.*

Comments: Eighteen dune areas are scattered throughout the deserts of transmontane California, each with its own set of plant species (Pavlik 1985). Dunes that have been studied floristically are Algodones, Ballarat, Borrego, Cadiz, Chuckwalla Valley, Death Valley, Deep Springs, Dumont, Eureka, Kelso, Mono, Olancha, Panamint Valley, Rice Valley, Saline Valley, and Saratoga. Sawyer and Keeler-Wolf (1995) considered all desert dunes to be included within *Abronia villosa* series; however, much seasonal and within-dune system variation occurs, some of which requires further research to clarify. Currently there is sufficient information to break out some components of dune vegetation into separate alliances (see *Panicum urvilleanum* and *Achnatherum hymenoides* Herbaceous Alliances).

Other alliances on sand dunes and flats include *Achnatherum hymenoides, Atriplex canescens, Larrea tridentata-Ambrosia dumosa, Panicum urvilleanum, Pleuraphis jamesii,* and *Pleuraphis rigida*-dominated alliances and unique stands of *Swallenia alexandrae.*

Sand dunes are used for many uses other than passive recreation. Algodones (Imperial) and Dumont dunes are open to motorized recreation. Eureka Dunes have been used for sand-boarding. Various plant species each have their peculiar adaptations to growing on sand. Psammophitic grasses such as *Swallenia alexandrae, Achnatherum hymenoides, Panicum urvilleanum,* and *Pleuraphis rigida* each have different tolerances and tend to arrange themselves accordingly within dune systems. Annual psammophytes tend to rearrange themselves based on varying annual rainfall and temperature conditions. Some have adapted seasonally, like *Dicoria canescens* and grow in summer-fall; others such as *Abronia villosa* and *Oenothera deltoides* are early spring species.

Regional Status:
Mojave Desert: Ballarat Dunes, Death Valley Dunes, Dumont Dunes, Kelso Dunes Olancha Dunes, Panamint Valley Dunes
Southern California Mountains and Valleys: Colton Dunes
Southeastern Great Basin: Deep Springs Dunes, Eureka Dunes, Saline Valley Dunes

Management Considerations: Sand sheets and dunes are relatively rare. OHV use and disruption of sand sources have degraded many. Protection from impacts has been implemented on a portion of California dunes, but many, such as Dumont, Algodones, and Rice Valley dunes, have had long-term quantifiable negative impacts.

Hymenoclea salsola Shrubland Alliance

Figure A22. *Hymenoclea salsola* Shrubland Alliance, Jubilee Pass, Death Valley

Hymenoclea salsola is the sole or dominant shrub in overstory. *Ephedra californica, Encelia farinosa, Ericameria paniculata, Eriogonum fasciculatum, Larrea tridentata, Opuntia echinocarpa, O. basilaris, Psorothamnus schottii,* or *Salazaria mexicana* may be present. Emergent *Acacia greggii, Parkinsonia florida, Chilopsis linearis, Olneya tesota* or *Psorothamnus spinosus* may be present. *Bromus madritensis* and other weedy annuals may be in ground layer. Shrubs open to intermittent cover; < 2 m tall. Emergent tall shrubs or low trees < 6 m tall. Ground layer sparse or seasonally present.

Habitat: Valleys, flats, rarely flooded low-gradient deposits. Soils are shallow; sandy, gravelly, or disturbed desert pavement. Wetland habitats such as washes, intermittent channels, arroyos, intermittently flooded riverine or palustrine. Soils are coarse, well drained, and moderately acidic to slightly saline.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Southeastern Great Basin, Great Valley, Central California Coast Ranges, Arizona, Nevada, and perhaps Utah

Elevation: 0 to 1,600 m

NDDB Rank: G4 S4

Synonyms:
Holland: Mojave wash scrub (34250), Mojave creosote bush scrub (34100), Sonoran creosote bush scrub (33100)
Munz: Creosote bush scrub, Shadscale scrub

References: FEIS (2001), Johnson (1976), Vasek and Barbour (1977); plot-based descriptions are found in Keeler-Wolf et al. (1998).

Membership Rules: *Hymenoclea salsola* > 1%. Other shrubs, if present, are each less than half the cover of *Hymenoclea Salsola,* with the exceptions of *Hyptis emoryi* or *Salvia dorrii*, which may have higher cover.

Comments: *Hymenoclea salsola* is widespread in many alliances in the hot deserts of California. However, canopy dominance by *Hymenoclea salsola* is necessary to define the alliance. *Hymenoclea salsola* Shrubland is the ubiquitous native indicator of recent disturbance throughout the hot deserts of California. It occurs commonly in washes, but also in burned and heavily grazed areas from below sea level to at least 1,600 m. Flooding is the most frequent natural disturbance associated with this alliance. However, it has benefited from increased fire frequencies resulting from the fuels built up from non-native annual *Bromus* spp. It has also benefited from over-grazing by livestock in certain parts of the desert. Thus, it currently occupies upland sites as well as wash and bottomland sites throughout its distribution. It has varied relationships to other vegetation types, given its geographic and ecological range. In many lower elevation washes, it occurs adjacent *to Psorothamnus spinosus, Olneya tesota, Parkinsonia florida*, *Atriplex polycarpa, Ephedra californica*, and *Bebbia juncea*-dominated alliances. At mid-elevations, it is commonly associated with *Ericameria paniculata, Salazaria mexicana, Chilopsis linearis, Eriogonum fasciculatum, Ephedra californica, Larrea tridentata, Larrea tridentata-Ambrosia dumosa,* and *Yucca brevifolia*-dominated alliances. On calcareous substrates, it may occur with *Encelia virginensis* and *Viguiera reticulata*-dominated alliances in washes and on slopes having *Artemisia nova* Shrubland. It occurs adjacent to *Acacia greggii* Shrubland in both washes and upland settings. In some upland, settings it may occur with non-native *Bromus madritensis* stands. It may coexist with *Atriplex confertifolia, Prunus fasciculata* and *Ericameria nauseosa* Shrublands at high elevations.

The *Hymenoclea salsola* Shrubland Alliance is indicative of disturbed sites. In wash and arroyo settings, flooding regimes for the alliance are generally of high frequency and have variable intensity. The seeds have high viability and high germination rates compared to other desert shrubs. Seeding is prolific; and flowering, leaf-flush, and seed set are opportunistic whenever water is available (FEIS 2001). The species is short-lived and has a shallow root system consisting of a relatively short taproot with prominent laterals. It not only seeds from adjacent sites and colonizes bare mineral soil, but it also re-sprouts following mechanical above-ground damage from flood and from fire (FEIS 2001). *Hymenoclea salsola* Shrublands recover quickly after fire via off-site seeds and sprouting. Five years after the Snow Creek fire, *Hymenoclea salsola* frequency and cover were greater on burned than unburned sites (O'Leary and Minnich 1981). Following a fire in the San Ysidro Mountains, more than 90% of *Hymenoclea salsola* plants survived by sprouting. Some *Hymenoclea salsola* started sprouting within 2 months after the fire (Tratz 1978).

Regional Status:
Mojave Desert: This alliance occurs throughout the Mojave Desert. In all parts of the Mojave Desert, it is a disturbance-related alliance of washes, roadsides, OHV, military camps, heavily grazed land, and recently burned slopes. It may occupy limestone and other calcareous substrates and granitic- and volcanic-derived soils. Its elevation range is up to 1,500 m, as in the mid-hills**.**

Management Considerations: *Hymenoclea salsola* with its natural colonizing ability is well suited for being the primary early-seral wash alliance through most of the hot deserts of California. However, its current distribution is more abundant than its historic distribution in much of the desert because of recent human-mediated disturbance patterns. This is another alliance where coincidence of non-native annual grass invasion and human-related fires has threatened the structure and diversity of the vegetation. In the deserts, fires should be excluded at all times of the year, and core areas should be identified where grass cover is low and thus stands are defensible.

Hyptis emoryi Intermittently Flooded Shrubland Alliance

No photograph is available.

Hyptis emoryi is the emergent or important tall shrub over a lower-shrub canopy. Emergent *Acacia greggii, Parkinsonia florida, Chilopsis linearis, Olneya tesota* or

Psorothamnus spinosa may be present. Tall shrubs or emergent trees < 6 m tall; intermittent to open cover. Small shrubs < 3 m tall; canopy intermittent to open. *Bebbia juncea, Encelia farinosa, Eriogonum inflatum, Hymenoclea salsola, Justicia californica, Larrea tridentata, Psorothamnus schottii, Opuntia basilaris,* or *Trixis californica* may be present. Ground layer open; annuals seasonally present.

Habitat: Steep, very rocky colluvium on lower portion of canyon slopes. Soils are azonal and very rocky. It also occurs in wetland habitats such as bouldery or rocky arroyo margins, seasonal watercourses, and washes. Soils intermittently flooded, saturated. Water chemistry: fresh. Cowardin class: temporarily flooded, palustrine shrub-scrub wetland.

Distribution: Colorado Desert, Sonoran Desert and southern Mojave Desert in California, Baja California, and perhaps Sonoran Desert in Arizona.

Elevation: 10 to 800 m

NDDB Rank: G3 S3

Synonyms:
Holland: Desert dry wash woodland (62200 *in part*), Mojave desert wash scrub (63700 *in part*), Mojave wash scrub (34250 *in part*)
Thorne: Desert microphyll woodland (in part)
WHR: Desert wash
Munz: Creosote bush scrub

References: Plot-based descriptions are based on Keeler-Wolf et al. (1998)

Membership Rules: Vegetation characterized by the tall, aromatic shrub *Hyptis emoryi* (desert lavender). It is local in rocky washes of upper bajadas and canyons in the southern portion of the Mojave Desert.

Comments: *Hyptis emoryi* forms scraggly stands along many of the minor washes in the low, hot, and very dry Colorado and Sonoran deserts of California. They tend to occupy narrow washes with moderate-to-steep gradients and along washes that are not big enough to support stands of the microphyllous legume trees of the desert. The *Hyptis emoryi* Shrublands appear to prefer the rocky and bouldery stretches of washes, rather than the broad and sandier portions. Stands are often only narrow strips that ascend drainages in old-dissected alluvial fans or badlands. This alliance seems to be limited by temperature, as it does not ascend > 700 m in the desert mountains and it does not occur very far north into the Mojave Desert.

Hyptis emoryi appears to tolerate a high degree of flood disturbance. It is a long-lived species that resprouts following flood or severe damage. Shrubs are often positioned in the center of small washes and sustain repeated damage from flooding. Stems appear to ramify following damage. Flooding in the smaller washes probably occurs at least every

10 years. The relationship between this alliance and other similar ones such as *Acacia greggii* Shrubland needs to be determined. Seeds are probably dispersed in water. Flowering and seed set are opportunistic following rain and flooding (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Regional Status:
Mojave Desert: Stands occur on the north side of Joshua Tree National Park and at least as far north as the southern bajadas of the Marble Mountains.

Management Considerations: Burro and OHV use affects many small washes in the Sonoran and Colorado deserts**.** Their impacts to this alliance have not been quantified.

Juncus cooperi Seasonally Flooded Herbaceous Alliance

Figure A23. *Juncus cooperi* Seasonally Flooded Herbaceous Alliance, Death Valley

Juncus cooperi is the sole dominant or important species in this herbaceous alliance. *Atriplex spp., Juncus mexicanus, Distichlis spicata, Schoenoplectus americanus, Phragmites australis, Anemopsis californica, Iva acerosa,* or *Heliotropium curassavicum* may be present. Grasses and herbs < 1 m tall. Canopy intermittent to continuous.

Habitat: Habitat intermittently saturated with shallow water table. Water chemistry: fresh, mixohaline, mixosaline. Cowardin class: palustrine persistent emergent wetland. The national list of wetland plants (Reed 1988) lists *Juncus cooperi* as a Facultative Wetland species.

Distribution: Mojave Desert, Southeastern Basin and Range, Nevada

Elevation: -75 to 950 m

NDDB Rank: G3 S3.2

Synonyms:
Holland: Transmontane alkali marsh (52320)
Barry: G7412331
Cheatham and Haller: Great Basin alkali marsh
Thorne: Alkali meadow, freshwater marsh
WHR: Fresh emergent wetland
Munz: Freshwater marsh

References: None

Membership Rules: Vegetation characterized by the relative dominance of *Juncus cooperi*. Usually, small stands are associated with other species of low-lying alkali seeps or meadows in such areas as Zzyzx, Tecopa, Shoshone, and Death valleys.

Comments: *Juncus cooperi* Herbaceous Alliance is apparently restricted to the Mojave Desert and the adjacent Southeastern Great Basin. It occurs in typically small stands around the margins of alkaline springs associated with *Distichlis spicata* Intermittently Flooded Herbaceous Alliance, and frequently surrounds other more hydrophilic alliances that are dominated by *Schoenoplectus americanus* and *Phragmites australis*. There is often a salt crust on the surface, suggesting that the distribution of the alliance is related to alkaline/saline soils. Many of the stands are associated with springs adjacent to desert basins containing Pleistocene lake playas. These stands are located in relatively low, hot portions of the Mojave Desert and Southeastern Great Basin where temperatures commonly rise above 40º C for many consecutive days in the summer. Plot data are limited, but observation of this alliance in many stands throughout the Mojave Desert supports defining it as an alliance.

Juncus cooperi occupies relatively dry margins of springs and seeps with access to subterranean moisture for at least part of the growing season. The species forms dense, monospecific stands in relatively moist areas, and tends to form more open stands in drier areas, with an understory of *Distichlis spicata* and other salt-tolerant species. Stands typically form rings around more moisture-loving alliances dominated by *Phragmites australis* or *Schoenoplectus americanus*. These alliances are in turn surrounded by *Distichlis spicata*, *Atriplex* spp., *Suaeda moquinii*, or *Allenrolfea occidentalis*-dominated alliances.

Regional Status:
Mojave Desert: Stands are found at springs and seeps in low-lying valleys and playa edges.

Southeastern Basin and Range: Stands have been observed in Saline Valley.

Management Considerations: Poor management of the wetlands in which it exists can easily threaten this relatively rare and little-known alliance.

Juniperus osteosperma Wooded Shrubland Alliance

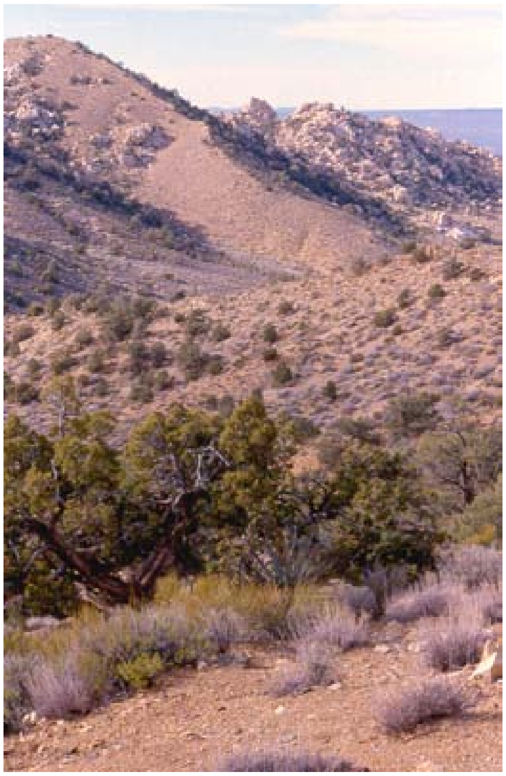


Figure A24. *Juniperus osteosperma* Wooded Shrubland Alliance

Juniperus osteosperma is the sole or dominant tree or large shrub occurring over a shorter-shrub canopy. *Pinus monophylla* may be present. *Ambrosia dumosa*, *Artemisia tridentata, Atriplex confertifolia*, *Ericameria* spp., *Coleogyne ramosissima*, *Ephedra nevadensis, Ephedra viridis, Eriogonum fasciculatum, Grayia spinosa, Gutierrezia microcephala, Purshia tridentata, Salvia dorrii,* or *Yucca baccata* may be present. Trees < 15 m tall; canopy intermittent or open. Shrubs < 2 m tall; continuous or intermittent. Ground layer sparse or grassy.

Habitat: Pediments, slopes, ridges, ravines. Soils rocky or alluvial, commonly well-drained.

Distribution: Mojave Desert, Sierra Nevada, Southeastern Great Basin, Southern California Mountains and Valleys, Mono, Nevada, Utah, Arizona.
Elevation: 1100 to 2100 m

NDDB Rank: G5 S3.2 (some associations may be S2.2)

Synonyms:
Holland: Great Basin juniper woodland and scrub (72123 *in part*), Mojavean juniper woodland and scrub (72220 *in part*)
Cheatham and Haller: Nevadan pinyon-juniper woodland
Rangeland: SRM 414
Thorne: Pinyon-juniper woodland
WHR: Pine-juniper
CALVEG: Utah Juniper series
Munz: Pinyon-juniper woodland

References: *Juniperus osteosperma* range in California (Griffin and Critchfield 1972), Meeuwig and Bassett (1983), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Tueller et al. (1979), Vasek and Thorne (1977)

Membership Rules: *Juniperus osteosperma* ≥ 1%, *Pinus monophylla* not present (< 1% cover), and dominant understory species is a shrub.

Comments: In the Mojave Desert *Juniperus osteosperma* Wooded Shrubland Alliance usually forms a band between the *Pinus monophylla, Artemisia tridentata, Purshia tridentata,* or other high-elevation shrubland alliances above, and various desert scrubs such as *Grayia spinosa, Coleogyne ramosissima, Ephedra nevadensis, Eriogonum fasciculatum, Ericameria teretifolia,* and *Yucca schidigera* Shrublands or *Yucca brevifolia* Wooded Shrubland below. Species diversity is often high, with commonly > 30 woody species per stand.

The alliance occurs in a band that is generally narrow and is only extensive in a few areas where topography levels out at the appropriate climatic zone. As currently treated, the species characteristic species of the alliance, *Juniperus osteosperma*, also can be characteristic of *Pinus monophylla* - (*Juniperus osteosperma*) Woodland Alliance (see that description). Thus, only the lower-elevation, warmer, and drier portion of the species' range, where tree cover is typically more open than in a woodland, supports the *Juniperus osteosperma* Wooded Shrubland Alliance. The alliance is typically composed of savanna-like canopy (< 25% cover) of *Juniperus osteosperma* with a shrubby understory. All plots analyzed in California have been under 25% cover, and most range between 2 and 21% *Juniperus osteosperma* (mean = 5% n = 77). In other parts of its range outside California *Juniperus osteosperma* may have an herbaceous understory, hence *Juniperus osteosperma* Wooded Herbaceous Alliance. The similar *Juniperus californica* Wooded Shrubland Alliance occupies the area west of the main distribution of the *Juniperus osteosperma* Wooded Shrubland. Overlap may occur in several places in the Mojave Desert and in the Southern California Mountains and Valleys. However, *Juniperus californica* stands tend to range lower in elevation than does *Juniperus osteosperma.*

Lightning frequency is higher in the Mojave Desert than in the lower-elevation desert shrublands and woody fuels are also more abundant. Thus, fire is naturally a more important disturbance element than in many lower-elevation alliances; however, *Juniperus osteosperma* does not resprout after fire. Even light to moderate fires can kill or seriously damage individuals (FEIS 2001). Lightly grazed ecotonal areas with a dense understory most readily burn and fire does not carry in some more-open-wooded shrublands. Recolonization by seed takes a long time for this slow-growing, long-lived tree. Some older trees can survive low-intensity fires and function as a seed source. Reoccupation of a site is generally through water or animal-dispersed seed. Most *Juniperus osteosperma* seedlings become established within one to two years after a fire. However, the rate at which *Juniperus osteosperma* spreads into an area depends on the size of burn, maturity (seed-producing capabilities) of the nearest stands, and on the presence of dispersal agents. Islands of unburned juniper are generally present and speed the rate of reestablishment. Trees generally become reestablished on a site 20 to 30 years after the burn, with well-developed woodland present from 85 to 90 years following fire (FEIS 2001). In a west-central Utah study, the crown cover of juniper was found to increase slowly during the first 46 years after a burn, and then to increase more rapidly. Utah juniper began to dominate these sites from 46 to 71 years after the burn (FEIS 2001). In many cases, the effects of the fire can still be seen more than 100 years later (FEIS 2001). Narrow linear stands of *Juniperus osteosperma* may also occur along washes, particularly at the lower limits of the *Juniperus osteosperma* Wooded Shrubland elevation range. Such stands are subject to flooding disturbance. Animals and water disperse the seeds (FEIS 2001).

Regional Status:
Mojave Desert: The alliance occupies narrow bands below the pinyon zone in many of the eastern mountains. In the Kingston Range, it occurs adjacent to stands of *Nolina parryi* Shrubland. Stands form the highest elevation vegetation in the Avawatz Mountains.
Southeastern Great Basin: Stands of *Juniperus osteosperma* are common adjacent to *Artemisia tridentata* and *Pinus monophylla* dominated alliances. Stands may occur at lower elevations where they may form open stands with *Cercocarpus intricatus* (unsampled in California).

Management Considerations: A likely result of long-term grazing of livestock in the *Juniperus osteosperma* alliance has been the introduction and spread of non-native annual *Bromus* spp. The impact of *Bromus madritensis* and *Bromus tectorum* in *Juniperus osteosperma* Wooded Shrubland has been substantial in certain parts of its range. A flammable thatch of annual grass stems, which carry fire through many stands, now augments the open-scrub understory. Many of these stands would not have carried fire previously. The result is that there are more *Juniperus osteosperma* Wooded Shrublands being burned at a higher frequency, causing a net reduction in the acreage of stands in certain parts of the alliance's range. It is not clear how much California *Juniperus osteosperma* Wooded Shrubland has been damaged from fire. Stands should be mapped and monitored throughout their range.

Krascheninnikovia lanata Dwarf-shrubland Alliance

Figure A25. *Krascheninnikovia lanata* Dwarf-Shrubland Alliance, Panamint Mountains

Krascheninnikovia lanata is the sole or dominant shrub in canopy. *Artemisia nova, Coleogyne ramosissima, Atriplex confertifolia,* or *Chrysothamnus viscidiflorus* may be present. Shrubs < 1 m tall; canopy continuous, intermittent, or open. Ground layer sparse, grassy.

Habitat: Flats and lower slopes. Soils may be rocky to silty clay loams. Plains, old lakebeds, and perched wetlands above current drainages. Intermittently flooded, saturated. Water chemistry: mixosaline. Cowardin class: palustrine shrub-scrub wetland.

Distribution: Southeastern Great Basin, Mojave Desert, Mono, Northwestern Basin and Range, Nevada, Idaho, Oregon, Washington, Utah, Colorado, Montana, Canada.

Elevation: 100 to 2,700 m

NDDB Rank: G4 S1

Synonyms:
Holland: Shadscale Scrub (36140 *In Part*)
Barry: G7411221
Brown, Lowe and Pase: 153.152, 152.152.
Cheatham and Haller: Shadscale Scrub
Rangeland: Srm 414

Thorne: Alkali Sink Scrub
WHR: Alkali Sink

References: Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Turner (1982a), Young et al. (1977), West (1988).

Membership Rules: *Krascheninnikovia lanata* is strongly dominant (> 60% relative cover) with no other species equaling or exceeding it in cover. If *Atriplex confertifolia, Grayia spinosa, Salazaria mexicana,* or *Coleogyne ramosissima* equal or only exceed *Krascheninnikovia lanata* by 1-2%, then the stands are named after those species. This vegetation is usually of mid-to upper elevation flats and small basins and is uncommon in mapping area.

Comments: *Krascheninnikovia lanata* is a widespread species ranging from the northern Great Plains of southern Canada to New Mexico and west to Santa Barbara, Kern, and San Luis Obispo counties, California. Its main distribution is in the Great Basin. In California, it ranges south into the Mojave Desert and the adjacent Southeastern Great Basin. The species does not usually form single species-dominant stands throughout most of its California range but is a component of several alliances including annual grasslands, *Bromus tectorum, Artemisia nova, Atriplex confertifolia, Atriplex polycarpa, Atriplex canescens, Grayia spinosa, Coleogyne ramosissima, Salazaria mexicana, Eriogonum fasciculatum,* and *Yucca brevifolia*. The only stands of the alliance that have been defined in California occur in the Southeastern Great Basin. Here they occupy small montane basins in the Chalfant Valley, Inyo, Cottonwood, and White mountains. Similar stands probably occur in the Mono Basin and surrounding terrain and in the northwestern Basin and Range. In these settings, they occur as small stands in seasonally flooded or saturated shallow basins or flats surrounded by other more extensive upland alliances.

Krascheninnikovia lanata is a long-lived shrub, up to 136 years (FEIS 2001), that is relatively sensitive to disturbance including grazing and fire. Fire can kill *Krascheninnikovia lanata,* but the response is apparently dependent on fire severity. *Krascheninnikovia lanata* is able to sprout from buds near the base of the plant; however, if fire destroys these buds, *Krascheninnikovia lanata* will not sprout. *Krascheninnikovia lanata* can sprout vigorously after low-severity fires in spring or summer (FEIS 2001), but subsequent populations may be reduced. The native disturbance-related grass *Elymus elymoides* and non-native *Bromus tectorum* have been implicated as the major fuels in carrying fire in this naturally open alliance (FEIS 2001). Regeneration from seed is rare after fire. Heavy grazing practices have reduced or eliminated *Krascheninnikovia lanata* on some areas, even though it is somewhat resistant to browsing. Effects depend on severity and season of grazing; *Krascheninnikovia lanata* decreases on moderately-to-heavily grazed native grasslands in much of its range (FEIS 2001).

