EXHIBIT 424

STATE OF CALIFORNIA
California Energy Commission

In the Matter of: The Application for Certification for the **CALICO SOLAR PROJECT** (formerly SES Solar One)	Docket No. 08-AFC-13

REBUTTAL TESTIMONY OF SCOTT CASHEN ON BEHALF OF CALIFORNIA UNIONS FOR RELIABLE ENERGY ON BIOLOGICAL RESOURCES FOR THE CALICO SOLAR PROJECT

July 29, 2010

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I am an environmental biologist with 18 years of professional experience in wildlife ecology, forestry, and natural resource management. For the past 10 years I have served as an environmental consultant focusing on biological resource investigations. I have additional professional experience as a wildlife researcher, consulting forester, and instructor of wildlife management for the Pennsylvania State University. My educational background includes a B.S. in Resource Management from the University of California at Berkeley, and a M.S. in Wildlife and Fisheries Science from the Pennsylvania State University.

The testimony contained herein is based on my knowledge and experience; my review of environmental documents pertaining to the Project; information presented in scientific literature; site visits; and consultations with numerous biological resource experts. The information gathered from these sources has led me to the following conclusions:

1. The Project would have an unmitigated, significant impact on the State and federally threatened desert tortoise and it would cause further decline of the species.
2. The Project would have a significant adverse impact on numerous other special-status plant and animal species, including species protected by the Endangered Species Act and West Mojave Plan.
3. The Project would jeopardize the continued existence of at least two special-status plant species.
4. The Project would cause irreparable damage to a healthy desert ecosystem.
5. The Project would compromise the ecological integrity of the surrounding conservation areas (e.g., Pisgah ACEC, Ord-Rodman DWMA, and Cady Mountains Wilderness Study Area).
6. The Supplemental Staff Assessment (SSA) has not provided sufficient information on many of the sensitive biological resources that would (or might) be affected by the Project.
7. The Project's direct, indirect, and cumulative impacts on many sensitive biological resources have not been thoroughly analyzed.
8. Many of the measures that have been proposed to avoid, minimize, or compensate for Project impacts would not mitigate Project impacts below the significance threshold.
9. The Project would not comply with the West Mojave Plan.

In the subsequent sections I provide more specific discussion of the factors that led me to these conclusions.

I. THE PROJECT WOULD CAUSE UNMITIGABLE DAMAGE TO A VERY HEALTHY DESERT ECOSYSTEM

The site for the proposed Calico Solar Project ("Project") contains thousands of acres of land within a relatively undisturbed portion of the Mojave Desert.[1] This land contains a large block of habitat that supports many unique plant and animal species, including the Nelson's bighorn sheep, Mojave fringe-toed lizard, and golden eagle. It is known to contain 282 acres of Waters of the State, 9 special-status plant species, and at least 1 sensitive natural community. In contrast to many other regions of the Mojave Desert, the site has a relatively large and healthy population of desert tortoises occupying some of the highest quality habitat remaining for the species.[2] The proposed Project would have an adverse affect on all of these resources. The ecological consequences of eliminating a broad expanse of relatively undisturbed Mojave Desert habitat cannot be mitigated.

The Supplemental Staff Assessment ("SSA") makes numerous references to the ecological values of the site and the anticipated consequences of the Project. It concludes the Project area supports a "broad diversity of wildlife species" and a "diverse assemblage of annual and perennial herbs."[3] It also notes that the Project site contains "a number of unique features" that are essential for "habitat specialists," and that unique genetic variants of several species have been documented in the region.[4] According to the SSA, the overall effects to any wildlife within the project perimeter are expected to be ***severe***. [5]

Although the SSA makes clear that the Project site contains a high degree of biodiversity and ecological function,[6] ecosystems are complicated entities with numerous components and interacting processes that are difficult to assess. Given numerous variables, many monitoring programs utilize indicators of ecosystem or population condition, rather than measuring the specific processes or species themselves.[7] Given the complexity of the Project site and the dearth of biological information generated so far, I have utilized this technique for the Project site. And, because birds occupy a wide diversity of ecological niches in desert habitat, they serve as good indicators of the health of the larger ecosystem in which they reside.[8] Therefore, the conclusions below are based on a commonly utilized monitoring program for birds.

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[1] SSA, p. C.2-1.
[2] 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.
[3] SSA, p. C.2-20, 23.
[4] SSA, p. C.2-23.
[5] SSA, p. C.2-2.
[6] E.g., SSA, p. C.2-23.
[7] Belnap, Jayne, Webb, R.H., Miller, D.M., Miller, M.E., DeFalco, L.A., Medica, P.A., Brooks, M.L., Esque, T.C., and Bedford, D.R., 2008, Monitoring ecosystem quality and function in arid settings of the Mojave Desert: U.S. Geological Survey Scientific Investigations Report 2008-5064, 119 p.
[8] CalPIF (California Partners in Flight). 2009. Version 1.0. The Desert Bird Conservation Plan: a Strategy for Protecting and Managing Desert Habitats and Associated Birds in California. California Partners in Flight. http://www.prbo.org/calpif/plans.html.

California Partners In Flight ("CalPIF") has designed an ecological monitoring program and conservation plan for the Mojave and Colorado Deserts. The program established several criteria to select a suite of 15 "focal species," whose requirements define different spatial attributes, habitat characteristics, and management regimes representative of a healthy desert system.[9]

Of the 15 focal species identified by CalPIF, I excluded one, Gila woodpecker, from my analysis because the Project site is well outside of the species' known range. The Project site appears to be outside of the range of at least two of the other focal species, but I included them in the analysis to prevent what might be perceived as a biased approach. As a result, I made a conservative assumption that a maximum of 14 focal species *could* occur at the Project site. I then used the list of bird species provided in the Biological Resources Technical Report and SSA to tally the number of focal species detected on the Project site by the Applicant. Because the Applicant did not conduct focused bird surveys, but instead relied on incidental detections of birds made during other field efforts, the Applicant's information provides the *minimum* number of focal species present on the Project site (i.e., additional focal species may be present).[10]

Through this investigation I determined that at least 8 of the possible 14 focal species (57%) occur on the Project site (excluding the transmission line corridor).[11] This represents one of the highest relative percentages of focal species occurrence reported by CalPIF contributors.[12] Based on the conservation strategy established by