Regional Status:
Mojave Desert: A few stands of *Krascheninnikovia lanata* occur in the Mojave Desert; however, these are marginally dominated by *Krascheninnikovia lanata* and are ecologically similar to *Atriplex confertifolia* or *Grayia spinosa* Shrublands.

Southeastern Great Basin: Small, closed basins and intermontane flats and valleys in the Inyo Mountains (Cowhorn and Little Cowhorn Valleys) are the only known locations for *Krascheninnikovia lanata* stands in California. These stands are generally of small to moderate size (< 100 ha), *Krascheninnikovia lanata* strongly dominates, and few other species occurr. More information is needed about these stands, which occur on U.S. Forest Service, BLM, and National Park Service lands.

Management Considerations: Fire should be excluded from stands of *Krascheninnikovia lanata*. To protect salt-desert shrub communities from fire, greenstrip vegetative fuel breaks have been created in some areas (FEIS 2001). FEIS (2001) recommends that burned sites be seeded before *Bromus tectorum* or other non-native annual grasses are able to establish or gain dominance. Light grazing is not detrimental, but moderate to heavy grazing is. Grazing season has more influence on *Krascheninnikovia lanata* than grazing intensity. Late winter or early spring grazing is detrimental (FEIS 2001). Because this alliance is naturally rare in California and is sensitive to fire and moderate to heavy grazing, stands should be inventoried and actively managed in California.

Larrea tridentata - Ambrosia dumosa Shrubland Alliance

Figure A26. *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance, Lanfair Valley

Larrea tridentata and *Ambrosia dumosa* are the important or conspicuous shrubs in the canopy. Other species that can be present are *Achnatherum speciosum, Amphipappus fremontii, Atriplex confertifolia, Atriplex hymenelytra, Atriplex polycarpa, Bebbia* *juncea, Croton californica, Dalea mollossima, Echinocactus polycephalus, Encelia farinosa, Encelia virginensis, Ephedra californica, Ephedra funerea, Ephedra nevadensis, Eriogonum fasciculatum*, *Eriogonum inflatum*, *Hymenoclea salsola, Krameria erecta, Krameria grayi, Lepidium fremontii, Lycium andersonii, Opuntia ramosissima*, *Pleuraphis rigida, Psorothamnus arborescens, Psorothamnus fremontii*, *Salazaria mexicana, Senna armata*, *Viguiera parishii,* or *Yucca schidigera*. Shrubs < 3 m tall; open canopy. Shrub canopy is two-tiered. Emergent *Yucca brevifolia* may be present in the Mojave Desert and *Fouquieria splendens* present in the Sonoran Desert. Ground layer open; annuals seasonally present.

Habitat: Alluvial fans, bajadas, upland slopes; minor washes and rills. Soils well-drained, colluvial, sandy, and/or alluvial, often underlain by a caliche hardpan; may be calcareous and/or have pavement surface.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Southeastern Great Basin, Nevada, Arizona, Sonora, Baja California.

Elevation: -75 to 1,200 m

NDDB Rank: G5 S5 Some associations are rare (e.g., those with high *Pleuraphis* cover, and with high diversity of perennials), some are threatened (west Mojave Desert types that are grazed and burned)

Synonyms:
Holland: Mojave creosote bush scrub (34100 *in part*), Sonoran creosote bush scrub (33100 *in part*)
Barry: G74 G7411211
Brown, Lowe and Pase: 153.112, 153.141, 154.112
Cheatham and Haller: Mojave creosote bush scrub, Sonoran creosote bush scrub
Rangeland: SRM 211, SRM 506
Thorne: Creosote bush scrub
WHR: Desert scrub

References: Burk (1977), Holzman (1994), Hunt (1966), MacMahon (1988), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Turner (1982b), Turner and Brown (1982), Vasek and Barbour (1977): plot-based descriptions are based on Keeler-Wolf et al. (1998)

Membership Rules: *Larrea tridentata* and *Ambrosia dumosa* present (≥ 1% cover), *Ambrosia dumosa* may have higher cover than *Larrea tridentata.* No shrub with cover greater than *Larrea tridentata* or *Ambrosia dumosa,* with the following exceptions: *Krameria* spp., *Bebbia juncea, Ericameria teretifolia,* or *Acamptopappus spherocephalus*. *Ephedra nevadensis* or *Opuntia acanthocarpa* may have higher cover, but no more than three times.

Comments: The co-occurrence of the medium to tall shrub *Larrea tridentata* over the subshrub *Ambrosia dumosa* defines the matrix vegetation of the vast majority of the California hot deserts. This is the most widespread and abundant desert alliance in California. It covers 58% of the California Mojave Desert (Thomas 1996), over 14% of Anza-Borrego Desert State Park (Keeler-Wolf et al.1998), and probably over 70% of the Colorado and Sonoran deserts of California (BLM 2001). It is the modal vegetation of the bajadas, alluvial fans, and lower slopes of these areas, with a wide range of variability defined within the alliance. Conditions range from extremely hot, dry stands with very low species diversity below sea level in Salton Sink and Death Valley to relatively diverse mesic stands at > 1100 m in the eastern Mojave Desert (e.g., Clipper Valley).

The *Larrea tridentata* Shrubland is in some cases a degraded version of the *Larrea tridentata-Ambrosia dumosa* Shrubland with little or no *Ambrosia dumosa*, a result of very poor shallow soils or heavy grazing pressure. The *Ambrosia dumosa* Dwarf-Shrubland shows relatively high recent disturbance from fire or mechanical removal of vegetation, or occurs on relatively clay-rich soils. *Atriplex confertifolia*, *Coleogyne ramosissima, Grayia spinosa,* and *Yucca schidigera* Shrublands and *Yucca brevifolia* Wooded Shrubland occur at moister and/or cooler settings. *Larrea tridentata-Encelia farinosa* Shrubland occurs in hotter, more exposed settings than does *Atriplex hymenelytra* Shrubland. *Hymenoclea salsola* Shrubland occurs in heavily grazed and otherwise disturbed settings. *Atriplex polycarpa* and *Atriplex spinescens* Shrublands occur in heavier-soil, more alkaline settings.

Much has been written on the ecology of these two species (Vasek and Barbour 1977, FEIS 2001). *Larrea tridentata* is a very long-lived shrub (up to 10,000 + years in clones) and under good conditions develops a deep and widely spreading root system. *Ambrosia dumosa* is a short-lived shrub living generally < 50 years, although it does have limited cloning abilities, with relatively shallow and restricted roots. Both species tap different water resources and employ different strategies for desert survival. *Ambrosia dumosa*, with its high recruitment and mortality rates, dominates in the colonizing stage and *Larrea tridentata*, with low recruitment and mortality, eventually dominates the landscape, although colonizing species usually remain present. In the Sonoran Desert, *Larrea tridentata* uses *Ambrosia dumosa* as a nurse plant (McAuliffe 1988). *Larrea tridentata* exhibits root-mediated allelopathy. In a laboratory study, test roots grew freely through soil occupied by *Ambrosia dumosa* roots, but *Ambrosia dumosa* test roots grew at reduced rates into soil occupied by *Larrea tridentata.* Mature *Larrea tridentata* may be allelopathic to its own seedlings, thus encouraging an open community structure (FEIS 2001).

Natural disturbance in most *Larrea tridentata-Ambrosia dumosa* stands involves shifting moisture availability related to series of wet and dry years. Both species may die following severely long periods of drought, but *Larrea tridentata* typically will persist longer and can resprout from the base when moisture returns. *Ambrosia dumosa* individuals die more quickly from drought stress, but will regenerate from seed banks and off-site dispersal quickly following sufficient precipitation. Wind and substrate deflation also act as disturbance agents in some stands on sandy substrates. Both species will grow in sand. However, *Larrea tridentata* tends to persist and dominate on deeper mobile sand dunes, while both *Ambrosia dumosa* and *Larrea tridentata* occupy dune aprons, sand sheets, and stabilized dunes. Vasek (1980) studied succession on a cleared and bulldozed site in the eastern Mojave Desert. He found rapid recolonization by *Ambrosia dumosa, Encelia farinosa, Opuntia bigelovii,* and *Stephanomeria pauciflora,* while *Larrea tridentata* colonized more slowly.

In the modal Mojave, Colorado, and Sonoran desert landscapes, both species tend to co-occur in mixed stands. *Ambrosia dumosa* occurs without *Larrea tridentata* in active wash terraces with a higher salinity or alkalinity than *Larrea tridentata* can tolerate. *Ambrosia dumosa* also occurs in recently disturbed areas, where it can more quickly recolonize by seed than *Larrea tridentata*. *Larrea tridentata* occurs without *Ambrosia dumosa* in areas where grazing or drought stress has eliminated *Ambrosia dumosa.* The *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance is replaced by *Atriplex polycarpa, Atriplex canescens,* or *Atriplex spinescens* Shrublands in alkaline soils and gives way to *Larrea tridentata - Encelia farinosa or Atriplex hymenelytra* Shrubland in extremely hot, dry situations.

Larrea tridentata and *Ambrosia dumosa* are poorly adapted to fire because of their limited sprouting ability (FEIS 2001). The resinous foliage of *Larrea tridentata*, however, is very flammable. Even low-intensity fires can cause close to 100% mortality in both shrubs (Brown and Minnich 1986). The recent invasion of non-native grasses in the hot deserts of California has rapidly increased fire frequencies and has led to the destruction and degradation of many acres of *Larrea tridentata-Ambrosia dumosa* Shrubland particularly in the western Mojave and Colorado deserts. Although fire may be as a natural exclusionary process for *Larrea tridentata* in Arizona, New Mexico, and in Texas desert grasslands (FEIS 2001) it is a de-stabilizing influence in the California deserts, where adjacent desert grasslands typically occur without fire.

Regional Status:
Mojave Desert: This alliance occurs throughout the Mojave Desert. The range of variability of this alliance is better studied and probably wider than in any other part of its range. Associations have been defined that range from simple two species co-dominance to high-diversity, mid-desert scrubs with up to 20 co-occurring perennials. In the northern Mojave Desert (northern Death Valley National Park), it occurs adjacent to *Grayia spinosa, Atriplex confertifolia,* and other Great Basin characteristic alliances, while in the southern Mojave Desert it occurs adjacent to *Opuntia bigelovii, Viguiera parishii*, and other Colorado and Sonoran Desert characteristic alliances. Virtually all stands have some component of non-native grass. *Bromus madritensis* is the most common in upland and upper bajada sites, while *Schismus* spp. is more common in lower-lying areas. *Bromus madritensis* acts as the principal fuel for fires in the area, although following years of high rainfall *Schismus* may also carry fire (M. Brooks, personal communication). Human mediated fires have converted *Larrea tridentata-Ambrosia dumosa* Shrublands to stands dominated by *Bromus spp., Brassica tournefortii*, *Salsola* spp. and other weedy species. In the south Mojave Desert some *Larrea tridentata-Ambrosia dumosa*

Shrublands have been converted to *Encelia farinosa* stands, although this is more common in the Colorado Desert.
Southeastern Great Basin: The alliance is restricted to Saline and Eureka valleys and the lowest elevation slopes of the Inyo, Grapevine, Coso and Argus mountains where they border the Mojave Desert. Northernmost stands in Eureka Valley are relatively simple (mostly *Larrea tridentata Ambrosia dumosa-Psorothamnus fremontii* association). The alliance forms mosaics with *Atriplex confertifolia, Atriplex hymenelytra, Ephedra funerea,* and *Artemisia nova* Shrubland, the latter two particularly on calcareous substrates.

Management Considerations: Human-caused fire following the introduction of the non-native annual grasses (in particular *Bromus madritensis*) is a threat to this alliance. This is particularly true after a sequence of relatively wet years as has occurred in the last two or three decades (R. Minnich, personal communication). A series of dry years tends to reduce the threat due to the lack of *Bromus* spp. germination and flashy fuel build-up. Because *Bromus* species do not survive in the seed bank more than a few years, prolonged drought may eliminate these species from the drier portions of the desert. Long-term intensive grazing has also degraded thousands of acres of *Larrea tridentata-Ambrosia dumosa* stands into disturbed *Larrea tridentata* Shrubland stands by eliminating the more palatable *Ambrosia dumosa* from the understory. The relationship between disturbance (primarily grazing, but also OHV activity, mining, and military operations) and the invasion of exotic grasses has brought an immense change to this alliance and the California deserts. Fire ignitions have increased substantially in the desert, primarily in this alliance. Wildlife habitat values of this alliance are strongly altered because of fire. Relatively exotic-free areas should be identified and defended against excessive human-caused disturbances.

Larrea tridentata - Encelia farinosa Shrubland Alliance

Figure A27. *Larrea tridentata-Encelia farinosa* Shrubland Alliance, Panamint Mountains

Larrea tridentata and *Encelia farinosa* are the important or conspicuous shrubs in canopy. *Agave deserti, Ambrosia dumosa, Atriplex hymenelytra, Bebbia juncea, Eriogonum inflatum, Dasyochloa pulchella, Fagonia laevis, Ferocactus cylindraceus, Krameria grayi, Opuntia bigelovii, O. basilaris*, or *Stephanomeria pauciflora* may be present. Emergent *Fouquieria splendens* may be present in the Sonoran Desert. Shrubs < 3 m tall; open to intermittent, two-tiered canopy. Trees < 5 m tall; scattered canopy. Ground layer open; annuals seasonally present.

Habitat: Alluvial fans, bajadas, colluvium, upland slopes, small washes, and rills. Soils well drained, rocky, may have desert pavement surface, often derived from granitic or volcanic rock.

Distribution: Mojave, Sonoran, and Colorado deserts; Arizona, Nevada, Utah, Mexico.

Elevation: -75 to 1,400 m

NDDB Rank: G5 S4

Synonyms:
Sawyer and Keeler-Wolf (1995): Brittlebush series (in part), Creosote bush series (in part)

Holland: Mojave creosote bush scrub *in part* (34100), Sonoran creosote bush scrub *in part* (33100)
Barry: G7411221
Brown, Lowe and Pase: 154.126
Cheatham and Haller: Creosote bush scrub
PSW-45: Encelia series
CALVEG: Encelia series
WHR: Desert scrub
Munz: Creosote bush scrub

References: Barbour (1994), Burk (1977), Hunt (1966), MacMahon (1988), Pase and Brown (1982), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Vasek and Barbour (1977); plot-based descriptions are found in Minnich et al. (1993) and Keeler-Wolf et al. (1998).

Membership Rules: *Encelia farinosa* > 1% cover with *Larrea tridentata* at least 1%. *Ambrosia dumosa* may be present. Widespread on hot (southerly exposure) mountain slopes and upper bajadas.

Comments: Many of the stands formerly considered part of the *Encelia farinosa* series and *Larrea tridentata* series (Sawyer and Keeler-Wolf 1995) are actually composed of a mixture of both species. *Larrea tridentata-Encelia farinosa* Shrubland is analogous to the *Larrea tridentata-Ambrosia dumosa* Shrubland but occurs on hotter, rockier, and often steeper environments. In areas where both alliances occur, *Larrea tridentata-Encelia farinosa* Shrubland tends to occupy steeper, southerly or westerly exposures, while *Larrea tridentata-Ambrosia dumosa* Shrubland occupies more gentle slopes having northerly or neutral exposures. Compared to *Larrea tridentata-Ambrosia dumosa* Shrubland, *Larrea tridentata-Encelia farinosa* Shrubland tends to be less diverse and has a lower proportion of annual herbs (in higher rainfall years). It also does not tolerate sandy or clay-rich soils as much as *Larrea tridentata-Ambrosia dumosa* Shrubland.

This alliance is related to both the *Encelia farinosa* and the *Larrea tridentata-Ambrosia dumosa* Shrubland Alliances. This alliance represents a drought-tolerant extension of the *Larrea tridentata* Shrubland, which is less cold-hearty and more heat-tolerant than *Larrea tridentata-Ambrosia dumosa* Shrubland.

Encelia farinosa, like *Ambrosia dumosa*, is a sub-shrub that forms an open to intermittent subcanopy beneath the taller *Larrea tridentata* shrubs. However, it is even more tolerant of hot, dry conditions and is more of an aggressive colonizer than *Ambrosia dumosa*. Leafing and flowering is opportunistic whenever moisture is available. *Encelia farinosa* rapidly colonizes burns and other disturbance in both the south coastal scrub and desert vegetation (FEIS 2001). *Encelia farinosa* is short lived; maximum reported age 32 yrs (FEIS 2001), It reproduces entirely by seed and resprouts weakly from damaged stems. It is frost-sensitive, limiting the elevation at which it occurs and its geographic range. It grows poorly on clay soils, but survives on coarse, steep, and very rocky soils better than *Ambrosia dumosa*. It may replace longer-lived perennials after fire and, once established, may persist as an alliance for decades. The species is allelopathic to several winter annuals (FEIS 2001), suggesting that biodiversity will be reduced if the alliance replaces other desert vegetation. It is fire-sensitive, intolerant of heat from fire, making resprouting weak or non-existent; however, it recolonizes from off-site seed readily. Recurrent desert fire selects for *Encelia farinosa* over longer-lived shrubs.

In general, because of the hot, dry conditions of most stands, *Larrea tridentata-Encelia farinosa* Shrubland is typically even more open than in stands of *Larrea tridentata-Ambrosia dumosa* Shrubland. Despite the colonizing properties of *Encelia farinosa*, the *Larrea tridentata-Encelia farinosa* Shrubland is generally stable, occupying rocky harsh sites that are not conducive to *Larrea tridentata-Ambrosia dumosa* Shrubland. Seral stages following fire, or other unnatural disturbance, are likely to involve a state dominated by *Encelia farinosa* Shrubland for several years before *Larrea tridentata* and other long-lived shrubs re-establish.

Regional Status:
Mojave Desert: This alliance occurs throughout the Mojave Desert except in the northernmost and westernmost parts. In most parts of the Mojave Desert, it is an alliance of moderate to steep slopes with rocky substrates. It may occupy limestone and other calcareous mountains such as Nopah Range and Silurian Hills, and granitic and volcanic substrates. It is likely that higher species diversity occurs in the limestone settings where several calcophiles can co-occur. The northernmost stands occur on volcanic substrate near Panamint Springs on the boundary of the Southeastern Great Basin.

Management Considerations: This is another alliance where coincidence of non-native annual grass invasion and human-related fires can threaten the structure and diversity of the vegetation. The rocky, steep nature of many of the stands precludes the establishment of dense cover of *Bromus madritensis.* Thus the resistance of this alliance to non-natural fire and weed invasion is higher than for the *Larrea tridentata-Ambrosia dumosa* Shrubland.

Larrea tridentata Shrubland Alliance

Figure A28. *Larrea tridentata* Shrubland Alliance, Stovepipe Wells

Larrea tridentata is the sole or important shrub in canopy. *Acamptopappus spherocephalus, Acamptopappus shockleyi*, *Atriplex confertifolia*, *Atriplex hymenelytra*, *Atriplex polycarpa*, *Brickellia incana*, *Ephedra californica*, *Ephedra nevadensis, Hymenoclea salsola*, or *Lycium andersonii* may be present. Shrubs < 4 m tall; canopy open. Emergent *Yucca brevifolia* or *Prosopis glandulosa* may be present. *Achnatherum speciosum, Eriogonum inflatum*, *Eriophyllum confertiflorum, Poa secunda,* or *Pleuraphis rigida* may be present. Ground layer open; annuals seasonally present.

Habitat: Alluvial fans, bajadas, upland slopes, minor intermittent wash channels, and upland slopes. Soils well drained, may have desert pavement surface.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Southeastern Great Basin, Southern California Mountains and Valleys, Arizona, Nevada, New Mexico, Texas, Mexico.

Elevation: -75 to 1,000 m

NDDB Rank: G5 S5

Synonyms:
Holland types: Mojave creosote bush scrub (34100 *in part*), Sonoran creosote bush scrub (33100 *in part*)
Barry: G74 G7411211 CLADI20
Brown, Lowe and Pase: 153.111, 153.113, 153.111
Cheatham and Haller: Mojave creosote bush scrub, Sonoran creosote bush scrub
PSW-45: Creosote bush series
Rangeland: SRM 211
Stone and Sumida: Creosote bush scrub
Thorne: Creosote bush scrub
WHR: Desert scrub
CALVEG: Creosote bush series
Munz: Creosote bush scrub

References: Burk (1997), Holzman (1994), Hunt (1966), MacMahon (1988), O'Leary and Minnich (1981), Paysen et al. (1980), Phillips and MacMahon (1981), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Turner (1982b), Turner and Brown (1982), Vasek (1980), Vasek and Barbour (1977), Vasek et al. (1975); plot-based descriptions are based on Davidson and Fox (1974), McHargue (1973), Randall (1972), Vasek and Barbour (1977), Minnich et al. (1993) Spolsky (1979) and Keeler-Wolf et al. (1998).

Membership Rules: *Ambrosia dumosa* or *Encelia farinosa* absent or less than 1% cover. No shrub with cover greater than *Larrea tridentata* with the following exceptions: *Krameria* spp. *Bebbia juncea, Ericameria teretifolia* or *Acamptopappus spherocephalus*. *Ephedra nevadensis* or *Opuntia acanthocarpa* may have higher cover, but no more than twice the cover.

Comments: This alliance is part of the creosote bush scrub ecological system which is a collection of alliances. Following substantial data analysis of plot data collected in this project and others (Keeler-Wolf et al.1998), we define this alliance somewhat differently than Sawyer and Keeler-Wolf (1995). In *Larrea tridentata* Shrubland, *Larrea tridentata* dominates and *Ambrosia dumosa* is absent or < 1% cover (see *Larrea tridentata-Ambrosia dumosa* Shrubland). Those stands with *Larrea tridentata* that contain an understory of *Encelia farinosa* are now considered part of the *Larrea tridentata-Encelia farinosa* Shrubland. *Larrea tridentata-Ambrosia dumosa* Shrubland is the most common vegetation alliance in the Mojave, Colorado and Sonoran deserts of California, while the *Larrea tridentata* Shrubland is less common and less diverse. The *Larrea tridentata* Shrubland is in some cases a degraded form of the *Larrea tridentata-Ambrosia dumosa* Shrubland, often as the result of prolonged livestock or burro grazing (see below). It may also represent a natural state related to extreme xeric settings on certain rocky slopes or desert pavements, where *Larrea tridentata* forms low cover stands without *Ambrosia dumosa* or *Encelia farinosa*. It also may occur in or adjacent to certain small washes or rills, or on sand sheets or dune aprons. In some cases, it forms a diverse scrub in the mid elevations of the eastern Mojave Desert with greater than 10 species of other woody perennials.

Larrea tridentata is a very long-lived shrub (up to 10,000 + years in clones) and under good conditions develops a deep and widely spreading root system. *Larrea tridentata*, with low recruitment and mortality, eventually dominates the landscape throughout most of the California hot desert. However, in most unaltered settings, it occurs with the subshrub *Ambrosia dumosa*. In the Sonoran Desert, *Larrea tridentata* uses *Ambrosia dumosa* as a nurse plant McAuliffe (1988). Mature *Larrea tridentata* may be allelopathic to its own seedlings, thus encouraging an open community structure (FEIS 2001). Where *Larrea tridentata* occurs without *Ambrosia dumosa,* disturbance history may be responsible. *Ambrosia dumosa,* as a small, relatively palatable subshrub, is more vulnerable to browsers such as cattle, sheep, and burros (FEIS 2001). In many parts of the desert, *Larrea tridentata-Ambrosia dumosa* Shrubland has been converted to *Larrea tridentata* Shrubland by the long-term effects of livestock foraging (personal observation). However, in certain settings, natural disturbance patterns may be the cause of the sole dominance by *Larrea tridentata*. *Larrea tridentata* is a more drought-resistant species than *Ambrosia dumosa* or *Encelia farinosa. Larrea tridentata* may die following severe long periods of drought, but it typically will persist longer and can resprout from the base when moisture returns than many of the subshrubs with which it associates. Thus, certain stands of *Larrea tridentata* Shrubland may be the result of locally intense drought conditions that have eliminated, at least temporarily, *Ambrosia dumosa* and other species. In deep, sandy soils *Larrea tridentata* can survive more effectively than *Ambrosia dumosa* because of its deep spreading root system. In sandy situations it often co-occurs with the grass *Pleuraphis rigida* as an understory component. Along certain washes and wash terrace deposits with somewhat alkaline soils, *Larrea tridentata* co-dominates with *Atriplex polycarpa*. *Larrea tridentata* may also form semi-riparian stands along low-gradient, sandy and silty washes. It may form stands in small, low alkalinity, or salinity basins with fine, silty soils.

Larrea tridentata is poorly adapted to fire because of its limited sprouting ability (FEIS 2001). Its resinous foliage, however, is very flammable. Even low-intensity fires can cause close to 100% mortality (Brown and Minnich 1986). The recent invasion of non-native grasses in the hot deserts of California has rapidly increased fire frequencies and has led to the destruction and degradation of many acres of *Larrea tridentata-Ambrosia dumosa* Shrubland, particularly in the western Mojave and Colorado deserts. Although fire is a natural exclusionary process for *Larrea tridentata* in Arizona, New Mexico, and Texas desert grasslands (FEIS 2001), it is a de-stabilizing influence in the California deserts where adjacent desert grasslands typically occur without fire.

Regional Status:
Mojave Desert This alliance occurs throughout the Mojave Desert. The degraded form is particularly common in the central and western Mojave Desert probably because of the combined effects of grazing, fire, and mechanical OHV and military operations disturbance.

Management Considerations: Presence of this alliance may be indicative of certain disturbance (either grazing, or mechanical disturbance) patterns that have caused local degradation of the more common *Larrea tridentata-Ambrosia dumosa* Shrubland. In general, extremely xeric settings with southerly exposures and steep rocky slopes are more likely to be natural *Larrea tridentata* Shrublands than those of less extreme situations where the subshrub *Ambrosia dumosa* and other species may have been eliminated because of excessive disturbance.

Lepidospartum squamatum Intermittently Flooded Shrubland Alliance

Figure A29. *Lepidospartum squamatum* Intermittently Flooded Shrubland Alliance

Lepidospartum squamatum is the sole, dominant, or important shrub with other shrubs in the canopy. *Artemisia californica, Baccharis salicifolia, Encelia farinosa, Eriogonum fasciculatum Eriodictyon crassifolium, Hymenoclea Salsola, Eriastrum densifolium* ssp. *sanctorum, Dodecahema leptoceras, Isomeris arborea, Juniperus californica, Lotus scoparius, Opuntia littoralis, O. parryi, Malosma laurina, Rhus integrifolia, Rhus trilobata, R. ovata, Sambucus mexicana, Toxicodendron diversilobum* or *Yucca whipplei* may be present. Emergent trees such as *Cercocarpus betuloides, Juglans californica, Platanus racemosa,* or *Populus fremontii* may be present. Shrubs < 1.5 m tall; canopy continuous, intermittent, or open. Ground layer variable, may be grassy.

Habitat: Intermittent channels along washes and streams across alluvial fans and in semi-arid to arid valleys. Habitats intermittently flooded. Water chemistry: fresh. Cowardin class: riverine or palustrine shrub-scrub wetland.

Distribution: Mojave Desert, Southeastern Great Basin, Southern California Mountains and Valleys, Southern California Coast, Sierra Nevada, Sierra Nevada Foothills, Central California Coast Ranges, Colorado Desert.

Elevation: 50 to 1,500 m

NDDB Rank: G2 S2 (some associations are G1 S1.1)

Synonyms:
Holland: Riversidean alluvial fan sage scrub (32720 *in part*), Mojave Desert wash scrub (63700 *in part*), Alluvial fan chaparral (37H00 *in part*)
Barry: G7411221
Munz: Creosote bush scrub, Coastal Sage scrub

References: Barbour and Wirka (1997), Hanes et al. (1989), Kirkpatrick and Hutchenson (1977), Magney (1992), Smith (1980); plot-based descriptions are found in Hanes et al. (1989), Kirkpatrick and Hutchinson (1977), Smith (1980), Gordon and White (1994), Boyd (1983), Barbour and Wirka (1997)

Membership Rules: Vegetation characterized by the broom-like *Lepidospartum squamatum* (scale-broom). Stands concentrated along washes on eastern base of the San Bernardino Mountains in the extreme southwest portion of the mapping area. Other smaller stands occur at mid-elevations throughout the desert.

Comments: Early understanding of this alliance comes from the studies of Alluvial fan scrub (Smith 1980, Holland 1986, Haynes et al. 1989) that is a collection of vegetation assemblages based largely on disturbance histories at a given site. *Lepidospartum squamatum* Intermittently Flooded Shrubland is strongly tied to fluvial disturbance associated with intermittent streams and washes. *Lepidospartum squamatum* is an indicator and may or may not be the dominant species. In general, those stands with the most recent and regular disturbances tend to be more strongly dominated by *Lepidospartum squamatum*, while those with longer disturbance intervals tend to have higher diversity of woody species and lower absolute cover of *Lepidospartum squamatum*. The distribution of this alliance is centered in the Southern California Mountains and Valleys, and it ranges into the adjacent sections.

Ecologically, it is similar to several other shrubby wash alliances in the Mojave Desert including *Baccharis sergiloides* and *Ericameria paniculata* Intermittently Flooded Shrublands and *Hymenoclea salsola* Shrubland. However, it appears to be more restricted to the desert/cismontane transition zone and does not appear to tolerate the environmental conditions of the main core of the Sonoran, Mojave, or Colorado deserts. There is some evidence suggesting geographical replacement or fine-scale ecological differentiation of shrubby wash alliances depending upon the section in which the alliance occurs. For example, in the Mojave Desert *Lepidospartum squamatum* Intermittently Flooded Shrubland only occurs along the western margin and does not usually co-occur with other related shrubs of other alliances (Barbour and Wirka 1997).

Lepidospartum squamatum Intermittently Flooded Shrubland is fluvial disturbance-related. All stands known are associated with single or braided channel streams that have widely fluctuating flows and are generally intermittent. Stands are highly variable in age. Stand associates, flooding regimes, and successional characteristics have been studied elsewhere in California (Barbour and Wirka 1997, Woods and Wells 1996), but not in the Mojave Desert.

Regional Status:
Mojave Desert: Stands occur in the western Mojave Desert and the southern Mojave Desert along the boundaries of the Southern Sierra Nevada and Transverse ranges. Some of the best stands occur at Red Rock Canyon State Park and near Valyermo (Big Rock Wash).
Southeastern Great Basin Stands occur in the Argus Mountains and in other portions of China Lake Naval Weapons Center (M. Bagley, personal communication).

Management Considerations: Interruption of natural fluvial processes in many of the historic stands involves construction of dams, channelization, and gravel mining. The destruction of many older stands to create housing and golf courses has been cause for much concern in the core of its distribution (Southern California Mountains and Valleys). A few recent conservation acquisitions have preserved some stands, but upstream dams and flood control modifications do not bode well for the long-term persistence of many of these. Natural processes are being interrupted less frequently on the desert side of the Southern California Mountains and Valleys and elsewhere.

Menodora spinescens Dwarf-shrubland Alliance

Figure A30. *Menodora spinescens* Dwarf-Shrubland Alliance, Last Chance Range

Menodora spinescens is dominant or important in canopy. *Artemisia spinescens, Atriplex confertifolia, Coleogyne ramosissima, Ephedra nevadensis, Hymenoclea salsola, Krascheninnikovia lanata, Lepidium fremontii, Lycium andersonii, Sphaeralcea ambigua, Stanleya elata,* or *Tetradymia axillaris* may be present. *Yucca brevifolia* may be a scattered, emergent tree or tall shrub. Shrub height 0.5-2 m.

Habitat: Ridges, slopes, upper alluvial fans, and bajadas. Soils bedrock or alluvium-derived.

Distribution: Mojave Desert, Southeastern Great Basin, Nevada.

Elevation: 900 to 1,500 m

NDDB Rank: G4 S4

Synonyms:
Holland: Mojave mixed woody scrub (34210), Mojave mixed woody and succulent scrub (34240), Blackbrush scrub (34300), Mojavean juniper woodland and scrub (72220), Joshua tree woodland (73000)
Barry: G74G7411112BJUCA00
Cheatham and Haller: Mojavean pinyon juniper and Joshua tree woodlands
PSW-45: Joshua tree series
Thorne: Joshua tree woodland
WHR: Joshua tree
CALVEG: Joshua tree
Munz: Joshua tree woodland, Shadscale scrub, and Creosote bush scrubs

References: Beatley 1976

Membership Rules: *Menodora spinescens* ≥ 2% cover, no other single species with greater cover, although many other species may be present. It is represented by a few localized stands in well-defined, shallow, rocky soils characteristically just above *Larrea tridentata-Ambrosia dumosa.*

Comments: This alliance is one of several related dwarf shrub alliances of the mid-elevation Mojave Desert. *Menodora spinescens* is typically a low, compact, thorny shrub that usually occurs on shallow, rocky soils of uplands. Although the species is widespread from the upper *Larrea tridentata-Ambrosia dumosa* Shrubland into the lower *Pinus monophylla - (Juniperus osteosperma)* Woodland, it only locally dominates. It appears to be sensitive to disturbance such as intensive grazing and fire, and tends to occur in relatively stable sites. In the Mojave Desert, this alliance occupies similar environments to the upland associations of the *Atriplex confertifolia* and *Ephedra nevadensis* Shrublands. Seral relationships are uncertain, but the presence of *Menodora spinosa* in areas otherwise occupied by upland associations of *Atriplex confertifolia* Shrubland suggests that it may remain a more stable component to some stands where

Atriplex confertifolia increases and decreases as a result of natural pathogen disturbance (see *Atriplex confertifolia* Shrubland Alliance).

Menodora spinescens occurs in the northern, eastern, and southern Mojave Desert and adjacent Southeastern Great Basin. It is leafless most of the year and presents itself as a dense, low green-stemmed, and extremely spiny low shrub. Although the species is common and widespread, *Menodora spinescens* Shrubland occurs locally. Little is known of natural disturbance patterns in this vegetation. Webb et al. (1988) has shown that *Menodora spinescens* tends to colonize disturbed sites in Death Valley at a low rate, similar to *Larrea tridentata.* It is thought to be a stress tolerator, but may have a more competitive strategy than *Larrea tridentata,* as suggested by its opportunistic flowering and leafing phenology. Where large stands occur, they are usually above the *Larrea tridentata-Ambrosia dumosa* Shrubland and below the *Pinus monophylla - (Juniperus osteosperma)* Woodland, *Juniperus osteosperma* Wooded Shrubland, or *Artemisia tridentata* Shrublands. Associated alliances are *Coleogyne ramosissima* Shrublands (generally at slightly higher elevations), *Atriplex confertifolia* Shrublands (often on more xeric exposures), and *Grayia spinosa* Shrublands (generally on deeper soils). In the few places where it associated with *Artemisia tridentata* Shrubland, *Menodora spinescens* Shrubland tends to occur on relatively steep, xeric, southerly-facing exposures.

Regional Status:
Mojave Desert: Stands occur in the southern and eastern Mojave Desert north through Death Valley National Park. Some stands have been subjected to long-term grazing (e.g., near Cima Dome). Although most stands are on rocky soils of pediments and low-gradient hills, some stands occur on upper bajadas on alluvial soil (Greenwater Valley). Effects of fire are unknown but likely detrimental.
Southeastern Great Basin: The alliance occurs in upper-elevation portions of Death Valley National Park. Some of the most extensive stands occur in this region including those in the Inyo and Last Chance ranges, and in the Darwin area.

Management Considerations: This alliance requires further study before any detailed recommendations are made. It is likely to be fire-sensitive, but may tolerate some degree of grazing due to its extremely spiny habit.

Nolina parryi Shrubland Alliance

Figure A31. *Nolina parryi* Shrubland Alliance, Kingston Mountains

Nolina parryi is the dominant or important shrub in overstory. *Pinus monophylla* or *Juniperus californica* may be present in tree layer. Emergent trees may be present over a shrub canopy. *Artemisia ludoviciana, Coleogyne ramosissima, Eriogonum fasciculatum, Eriogonum heermannii, Ericameria teretifolia, Gutierrezia microcephala, Opuntia acanthocarpa, Salazaria mexicana, Salvia mohavensis, Thamnosma montana,* or *Yucca schidigera* may be present in the overstory. *Achnatherum speciosum* and *Poa secunda* may form a scattered grass understory. Shrubs 0.5-4 m tall; canopy is intermittent to open. Grasses 0.5-1 m tall; canopy is intermittent to open.

Habitat: Ridges, slopes. Soils bedrock or colluvium derived. Substrates largely granitic or crystalline metamorphic (including calcareous types).

Distribution: Mojave Desert, Southern California Mountains and Valleys, Sierra Nevada

Elevation: 600 to 2,100 m

NDDB Rank: G3 S2.2

Synonyms:
Holland: Mojave Mixed woody scrub, Blackbrush scrub
Barry: G7411111
Cheatham and Haller: Enriched desert scrub

Stone and Sumida: Nolina woodland
Thorne: Semi-succulent scrub
WHR: Desert succulent scrub
Munz: Shadscale scrub, Pinyon-juniper woodland

References: Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Stone and Sumida (1983).

Membership Rules: *Nolina parryi* dominant tall shrub (> 3% cover), evenly distributed over scattered low shrubs and herbs. Uncommon, scattered in extreme southwest of study area and in Kingston Range.

Comments: *Nolina parryi* is a conspicuous tufted liliaceous shrub to small tree (up to 5m) that forms scattered stands in desert or desert-border mountains. *Nolina parryi* Shrubland is one of several mid-elevation xeromorphic upland scrub alliances above the broad belt of *Larrea tridentata-Ambrosia dumosa* Shrubland, but below the high-elevation scrubs with *Artemisia tridentata* Shrubland and the *Pinus monophylla - (Juniperus osteosperma)* Woodland. It is localized in the Mojave Desert, the Peninsular Ranges, and the southern Sierra Nevada.

Natural disturbance in *Nolina parryi* Shrubland was probably limited to occasional fires, which had a likely neutral or negative effect. Related species (*Nolina microcarpa*) have been shown to crown-sprout from the caudex in low-severity fires. However, the thick thatch of leaves that develops on older plants tends to increase heat, and thus older plants tend to succumb to moderate-to-severe fire (FEIS 2001). Anecdotal evidence (T. Keeler-Wolf personal communication, Desert Workshop 2000). suggests that individual *Nolina* spp. are relatively fire hardy and will resprout. *Nolina parryi* Shrubland tends to occur in steep, very rocky areas or on moderately steep desert slopes where total vegetation cover is less than 40%. *Nolina parryi* stands are highly localized; they regularly occur in steep rocky slopes or on bouldery terrain. This suggests that the alliance requires more moisture (channeled along cracks in bedrock) than is modally available. Stands tend to decrease off outcrops, where they are replaced by other vegetation better adapted to deeper soils. This includes *Coleogyne ramosissima, Salazaria mexicana, Eriogonum fasciculatum, Juniperus californica,* and *Quercus cornelius-mulleri* Shrublands. At the upper limits of its elevation range, *Nolina parryi* gives way to *Pinus monophylla* or *Pinus jeffreyi*-dominated alliances.

Regional Status:
Mojave Desert: Stands are known in the Kingston Range where they occupy the steep granitic slopes, particularly on southerly exposures between *Coleogyne ramosissima* Shrubland at the lower extent and *Pinus monophylla- (Juniperus osteosperma)* Woodland at the upper extent. Responses to fires within portions of the stands in the Kingston Range have not been described.

Management Considerations: Stands occur localized and appear naturally uncommon. As they are typically isolated from dense vegetation and from human influence, the alliance is likely to maintain similar disturbance patterns to pre-European days. As adjacent vegetation is becoming more prone to frequent fire, further study and monitoring of post-fire response to individuals of *Nolina parryi* would be useful.

Panicum urvilleanum **Sparsely Vegetated Herbaceous Alliance**

Figure A32. *Panicum urvilleanum* Sparsely Vegetated Herbaceous Alliance, Kelso Dunes

Panicum urvilleanum is the sole dominant or important grass in the canopy. *Helianthus annuus, Oenothera deltoides, Dicoria canescens,* or *Achnatherum hymenoides* may be present.
Canopy open, usually < 10% total vegetation.

Habitat: Sand bodies. Active, partially stabilized dunes and sand fields.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Southeastern Great Basin.

Elevation: -10 to 1200 m

NDDB Rank: G3 S1.2

Synonyms:
Sawyer and Keeler-Wolf: *Abronia villosa* series (in part)
Holland: Active desert dunes, Stabilized and partially stabilized dunes, Stabilized and partially stabilized desert sand fields
Barry: G7411323
Cheatham and Haller: Partially stabilized desert dunes, Stabilized desert dunes

PSW-45: Croton series
Stone and Sumida: Sand plant community
Thorne: Desert dune sand plant
WHR: Desert scrub

References: Henry (1979), Thorne (1982), Paysen et al. (1980), Vasek and Barbour (1977); plot-based descriptions are found in the California NDDB.

Membership Rules: Vegetation characterized by the presence of *Panicum urvilleanum* (dune panic grass). Usually a sparse rhizomatous grassland of open-dune areas, typically < 10% cover. Rare in Mojave Desert, associated with deep dune deposits at Kelso Dunes and Devils Playground.

Comments: *Panicum urvilleanum* generally forms a sparse cover on open dunes and deep sand deposits. The alliance usually occurs on the core of the large dune systems on the deepest sand and may occupy active tall dunes with relatively steep faces. In those settings, it is usually the sole dominant species and spreads across dunes with long underground rhizomes. Although perennial, cover varies annually based on precipitation.

Sand dunes are used for many uses other than passive recreation. Grazing has occurred on the Kelso Dunes. Algodones (Imperial) and Dumont dunes are open to motorized recreation. Eureka Dunes have been subjected to sand-boarding. *Panicum urvilleanum* Sparsely Vegetated Herbaceous alliances are usually far from the edges of dune systems and experience shifting sands more than alliances of the thinner sand sheets and dune margins.

Regional Status:
Mojave Desert: The alliance occurs on the Kelso Dunes.
Southeastern Great Basin: The alliance occurs on the Eureka Dunes.

Management Considerations: Sand sheets and dunes are relatively rare and many are degraded by OHV use and disruption of sand sources. Protection from impacts has been implemented on a portion of California dunes, but many such as Dumont, Algodones, and Rice Valley dunes have had long-term quantifiable negative impacts. Other dunes should be surveyed for this alliance. The alliance is very rare in California.

Phragmites australis Semipermanently Flooded Herbaceous Alliance

Figure A33. *Phragmites australis* Semipermanently Flooded Herbaceous Alliance, Salt Creek

Phragmites australis is the sole dominant species in herbaceous layer. *Anemopsis californica, Juncus balticus, J. mexicanus, J. cooperi, Schoenoplectus americanus, Schoenoplectus acutus,* or *Schoenoplectus californica* may be present. Emergent *Salix* species and *Populus fremontii* may be present. Grass < 4 m tall; cover continuous.

Habitat: Habitat permanently saturated with shallow water table. Water chemistry: fresh, mixohaline, mixosaline. Cowardin class: palustrine persistent emergent wetland. The national list of wetland plants (Reed 1988) lists *Phragmites australis* as a Facultative Wetland.

Distribution: Widespread throughout California, but largely within California Dry Steppe Province, American Semi-desert and Desert Province, and Intermountain Semidesert and Desert Province. It is virtually cosmopolitan.

Elevation: -45 to 1,600 m

NDDB Rank: G5 S3.2

Synonyms:

Holland: Transmontane alkali marsh (52320), Cismontane alkali marsh (52310), Transmontane freshwater marsh (52420), Coastal and valley freshwater marsh (52410)
Barry: G7412331
Cheatham and Haller: Coastal and valley freshwater marsh, Great Basin freshwater marsh, Valley alkali marsh, Great Basin alkali marsh
Thorne: Alkali meadow, freshwater marsh
WHR: Fresh emergent wetland
Munz: Freshwater marsh

References: Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Marks et al. (1994), FEIS (2001).

Membership Rules: *Phragmites australis* ≥ 2%. Usually associated with alkali wetlands adjacent to playas, alkali springs, and meadows; may also occur in freshwater wetlands**.**

Comments: *Phragmites australis* Semipermanently Flooded Herbaceous Alliance behaves differently in different regions of the state. In the Mojave Desert and Southeastern Great Basin, the alliance is limited to naturally occurring, unmanaged fresh or alkaline springs, slow creeks, and marshes in typically small stands adjacent to other wetland alliances. In general, *Phragmites australis* Semipermanently Flooded Herbaceous Alliance occurs in drier settings than *Schoenoplectus americanus* Semipermanently Flooded Herbaceous and *Typha (angustifolia, latifolia) – (Schoenoplectus* spp.) Semipermanently Flooded Herbaceous Alliance, but in moister settings than *Pluchea sericea* Seasonally Flooded Shrubland*, Juncus cooperi* Seasonally Flooded Herbaceous, and *Sporobolus airoides* and *Distichlis spicata* Intermittently Flooded Herbaceous Alliances.

In the Great Valley, it often acts as a ruderal alliance invading managed wetlands and proliferating in mowed, burned, or otherwise frequently disturbed marshes. Typical stands in either situation are monospecific, with only a few other plants entering into the periphery of the dense clonal clumps.

Phragmites australis Semipermanently Flooded Herbaceous Alliance typically occurs in seasonally flooded wetlands. Natural disturbance in stands is largely limited to fluvial disturbance except for occasional late-season fires in marshland. The primary mode of regeneration is vegetative. However, seed banks may build up in marshes and seeds may germinate in vegetation-free areas following water draw-down (FEIS 2001). Many of the stands along the major perennial creeks and rivers in the deserts probably flooded annually, and broken and damaged nodal sections of the strong rhizomes and rapidly growing stolons would break and establish on sand and gravel bars. In managed wetlands, burning, plowing, mowing, and other clearing techniques in conjunction with artificial draw-down, tend to spread the stands through vegetative regeneration and via seed banks. Most fire does not kill *Phragmites australis* Semipermanently Flooded Herbaceous stands. Only deep-burning peat fires can kill the rhizomes, which may run as deep as 100-200 cm (FEIS 2001).

Regional Status:
Mojave Desert: The alliance occurs in alkaline and freshwater marshes and along creeks throughout the Mojave Desert. In those situations, it often shares the marshes with various alliances that segregate based on moisture and alkalinity/salinity tolerances. Largest stands in the Mojave Desert may be along the Amargosa River between Shoshone and Tecopa.

Management Considerations: Stands in the desert sections are generally non-invasive. *Tamarix* may invade stands of this alliance. Stands in managed wetlands in the Sacramento-San Joaquin River delta respond to certain management practices by proliferating vegetatively and via seed. Managers concerned with the invasive qualities of *Phragmites australis* Semipermanently Flooded Herbaceous Alliance should consider its ecological setting in adjacent unmanaged wetlands, where it is generally stable and non-invasive.

Pinus flexilis Woodland Alliance

No photograph is available.

Pinus flexilis is the sole or dominant tree in canopy. *Abies concolor, Pinus albicaulis, P. balfouriana, P. contorta ssp. murrayana, P. jeffreyi,* or *P. longaeva* may be present. Trees < 18 m tall; canopy open. Shrubs are either infrequent or common. Ground layer sparse.

Habitat: All slopes, especially ridges and upper slopes below tree line. Soils commonly granitic-derived.

Distribution: Sierra Nevada (southern subalpine area), Southern California Mountains and Valleys, Mono, Southeastern Great Basin, from British Columbia east to Alberta, south to Texas, and west to California.

Elevation: 2,200 to 3,350 m

NDDB Rank: G4 S3.2

Synonyms:
Holland: Limber pine forest
Barry: G7411112 BPIFL20
Cheatham and Haller: Southern California subalpine forest
PSW-45: Limber pine series
Thorne: Limber pine forest
WHR: Subalpine conifer

References: Barney (1980), Griffin and Critchfield 1972, Paysen et al. (1980), Thorne (1976) Vasek and Thorne (1977); plot-based descriptions are found in Keeler-Wolf and Keeler-Wolf (1976), Keeler-Wolf (1989), Keeler-Wolf (1990b), Taylor (1979) in Keeler-

Wolf (1990b), Talley (1978) in Keeler-Wolf (1990b), Ball (1976) in Keeler-Wolf (1990b).

Membership Rules: *Pinus* flexilis is the major tree species (> 55% relative cover and > 25% absolute cover). Typically occurs on more gently sloping northerly exposures than *Pinus longaeva*, only on highest portion of Inyo and Panamint mountains.

Comments: *Pinus flexilis* grows in dry, rocky, exposed sites from the foothills to alpine, defining both lower and upper limits of tree growth in many mountain ranges. Outside California, it mixes with *Populus tremuloides* in a mixed forest that is part of a broad mosaic with conifer forests, shrublands, and grasslands that symbolizes much of the West. In the southern Rocky Mountains, it grows with *Pinus longaeva* and other high-elevation conifers as in California.

Pinus flexilis is a slow-growing, long-lived tree the can be replaced on productive sites by more shade-tolerant species, but is persistent on non-productive sites. Trees have thin bark; even moderate fire kills large trees with thicker bark. Seedlings establish from cached seed. Intermediate fire frequency permits coexistence of *Pinus flexilis* with other trees on productive sites, and it is common in locations with long fire intervals of low-intensity fire.

Regional Status:
Southeastern Great Basin: The alliance occurs in the Inyo Mountains and Panamint Range, where it grows with *Pinus longaeva*. It also occurs along the California-Nevada border in the Grapevine Mountains in Death Valley National Park.

Management Considerations: Several recently killed stands of *Pinus flexilis* Woodland occur along the east slope of the Sierra Crest between Tioga Pass and Lundy Canyon in the Mono Basin. A blister rust or a related fungus apparently attacked these stands.

Pinus longaeva Woodland Alliance
No photograph is available.

Pinus longaeva is the sole, dominant, or important tree with *Pinus flexilis* in the canopy. Trees < 18 m tall; canopy open. Shrubs are infrequent or conspicuous; the ground layer is sparse.

Habitat: All slopes, especially ridges and upper slopes below tree line. Soils are dolomite, limestone, or granite-derived.

Distribution: Mono, Southeastern Great Basin Mojave Desert, Intermountain West.

Elevation: 2,600 to 3,600 m

NDDB Rank: G4 S2.3

Synonyms:
Holland: Bristlecone pine forest
Barry: G7411112 BPILO00
Cheatham and Haller: Bristlecone pine forest
PSW-45: Bristlecone pine series
Thorne: Bristlecone pine woodland
WHR: Subalpine conifer

References: *Pinus longaeva* range in California (Griffin and Critchfield 1972). Beasley and Klemmedson (1980), Billings and Thompson (1957), Fritts (1969), Lanner (1984), Lloyd and Mitchell (1973), Marchand (1973), Mooney (1973), Mooney et al. (1962), Paysen et al. (1980), Schulman (1954), Vasek and Thorne (1977), Wright and Mooney (1965); plot-based descriptions are found in Taylor (1979) in Keeler-Wolf (1990b)

Membership Rules: *Pinus flexilis* ≥ 25% cover or total cover greater than either shrubs or herbaceous. Found only in the highest portions of the Inyo and Panamint mountains. When occurring with *Pinus flexilis*, as on the upper, east-facing slopes of Wacoba Mtn. (Inyo Mountains), it may have equal cover with *Pinus longaeva*.

Comments: *Pinus longaeva* may form single-species stands or mix with *Pinus flexilis*. The most famous stands are at Schulman Grove in the White Mountain Research Natural Area (Keeler-Wolf 1990b) and in the Ancient Bristlecone Pine Botanical Area in Mono Co. Here *Pinus longaeva* grows on dolomite. Keeler-Wolf (1990b) qualitatively describes forests of *Pinus longaeva* and *Pinus flexilis* at Whippoorwill Flat RNA in Inyo Co. *Pinus longaeva* is a rare (CNPS List 4) plant (Skinner and Pavlik 1994).

Pinus longaeva is a long-lived (5,000 years) conifer. Trees retain needles up to 30 years, and have deep and spreading roots. Cones ripen and seed dispersal occurs in the fall. Clark’s nutcracker, other birds, and small mammals cache seeds. *Pinus longaeva* stands are open with a ground cover of bare soil and rock with a few scattered herbs. Lightning caused fire is restricted to individual trees.

Regional Status:
Southeastern Great Basin: The alliance occurs on ridges and peaks of the Inyo and Panamint mountains.

Management Considerations: No additional information is available.

Pinus monophylla Sparsely Wooded Shrubland Alliance

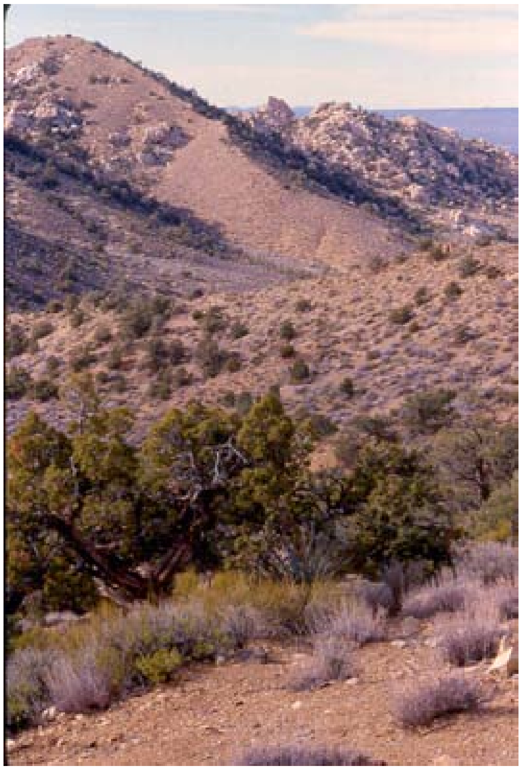


Figure A34. *Pinus monophylla* Sparsely Wooded Shrubland, Mid Hills, San Bernardino County.

Pinus monophylla is present as an emergent tree over a shrub canopy. *Juniperus osteosperma, Juniperus californica, J. occidentalis* ssp. *australis, Quercus cornelius-mulleri,* or *Quercus john tuckeri* may be present as emergent trees or large shrubs over a shorter shrub canopy. *Artemisia tridentata, Artemesia nova, Artemesia arbuscula*, *Chrysothamnus viscidiflorus, Chrysothamnus nauseosus, Ephedra viridis, Eriogonum fasciculatum, Eriogonum umbellatum, Grayia spinosa, Opuntia erinacea, Purshia tridentata, Purshia stansburiana,* or *Yucca baccata* may be present. Trees < 15 m tall; canopy intermittent to open. Shrubs common. Ground layer absent, sparse, or grassy.

Habitat: Alluvial fans, pediments, slopes, ridges, canyons, and ravines at lower elevations. Soils commonly coarse sand and/or rocky, well drained, ranging to sandy loam. Canyon bottoms and small desert mountain drainageways, intermittently flooded streamcourses.

Distribution: Southeastern Great Basin, Mono, Mojave Desert, Sierra Nevada, Southern California Mountains and Valleys, Nevada, Utah, Arizona, Idaho

Elevation: 1,000 to 1,800 m

Synonyms:
Sawyer and Keeler-Wolf (1995): Single-leaf pinyon series (*in part*), Single-leaf pinyon-Utah juniper series (*in part*)
Holland: Great Basin pinyon woodland (72122), Mojavean pinyon woodland (72210), Great Basin pinyon-juniper woodland (72121), Peninsular pinyon woodland (72310)
Cheatham and Haller: Pinyon-juniper woodland
PSW-45: Pinyon series
CALVEG: Single-leaf pinyon-Utah Juniper series
Rangeland: SRM 412
Thorne: Pinyon-juniper woodland
Munz: Juniper-pinyon woodlands
WHR: Pinyon-juniper

References: Brown (1982), Griffin and Critchfield (1972), Meeuwig et al. 1990, Meeuwig and Bassett (1983), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Tueller et al. (1979), Vasek and Thorne (1977), West (1994); plot-based descriptions are found in Keeler-Wolf (1990a), Parikh (1993), Vasek and Thorne (1977), Keeler-Wolf and Keeler-Wolf (1976), Keeler-Wolf (1989) in Keeler-Wolf (1990b), Keeler-Wolf et al. (1998)

Membership Rules: *Pinus monophylla* ≥ 1% but < 25% cover. *Juniperus osteosperma* or *californica* may be present but with low cover. Dominant strata are shrubs. *Pinus monophylla* occurs over a sparse to relatively dense cover of shrubs, widespread in all of the higher mountains of mapping area.

Comments: We included this alliance in the pinyon-juniper ecological system with *Pinus monophylla* – (*Juniperus osteosperma*) Woodland and *Juniperus californica* or *Juniperus osteosperma* Wooded Shrubland Alliance. Stands with an emergent layer of *Pinus monophylla* generally < 25% cover over a varied shrub canopy are considered part of this wooded shrubland alliance. It occupies lower, drier and warmer sites than the *Pinus monophylla* – (*Juniperus osteosperma*) Woodland alliance. The alliance occurs with *Artemisia tridentata, Artemesia nova, Artemesia arbuscula* and *Cercocarpus ledifolius* scrubs in the Southeastern Great Basin, the eastern Sierra Nevada, and the Mono. In the Transverse and Peninsular ranges, it is associated with *Cercocarpus ledifolius*, *Coloegyne ramosissima* and *Juniperus californica* scrubs at lower elevations. In the Southeastern Great Basin and Mono, it occupies topographic settings between *Juniperus osteosperma* or deep-soil *Artemisia tridentata* associations and shallow-soil versions *of Artemesia tridentata, Artemesia arbuscula,* or *Artemisia nova* scrubs.

Pinus monophylla is a slow- to moderately fast-growing tree with a maximum age of several hundred years. It is an obligate seeder and does not sprout after fire. Small-to-moderate-sized individuals are killed by moderate fire. For example, where *Pinus monophylla* trees have recently invaded sagebrush-grassland communities, young trees < 1.2 m are easily killed (FEIS 2001). Associated species may vary, but most (*Juniperus* spp., *Cercocarpus ledifolius, Artemisia* spp.) are not strongly fire-adapted, and stands are eliminated by repeated moderate fire. Stand-replacing fires were probably uncommon naturally. Fire has always been a natural process in the *Pinus monophylla* alliance, although the extent and frequency of fires have increased in many areas as a result of human ignition rates and the invasion of non-native annual grasses, in particular *Bromus tectorum*. Much of the following information is taken from the FEIS 2001 account of *Pinus monophylla*.

High temperatures, moderate winds, dry weather, and generally dense stands (> 1000 trees per ha) are necessary for crown fire to carry in *Pinus monophylla* stands. The effect of fire depends largely upon stand structure and understory composition. The historic regimes were likely based on relatively localized lightning strike ignitions that were limited by relatively wide spacing of trees, low shrub and grass understory density, and natural fuel breaks in rugged mountainous terrain. Lightly grazed ecotonal areas with a dense understory burn easily. Fire does not carry in some open stands.

Following fire, *Pinus monophylla* is absent from early successional stages. Seedlings reestablish primarily via the postburn food caches of birds and rodents; successful establishment requires a nurse plant. Apparently, the rate of *Pinus monophylla* reinvasion of burned areas is determined by relay floristics. In general, if adjacent stands remain, *Pinus monophylla* becomes established 20 to 30 years after fire.

Regional Status:
Mojave Desert: Stands occur in the eastern Mojave Desert. Some contain relict elements such as *Pinus edulis, Quercus chrysolepis, Quercus turbenella, Abies concolor, Garrya flavescens,* and *Arctostaphylos pungens*.
Southeastern Great Basin: *Pinus monophylla* woodlands are widespread in all the mountains > 1800 m in the Southeaster Great Basin and include those with *Juniperus, Cercocarpus*, and *Artemisia* spp. as the principal associates. Some unusually large-stature stands exist at Whippoorwill Flat in the Inyo Mountains (Keeler-Wolf 1989).

Management Considerations: As this alliance consists of open to very open stands of *Pinus monophylla*, they are particularly susceptible to decimation by fire. All of the shrubs associated with the currently defined associations in this alliance are re-sprouters and are thus capable of re-establishing dominance before the establishment of *Pinus monophylla* in the overstory. It is likely that this is a transient community in many areas and will convert to shrubland under relatively high fire frequencies.

Pinus monophylla – (Juniperus osteosperma) Woodland Alliance

Figure A35. *Pinus monophylla - (Juniperus oseteosperma)* Woodland Alliance, Clark Mountain (*Abies concolor* Unique Stands along crest)

Pinus monophylla is the sole, dominant, or important tree in canopy. *Juniperus osteosperma, Juniperus californica, J. occidentalis* ssp. *australis, Pinus jeffreyi, Quercus chrysolepis, Quercus cornelius-mulleri,* or *Quercus john-tuckeri* may be present as emergent trees over a shrub canopy. *Artemisia tridentata, Artemesia nova, Artemesia arbuscula*, *Chrysothamnus viscidiflorus, Chrysothamnus nauseosus, Ephedra viridis, Eriogonum fasciculatum, Eriogonum umbellatum, Grayia spinosa, Opuntia erinacea, Purshia tridentata, Purshia stansburiana,* or *Yucca baccata* may be present. Trees < 15 m tall; canopy intermittent to open. Shrubs common. Ground layer absent, sparse, or grassy.

Habitat: Alluvial fans, pediments, slopes, ridges, canyons, and ravines at lower elevations. Soils commonly coarse sand and/or rocky, well drained, ranging to sandy loam. Canyon bottoms and small desert mountain drainageways, intermittently flooded streamcourses.

Distribution: Southeastern Great Basin, Mono, Mojave Desert, Sierra Nevada, Southern California Mountains and Valleys, Nevada, Utah, Arizona, Idaho

Elevation: 1,000 to 2,800 m

NDDB Rank: Unknown

Synonyms:

Sawyer and Keeler-Wolf : Single-leaf pinyon series (*in part*), Single-leaf pinyon-Utah juniper series (*in part*)
Holland: Great Basin pinyon woodland (72122), Mojavean pinyon woodland (72210), Great Basin pinyon-juniper woodland (72121), Peninsular pinyon woodland (72310)
Cheatham and Haller: Pinyon-juniper woodland
PSW-45: Pinyon series
CALVEG: Single-leaf pinyon-Utah Juniper series
Rangeland: SRM 412
Thorne: Pinyon-juniper woodland
Munz: Juniper-pinyon woodlands
WHR: Pinyon-juniper

References: Brown (1982), Griffin and Critchfield (1972), Meeuwig et al. 1990, Meeuwig and Bassett (1983), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Tueller et al. (1979), Vasek and Thorne (1977), West (1994): plot-based descriptions are found in Keeler-Wolf (1990a)**,** Parikh (1993), Vasek and Thorne (1977), Keeler-Wolf and Keeler-Wolf (1976), Keeler-Wolf (1989) in Keeler-Wolf (1990b), Keeler-Wolf et al. (1998)

Membership Rules: *Pinus monophylla* ≥ 25% cover or total cover greater than either shrubs or herbaceous cover. No other tree species approaches or exceeds it in cover. *Juniperus osteosperma* may be present. Restricted to cooler, moister sites than *Pinus monophylla* Wooded Shrubland alliance. Keeler-Wolf et al. (1998) *Pinus monophylla* dominant tree (≥ 5% cover) over varied shrub understory, *Pinus monophylla* taller and more conspicuous than any other species.

Comments: We included this alliance in the pinyon-juniper ecological system with *Pinus monophylla* Wooded Shrubland and *Juniperus californica* or *Juniperus osteosperma* Wooded Shrubland Alliance. Stands with an emergent layer of *Pinus monophylla* generally < 25% cover over a varied shrub canopy are considered to be *Pinus monophylla* Wooded Shrubland Alliance. *Pinus monophylla* – (*Juniperus osteosperma*) Woodland alliance occupies higher, cooler sites than the *Pinus monophylla* Wooded Shrubland Alliance. It occurs with *Artemisia tridentata, Artemesia nova, Artemesia arbuscula* and *Cercocarpus ledifolius* scrubs in the Southeastern Great Basin, the eastern Sierra Nevada, and the Mono. In the Transverse and Peninsular ranges, it is associated with *Cercocarpus ledifolius*, *Coloegyne ramosissima* and *Juniperus californica* scrubs at lower elevations. In the Southeastern Great Basin and Mono, it occupies topographic settings between *Juniperus osteosperma* or deep-soil *Artemisia tridentata* associations and shallow-soil versions *of Artemesia tridentata, Artemesia arbuscula,* or *Artemisia nova* scrubs.

Pinus monophylla-(Juniperus osteosperma) Woodland Alliance is the highest elevation regional vegetation of the Mojave Desert. It occurs with *Artemisia tridentata, Artemesia nova, Artemesia arbuscula* and *Cercocarpus ledifolius* scrubs and with *Pinus jeffreyi, Pinus contorta murrayana, Pinus flexilis,* and *Pinus longaeva* woodlands in the Southeastern Great Basin, the eastern Sierra Nevada, and the Mono. In the Transverse and Peninsular ranges, it is associated with *Cercocarpus ledifolius*, *Coloegyne* *ramosissima* and *Juniperus californica* scrubs (at lower elevations) and occurs adjacent to *Pinus flexilis* and *Pinus contorta murrayana* alliances at higher elevations. In the Southeastern Great Basin and Mono, it occupies topographic settings between *Juniperus osteosperma* or deep-soil *Artemisia tridentata* associations (below) and shallow-soil versions *of Artemesia tridentata, Artemesia arbuscula,* or *Artemisia nova* scrubs or woodlands of *Pinus flexilis* or *Pinus longaeva* (above). In parts of the Panamint, Inyo and White mountains, an upper-elevation *Artemisia tridentata* scrub separates *Pinus monophylla* stands from *Pinus flexilis* or *Pinus longaeva* stands, suggesting upslope retreat of *Pinus flexilis* and *Pinus longaeva* (Keeler-Wolf 1990b).

Pinus monophylla is a slow- to moderately fast-growing tree with a maximum age of several hundred years. It is an obligate seeder and does not sprout after fire. Small-to-moderate-sized individuals are killed by moderate fire. For example, where *Pinus monophylla* trees have recently invaded sagebrush-grassland communities, young trees < 1.2 m are easily killed (FEIS 2001). Associated species may vary, but most (*Juniperus* spp.*, Cercocarpus ledifolius, Artemisia* spp.) are not strongly fire-adapted, and stands are eliminated by repeated moderate fire. Stand-replacing fires were probably uncommon naturally. Fire has always been a natural process in the *Pinus monophylla* alliance, although the extent and frequency of fires has increased in many areas as a result of human ignition rates and the invasion of non-native annual grasses, in particular *Bromus tectorum*. Much of the following information is taken from the FEIS 2001 account of *Pinus monophylla*.

High temperatures, moderate winds, dry weather, and generally dense stands (> 1,000 trees per ha) are necessary for crown fire to carry in *Pinus monophylla* stands. The effect of fire depends largely upon stand structure and understory composition. The historic regimes were likely based on relatively localized lightning strike ignitions that were limited by relatively wide spacing of trees, low shrub and grass understory density, and natural fuel breaks in rugged mountainous terrain. Lightly grazed ecotonal areas with a dense understory burn easily. Fire does not carry in some open stands.

Following fire, *Pinus monophylla* is absent from early successional stages. Seedlings reestablish primarily via the postburn food caches of birds and rodents; successful establishment requires a nurse plant. Apparently, the rate of *Pinus monophylla* reinvasion of burned areas is determined by relay floristics. In general if adjacent stands remain, *Pinus monophylla* becomes established 20 to 30 years after fire, but cover and density are relatively low until approximately 60 years after a fire, when tree dominance begins to exceed that of the understory. Pinyons are able to dominate a site within 100 to 150 years of burning. As tree dominance increases and the understory is gradually suppressed, the ability of the understory to carry fires intense enough to kill larger trees also decreases. Fire supression in some stands has led to denser-than-historic stands, which may burn with increasing frequency due to dense, fine, non-native grass fuels. Natural disturbance regimes also include periodic avalanches in snow chutes in the higher mountains.
In the Transverse Ranges (Brown and Minnich 1986), fire in naturally dense stands tends to be passive crown fires with fire size up to 7,000 ha. Periodic fire regimes may be

around 200 years and have not changed substantially over the past several hundred years (R. Minnich, personal communication).

Regional Status:
Mojave Desert: Stands occur in the eastern Mojave Desert; some contain relict elements such as *Pinus edulis, Quercus chrysolepis, Quercus turbenella, Abies concolor, Garrya flavescens,* and *Arctostaphylos pungens*.
Southeastern Great Basin: *Pinus monophylla* woodlands are widespread in all the mountains > 1800 m in the Southeastern Great Basin and include those with *Juniperus, Cercocarpus* and *Artemisia* spp. as the principal associates. Some unusually large stature stands exist at Whippoorwill Flat in the Inyo Mountains (Keeler-Wolf 1989).

Management Considerations: Prescribed fire has commonly been used by range managers to open up *Pinus monophylla* stands and promote grass and other forage species. However, it is no longer an effective management option on some *Pinus monophylla* sites where prolonged tree dominance due to fire suppression has reduced the understory. Fuels on such sites are often insufficient to carry fire. In addition, understory plants in closed stands do not withstand fire as well as those in more open stands. When fires occur in closed stands, they are usually of such high severity that soil seed reserves are depleted. Without successful post-fire seeding, highly flammable annual grass communities often establish. Losses due to fire in some areas of its range are likely a combination of fire suppression and high cover of *Bromus tectorum.*

Pleuraphis rigida Herbaceous Alliance

Figure A36. *Pleuraphis rigida* Herbaceous Alliance, East of Superior Lake

Pleuraphis rigida is the sole or dominant grass in ground layer. *Achnatherum hymenoides, Ambrosia dumosa, Bouteloua eriopoda, Bromus madritensis, Dalea mollossima, Ericameria cooperi, Gutierrezia sarothrae, Panicum urvilleanum,* or *Sphaeralcea ambigua* may be present. Scattered trees and shrubs are typically emergent including the species: *Acacia greggii, Atriplex canescens, Chilopsis linearis, Ephedra californica, Ephedra nevadensis, Hymenoclea salsola, Larrea tridentata, Lycium andersonii, Opuntia acanthocarpa, Petalonyx thurberi, Yucca brevifolia,* and *Yucca schidigera*. Grass < 1 m tall; canopy open to intermittent. Shrubs < 3 m tall; open canopy. Trees < 6 m tall; scattered canopy. Annuals may be seasonally present.

Habitat: Flat ridges, lower bajadas, slopes, dune aprons and stabilized dunes. Soils well drained, may be sandy or rocky. Growth is poor on clays.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Southern California Mountains and Valleys, south Nevada, Arizona, Mexico.

Elevation: 500 to 1,400 m

NDDB Rank: G3 S2.2 (some associations may be more rare)
Synonyms:
Holland types: Mojave mixed steppe (34220 *in part*), Mojave yucca scrub and steppe (34230 *in part*), Sonoran creosote bush scrub (33100 *in part*), Mojave creosote bush scrub (34100 *in part*)
Barry: G7411331 BHIRI00
Cheatham and Haller: Creosote bush scrub
PSW-45: Galleta grass series
Thorne: Creosote bush scrub
CALVEG: Galleta series
Munz: Creosote bush scrub, Joshua tree woodland

References: Brown (1982), Burk (1977), Paysen et al. (1980), Sawyer and Keeler-Wolf (1995), Reid et al. (1999), Vasek and Barbour (1977); plot-based descriptions are found in Minnich et al. (1993), Keeler-Wolf et al. (1998).

Membership Rules: *Pleuraphis rigida* ≥ 2%. This species occurs in low sandy areas and occasionally in uplands at mid elevations, often with emergent shrubs such as *Yucca schidigera* and *Ephedra nevadensis*. As an alliance in the Mojave Desert, it is generally uncommon in upland areas and more common in low sandy areas. Keeler-Wolf et al. (1998) defines upland stands: *Pleuraphis rigida* dominant (> 60% relative cover, usually 10-35% actual cover) may have emergent shrubs up to 10% actual cover.

Comments: Many other classifications include this alliance in creosote bush scrub type assemblages. Stands of *Pleuraphis rigida* Herbaceous Alliance often form fine-grain mosaics with stands *of Larrea tridentata, Larrea tridentata-Ambrosia dumosa*, *Yucca brevifolia* Wooded or *Yucca schidigera* Shrublands. *Pleuraphis rigida* may be a common ground layer species in shrub or tree-dominated stands. Almost all California stands have at least 1% shrubs or trees emergent.

Pleuraphis rigida Herbaceous Alliance is a relatively rare alliance in the California deserts. It is considered as a warm-rain-season species and does not occur in the western Mojave Desert where cold season rain predominates (G. Harris, personal communication). Its range has probably decreased in areas with prolonged heavy grazing. It occurs either in open stands around margins of dunes or other sandy areas at low elevations, or in more closed mid-elevation upland sites on slopes and bajadas. In dune areas, it gives way to very open stands of *Panicum urvillianum* Sparsely Vegetated Herbaceous Alliance on the deepest sand deposits and is often interspersed with small stands of the *Abronia villosa* Sparsely Vegetated Alliance. *Pleuraphis rigida* was previously *Hilaria rigida* and is referred to as such in existing ecological literature.

Pleuraphis rigida is an unusual shrubby-looking grass with exposed renewal buds raised above the ground. It tolerates drought better than any other species in the genus (FEIS 2001). Its clumped growth form is a result of the tillers and short rhizomes it produces. Although fire effects are not well known, compared to other species in its genus, it is likely to be relatively sensitive to fire, particularly in its dried state (FEIS 2001). Although evidence is scant, observations suggest *Pleuraphis rigida* stands have declined in areas with long-term, moderate-to-heavy grazing pressure (T. Keeler-Wolf personal communication, Desert Workshop 2000).

In the lower Colorado River Valley of the Sonoran Desert and in some Mojave Desert communities, *Pleuraphis rigida* serves as the main stabilizer over wide areas of sand dunes. Stands in dune areas are relatively open and less likely to carry fire than even the open stands on rocky substrates. Thus, shifting sand and wind deflation are the primary agents of disturbance.

Some of the upland stands are affected by recent fire and seem to have maintained or extended themselves (Keeler-Wolf, personal communication) although they may be invaded by other shrubby disturbance related species.

Regional Status:
Mojave Desert: *Pleuraphis rigida* Herbaceous Alliance occurs in the eastern and southern Mojave Desert. It does not occur in the western Mojave Desert because of the paucity of warm-season rains compared to the central and eastern Mojave Desert. Most of the stands in the eastern and southern Mojave Desert are associated with sandy substrates (Devil's Playground, Kelso Dunes, Rasor Road, Cronese Lakes, Pinto Basin), but several upland stands exist (e.g., Clipper Valley, Joshua Tree National Park, Lanfair Valley). Some of these upper elevation stands have been grazed and burned and contain higher cover of disturbance-related emergent shrubs such as *Opuntia acanthocarpa, Sphaeralcea ambigua, Gutierrezia microcephala*, and *Hymenoclea salsola*.

Management Considerations: Altered fire frequencies and increased livestock grazing have likely affected the non-sandy stands of *Pleuraphis rigida* throughout its range. It is particularly susceptible to these impacts when the grass is dry (most of the time). Further studies should be conducted to monitor change in the particularly sensitive upper elevation non-sandy stands. Stands on shallow sandy soil are frequently invaded by the aggressive non-native annual *Brassica tournefortii*. Intensive livestock grazing has possibly negatively affected both sandy and non-sandy stands.

Pleuraphis jamesii Herbaceous Alliance

Figure A37. *Pleuraphis jamesii* Herbaceous Alliance, Inyo County

Pleuraphis jamesii is the sole or dominant grass in ground layer. *Bouteloua gracilis, Elymus elymoides, Eriogonum wrightii, Muhlenbergia porteri,* or *Sphaeralcea ambigua* may be present. Emergent shrubs such as *Artemisia tridentata*, *Ephedra nevadensis, Ephedra viridis*, *Eriogonum fasciculatum, Gutierrezia microcephala,* or *Opuntia acanthocarpa* may be present. Emergent *Yucca brevifolia* may be present. Grass < 1 m tall; cover is open to intermittent.

Habitat: Upper bajadas, gentle to moderately steep slopes, valleys, mesas. Soils range from deep, coarse, sandy soils to gravelly or rocky sites.

Distribution: Mojave Desert, Southeastern Great Basin Nevada, Utah, Colorado, Wyoming, Texas, Oklahoma.

Elevation: 1,200 to 2,800 m

NDDB Rank: G3 S2.2

Synonyms:
Holland types: Mojave mixed steppe (34220 *in part*), Mojave yucca scrub and steppe (34230 *in part*), Sonoran creosote bush scrub (33100 *in part*), Mojave creosote bush scrub (34100 *in part*)
Barry: G7411331 BHIRI00
Cheatham and Haller: Creosote bush scrub
PSW-45: Galleta grass series
Thorne: Creosote bush scrub
CALVEG: Galleta series
Munz: Creosote bush scrub, Joshua tree woodland

References: Brown (1982), Burk (1977), Paysen et al. (1980), Sawyer and Keeler-Wolf (1995), Reid et al. (1999), Vasek and Barbour (1977).

Membership Rules: Herbaceous cover exceeds cover of trees or shrubs, *Pleuraphis jamesii* > 2% cover. This species occurs in upper mid-elevation Mojave Desert of the eastern part of the mapping area, often associated with *Yucca brevifolia*, *Opuntia acanthocarpa* and *Gutierrezia spp.*

Comments: In California, *Pleuraphis jamesii* Herbaceous is restricted to the eastern Mojave Desert near the New York Mountains, Lanfair Valley, and the Mid Hills and in the Southeastern Great Basin in the Inyo and Panamint mountains. It occurs locally in small patches associated with stands of the following alliances: *Yucca brevifolia* Wooded Shrubland*; Artemisia tridentata, Coleogyne ramosissima, Ephedra nevadensis, Ericameria nauseosa,* and *Krascheninnikovia lanata* Shrublands*;* and *Pleuraphis rigida* Herbaceous Alliance. This is a more cold desert shrub-steppe than the *Pleuraphis rigida* Herbaceous Alliance, ranging well into the northern Great Basin and adjacent Great Plains. However, it is not known from other portions of the Californian Great Basin. It may be restricted in California to areas of relatively high summer precipitation.

This alliance is more resistant to grazing and fire than the *Pleuraphis rigida* Alliance. Compared to *Pleuraphis rigida*, this species has a lower growth habit and is more strongly rhizomatous, often forming an open turf or sod. It has the reputation in some parts of its range as being tolerant of heavy grazing. It is a better soil stabilizer than *Pleuraphis rigida* due to its rhizomatous nature. Some evidence suggests that in drier parts of its range (north-central Arizona), it is not as tolerant of grazing, and increased grazing pressure can reduce its distribution (FEIS 2001). This is likely to be the case in California. *Pleuraphis jamesii* regenerates primarily through rhizome expansion. *Pleuraphis jamesii* resprouts from rhizomes following fire. Reestablishment is usually completed within 2 years. In some parts of its range, with repeat burns, *Pleuraphis jamesii* Herbaceous Alliance may spread at the expense of other shrubs injured by fire. After winter burns conducted when soil moisture was sufficient, it yielded 75 % as much forage the first growing season as the unburned control. It is more susceptible to heat and desiccation during periods of low humidity.

Regional Status:
Mojave Desert: The alliance occurs in the New York Mountains, Lanfair Valley, and the Mid Hills.
Southeastern Great Basin: Stands in the Inyo Mountains are generally small (< 5 ha) and may occur on relatively steep slopes adjacent to valley bottoms associated with *Artemisia tridentata* and *Grayia spinosa* Shrublands and *Yucca brevifolia* Wooded Shrublands. The clonal stands may occur in shallow ravines or swales where soil is slightly better developed and/or moisture is more available. Some stands in the Inyo Mountains ascend to 2,800 m (T. Keeler-Wolf personal communication, Desert Workshop 2000). Stands also occur in the Panamint Mountains and in Deep Springs Valley (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Management Considerations: This is a rare alliance in California and exists here at the limits of its range. All stands should be monitored and managed for long-term persistence. Fire in the California portion of its range is uncommon. The few stands observed have had a history of grazing and contain disturbance-related shrubs and non-native annual grasses including *Bromus tectorum.* The local effects of grazing should be monitored and appropriate action taken, if necessary.

Pluchea sericea Seasonally Flooded Shrubland Alliance

Figure A38. *Pluchea sericea* Seasonally Flooded Shrubland Alliance, Devils Cornfield, Death Valley National Park

Pluchea sericea is the sole or dominant shrub in canopy. *Allenrolfea occidentalis, Atriplex torreyi, Atriplex canescens, Baccharis sergiloides, Baccharis emoryi, Distichlis spicata, Salix exigua, Suaeda moquinii, Schoenoplectus americanus, Tamarix* spp., or

Typha angustifolia may be present. Shrubs < 5 m tall; canopy continuous to open. Ground layer sparse to grassy.

Habitat: Habitats seasonally flooded, saturated. Water chemistry: fresh, mixohaline. Canyon bottoms, irrigation ditches, streamsides, around springs, and seasonally wet flats in basins and playa margins. Cowardin class: Palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Pluchea sericea* as a Facultative Wetland species.

Distribution: Central California Coast Ranges, Great Valley, Southern California Coast, Mojave Desert, Colorado Desert, Sonoran Desert, Arizona, Nevada, New Mexico, Texas, Mexico.

Elevation: -75 to 600 m

NDDB Rank: G4 S3.3

Synonyms:
Holland: Arrowweed scrub (63820)
Barry: G7411211
Cheatham and Haller: Bottomland woodlands and forest
PSW-45: Arrow weed series
Thorne: Riparian woodland
WHR: Desert riparian
Munz: Creosote bush scrub

References: Paysen et al. (1980), Sawyer and Keeler-Wolf (1995), Reid et al. (1999)

Membership Rules: *Pluchea sericea* ≥ 2% cover. No other species with greater or equal cover. Occurs as narrow stringers at alkaline springs and seeps and as rare extensive stands on alkaline flats such as Devil's Golfcourse and Saline Valley.

Comments: *Pluchea sericea* Seasonally Flooded Shrublands often form pure stands. Secondary species, if present, vary regionally. *Pluchea sericea* Seasonally Flooded Shrublands may form a fine mosaic with other wetland alliances. This alliance is widespread in the warm deserts of California. It exists adjacent to many saline/alkaline springs in Death Valley National Park, along the Colorado River, and in the Colorado Desert. It may form dense, small stands adjacent to other wetland alliances such as *Schoenoplectus americanus, Distichlis spicata, Sporobolus airoides, Typha, Prosopis glandulosa, Pluchea pubescens*, and *Salix exigua.* At the Devil's Cornfield in Death Valley National Park and in parts of the Saline Valley, this alliance covers extensive flats and forms open shrublands with wide patches of sparsely vegetated *Distichlis spicata* Intermittently Flooded Herbaceous Alliance beneath the shrubs, over a strongly alkaline soil crust. In such cases, the groundwater is available a few feet below the surface but is rarely present at the surface.

Pluchea sericea Seasonally Flooded Shrublands are strongly tied to moisture and can tolerate relatively saline and alkaline conditions. Two phases exist, Devil's Cornfield type and spring type, and each is clearly affected by different ecological regimes. The Devil's Cornfield type probably establishes under abnormally wet conditions and persists by tapping into the subterranean water supply. Wind-induced deflation and accretion may isolate and build up fine sandy soil mounds around the bases of the shrubs. Competition for water may also limit establishment of *Pluchea sericea* in the interstices between shrubs. These mounds may have lower salinity than the basal soils. The dense narrow switches of *Pluchea sericea* Seasonally Flooded Shrublands stem along permanent springs. Slow-flowing streams have 100 % cover and likely suffer from occasional flooding events or die from fluctuations in the water table. Groundwater pumping may be a problem for persistence in some areas.

Fire effects, age, and asexual reproduction have not been quantified for this alliance. The plant flowers and sets seed over a long season and probably colonizes open moist sites readily from wind-blown seed. Resprouting has been observed (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Regional Status:
Mojave Desert: Stands of both types occur in this region, although the spring type stands (typically < 1 ha in size) are by far the most frequent.

Management Considerations: Groundwater pumping, grazing pressures, *Tamarix* invasion, and other recreational uses of desert springs and riparian area are negatively affecting some stands of this alliance.

Populus fremontii Seasonally Flooded Woodland Alliance

Figure A39. *Populus fremontii* Seasonally Flooded Woodland Alliance, Darwin Falls

Populus fremontii is the sole, dominant, or important tree in canopy. *Acer negundo, Fraxinus latifolia, Juglans californica* and hybrids, *Platanus racemosa, Salix exigua, Salix gooddingii, Salix laevigata, Salix lasiolepis, Salix lucida* ssp. *lasiandra,* or *Salix lutea* may be present. Trees < 25 m tall; canopy continuous or open. Shrubs and *Vitis californica* lianas (woody vines) are infrequent to common. Ground layer variable.

Habitats: Soils temporarily or seasonally flooded, saturated. Water chemistry: fresh. Riparian corridors, flood plains subject to high-intensity flooding. flood plains, low-gradient depositions along rivers, streams, seeps, stream and river banks, and terraces. Cowardin class: Palustrine forested wetland. The National Inventory of Wetland Plants (Reed 1988) lists *Populus fremontii* as a Facultative Wetland species.

Distribution: Central California Coast, Southern California Coast, Klamath Mountains, Northern California Coast Ranges, Northern California Interior Coast Ranges, Sierra Nevada Foothills, Great Valley, Central California Coast Ranges, Southern California Mountains and Valleys, Mojave Desert, Sonoran Desert, Colorado Desert and the western U.S.

Elevation: 0 to 2,400 m

NDDB Rank: G4 S3.2

Synonyms:

Holland: Central Coast cottonwood-sycamore, Southern cottonwood-willow, Great Valley cottonwood, Great Valley mixed, Modoc-Great Basin cottonwood-willow, Mojave, and Sonoran cottonwood-willow riparian forests

Barry: G7411121 BPPFR20.

Cheatham and Haller: Central Valley bottomland, Northern riparian, Southern riparian, Southern alluvial woodlands

PSW-45: Cottonwood series

Rangeland: SRM 203

Thorne: Riparian woodlands

WHR: Valley foothill, Desert riparian

References: Bowler (1989), Capelli and Stanley (1984), Conard and Robichaux (1980), Faber et al. (1989), Griffin and Critchfield (1972), Holstein (1984), MacMahon (1988), McBride (1994), Minckley and Brown (1982), Paysen et al. (1980), Sands (1980); plot-based descriptions are found in Gray and Greaves (1984), Conard and Robichaux (1980), Bahre and Whitlow (1982); Hanes (1976), Zembal (1989), Spolsky (1979), Keeler-Wolf et al. (1998).

Membership Rules: *Populus fremontii* dominates stands (> 50% relative cover in tree layer). The temporary forest and seasonally flooded woodland types are not documented in California. The California associations defined in the deserts apply to the temporarily flooded woodland type, which occurs throughout the southwest U.S.

Comments: *Populus fremontii* Seasonally Flooded Woodland may dominate or mix with other trees in wetland settings. Most stands have been eliminated, reduced in size and extent, or altered greatly, especially in areas amiable to agriculture. Structure and composition of remaining stands are changed as a result of hydrologic alternations, introduction of exotic species, grazing, clearing, cutting for fence posts, fuel and wood projects, and other human impacts.

Populus fremontii is a fast-growing, short-lived tree that is intolerant of shade. Copious wind-dispersed seed are produced in the spring and are viable for up to 5 days. Seeds germinate on moist alluvium and other recently disturbed sites. Seedlings establish in areas where subsurface water is available during the growing season. *Populus fremontii* vegetatively regenerates by root suckers, but seed is the primary mode of reproduction. Trees are damaged by cutting. Trees will resprout after fire if the trees are not old. Extensive riparian stands usually originate from a major disturbance event.

Populus fremontii is browse for livestock and wildlife and supplies cool shady cover for many animals in the summer. The fire interval was probably long in original stands. Those invaded by *Tamarix* species have a shorter fire interval of 10-20 years in Arizona (Ohmart et al. 1977).

Regional Status:
Mojave Desert: The alliance occurs locally with the most extensive stands occurring along the Mojave River.

Management Considerations: Many *Populus fremontii* Seasonally Flooded Woodland stands are extirpated. Natural flooding regimes and reduced water availability through groundwater pumping, livestock use, irrigation schemes, competition from exotics, and direct habitat destruction have taken their toll on this alliance throughout much of its California range.

Prosopis glandulosa Shrubland Alliance

Figure A40. *Prosopis glandulosa* Shrubland Alliance, East of Tecopa

Prosopis glandulosa is the sole canopy shrub or small tree. Trees or shrubs < 10 m tall; canopy continuous or open. *Atriplex canescens, Atriplex polycarpa, Allenrolfea occidentalis, Isocoma acradenia, Rhus ovata, Salix exigua,* or *Suaeda moquinii* may be present.

Habitat: It occurs along rarely flooded margins of arroyos and washes, floodplains, fringes of playa lakes, sand dunes, stream banks, river terraces, surrounding alkali sinks, and washes. Soils intermittently flooded, saturated. Water chemistry: fresh. The National Inventory of Wetland Plants (Reed 1988) lists *Populus glandulosa* var. *torreyana* as a Facultative Upland species.

Distribution: Mojave Desert, Colorado Desert, Sonoran Desert, Southeastern Great Basin Baja California, Arizona, south Nevada, New Mexico, Texas.

Elevation: -75 to 1,100 m

NDDB Rank: G4 S3.2 (some associations may be S2.2 or lower)

Synonyms:
Sawyer and Keeler-Wolf: Mesquite series (Tree dominated, *in part*)
Holland: Mesquite bosque (61820 *in part*), Great Valley mesquite scrub (63420 *in part*)
Barry: G7411121
Brown, Lowe and Pase: 143.112, 143.152, 144.331, 153.131, 154.114, 154.173
Cheatham and Haller: Desert dry wash woodland, Southern alluvial woodland
PSW-45: Mesquite series
Thorne: Desert riparian woodland
WHR: Desert riparian

References: Brown (1982), Bukart (1976), Hilu et al. (1982), MacMahon (1988), Martin (1980), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Sharf et al. (1982), Vasek and Barbour (1977); plot-based descriptions are found in Bradley (1970), Spolsky (1979) and Keeler-Wolf et al. (1998).

Membership Rules: *Prosopis glandulosa* ≥ 2% cover. No other species with greater or equal cover. Trees and/or large shrubs of washes, dunes, or riparian stands.

Comments: *Prosopis glandulosa* is a deciduous, thorny shrub or small tree. The alliance may be composed of broad-crowned trees up to about 10 m in height (river margins), low (about 1 m tall), spreading, multi-stemmed shrubs (sandy, windswept soils, where dunes often form), or shrubs that are somewhat intermediate between these two extremes (springs, playa edges). In contrast to previous classifications, the NVC describes this alliance as a shrubland rather than woodland. This is in keeping with the recent plot descriptions obtained from the Mojave and Colorado deserts and the NVC, which describe all stands from California, Nevada, and western Arizona as dominated by relatively low-shrubby morphs of this variable species. The NVC describes woodland and seasonally flooded woodland alliances of *Prosopis glandulosa* (including both var. *glandulosa* and var. *torreyana*) as occurring in Texas, New Mexico, Arizona and Mexico.

This is a variable alliance in California occurring on dunes and playa edges, adjacent to both fresh and alkaline springs, and along washes and rivers. *Prosopis glandulosa* is a phreatophyte, occupying a number of situations where it has access to permanent undergroundwater. The deep roots of *Prosopis glandulosa* allow it to tap into constant water supplies up to at least 15 m below the surface (FEIS 2001). *Prosopis glandulosa* occurs along the Colorado and Mojave rivers, forming bosque (woodland) communities. It may occur adjacent to other wash or riparian alliances dominated by *Atriplex lentiformis, Atriplex canescens, Parkinsonia florida, Chilopsis linearis, Olneya tesota, Populus fremontii, Tamarix* sp.*, Salix gooddingii* and *Prosopis pubescens*. *Prosopis* *glandulosa* seems to be less flood-tolerant than other riparian species, and often dominates the outer floodplain. It occupies playa edges adjacent to stands of *Allenrolfea occidentalis* and *Atriplex canescens* Shrublands and *Suaeda moquinii* Intermittently Flooded Shrublands. It occurs at alkaline springs adjacent to herbaceous alliances including *Phragmites australis* and *Schoenoplectus americanus* Semipermanently Flooded, *Pluchea sericea* Seasonally Flooded, and *Salix exigua* Temporarily Flooded Shrublands. On dunes, it occurs adjacent to stands of *Abronia villosa* Sparsely Vegetated and *Atriplex canescens* Shrubland Alliances.

Prosopis glandulosa produces abundant seed. Many species of animals from small rodents to birds and ungulates relish the seeds, and dispersal is via animal gut or water. Although the seeds are high in protein, they are largely indigestible, and many pass through large mammals' digestive tracts intact and viable. Either means is effective in scarifying the seed, a treatment necessary for germination. *Prosopis glandulosa* seedlings commonly germinate from rodent caches. Seeds remaining in pods not consumed by animals most likely remain dormant until weathering breaks the seed coat. Seeds may remain viable for > 40 years (FEIS 2001).

In the deserts of southern California, conditions that favor plant establishment may occur only once every 5 to 10 years, following intense rains. Because *Prosopis glandulosa* seeds can remain viable for several years, seeds stored in the soil may germinate following such rains. *Prosopis glandulosa* can resprout if the aboveground portion of the plant is damaged or removed, such as by freezing weather, drought, fire, trampling, browsing, or cutting (FEIS 2001).

Natural disturbance processes in most California stands are related to flooding, shifting sand, and localized fire, particularly at the edge of the Peninsular ranges adjacent to chaparral stands. Groundwater pumping or alterations of the flooding regime have precipitated the decline of numerous stands in the California deserts. Little specific information exists on fire response of *Prosopis glandulosa*. Based on observations from prescribed fires and wildfires, top-kill and mortality of other mesquites (*Prosopis glandulosa* var. *glandulosa*, *Prosopis velutina*) are most influenced by the size of the plant and the intensity of the fire (FEIS 2001). Following a moderate summer fire in Anza-Borrego, *Prosopis glandulosa* shrubs resprouted weakly. Along the lower Colorado River, *Prosopis glandulosa* was reported to recover much slower following fire than *Salix gooddingii* and *Pluchea sericea*. The response of *Prosopis glandulosa* following fire in Joshua Tree National Park was found to vary with fire intensity. In general, it sprouted vigorously following low-intensity winter burns, but when plants were cut and the brush piled over the stumps to achieve a hot burn, plants displayed weak sprouting and poor regrowth (A.M. La Rosa, personal communication).

Frost sensitivity limits the alliance distribution to below 1,100 m in California, and may result in the low, shrubby forms at its extreme northerly and high-elevation occurrences. Fluvial activity along rivers and larger streams causes local site establishment when *Prosopis glandulosa* seeds germinate on bars, but also depletes stands by undercutting and erosion. It is likely that the dune and playa margin clonal stands are very old and only rarely are augmented by seedling recruitment.

Regional Status:
Mojave Desert: Stands on dunes, playa margins, springs, and riparian situations exist throughout the Mojave Desert. The westernmost stands occur in Fremont Valley and are degraded by groundwater pumping. The most extensive riparian stands may be near Tecopa. Several playa margin stands as at Cronese Dry Lakes have been invaded by *Tamarix sp*. Dune stands occur as far north as Mesquite Flat in Death Valley National Park.
Southeastern Great Basin: The northern-most stands of *Prosopis glandulosa* in California occur in the Saline Valley. These are adjacent to alkaline springs with *Phragmites australis, Schoenoplectus americanus* and *Juncus cooperi* dominated alliances on the eastern scarp of the Inyo Mountains and in the salty soil adjacent to the marsh on the west side of Salt Lake. They also occur adjacent to springs in the valley floor with *Salix exigua* Temporarily Flooded and *Prosopis pubescens* Shrublands, and on sand dune hummocks in the valley bottom. These stands are surrounded by *Larrea tridentata-Ambrosia dumosa, Allenrolfea occidentalis,* and *Pluchea sericea* Seasonally Flooded Shrublands.

Management Considerations: The chief use of western honey mesquite wood is for firewood. Some stands in California have been decimated, although cutting in the state is regulated by the native plant protection act. The sweet-tasting pods of *Prosopis glandulosa* are high in protein and sugars and are avidly eaten by most livestock. Livestock often remove the fruits as high on the tree as they can reach and eat fallen pods lying on the ground.

Tamarix ramosissima, and related species, is established along many rivers and desert wetlands of the California. In some areas, it has invaded and replaced *Prosopis glandulosa* Shrubland. Groundwater pumping is a serious threat in many locations.

Prosopis glandulosa Shrublands are one of the most degraded vegetation types in California. They were once much more common, reaching their peak height along the Colorado River. These mesquite shrublands were an early target for firewood cutting and construction materials and were grazed by livestock. More recently, they have been removed to make way for agriculture or construction and damaged, and in some cases eliminated, by falling water tables due to extensive groundwater pumping (D. Bainbridge, personal communication).

Prosopis pubescens Shrubland Alliance

Figure A41. *Prosopis pubescens* Shrubland Alliance, Shoshone

Prosopis pubescens is the dominant or important large shrub in canopy. *Prosopis glandulosa, Baccharis salicifolia, B. emoryi, Isocoma acradenia, Salix exigua, Populus fremontii, Suaeda moquinii, Atriplex canescens, Atriplex polycarpa,* or *Sporobolus airoides* may be present. Large shrubs or small trees < 8 m tall; canopy open to intermittent. Ground layer open to intermittent; may be grassy.

Habitat: Habitat intermittently saturated with shallow water table. Water chemistry: fresh, mixohaline, mixosaline. Cowardin class: palustrine shrubland. The National Inventory of Wetland Plants (Reed 1988) list *Prosopis pubescens* as a Facultative Wetland species.

Distribution: Mojave Desert, Southeastern Basin and Range, Colorado Desert, Nevada, Arizona, New Mexico, Texas, Mexico.

Elevation: 0 to 800 m

NDDB Rank: G3 S2.2

Synonyms:
Sawyer and Keeler-Wolf (1995): Mesquite series (Tree dominated, *in part*)
Holland types: Mesquite bosque (61820 *in part*)
Barry: G7411121
Brown, Lowe and Pase: 143.112, 143.152, 144.331, 153.131, 154.114, 154.173

Cheatham and Haller: Desert dry wash woodland, Southern alluvial woodland
PSW-45: Mesquite series
Thorne: Desert riparian woodland
WHR: Desert riparian

References: Brown (1982), Bukart (1976), Hilu et al. (1982), Holland (1986) MacMahon (1988), Martin (1980), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Sharf et al. (1982), Vasek and Barbour (1977).

Membership Rules: *Prosopis pubescens* ≥ 2% cover. No other species of tree or tall shrub with greater or equal cover.

Comments: *Prosopis pubescens* is a deciduous, thorny, arborescent shrub or small tree. *Prosopis pubescens* Shrubland typically is restricted to riparian settings more than *Prosopis glandulosa* Shrubland, occurring around springs, desert streams and rivers, and not around dunes and playas. In California, this alliance is relatively rare, with individuals of the species occurring within stands of other alliances far more commonly than forming a distinct alliance. The most extensive stands known are in the Amargosa River Drainage between Shoshone and Tecopa. There they form open low woodlands in several broken stands surrounded by *Suaeda moquinii* Intermittently Flooded Shrubland, *Atriplex canescens* Shrubland, *Sporobolus airoides* Intermittently Flooded Shrubland or *Distichlis spicata* Intermittently Flooded Herbaceous. Other small stands occur in the Saline Valley, Death Valley and in Anza Borrego. Stands that were more extensive once existed along the lower Colorado River. However, many of these have been cleared or supplanted by *Tamarix* spp. stands (Holland 1986).

Prosopis pubescens Shrubland are associated with riparian settings like river terraces (Colorado River, Amargosa River) or in moist soil adjacent to springs. Although *Prosopis pubescens* has a deep root system similar to *Prosopis glandulosa*, *Prosopis pubescens* is usually more closely associated with shallow water tables and with fresh water sources. Disturbance events are typically intermittent and sporadic floods. The species produces abundant seed in characteristically twisted "screwbean pods". Seeds are scarified by flooding events or by passing through animal guts (FEIS 2001). Seeds require some cover by soil for survival.

Fires in *Tamarix* species-dominated stands along the Colorado River have produced an overall reduction in *Prosopis pubescens* and an increase in Tamarix (FEIS 2001). Vogl and McHargue (1966) reported that the species resprouts weakly in the Coachella Valley.

Regional Status: No information available.

Management Considerations: The alliance is rare in California and is restricted to relatively sensitive habitats that have been degraded in part by woodcutting and by invasion of *Tamarix* spp. Further sampling and monitoring of stands is needed to describe variation and trends.

Prunus fasciculata Intermittently Flooded Shrubland Alliance

Figure A42. *Prunus fasciculata* Intermittently Flooded Shrubland Alliance, Black Canyon (with scattered *Chilopsis linearis*, both plants dormant)

Prunus fasciculata is the sole or dominant shrub in canopy. *Achnatherum speciosum, Atriplex confertifolia, Ephedra nevadensis, Eriogonum fasciculatum, Grayia spinosa, Hymenoclea salsola, Krascheninnikovia lanata, Larrea tridentata*, *Lycium andersonii, Salvia dorrii*, *Thamnosma montana* or *Viguiera reticulata* may be present. Emergent *Acacia greggii, Juniperus osteosperma, J. californica, Pinus monophylla* or *Yucca brevifolia* may be present. Shrubs < 3 m tall; canopy continuous, intermittent, or open. Ground layer sparse.

Habitat: The alliance occurs on alluvial fans and bajadas, and intermittently flooded washes, arroyos and canyons in desert mountains. Soils alluvial, may be disturbed.

Distribution: Mojave Desert, Arizona

Elevation: 1,300 to 1,880 m

NDDB Rank: G3 S3.3

Synonyms:
Holland: Mojave mixed woody scrub (34210)
Cheatham and Haller

Munz: Creosote bush scrub, Shadscale scrub
WHR: Desert scrub

References: Beatley (1976) Evens (2000); plot-based descriptions are found in Evens (2000)

Membership Rules: *Prunus fasciculata* ≥ 2% cover. Must be ≥ 25% of total cover. *Gutierrezia sarothrae* may have higher cover. If *Prunus fasciculata* co-occurs with other tall shrubs such as *Acacia greggii*, it must have twice the cover of other species to make alliance definition. Typically of washes, but may occur on wash terraces and valleys.

Comments: *Prunus fasciculata* is a common, large shrub of wash margins in the upper Mojave Desert. It occurs as the highest elevation component of the wash continuum in the Mojave Desert. Thus, this alliance receives higher precipitation and cooler temperatures than other wash vegetation. It is characterized by the dominance of *Prunus fasciculata* but is most frequently mixed with several other shrubs.

Small stands of this alliance occur in canyons, arroyos, washes, and on disturbed upland sites (disturbed by livestock or OHV activity). The life-history attributes of *Prunus fasciculata* are not well known.

Regional Status:
Mojave Desert: Stands occur throughout the northern, eastern, southern, and central Mojave Desert. Most are in canyons and arroyos well up into the desert mountains (Evens 2000). Some stands occur on bedrock on the lower third of slopes above canyon bottoms, some in valleys or wash terraces with disturbance.

Management Considerations: More information is needed on the role these stands play in the upper Mojave Desert.

Psorothamnus spinosus Intermittently Flooded Shrubland Alliance

Figure A43. *Psorothamnus spinosus* Intermittently Flooded Shrubland Alliance

Psorothamnus spinosus is the sole, dominant, or important tall shrub or small tree in canopy. *Parkinsonia florida, Acacia greggii, Chilopsis linearis*, or *Olneya tesota* may be present. Emergent trees may be present over a shrub canopy. *Hymenoclea salsola, Bebbia juncea, Hyptis emoryi, Larrea tridentata, Ambrosia dumosa, Encelia farinosa, Baccharis emoryi, Petalonyx thurberi*, or *Stephanomeria pauciflora* may form sparse to intermittent shrub layer. Shrubs < 3 m tall; intermittent or open canopy. Ground layer sparse; annual herbs or grasses seasonally present.

Habitat: The alliance occurs in washes, intermittent channels, arroyos, and intermittently flooded riverine or palustrine sites. The soils it occurs in are sandy, well drained, moderately acidic to slightly saline.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, south Nevada, west Arizona, Baja California, Sonora.

Elevation: 0 to 900 m

NDDB Rank: G4 S3.3

Synonyms:
Holland: Mojave wash scrub (34250), Mojave Desert Wash Scrub (63700)
Barry: G7411124
Cheatham and Haller: Desert dry wash woodland

Thorne: Desert microphyll woodland
WHR: Desert wash
Munz: Creosote bush scrub

References: Johnson (1976), MacMahon (1988), Paysen et al. (1980), Thorne (1982), Turner and Brown (1982), Vasek and Barbour (1977), Sawyer and Keeler-Wolf (1995); plot-based descriptions are found in Keeler-Wolf et al. (1998)

Membership Rules: *Psorothamnus spinosus* must be at least 2% cover, although smaller shrubs may have up to twice the cover of the *Psorothamnus spinosus*. No other species with greater or equal cover. Occurs in low-elevation washes in southern and central portion of mapping area.

Comments: *Psorothamnus spinosus* Intermittently Flooded Shrubland occurs strictly in washes throughout the hot deserts of California. It is strongly tied to active wash and arroyo channels where flooding is relatively common. Sawyer and Keeler-Wolf (1995) included this alliance within the "blue paloverde-ironwood-smoketree series". Compared to other wash alliances characterized by tall woody shrubs or small trees, *Psorothamnus spinosus* occurs in the most active channels, prefers sandy, not bouldery or cobble substrates, and stands are relatively short-lived. It occurs farther north into the Mojave Desert (vicinity of Baker and the Cady Mountains.) and ascends to higher elevations (more cold-tolerant) than *Olneya* or *Parkinsonia* dominated alliances. This alliance in many cases occurs as part of a matrix with other shrub and small tree alliances comprising a patchwork of small stands within a wash system. Compared to *Chilopsis linearis* Intermittently Flooded Shrubland, it is less cold-tolerant and more likely to occupy wash bottoms as opposed to margins.

Psorothamnus spinosus Intermittently Flooded Shrubland is dependent upon intermittent flooding events for stand establishment. It is dominated by a relatively short-lived species with maximum ages probably not over 50 years. Seeds have a hard seed coat that requires scarification to germinate. Even-aged stands are common, although some stands have two or three age classes represented. It is possible that seeds survive for relatively long periods in the substrate and may even out-survive existing plants. Flood intensities are highly variable and range from < 2 cfs to > 10,000 cfs (Waananen and Crippen 1977). Peak discharge in many of the washes at 100 yr flood intervals is < 500 cfs (Waananen and Crippen 1977). It is likely that 25-year peak discharges as low as 16 cfs are adequate to initiate significant stand regeneration. The largest and densest stands occurs primarily on sand or small gravel within channels of a wash, suggesting that minor flooding is responsible for establishment of the denser stands in most cases. Resprouting is evident after mechanical damage.

Regional Status:
Mojave Desert: The alliance occurs along mostly moderate-sized washes in Pahrump, Silurian, Lanfair, and Piute Valleys. It is a warm-season rain species and consequently

does not occur in the western Mojave Desert (T. Keeler-Wolf personal communication, Desert Workshop 2000). It reaches elevations of over 800 m (upper Sleeping Beauty Wash). Associated alliances are *Hymenoclea salsola, Ericameria paniculata, Acacia greggii,* and *Chilopsis linearis* Intermittently Flooded Shrublands.

Management Considerations: *Psorothamnus spinosus* Intermittently Flooded Shrubland is a flood-related alliance that is relatively insensitive to human-mediated changes. For example, it occurs in many parts of the Sonoran Desert along modified channels adjacent to highways. A relatively frequent uninterrupted flooding regime is required and big wash systems are needed to represent this alliance over long-term in conservation planning. Intensive human use of washes (OHV and gravel mining) is detrimental to stands of the alliance.

Purshia stansburiana Shrubland Alliance

Figure A44. *Purshia stansburiana* Shrubland Alliance, Clark Range

Purshia stansburiana is the dominant or important shrub in the canopy. *Agave utahensis, Artemisia nova, Ephedra viridis, Mortonia utahensis, Achnatherum speciosum, Prunus fasciculata, Thamnosma montana, Salvia mohavensis, Opuntia chlorotica* or *Yucca baccata* may be present. Emergent *Pinus monophylla* and *Juniperus osteosperma* may be present. Shrubs < 5 m; cover open. Ground layer sparse.

Habitat: The alliance occurs on steep slopes, cliffs, and hills, canyons and edges of intermittent watercourses. It occurs on soils that are well drained, shallow, rocky, rapidly permeable, and usually calcareous.

Distribution: Northern and eastern southern California Mountains, Mojave Desert, Southeastern Great Basin, Arizona, Utah.

Elevation: 1,000 to 2,100 m

NDDB Rank: G3 S3.2

Synonyms:
Holland: Great Basin mixed scrub, Big sagebrush, Sagebrush steppe
Barry: G74
Brown, Lowe and Pase: 132.15
Cheatham and Haller: Great Basin sagebrush
Rangeland: SRM 210
Thorne: Great Basin sagebrush scrub
WHR: Sagebrush
Munz: Sagebrush scrub

References: Reid et al. (1999), FEIS (2001)

Membership Rules: *Purshia stansburiana* ≥ 2% cover, no other single species with greater cover. Tends to occur in eastern Mojave Desert limestone mountains in washes in the pinyon and juniper belt.

Comments: In California, *Purshia stansburiana* Shrubland appears restricted to the mountains of the eastern Mojave Desert and adjacent Southeastern Great Basin. There it occurs in scattered stands often adjacent to *Pinus monophylla- (Juniperus osteosperma)* Woodland and *Purshia tridentata* or *Artemisia tridentata* Shrublands. Some stands of this alliance may have scattered trees. Most stands are on relatively steep slopes with either southerly or westerly exposures. Cover in the few stands sampled in California is low, averaging between 3 and 14% for all species. Virtually all stands observed occur on limestone or marble. Stands are usually relatively small, resulting from slope breaks and substrate changes.

Purshia stansburiana is a relatively long-lived shrub that typically reproduces by seed. According to FEIS (2001), it has varying ability to resprout that may vary geographically. In California, it is not considered a resprouter and is usually killed after fire. In other parts of its range (e.g., Utah) smaller to mid-size individuals usually resprout weakly, while arborescent individuals with a single large trunk tend to be killed by fire. Fire in the rocky, sparsely vegetated stands in California is probably very rare. Disturbance from flooding events is likely for the canyon bottom stands. Recruitment in some parts of its range is sporadic and limited (Reid et al. 1999).

Regional Status:
Mojave Desert: *Purshia stansburiana* Shrubland is locally present in stands occurring in the Clark, New York, and Providence mountains.
Southeastern Great Basin: The alliance probably occurs in the Inyo, White, Panamint, and Last Chance ranges.

Management Considerations: This alliance is rare and local in California.

Purshia tridentata Shrubland Alliance

Figure A45. *Purshia tridentata* Shrubland Alliance

Purshia tridentata is the sole, dominant, or important shrub with *Artemisia tridentata* or *Ericameria nauseosa* in canopy. *Cercocarpus ledifolius*, *Chrysothamnus viscidiflorus, Ephedra viridis*, *Prunus andersonii* and/or *Tetradymia canescens* may be present. Emergent junipers, pines, or *Yucca brevifolia* may be present. Shrubs < 5 m tall; cover continuous, intermittent or open. Ground layer sparse or grassy.

Habitat: The alliance occurs on slopes and flats. It occurs on soils that are well drained and rapidly permeable.

Distribution: Klamath Mountains, Southern Cascades, subalpine Sierra Nevada, Modoc Plateau, northern and eastern Southern California Mountains and Valleys, Mojave Desert, Mono, Southeastern Great Basin, Northwestern Basin and Range, Nevada, Idaho.

Elevation: 1,000 to 3,400 m

NDDB Rank: G4 S3.2

Synonyms:
Holland: Great Basin mixed scrub, Big sagebrush, Sagebrush steppe
Barry: G74
Brown, Lowe and Pase: 132.15
Cheatham and Haller: Great Basin sagebrush
Rangeland: SRM 210
Thorne: Great Basin sagebrush scrub
WHR: Sagebrush
Munz: Sagebrush scrub

References: Neal (1994), Nord (1965), Young et al. (1977)

Membership Rules: *Purshia tridentata* ≥ 2% cover. If *Artemisia tridentata* or *Ephedra viridis* are present, they have less than 1% cover. Most stands in California have at least some *Artemisia tridentata* and usually some *Ericameria nauseosa*. A local type in high eastern and northern portions of mapping area**.**

Comments: Some stands of *Purshia tridentata* Shrubland may have scattered trees. The dominant species, *Purshia tridentata,* may be a component of other shrub alliances (see *Artemisia tridentata* and *Ericameria nauseosa* Shrubland). *Purshia tridentata* is also an important understory shrub in open woodland and forest alliances in transmontane California.

In *The Jepson Manual* (Hickman 1993), *Purshia tridentata* includes two varieties that are treated as species in many manuals. *Purshia tridentata* var. *glandulosa* and *Purshia tridentata* var. *tridentata* are generally differentiated by range, but both grow in the Southeastern Great Basin. Both varieties are included in *Purshia tridentata* Shrubland.

The dominant subspecies, *Purshia tridentata* var. *tridentata,* is a long-lived (125 years), deep-rooted shrub that varies greatly in habit and local ecotype response. An erect form tends to grow at lower elevations than a decumbent form that is more common at moister, higher ones. It establishes easily on disturbed sites that have some plant cover. Ants and birds, can carry cleaned and cached seeds, and rodents can carry seeds up to 350 m from source shrubs. Seedling establishment is sporadic and episodic, occurring in years of heavy seed crop, moderate rodent populations, sufficiently cold winters to promote seed ripening, and favorable spring and summer moisture and temperature conditions. Many stands tend to be all one age.

Purshia tridentata var. *tridentata* is important browse for livestock in the spring and wildlife in the winter. It is often killed by fire. It regenerates after fire by resprouting or by seedlings from cached seed. The erect form resprouts from buds just above the root collar; the decumbent from resprouts from buds just above the root collar or buds along layered branches. Young shrubs, less than 5-years old, and those over 60 years do not resprout as well as mid-aged, vigorously growing ones. Fires that reduce duff, litter, and competitive plants in years of favorable conditions are associated with high seedling establishment.

The other dominant subspecies, *Purshia tridentata* var. *glandulosa,* is also a long-lived, deep-rooted shrub, varying in habit and in local ecotype response. It establishes in the same manner as *Purshia tridentata* var. *tridentata* but grows in drier environments.

Purshia tridentata var. *glandulosa* is important browse, especially in the winter for mule deer. It is not easily killed by fire, readily resprouts after fire, and can persist with recurring fire. It regenerates after fire by resprouting from roots or buds just about the root collar, along upright and layered branches or by seedlings from cached seed.

Regional Status:
Mojave Desert: In the Mojave Desert the alliance is not common and generally restricted to granitic and metamorphic substrates in the eastern mountains.
Southeastern Great Basin: The alliance is found in the northern areas**.**

Management Considerations: This alliance is on the decline in much of its California range due to an altered fire regime (intervals have become too frequent and stands have been converted to *Ericameria nauseosa*, *Bromus tectorum* or *Taeniatherum caput-medusae*). Long-term intensive grazing has also reduced the vigor and reproductive capacity of some stands. Stands of this alliance are extremely important rangelands for livestock and for deer due to the palatability of *Purshia tridentata.* Thus, conservation management is economically and ecologically important.

Quercus turbinella Shrubland Alliance

Figure A46. *Quercus turbinella* Shrubland Alliance

Quercus turbinella is the sole or important shrub or small tree in canopy. *Pinus monophylla* may be an emergent or small tree with near equal cover. *Fallugia paradoxa, Eriogonum wrightii, Galium munzii, Rhus trilobata, Artemisia ludoviciana, Gutierrezia sarothrae, Elymus elymoides,* or *Yucca baccata* may be present. Shrubs or small trees < 6 m tall; canopy intermittent to dense. Ground layer is open and includes native grasses such as *Poa fendleriana, Agrostis viridis*, and *Elymus elymoides*.

Habitat: The alliance occurs in intermittently flooded canyons in desert mountains on alluvial soils derived from granitic substrates (coarse- to medium- textured sand).

Distribution: Mojave Desert, Arizona, Nevada, Utah, New Mexico, Texas, Mexico.

Elevation: 1,200 to 2,000 m

NDDB Rank: G4 S1.3 (both California associations are rare and local in the eastern Mojave Desert)

Synonyms:
Holland types: Mojave Pinyon Pine Woodland (72210)
Cheatham and Haller types: Pinyon-Juniper Woodland
CALVEG: Pinyon Pine Series

Munz: Pinyon-Juniper Woodland

References: Evens (2000), Reid et al. (1999); plot-based descriptions are found in Evens (2000)

Membership Rules: Vegetation characterized by the scrub oak *Quercus turbinella*. Occurs in New York Mountains and perhaps Clark Mountains. *Quercus turbinella* is the dominant shrub or canopy tree ranging from 5-20% (Evens 2000). It may only slightly dominate over *Pinus monophylla* in some stands.

Comments: Some confusion in the past existed about the identity of desert scrub oaks along the western edge of the Mojave Desert and in the inner south coast ranges of California. These taxa were once called *Quercus turbinella*. Now these are considered *Quercus john-tuckeri, Quercus cornelius-mulleri,* or hybrids between several other scrub or tree oaks (Hickman 1993). *Quercus turbinella* Shrubland is rare in California. The alliance is common on the Mogollon Rim and in other parts of the Colorado Plateau (Reid et al. 1999) but in California, it has been observed only in the New York Mountains. In the New York Mountains, it occurs as a semi-riparian alliance along upper canyon watercourses within *Pinus monophylla - (Juniperus osteosperma)* Woodland. Evens (2000) discusses the *Quercus turbinella* Shrublands in the New York Mountains, where stands occur in steep-walled-canyon watercourses and slopes of decomposed granite with boulders and smoother bedrock surfaces.

The *Quercus turbinella* Shrubland in Arizona and New Mexico is a fire-type, which is adapted to fires by the ability to resprout vigorously from the basal root crown (Reid et al. 1999 and FEIS 2001). However, fire in the stands in the New York Mountains is probably rare. The size and arborescent life form of many of the individuals in these stands suggests that fire has not been a component for perhaps greater than 100 yrs. Flooding has initiated stem breakage and resprouting of some of the canyon bottom stands.

Regional Status:
Mojave Desert: New York Mountains

Management Considerations: This alliance and the two associations known from California are rare and localized.

Quercus chrysolepis Forest Alliance

Figure A47. *Quercus chrysolepis* Forest Alliance

Quercus chrysolepis is the sole, dominant, or important tree with *Arbutus menziesii, Lithocarpus densiflorus, Pinus lambertiana,* or *Quercus garryana* in the tree canopy. *Abies concolor, Acer macrophyllum, Calocedrus decurrens, Pinus coulteri, Pinus monophylla, Pinus ponderosa, Pseudotsuga menziesii, Pseudotsuga macrocarpa, Quercus kelloggii,* and/or *Umbellularia californica* may be present. Trees < 30 m tall; canopy continuous, may be one- or two-tiered. Shrubs are infrequent. Ground layer is sparse or absent.

Habitat: This alliance occurs on all aspects, raised stream benches and terraces, and may occur in canyon bottoms near streams. It occurs on shallow, well-drained soils. The National Inventory of Wetland Plants (Reed 1988) does not list *Quercus chrysolepis*.

Distribution: Northern California Coast, Northern California Interior Coast Ranges, Central California Coastal Ranges, Klamath Mountains, Klamath River, Southern Cascades, Sierra Nevada, Southern California Mountains and Valleys, Mojave Desert, Baja California.

Elevation: 450 to 2,000 m

NDDB Rank: G5 S5. Some associations rare, including those in Mojave Desert

Synonyms:
Holland types: Canyon live oak forest, Canyon live oak ravine forest
Barry: G74 G7411111 CQUCH20
PSW-45: Canyon live oak series
Thorne: Northern mixed evergreen forest
WHR: Montane hardwood

References: Barbour (1988), Borchert and Hibberd (1984), Cooper (1922), Griffin and Critchfield (1972); Mallory (1980), McDonald et al. (1983), Minnich (1976, 1980), Myatt (1980), Paysen et al. (1980), Pavlik et al. (1991), Shreve (1927), Thornburgh (1990); plot-based descriptions are found in Gray (1978), Gudmonds and Barbour (1987), Sawyer and Stillman (1978) in Keeler-Wolf (1990b), Sawyer and Stillman (1977) in Keeler-Wolf (1990b), Taylor and Randall (1977) in Keeler-Wolf (1990b), Meier (1979) in Keeler-Wolf (1990b), Minnich (1980), Myatt (1980), White and Sawyer (1995), Keeler-Wolf (1988) in Keeler-Wolf (1990b), Gordon and White (1994), Evens (2000), Keeler-Wolf (1990b), Keeler-Wolf (1990), Keeler-Wolf (1992), Keeler-Wolf (1991), Keeler-Wolf (1990b), Minnich (1976), Evens (2000).

Membership Rules: Vegetation characterized by the relative dominance of *Quercus chrysolepis* (Canyon Live Oak) in the tree layer. Represented in the study area only by the rare canyon bottom stands in the higher eastern Mojave Desert such as Caruthers Canyon.

Comments: The dominant species, *Quercus chrysolepis,* is common in many alliances in the state. In the *Quercus chrysolepis* Forest, species other than *Pinus lambertiana* may occur but with low cover. If the conifer component is important, then the stand is assigned to a different forest alliance characterized by the dominant conifer species, or if the stand is composed of shrubs of *Quercus chrysolepis,* then it is assigned to a shrub alliance. Stands in the Mojave Desert are restricted to upper montane canyons and are usually surrounded by *Pinus monophylla – (Juniperus osteosperma*) Woodland.

Regional Status:
Mojave Desert: Only known from a few canyons in the eastern Mojave Desert above 1,400 m. Stands are generally well protected from fire in steep bouldery canyon bottoms and probably have lower fire frequency than the surrounding *Pinus monophylla - (Juniperus osteosperma)* Woodland.

Management Considerations: The *Quercus chrysolepis/Rhamnus illicifolia* association of this alliance is rare in California and probably covers less than 1,000 acres.

Salazaria mexicana Shrubland Alliance

Figure A48. *Salazaria mexicana* Shrubland Alliance, Panamint Mountains

Salazaria mexicana is the sole or dominant shrub in canopy. *Achnatherum speciosum, Atriplex confertifolia, Ephedra nevadensis, Eriogonum fasciculatum, Grayia spinosa, Hymenoclea salsola, Krascheninnikovia lanata, Larrea tridentata*, *Lycium andersonii, Mirabilis bigelovii, Salvia dorrii*, *Thamnosma montana* or *Viguiera reticulata* may be present. Emergent *Acacia greggii* and *Yucca brevifolia* may be present. Shrubs < 3 m tall; canopy continuous, intermittent, or open. Ground layer sparse.

Habitat: The alliance occurs on slopes, hills, alluvial fans, bajadas, and intermittently flooded washes and arroyos. It occurs on colluvial and alluvial soils that may be disturbed.

Distribution: Mojave Desert, Arizona

Elevation: 875 to 1,680 m

NDDB Rank: G3 S3.3

Synonyms:
Holland: Mojave mixed woody scrub (34210)
Munz: Creosote bush scrub, Shadscale scrub
WHR: Desert scrub

References: Beatley (1976)

Membership Rules: *Salazaria mexicana* ≥ 2% cover. Other shrubs, if present, are each less than half the cover of *Salazaria mexicana* with the exception of *Salvia dorrii,* which may have higher cover.

Comments: We defined *Salazaria mexicana* Shrubland based on analysis of 15 stands collected as part of this project. It appears to be local and largely disturbance-related. It is characterized by the dominance of *Salazaria mexicana*, but most frequently is mixed with several other shrubs. The dominant species, *Salazaria mexicana,* also occurs in many mid- and upper-elevation Mojave Desert alliances: *Juniperus osteosperma* and *Yucca brevifolia* Wooded Shrublands and *Eriogonum fasciculatum, Ephedra nevadensis, Larrea tridentata-Ambrosia dumosa, Coleogyne ramosissima, Hymenoclea salsola,* and *Yucca schidigera* Shrublands.

Small stands of this alliance occur in washes and on disturbed upland sites (disturbed by livestock or OHV activity). The life-history attributes of *Salazaria mexicana* are not well known. Webb et al. (1988) demonstrate that *Salazaria mexicana* can re-establish ghost town sites readily. It is also common on actively eroding edges of alluvial terraces along with other disturbance related taxa such as *Hymenoclea salsola, Acamptopappus spherocephalus, Eriogonum inflatum,* and *Ephedra nevadensis.*

Regional Status:
Mojave Desert: Stands occur throughout the northern, eastern, southern, and central Mojave Desert. Most are in washes, some on slopes with disturbance. A few exist in rocky southwest-facing areas without evident disturbance.

Management Considerations: More information is needed on the role *Salazaria mexicana* Shrubland plays in the upper Mojave Desert.

Salix (exigua) Temporarily Flooded Shrubland Alliance

Figure A49. *Salix (exigua)* Temporarily Flooded Shrubland Alliance, Mojave River near Victorville

Salix exigua is sole or dominant shrub in the canopy. *Populus fremontii, Baccharis salicifolia, Baccharis sergiloides, Baccharis emoryi, Alnus rhombifolia, Salix lasiolepis, Salix laevigata, Salix lucida,* or *Salix gooddingii* may be present. Emergent trees may be present. Shrubs < 7 m tall; canopy continuous. Ground layer is variable.

Habitat: The alliance occurs in habitats that are temporarily (seasonally) flooded or saturated such as floodplains, depositions along rivers, streams, and springs. Water chemistry: fresh. Cowardin class: Palustrine shrub scrub wetland. The national list of wetland plants lists *Salix exigua* as an Obligate Upland species.

Distribution: Central California Coast, Southern California Coast, Great Valley, Northern California Coast, Northern California Coast Ranges, Northern California Inner Coast Ranges, Sierra Nevada, Sierra Nevada Foothills, Central California Coast Range, Southern California Mountains and Valleys, Mojave Desert, Sonoran Desert, Colorado Desert, western North America.

Elevation: 0 to 2,700 m

NDDB Rank: G5 S3.2

Synonyms:

Holland: North coast riparian scrub, Central coast riparian scrub, Great Valley riparian scrub, Southern willow scrub, Mojave Desert riparian forest, Sonoran cottonwood-willow riparian forest, Modoc-Great Basin cottonwood-willow riparian forest, Southern cottonwood-willow riparian forest, Great Valley cottonwood riparian forest
Barry: G7411221
Cheatham and Haller: Bottomland woodlands and forests
PSW-45: Willow series
Thorne: Riparian woodland
WHR: Desert riparian, Coastal and Valley riparian

References: Bowler (1989), Brayshaw (1976), FEIS (2001), Holstein (1984), Paysen et al. (1980), Reid et al. (1999); plot-based descriptions are found in Evens (2000).

Membership Rules: *Salix exigua* dominates stands (> 50% relative cover in tree layer). Evens (2000) *Salix exigua* is dominant canopy species with cover ≥ 5%.

Comments: The *Salix exigua* Temporarily Flooded Shrubland is widespread and common throughout most of California. Genetic variations are likely and were responsible for prior separation of taxa such as " *Salix hindsiana*" (Hickman 1993). These shrubby willow thickets are common along rivers, streams and seeps in may ecological settings. There is great variation in the understory and shrub composition ranging from eastern Sierra mountain meadow stands to Mojave and Colorado desert oasis stands. Stands are often clonal with above-ground stems spreading by lateral roots with adventitious buds. The alliance often occurs as dense stands adjacent to other riparian/wetland vegetation.

The dominant species, *Salix exigua,* is a prolific seeder and can colonize isolated moist, sandy, or gravelly substrates via wind-dispersed seeds. The species spreads clonally via lateral roots and can spread across banks of rivers and streams rapidly (FEIS 2001). Individual stems rarely reach more than 6 cm diameter breast height (DBH) and 8 m in height. Hence, a stand usually develops into a network of dense small stems if water is regularly available through a series of growing seasons. *Salix exigua* can sprout readily following fire and will rapidly colonize burned riparian stands. *Salix exigua* clones probably do not live much longer than 50 years, and an average clonal stem is usually only 3-4 years old (FEIS 2001).

The standard view (e.g., Holland 1986, Sands 1980) of the stands along the Sacramento and other major California rivers is that this alliance is often the first to colonize point bars and cut banks, followed by *Populus fremontii* and other taller, longer-lived species. Rivers with flood control dams in place may have reduced acreage of *Salix exigua* stands and attained increases of stands of longer-lived tree willows such as *Salix lucida, Salix laevigata* and *Salix gooddingii*.

Regional Status: No information available.

Management Considerations: Because the alliance is so widespread, it is an integral part of riparian systems throughout most of the state. Its colonizing and stabilizing characteristics make it an important member in the riparian disturbance cycle, and reduced flooding regularity has diminished its representation along some rivers and streams.

Salvia dorrii Dwarf-shrubland Alliance

No photograph is available.

Salvia dorrii is dominant in low shrub canopy. *Coleogyne ramosissima, Ericameria cooperi, Heliomeris multiflora, Castilleja angustifolia, Rhus trilobata*, or *Yucca baccata*, may be present. *Chilopsis linearis*, *Fallugia paradoxa, Prunus fasciculata,* or *Purshia stansburiana* may occur as emergent tall shrubs. *Pinus monophylla* may be an emergent tree. Shrubs < 2 m tall; canopy cover intermittent.

Habitat: The alliance occurs in intermittently flooded upper arroyos and canyons in desert mountains. It occurs in coarse, alluvial soils derived from calcareous substrates.

Distribution: Mojave Desert, Arizona

Elevation: 1,200 to 1,800 m

NDDB Rank: G3 S2.3

Synonyms:
Holland: Mojave mixed woody scrub (34210)
Munz: Pinyon-juniper woodland
Thorne: Pinyon-juniper
WHR: Desert scrub

References: Evens (2000), Reid et al. (1999); plot-based descriptions are found in Evens (2000).

Membership Rules: Evens (2000) *Salvia dorrii* is the dominant canopy subshrub averaging 7% cover.

Comments: The dominant species**,** *Salvia dorrii,* is a common shrub of the cooler western deserts. However, in California it is usually only a component of other alliances such as *Artemisia tridentata, Yucca schidigera, Juniperus osteosperma, Pinus monophylla, Salazaria mexicana*, and *Eriogonum fasciculatum* dominated alliances. It ranges to the edge of the deserts on calcareous substrates (e.g., Southern Sierra Nevada, Paiute Range, Keeler-Wolf 1989). Before recent work by Evens (2000) in the mountains of the eastern Mojave Desert, *Salvia dorrii* Dwarf-shrubland was not known from the state, but was known from eastern Oregon (Reid et al.1999). There it occurs on volcanic tablelands on shallow rock soil. In California, it is only known from rocky limestone alluvium in arroyos and canyons in the Providence and Clark mountains. There it occupies intermittently flooded washes and wash terraces and occurs adjacent to *Chilopsis linearis* and *Prunus fasciculata* Intermittently Flooded Shrublands within a surrounding matrix of upland alliances including *Pinus monophylla- (Juniperus osteosperma*) Woodland*, Juniperus osteosperma* Wooded Shrubland, and *Purshia tridentata* Shrubland.

Small stands of this alliance occur in canyons and arroyos. Stands are restricted to calcareous substrates that are subjected to intermittent flooding disturbance. The presence of *Salvia dorrii* in other alliance stands that have been subject to grazing, and fire suggests that the species is tolerant of some disturbance. However, the presence of *Coleogyne ramosissima* as an indicator (Evens 2000) in the eastern Mojave Desert stands suggests that disturbance is relatively infrequent (Webb et al. 1988).

Regional Status:
Mojave Desert: Stands have been studied only in the northeastern Mojave Desert. Most are in canyons and arroyos well up into the Clark Mountains (Evens 2000).

Management Considerations: More information is needed on the of role of *Salvia dorrii* Dwarf-shrubland in the upper Mojave Desert.

Sarcobatus vermiculatus Shrubland Alliance

No photograph is available.

Sarcobatus vermiculatus is the sole or dominant shrub in canopy. *Allenrolfea occidentalis, Artemisia tridentata, Atriplex canescens, Atriplex confertifolia, Atriplex spinifera, Ericameria nauseosa, Chrysothamnus viscidiflorus*, *Frankenia salina, Kochia californica,* or *Suaeda moquinii* may be present. Shrubs < 3 m tall; canopy continuous or open. Ground layer variable and may be grassy.

Habitat: Badlands, plains, old lakebeds perched above current drainages, and stable sand dunes. Wetland habitats such as barrier beaches, dry lakebeds, lagoon bars that are intermittently flooded or saturated. Water chemistry: mixosaline. Cowardin class: Palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Sarcobatus vermiculatus* as a Facultative Upland species.

Distribution: Mojave Desert, Mono, Northwestern Basin and Range, western U.S. and northern Great Plains.
Elevation: 100 to 2,000 m

NDDB Rank: G4 S2.2

Synonyms:
Holland: Desert greasewood scrub, Desert sink scrub
Brown, Lowe and Pase: 152.171, 153.171, 154.171

Cheatham and Haller: Alkali sink scrub, Saltbush scrub
PSW-45: Greasewood series
Rangeland types: SRM 414, SRM 501
Thorne: Alkali sink scrub
WHR: Alkali sink
Munz: Alkali sink

References: Burk (1977), MacMahon (1988), Paysen et al. (1980), Thorne (1982), Vasek and Barbour (1977), Young and Young (1976), West (1988); plot-based descriptions are found in Young et al. (1986), Ferren and Davis (1991)

Membership Rules: *Sarcobatus vermiculatus* (Greasewood) ≥ 2%. *Sarcobatus* is the relative dominant shrub cover and may have *Suaeda moquinii* and *Atriplex* spp. associated in lesser cover. Only known in study area from the alkali dunes and flats above the east shore of Owens Lake.

Comments: This alliance is part of the alkali sink ecological system, which is a collection of alliances including *Allenrolfea occidentalis* Shrubland, *Distichlis spicata* Intermittently Flooded Herbaceous, and/or *Suaeda moquinii* Intermittently Flooded Shrubland. The dominant species of each can occur in all of the alkali sink ecological system, but the alliance in which a stand is classed depends on which species dominates. *Allenrolfea occidentalis* tolerates higher salt concentrations than *Sarcobatus vermiculatus* (MacMahon and Wagner 1985), so the *Sarcobatus vermiculatus* Shrubland Alliance is located further from sink edges where both alliances occur.

The dominant species, *Sarcobatus vermiculatus,* is a long-lived, facultative halophyte that tolerates alkaline and saline soils. This winter deciduous shrub's seeds mature in the fall and fruits dehisce in the winter. Seeds germinate under conditions of warm temperature and long periods of soil moisture. Individual plants and populations respond to different osmotic potentials and salt concentrations, which suggests much ecotype variation within the species. Shrubs will resprout when stems are removed.

Livestock and wildlife browse *Sarcobatus vermiculatus* in the fall and winter and the species may increase in grazed areas. It readily resprouts in low- to moderate-intensity burns. Seeds easily disperse into recently burned areas from unburned shrubs. Many stands are very open and lack continuous fuel. Stands invaded by *Bromus tectorum* easily burn.

Regional Status:
Southwestern Great Basin: Stands of *Sarcobatus vermiculatus* are local at Owens Valley.

Management Considerations: Although widespread in much of the Great Basin, stands of *Sarcobatus vermiculatus* Shrubland are not common in California.

Schoenoplectus americanus Semipermanently Flooded Herbaceous Alliance

Figure A50. *Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance, Soda Lake

Schoenoplectus americanus is the sole, dominant, or important tall graminoid. *Anemopsis californica, Potentilla anserina, Distichlis spicata, Juncus cooperi, Juncus balticus, Schoenoplectus californicus, Typha* spp., or *Phragmites australis* may be present. Grass < 4 m tall; cover continuous. Dense to intermittent understory of short grasses and herbs may be present.

Habitat: Habitat permanently saturated with shallow water table. Water chemistry: fresh, mixohaline, mixosaline. Cowardin class: palustrine persistent emergent wetland. The national list of wetland plants (Reed 1988) lists *Schoenoplectus americanus* as an Obligate Wetland species.

Distribution: Widespread throughout California, but largely within California Dry Steppe Province, American Semi-desert and Desert Province, and Intermountain Semidesert and Desert Province, throughout much of North America.

Elevation: -45 to 1,500 m

NDDB Rank: G5 S3.2

Synonyms:

Holland: Transmontane alkali marsh (52320), Cismontane alkali marsh (52310), Transmontane freshwater marsh (52420), Coastal and valley freshwater marsh (52410)

Barry: G7412331

Cheatham and Haller: Coastal and valley freshwater marsh, Great Basin freshwater marsh, Valley alkali marsh, Great Basin alkali marsh

Thorne: Alkali meadow, freshwater marsh

WHR: Fresh emergent wetland

Munz: Freshwater marsh

References: Reid et al. (1999)

Membership Rules: Vegetation characterized by the relative dominance of *Schoenoplectus americanus* (Three-square or American Bulrush). Generally in permanently moist alkali springs, meadows, or streamsides. Most stands less than 5 ha in extent.

Comments: *Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance occurs in many wetlands throughout California and the western U.S. The *Schoenoplectus americanus* alliance is most frequently associated with alkali or saline wetlands and may occur from coastal brackish marshes to interior settings adjacent to alkali playas and seeps. Data now exist to support the establishment of this alliance from the San Francisco Bay Delta to the Colorado and Mojave deserts and the Great Basin. In Texas and New Mexico, *Schoenoplectus americanus* is considered the dominant of a freshwater marsh alliance associated with high organic soil content with poor aeration and reduction of salinity (Reid et al.1999). In California desert stands, this alliance typically occupies the center of a small wetland where soil saturation is greatest. Associated with and often surrounding the stands are stands of other alliances that have reduced moisture requirements and are dominated by such species as *Phragmites australis, Juncus cooperi, Juncus balticus, Pluchea sericea, Atriplex spp., Sporobolus airoides* and *Distichlis spicata*. In the Bay Delta Region (Suisun Marsh), *Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance occupies the inner portions of marshes away from the tidally influenced brackish bays and large sloughs. They occur along narrow tidal creeks and in saturated relatively freshwater marshs often adjacent to *Distichlis spicata* Intermittently Flooded Herbaceous patches. In Suisun Marsh, the alliance is habitat for both the rare species *Aster lentus* and *Cirsium hydrophilum* ssp. *hydrophilum.*

Schoenoplectus americanus is rhizomatous and can survive surface fires by resprouting from the underground rhizomes. Seeds are small and are wind-born assisted by capillary bristles. Stands are subject to decimation and degradation by drought and by modified hydrology. Some stands are large enough and sufficiently long-persisting to have produced peat layers. Some peat fires have occurred in fossil stands of this alliance adjacent to desert playas (Koehn Dry Lake) (M. Faul, personal communication).

Regional Status:
Mojave Desert: *Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance occurs in alkaline and freshwater marshes and along creeks throughout the Mojave Desert. In some situations it often shares the marshes with various alliances that segregate based on moisture and alkalinity/salinity tolerances. In general, *Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance occurs in the wettest settings along with *Typha* alliances, and in moister settings than *Phragmites australis* Semipermanently Flooded Herbaceous*, Pluchea sericea* Seasonally Flooded Shrubland*, Juncus cooperi* Seasonally Flooded Herbaceous, *Sporobolus airoides* and *Distichlis spicata* Intermittently Flooded Herbaceous Alliances. Largest stands in the Mojave Desert may be along the Amargosa River between Shoshone and Tecopa.

Management Considerations: *Schoenoplectus americanus* Semipermanently Flooded Herbaceous Alliance can be decimated by grazing (e.g., Owens Lake). The alliance is the most widespread, saturated, fresh-water-emergent wetland alliance of the California deserts and is thus indicative of high quality and important resources for wildlife. If the stand is disturbed, *Tamarix* spp. can invade. Elsewhere, other invasive exotic species have invaded stands. For example, perennial pepperweed (*Lepidium latifolia)* is a threat to the alliance in the Bay-Delta region and can invade and overtake stands of this alliance without apparent physical disturbance.

Sporobolus airoides Intermittently Flooded Herbaceous Alliance

Figure A51. *Sporobolus airoides* Intermittently Flooded Herbaceous Alliance, Travertine Springs

Sporobolus airoides is the sole or dominant grass in the ground layer. *Distichlis spicata* or *Poa secunda* may be present. Emergent *Allenrolfea occidentalis, Atriplex lentiformis, Atriplex canescens,* or *Suaeda moquinii* shrubs may be present. Grass < 1 m tall; cover open.

Habitat: Habitat intermittently flooded or saturated. Water chemistry: saline. Valley bottoms or lower portions of alluvial slopes. Cowardin class: palustrine emergent saline wetland. The national list of wetland plants (Reed 1988) lists *Sporobolus airoides* as a Facultative species.

Distribution: Great Valley, Central California Coast Ranges, Mojave Desert, Mono, Southeastern Great Basin, Northwestern Basin and Range, western U.S.

Elevation: 0 to 2,100 m

NDDB Rank: G4 S2.2

Synonyms:
Holland: Valley sacaton grassland, Alkali meadow
Barry: G7412311 BSPAI00
Cheatham and Haller: Great Basin native grassland
PSW-45: Sacaton series
Thorne: Alkali meadow and aquatic
WHR: Wet meadow
Munz: Alkali sink

References: Bittman (1985), Brown (1982), Griggs (1980), Paysen et al. (1980), Thorne (1982), Werschskull et al. (1984); plot-based descriptions can be found in Ferren and Davis (1991) and Odion et al. (1992).

Membership Rules: Vegetation characterized by the canopy dominance of the bunchgrass *Sporobolus airoides*. Usually of margins of alkali springs and in alkali meadows as at Tecopa, Shoshone, and other sites along the Amargosa River. Most stands well below 5 ha in extent.

Comments: Many regional descriptions include this alliance in an alkali meadow ecological system. *Sporobolus airoides* or other species can dominate meadows of this habitat, so several alliances are included in the alkali meadow ecological system. Stands of *Sporobolus airoides* Intermittently Flooded Herbaceous Alliance form a fine scale mosaic with *Allenrolfea occidentalis, Atriplex canescens*, or *Atriplex lentiformis* Shrublands and with *Distichlis spicata* Intermittently Flooded Herbaceous or *Suaeda moquinii* Intermittently Flooded Shrubland at a coarser scale.

Sporobolus airoides is a tussock-forming grass with loosely clustered, coarse culms (to 1 m) that rapidly burn. It is tolerant of fire and grazing. *Sporobolus airoides* has an extensive range in the western United States including much of California, but the vegetation type is less extensive.

Shrubs have invaded alliance stands in New Mexico where overgrazing has occurred. Stands were extensive in the Tulare Lake Basin but are now greatly reduced by land conversion to agriculture.

Regional Status:
Mojave Desert: Stands are notable in the Amargosa Desert and occasional in playa settings in the northern Mojave Desert such as Mesquite Valley.
Southeastern Great Basin: Stands are expected in Fish Lake Valley and Saline Valley.

Management Considerations: This herbaceous alliance is a rare type in California. Groundwater pumping and invasive exotics threaten the alliance in some areas. A complete inventory of probable occurrences has not been completed.

Suaeda moquinii Intermittently Flooded Shrubland Alliance

Figure A52. *Suaeda moquinii* Intermittently Flooded Shrubland Alliance, near Tecopa

Suaeda moquinii is the sole, dominant, or the most important shrub in overstory. *Frankenia salina, Allenrolfea occidentalis, Atriplex polycarpa, Atriplex canescens, Sarcobatus vermiculatus, Kochia californica,* or *Sporobolus airoides* may be present. Shrubs < 1.5 m tall; canopy open to closed.

Habitat: Lower alluvial fans, bajadas, toe-slopes adjacent to alkaline playas, and other alkaline/saline areas. Wetland habitats intermittently flooded or saturated. Water chemistry: mixosaline. Dry lakebeds, plains, old lakebeds perched above current drainages. Cowardin class: Palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Suaeda moquinii* as a Facultative species.

Distribution: Mojave Desert, Sonoran Desert, Colorado Desert, Northwestern Basin and Range, Great Valley, Central California Coast Ranges, west Canada, Texas, Mexico.

Elevation: 0 to 1,300 m

NDDB Rank: G4 S3.2 (Great Valley associations are particularly rare)

Synonyms:
Holland: Desert sink scrub (36120 *in part*), Desert greasewood scrub (36130 *in part*), Valley sink scrub (36210 *in part*)
Barry: G7412321
Brown, Lowe and Pase: 153.171
Cheatham and Haller: Alkali sink scrub
PSW-45: Suaeda series
Thorne: Alkali sink scrub
WHR: Alkali sink
Munz: Alkali sink scrub
CALVEG: Suaeda series

References: Burk (1977), MacMahon (1988), Payson et al. (1980), Vasek and Barbour (1977), West (1988), Sawyer and Keeler-Wolf (1995); plot-based descriptions are found in Keeler-Wolf et al. (1998) and Bradley (1970).

Membership Rules: *Suaeda moquinii* ≥ 2% cover. No other species with greater or equal cover. Typically occupying strongly alkaline playas usually with distinct salt deposits in soil surface, but may occur in upland areas adjacent to playas (Owens Lake) where wind-blown salts are deposited.

Comments: *Suaeda moquinii* Intermittently Flooded Shrubland is largely restricted to alkaline substrates in desert or semi-desert environments. This alliance and *Allenrolfea occidentalis* and *Sarcobatus vermiculatus* Shrublands commonly occur around margins of and on dry and wet lakes and are often mapped co-jointly as an ecological system.

The alliance dominant, *Suaeda moquinii,* tolerates high salt concentrations. Although *Suaeda moquinii* typically occurs in low-lying areas around playas and basins, it also may range onto adjacent uplands, where it coexists with other desert sub-alkaline vegetation in such alliances as *Atriplex hymenelytra, Atriplex polycarpa*, and *Atriplex confertifolia* Shrublands.

Vegetation cover for the alliance may vary substantially (2 to > 80%). Disturbance effects are poorly known. However, *Suaeda moquinii* alliance appears opportunistic in its environment, occupying roadsides, other recently disturbed areas, bajada slopes, playas, and playa edges. Many plants appear to be short-lived and senesce and die in large groups, suggesting even-age stands, stemming probably from favorable moisture conditions. However, plants have lived to 100 years in Utah (R. Webb, personal communication). General observations (Keeler-Wolf, personal communication) suggest that *Suaeda moquinii* Intermittently Flooded Shrubland tolerates less flooding than *Allenrolfea occidentalis* Shrubland in playas in the Mojave Desert. Seeds are small (Young and Young 1986) and may establish easily following rain. Seeds are probably banked (T. Keeler-Wolf personal communication, Desert Workshop 2000). Seral relationships are simple due to the harsh environment. *Suaeda moquinii* alliance probably directly replaces itself following most disturbances.

Regional Status:
Mojave Desert: *Suaeda moquinii* Intermittently Flooded Shrubland occurs throughout the Mojave Desert but is generally restricted to low-lying alkaline playas and basins.
Southeastern Great Basin: *Suaeda moquinii* Intermittently Flooded Shrubland occurs around Saline Valley, where it occasionally ranges up on the lower bajadas. On the eastern shore of Owens Dry Lake, it ascends the lower bajadas of the Inyo Mountains and mixes with *Atriplex hymenelytra* and *Atriplex confertifolia.*

Management Considerations: *Suaeda moquinii* alliance is simple floristically and structurally. Management issues are direct alteration and disturbances such as evaporite mining and scraping and blading for road construction. In the stands with high cover, response to fire needs to be researched.

Tamarix spp. Semi-Natural Temporarily Flooded Shrubland Alliance

Figure A53. *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance, Carrizo Marsh

Tamarix species is sole or dominant shrub. *Acacia greggii, Atriplex* species*, Hymenoclea salsola, Populus fremontii,* or *Salix* species may be present. Shrubs < 5 m tall. Shrub canopy is continuous or open. Emergent trees may be present. Ground layer is sparse.

Habitat: Habitats intermittently flooded or saturated. Water chemistry: fresh, mixosaline. Arroyo margins, ditches, washes, and watercourses. Cowardin class: temporarily flooded palustrine shrub-scrub wetland. The national list of wetland plants (Reed 1988) lists *Tamarix* species as a Facultative Wetland species.

Distribution: Northern California Interior Coast Ranges, Central California Coast Ranges, Great Valley, Sierra Nevada Foothills, Southern California Coast, Mojave Desert, Sonoran Desert, Colorado Desert, central and western U.S.

Elevation: -75 to 800 m

NDDB Rank: G5 S5 (non native)

Synonyms:
Holland: Tamarisk scrub
Barry: G7411212 BTACH00
Cheatham and Haller: Alluvial woodlands

PSW-45: Salt-cedar series
Thorne: Desert riparian woodland
WHR: Desert riparian

References: Johnson (1987), Neill (1985), MacMahon (1988), Paysen et al. (1980)

Membership Rules: Vegetation dominated by tall shrubby invasive *Tamarix* spp. (either *T. ramosissima, T. chinensis*, or other similar species, not including the less invasive, taller T. *aphylla*). *Tamarix* spp. should strongly dominate (> 60% relative cover) over native tall shrubs and/or low trees in a stand.

Comments: *Tamarix*, commonly known as salt cedar, is an invasive exotic plant species. Five introduced species of *Tamarix* are known to grow in California. *Tamarix parviflora* and *Tamarix ramosissima* are the most common species (Hickman 1993) and are apparently the two most invasive species in California deserts and Central Valley. *Tamarix aphylla*, athel, is a taller tree that typically is not invasive in California; however, it is apparently invasive in Australia (T. Keeler-Wolf personal communication, Desert Workshop 2000).

Tamarix species are long-lived shrubs or trees. Seeds germinate on saturated soil or while afloat and establishing seedlings require moist soil. Once established, the plant resists desiccation. Plants resprout from root crowns, and freshly detached stems will root in moist soil.

Tamarix species are unpalatable for livestock and wildlife. Stands accumulate high fuel levels that readily burn when dry. Plants vigorously resprout after fire, and they increase flowering and seed production after fire. Mixed stands of *Tamarix* and native plants convert to *Tamarix* dominance after fire. *Tamarix* species supplant native plants and reduces water for wildlife. Ohmart et al. (1977) discuss its comparative value for wildlife habitat along the Colorado River.

Regional Status:
Mojave Desert: Tamarix spp. Semi-Natural Temporarily Flooded Shrubland occurs along the Mojave River and as stands or individuals at many springs.

Management Considerations: The impact of the *Tamarix* alliance to groundwater and stream flow is substantial (Reid et al.1999). Stands tend to invade and take over the wettest areas, while intermittently dry streambeds and springs are less likely invaded. The cost of time and labor to remove infestations of Tamarix from riparian and wetland settings is substantial. This involves a cycle of burning and stem poisoning, followed by pulling of young seedlings (T. Keeler-Wolf personal communication, Desert Workshop 2000). Active programs to remove tamarisk are ongoing in California.

Viguiera parishii Shrubland Alliance

Figure A54. *Viguiera parishii* Shrubland Alliance, Joshua Tree National Park

Viguiera parishii is the dominant or important shrub in the canopy. *Agave deserti, Bebbia juncea, Ericameria teretifolia, Ephedra nevadensis, Eriogonum fasciculatum, Encelia farinosa, Ferocactus cylindraceus, Galium stellatum, Gutierrezia microcephala, Krameria grayi, Opuntia acanthocarpa, Pleuraphis rigida, Salazaria mexicana, Salvia dorrii, Simmondsia chinensis,* or *Yucca schidigera* may be present. Shrubs < 2 m tall; canopy intermittent or open. Emergent tall shrubs or trees < 5 m tall such as *Acacia greggii, Fouquieria splendens,* or *Juniperus californica* may be present. Ground cover is open to intermittent. *Achnatherum speciosum, Adenophyllum porophylloides, Bromus madritensis Echinocereus engelmannii, Mirabilis bigelovii,* or *Opuntia basilaris* may be present. Annuals seasonally present.

Habitat: Colluvial slopes and valleys, rocky to bouldery alluvium, steep to moderate slopes, and wash and arroyo margins. Soils well drained and derived from granitic or volcanic rock.

Distribution: Colorado Desert, Mojave Desert, Sonoran Desert, Southern California Mountains and Valleys, Arizona, Nevada.

Elevation: 900 to 1,400 m

NDDB Rank: G4 S4 (some associations may be rare)

Synonyms:
Holland: Sonoran mixed woody scrub (33210 *in part*), Mojavean mixed woody scrub (34210 *in part*)
Cheatham and Haller: Enriched desert scrub
Thorne: Semi-succulent scrub
WHR: Desert succulent scrub (*in part*), Desert scrub (*in part*)

References: CalFlora (2000), Keeler-Wolf et al. (1998); plot-based descriptions are found in Keeler-Wolf et al. (1998).

Membership Rules: *Viguiera parishii* ≥ 2% cover. No other species with greater or equal cover. On northerly slopes in the Mojave Desert generally above *Larrea tridentata-Ambrosia dumosa* or in washes in east Mojave Desert. Keeler-Wolf et al. (1998) defines *Viguiera parishii* with greater than or equal cover to any other single shrub with tall emergent *Juniperus californica, Rhus ovata* or other tall shrubs < 5%.

Comments: The alliance is newly defined following analysis of plot data from the Anza-Borrego Desert State Park vegetation mapping effort (Keeler-Wolf et al.1998) and from the 16 plots obtained in this Mojave Desert Vegetation Mapping project. The alliance is a facultatively deciduous scrub characterized by the shrub *Viguiera parishii*.

Viguiera parishii Shrubland occurs on moderate to steep slopes and some stands occur in washes. The alliance occupies a transitional area between the lower hot Sonoran desert and the higher and cooler Mojave Desert. It appears to be distributed from the desert edges of the Peninsular Ranges north to the borderland between the Sonoran and the Mojave deserts. Species characteristic of this alliance are a mix of upper- and lower-elevation characteristic species. There is some evidence that this alliance is disturbance-related, given species composition and the occurrence of the type in and adjacent to washes. In Anza-Borrego it was one of the largest of the upper desert alliances covering an estimated 26,000 acres (10,236 ha). Although the dominant species is widespread in the southern portion of the California deserts (CalFlora 2000) from sea level to 1,500 m, the alliance is more restricted.

The species *Viguiera parishii* is not treated in the FEIS (2001) database. It may be a relatively short-lived species averaging around 15-20 years (T. Keeler-Wolf personal communication, Desert Workshop 2000). It is a facultatively deciduous species that flowers profusely in good rain years and remains largely dormant and bare of leaves in low-rainfall years. *Viguiera parishii* probably regenerates from seed in seed banks. It is not known whether it resprouts following fire or other disturbance.

In Anza-Borrego, *Viguiera parishii* Shrubland occurs in areas that have sustained fires recently. However, on other parts of its range the alliance has not likely been subjected to fire. Occurrences of the alliance in washes in the eastern Mojave Desert are probably related to fluvial disturbance.

Regional Status:
Little is known of the regional status of this alliance.

Management Considerations: Since this vegetation covers a large area in the Peninsular Range/Colorado Desert borderland, it is important to understand its vegetation dynamics. More monitoring and a better understanding of the stability of this alliance will provide useful management information.

Viguiera reticulata Intermittently Flooded Shrubland Alliance

Figure A55. *Viguiera reticulata* Intermittently Flooded Shrubland Alliance

Viguiera reticulata is dominant or important in canopy. *Ambrosia dumosa, Atriplex confertifolia, Encelia virginensis, Eriogonum fasciculatum, Gutierrezia microcephala, Hymenoclea salsola, Psorothamnus arborescens, Salvia dorrii, Salazaria mexicana, Senecio flaccidus,* or *Stephanomeria pauciflora* may be present. Canopy intermittent to open; short shrubs < 2 m tall. Sparse ground layer.

Habitat: Intermittently flooded arroyos, canyons and washes in desert mountains and on adjacent alluvial fans. Soils are alluvial, with gravel and/or cobble derived from calcareous substrates; texture is medium sand.

Distribution: Mojave Desert, Southeastern Great Basin, Nevada

Elevation: 700 to 1,900 m

NDDB Rank: G3 S3.2

Synonyms:
Holland: Mojave wash scrub (34250), Mojave creosote bush scrub (34100), Sonoran creosote bush scrub (33100)
Munz: Creosote bush scrub, Shadscale scrub, Pinyon-Juniper woodland

References: Reid et al. (1999), Peterson (1984), Evens (2000).

Membership Rules: *Viguiera reticulata* ≥ 2% cover. No other species with greater or equal cover. Of calcareous (mostly limestone) washes and arroyos in mountains in the mid- or upper-elevation eastern Mojave Desert.

Comments: *Viguiera reticulata* Intermittently Flooded Shrubland Alliance occurs on calcareous substrates throughout the mid and upper elevations of the eastern Mojave Desert and adjacent Southeast Great Basin. The alliance is locally common in washes where irregular flooding occurs. Six relevés were examined in the this project.

The species' life history is not well known. It is likely not a prolific stem or root sprouter and probably does not live for long periods. It seeds well after wet years and occupies recently disturbed ground whether in washes, road cuts, or other recently disturbed substrate. The species occurs in washes and occasionally on slopes in several vegetation alliances including *Encelia virginensis, Salazaria mexicana,* and *Grayia spinosa* Shrublands. However, *Viguiera reticulata* only forms its own alliance in washes.

Regional Status:
Mojave Desert: Stands may occur in northern Mojave Desert valleys adjacent to Southeastern Great Basin ranges.
Southeastern Great Basin: Stands are common on the east side of the Last Chance Range, the Cottonwood Mountains, the Funeral Range and the Panamint Mountains, all of which drain into Death Valley.

Management Considerations: More information on the role of *Viguiera reticulata* Intermittently Flooded Shrubland is needed.

Yucca brevifolia Wooded Shrubland Alliance

Figure A56. *Yucca brevifolia* Wooded Shrubland Alliance, Cima Dome

Yucca brevifolia is the emergent small tree (< 14 m tall) and abundant over a shrub canopy. *Artemisia tridentata, Chrysothamnus viscidiflorus, Coleogyne ramosissima, Ephedra nevadensis, Eriogonum fasciculatum, Gutierrezia microcephala, Hymenoclea salsola, Krascheninnikovia lanata, Larrea tridentata, Lycium andersonii, Opuntia acanthocarpa, Tetradymia axillaris, Yucca schidigera,* or *Yucca baccata* may be present. Shrubs < 3 m tall; canopy intermittent or open. Emergent *Pinus monophylla, Juniperus californica,* or *Juniperus osteosperma* may be also present. Ground layer may include several cacti and perennial grasses including *Pleuraphis rigida, Pleuraphis jamesii, Achnatherum speciosum,* or *Poa secunda*. Annuals seasonally present.

Habitat: Gentle alluvial fans, ridges, and gentle to moderate slopes. Soils colluvial- and alluvial-derived. Coarse sand, very fine silt, gravel, or sandy loam. Many sites have bimodal soils with both coarse sands and fine silts.

Distribution: Mojave Desert, Southeastern Great Basin, Southern Nevada, western Arizona, southwestern Utah.

Elevation: 750 to 1,800 m

NDDB Rank: G4 S3.2 (some associations are rare)

Synonyms:
Holland: Joshua tree woodland (73000), Mojave mixed steppe (*in part* 34220), Mojave mixed woody scrub (*in part* 34210)
Brown, Lowe and Pase: 153.151, 153.152, 153.153
Cheatham and Haller: Joshua tree woodland
PSW-45: Joshua tree series
Stone and Sumida: Joshua tree community
Thorne: Joshua tree woodland
CALVEG: Joshua tree series
WHR: Joshua tree

References: Johnson (1976), MacMahon (1988), Paysen et al. (1980), Reid et al. (1999), Sawyer and Keeler-Wolf (1995), Thorne (1982), Turner (1982a, 1982b), Vasek and Barbour (1977); plot-based descriptions are in Hogan (1977), Vasek and Barbour (1977)

Membership Rules: *Yucca brevifolia* ≥ 1% cover, *Juniperus spp.* and/or *Pinus spp.* absent. Dominant understory species are shrub species such as *Coleogyne ramosissima, Opuntia ramosissima* or the perennial grass *Pleuraphis rigida*. Common in shallow upland soils throughout the Mojave Desert.

Comments: The alliance dominant, *Yucca brevifolia,* is a quintessential Mojave Desert plant. Its range defines the biological extent of the Mojave Desert more so than any other species. Its conspicuous and picturesque life form is the signature for the desert. However, *Yucca brevifolia* is by no means evenly distributed; different ecotypes occupy different subregions and each has somewhat different environmental requirements. It is present in both cool-season and warm-season rain zones (T. Keeler-Wolf personal communication, Desert Workshop 2000). Short-leaved, tall forms from the eastern Mojave Desert have been called *Yucca brevifolia* var. *jaegeriana*; long-leaved tall forms from the central, northern, and southern Mojave Desert have been called var. *brevifolia*; short, clonal, multi-stemmed individuals from the western Mojave Desert have been called var. *herbertii* (Munz 1974). Some ecotypes may be better adapted to sprouting from adventitious roots and stems following damage by fire and other mechanical disturbance. However, a great deal of plasticity exists in the species, motivating the most recent taxonomic treatments (Hickman 1993) to subsume the varieties into a single variable species.

Despite Rowlands' (1978) suggestion that *Yucca brevifolia* might be a constituent of grasslands and shrublands, our analysis of 146 relevés shows *Yucca brevifolia* to be a reasonably good indicator species. Thus, although a high degree of variation occurs in the shrub and herbaceous understory, *Yucca brevifolia* defines a *Yucca brevifolia* Wooded Shrubland of mid- and upper-elevation desert. In this alliance, *Yucca brevifolia* forms an open or scattered, emergent canopy over either a shrubby- or a grass-dominated understory.

Yucca brevifolia is a long-lived plant, whose exact age is difficult to determine since annual rings are not produced and since many individuals may regenerate vegetatively.

Juvenile *Yucca brevifolia* are generally unbranched; middle-aged plants are forked and dense. Older trees generally have a single stem and an open crown. Seedlings are uncommon on many harsh sites except following a series of wet years. Some researchers believe that sexual reproduction was much more important during more favorable climatic regimes (late Pleistocene), when summers were cooler and annual precipitation greater (FEIS 2001). Vegetative reproduction is now the most important mode of regeneration on many sites (FEIS 2001). *Yucca brevifolia* can sprout from the roots and from underground rhizomes. *Yucca brevifolia* rhizomes are fast growing and numerous. The var. *herbertii* has aerial stems connected by underground rhizomes 0.2-1.3 m in length that quickly grow to the surface. In var. *jaegeriana,* rhizome development may be related to precipitation and stimulated by damage or injury to the stem (FEIS 2001).

Natural stand dynamics are at least partially related to fire. Summer lightning strikes are relatively frequent in the high desert stands in the northern, southern, and eastern Mojave Desert with large individuals of *Yucca brevifolia* making suitable targets. The fire resistance of trees increases with age. The thick mat of dried leaves along the trunk decreases with age, and the corky bark of older trunks serves as a firebreak between surface fuels and the flammable shag on upper limbs (FEIS 2001). However, observations by R. Minnich (personal communication) suggest that even large trees are susceptible to fire, with many scorched trees dying within 5 years. Grazing history has changed the fire regime by increasing non-native annual grasses. Formerly the fire interval was probably once per century.

Yucca brevifolia is generally capable of vigorous root and stump sprouting after fire. Seed can remain viable in the soil for several years. Reestablishment through on-site or off-site seed is possible, particularly on more mesic sites or in favorable years. Little is known of the resprouting response of *Yucca brevifolia* to variable timing of fires and of the different ecotypes' responses to fire. According to Minnich (personal communication), vigorous sprouting may take place in some populations following fire, while other populations will not sprout. More seriously, those that do resprout tend to die within a few years either by rodent predation or by other causes.

Certain assemblages including *Yucca brevifolia/Lycium* spp., *Yucca brevifolia/Salazaria mexicana,* and *Yucca brevifolia/Opuntia acanthocarpa* probably occur as a response to disturbance including fire and grazing. Others including *Yucca brevifolia/Larrea tridentata-Eriogonum fasciculatum, Yucca brevifolia/Larrea tridentata-Ephedra nevadensis, Yucca brevifolia/Artemisia tridentata,* and *Yucca brevifolia/Coleogyne ramosissima* probably have lower fire frequencies. Frequencies in areas invaded by annual exotic grasses (*Bromus madritensis, Schismus* spp.) are likely to have increased because of both natural and human-caused ignitions and have changed the understory composition and density of *Yucca brevifolia*. There has likely been a reduction in stands with fire-sensitive shrubs (e.g., *Larrea tridentata, Coleogyne*) as a result. Destruction or degradation of individual stands has resulted from OHV activity and vandalism.

Regional Status:
Mojave Desert: In the western Mojave Desert clonal stands occur on the bajadas at the bases of the San Gabriel, Liebre, Scodie, and Tehachapi mountains. Most of them form a mosaic with *Larrea tridentata* Shrubland or are degraded with *Hymenoclea salsola, Ericameria linearifolia,* or *Ericameria nauseosa* as main shrub components. Stands in the eastern Mojave Desert are adjacent to *Larrea tridentata-Ambrosia dumosa* Shrubland Alliance at lower elevations, *Coleogyne ramosissima* Shrubland Alliance at mid elevations and *Artemisia tridentata* Shrubland*, Pinus monophylla- (Juniperus osteosperma)* Shrubland*,* and *Juniperus osteosperma* Wooded Shrubland at upper elevations. Likewise, stands in Joshua Tree National Park occur in a variety of settings.
Southeastern Great Basin: The alliance occurs in the Coso, Inyo, and Cottonwood mountains where it is intermixed with *Artemisia tridentata, Atriplex confertifolia*, or *Coleogyne ramosissima* Shrublands or *Juniperus osteosperma* Wooded Shrubland. The alliance only occurs in a small area near Emigrant Pass in the Panamint Mountains**.**

Management Considerations: Livestock has heavily grazed many *Yucca brevifolia* Wooded Shrublands. Grazing does not improve range conditions, because of the extreme aridity and harshness of the environment. Efforts to improve these ranges tend to be expensive and yield few beneficial results (FEIS 2001). Extensive vandalism has occurred in many Joshua tree woodlands in California. Increased frequency of fires in *Yucca brevifolia* Wooded Shrubland, resulting from combined effects of human-caused ignition and fine fuels from non-native annual grasses, is likely to degrade certain assemblages. Natural fire regimes in various *Yucca brevifolia* Wooded Shrublands throughout the range of the alliance should be studied to determine the appropriate management actions.

Yucca schidigera Shrubland Alliance

Figure A57. *Yucca schidigera* Shrubland Alliance, southern Nopah Range

Yucca schidigera is emergent small tree or tall shrub over a shrub or grass canopy. *Ambrosia dumosa, Coleogyne ramosissima, Encelia farinosa, Ephedra nevadensis, Eriogonum fasciculatum, Larrea tridentata, Opuntia acanthocarpa, Pleuraphis rigida, Salazaria mexicana,* or *Viguiera parishii* may be present. Trees < 5 m tall. Shrub and ground layer open to intermittent. Annuals seasonally present.

Habitat: Rocky slopes, upper bajadas, and alluvial fans. Soils well drained, derived from various substrates including granitic, limestone, volcanic, and metamorphic.

Distribution: Mojave Desert, Southern California Mountains and Valleys, Colorado Desert, Sonoran Desert, Nevada, Utah, Arizona, Baja California.

Elevation: 700 to 1,800m

NDDB Rank: G4 S4 (some associations, e.g., *Yucca schidigera/Pleuraphis rigida* rare; G2 S2.2)

Synonyms:
Holland: Mojave mixed steppe (34220), Mojave yucca scrub and steppe (34230)
Cheatham and Haller: Low desert scrub
Thorne: Semi-succulent scrub
CALVEG: Creosote bush series (in part)
Munz: Creosote bush scrub
WHR: Desert succulent scrub

References: Burk (1977), MacMahon (1988), Reid et al. (1999), Sawyer and Keeler-Wolf 1995, Thorne (1982); plot-based descriptions are found in Minnich et al. (1993), Keeler-Wolf et al. *(*1998)

Membership Rules: *Yucca schidigera* ≥ 2% other species including *Larrea tridentata* and *Ambrosia dumosa* may be equal or higher cover.

Comments: *Yucca schidigera* Shrubland is part of the creosote bush scrub ecological system, which is a collection of alliances. Much of what was classified as the most diverse upland Mojave Desert scrubs, (i.e., Mojave mixed woody scrub or mixed woody and succulent scrubs, Holland 1986) can now be classified as *Yucca schidigera* Shrubland.

Yucca schidigera is one of the most characteristic shrubs of the mid-elevation eastern and central Mojave Desert and desert slopes of the Transverse and Peninsular ranges. However, *Yucca schidigera* rarely is dominant, but is an indicator species even at relatively low cover values. Ordination and classification of 94 relevés in this project suggest that *Yucca schidigera* Shrubland is ecologically similar to the *Yucca brevifolia* Shrubland, but it tends to occur at slightly lower elevations and on shallower soils. *Yucca schidigera* Shrubland grades into *Larrea tridentata-Ambrosia dumosa* Shrubland at lower elevations and is similar to several other mid-elevation alliances including *Ephedra nevadensis* (rockier slopes), *Coleogyne ramosissima* (often caliche layer), *Grayia spinosa* (deeper alluvial soils), and *Eriogonum fasciculatum* and *Salazaria mexicana* (higher disturbance) Shrublands.

The indicator species, *Yucca schidigera,* is a long-lived species indicative of long-persisting stands of vegetation. Evidence suggests that the slow-growing *Yucca schidigera* is particularly susceptible to deep soil disturbances and recovers very slowly (Tratz 1978). Although *Yucca schidigera* may persist for long periods; other components of the stand may be less persistent. Unlike several associated desert species, fire usually does not kill *Yucca schidigera,* even when aboveground vegetation is totally consumed. In chaparral-desert ecotones of southern California, less than 10% of all Mojave Desert yuccas were actually killed by fire (Tratz 1978). In desert grassland, only a few plants were killed by a summer fire, which removed old shoots to or near the ground level (Vasek et al. 1975). Mechanical injury other than fire can also result in re-sprouting, although the more severe the injury, the less vigorous the sprouting (Vasek et al. 1995). It can sprout from roots protected by overlying soil, or from surviving active tissues at the stem base. Certain dry, rocky sites occupied by *Yucca schidigera* may lack sufficient fuels to carry a fire under ordinary circumstances. It is likely that stands with a high understory cover of *Pleuraphis* spp. or disturbance-related shrubs may have had higher fire frequencies than those with long-lived, non-sprouting desert shrubs.

Very few seedlings have been observed on many of the harsher *Yucca schidigera* Shrubland sites. Reproduction by seed may have been much more important during more favorable climatic regimes. Most regeneration now probably occurs through root sprouting, after fire or mechanical disturbance.

Regional Status:
Mojave Desert: *Yucca schidigera* Shrubland occurs in the eastern part of the Mojave Desert. It does not occur west of Victorville and is largely absent from the Searles, Panamint, and Owens Valleys due to its preference for warm-season rains (T. Keeler-Wolf personal communication, Desert Workshop 2000). It occurs regularly above 900 m. It appears to replace *Yucca brevifolia* Shrubland in parts of the Mojave National Preserve but may co-occur with it in other areas. It does not occur commonly with *Pleuraphis rigida* understory, and its most widespread associations are with *Larrea tridentata* and *Ambrosia dumosa*.

Management Considerations: This is a naturally diverse upland alliance, and much of its biodiversity is due to the diversity of non-fire-adapted slow-growing, non-sprouting shrubs. Continued high fire frequencies in stands of *Yucca schidigera* Shrubland will reduce the diversity of non-fire resistant species and increase the cover of fire adapted grasses and short lived colonizing perennials. Other disturbance-adapted alliances such as *Acacia greggii, Ericameria teretifolia, Eriogonum fasciculatum,* and *Salazaria mexicana* Shrublands may increase relative to *Yucca schidigera* Shrublands if fire and the fire-carrying annual grasses continue to increase in the desert. Response of *Yucca schidigera*

Shrublands to fire may vary according to fire severity and intensity, season of burn, and specific site characteristics. These factors should be investigated.

BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION OF THE STATE OF CALIFORNIA
1516 NINTH STREET, SACRAMENTO, CA 95814
1-800-822-6228 – WWW.ENERGY.CA.GOV

APPLICATION FOR CERTIFICATION FOR THE *IVANPAH SOLAR ELECTRIC GENERATING SYSTEM*	**DOCKET NO. 07-AFC-5** **PROOF OF SERVICE** **(Revised 11/23/09)**

APPLICANT

Solar Partners, LLC
John Woolard,
Chief Executive Officer
1999 Harrison Street, Suite #500
Oakland, CA 94612

Todd A. Stewart, Project Manager
Ivanpah SEGS
sdeyoung@brightsourceenergy.com
E-mail Preferred

Steve De Young, Project Manager
Ivanpah SEGS.
1999 Harrison Street, Ste. 2150
Oakland, CA 94612
tstewart@brightsourceenergy.com

APPLICANT'S CONSULTANTS

John L. Carrier, J. D.
2485 Natomas Park Dr. #600
Sacramento, CA 95833-2937
jcarrier@ch2m.com

COUNSEL FOR APPLICANT

Jeffery D. Harris
Ellison, Schneider
& Harris L.L.P.
2600 Capitol Avenue, Ste. 400
Sacramento, CA 95816-5905
jdh@eslawfirm.com

INTERESTED AGENCIES

California ISO
e-recipient@caiso.com

Tom Hurshman,
Project Manager
Bureau of Land Management
2465 South Townsend Ave.
Montrose, CO 81401
UUtom_hurshman@blm.gov

Raymond C. Lee, Field Manager
Bureau of Land Management
1303 South U.S. Highway 95
Needles, CA 92363
Raymond_Lee@ca.blm.gov

Becky Jones
California Department of
Fish & Game
36431 41st Street East
Palmdale, CA 93552
dfgpalm@adelphia.netUU

INTERVENORS

California Unions for Reliable Energy ("CURE")
Tanya A. Gulesserian
Marc D. Joseph
Adams Broadwell Joseph & Cardozo
601 Gateway Boulevard, Ste 1000
South San Francisco, CA 94080
tgulesserian@adamsbroadwell.com

Western Watersheds Project
Michael J. Connor, Ph.D.
P.O. Box 2364
Reseda, CA 91337-2364
mjconnor@westernwatersheds.org

Gloria Smith, Joanne Spalding
Sidney Silliman, Devorah Ancel
Sierra Club
85 Second Street, 2nd Fl.
San Francisco, CA 94105
E-mail Service Preferred
gloria.smith@sierraclub.org
joanne.spalding@sierraclub.org
gssilliman@csupomona.edu
devorah.ancel@sierraclub.org

*indicates change

INTERVENORS CONT.
Joshua Basofin, CA Rep.
Defenders of Wildlife
1303 J Street, Ste. 270
Sacramento, CA 95814
E-mail Service Preferred
HHjbasofin@defenders.orgHH

Basin and Range Watch
Laura Cunningham
Kevin Emmerich
P.O. Box 70
Beatty, NV 89003
atomictoadranch@netzero.net

Center for Biological Diversity
Lisa T. Belenky, Sr. Attorney
Ileene Anderson, Public Lands Desert Director
351 California Street, Ste. 600
San Francisco, CA 94104
E-mail Service Preferred
lbelenky@biologicaldiversity.org
ianderson@biologicaldiversity.org

California Native Plant Society
Greg Suba, Tara Hansen & Jim Andre
2707 K Street, Suite 1
Sacramento, California, 95816-5113
E-mail Service Preferred
gsuba@cnps.org
thansen@cnps.org
granites@telis.org

***County of San Bernardino**
Bart W. Brizzee, Deputy Co. Counsel
385 N. Arrowhead Avenue, 4th Fl.
San Bernardino, California, 92415
bbrizzee@cc.sbcounty.gov

ENERGY COMMISSION
JEFFREY D. BYRON
Commissioner and Presiding Member
jbyron@energy.state.ca.us

JAMES D. BOYD
Vice Chairman and
Associate Member
HHjboyd@energy.state.ca.usHH

Paul Kramer
Hearing Officer
pkramer@energy.state.ca.us

John Kessler
Project Manager
jkessler@energy.state.ca.us

Dick Ratliff
Staff Counsel
dratliff@energy.state.ca.us

Public Adviser
publicadviser@energy.state.ca.us

*indicates change

DECLARATION OF SERVICE

I, Violet Lehrer, declare that on Dec 18, 2009, I served and filed copies of the attached, testimony dated, Dec 18, 2009. The original document, filed with the Docket Unit, is accompanied by a copy of the most recent Proof of Service list, located on the web page for this project at: **[www.energy.ca.gov/sitingcases/ivanpah]**.

The documents have been sent to both the other parties in this proceeding (as shown on the Proof of Service list) and to the Commission's Docket Unit, in the following manner:

(***Check all that Apply***)

FOR SERVICE TO ALL OTHER PARTIES:

✓ sent electronically to all email addresses on the Proof of Service list;

____ by personal delivery or by depositing in the United States mail at Sacramento, California with first-class postage thereon fully prepaid and addressed as provided on the Proof of Service list above to those addresses **NOT** marked "email preferred."

AND

FOR FILING WITH THE ENERGY COMMISSION:

✓ sending an original paper copy and one electronic copy, mailed and emailed respectively, to the address below (***preferred method***);

OR

____ depositing in the mail an original and 12 paper copies, as follows:

CALIFORNIA ENERGY COMMISSION
Attn: Docket No. 07-AFC-5
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512
docket@energy.state.ca.us

I declare under penalty of perjury that the foregoing is true and correct.

Viol Le

*indicates change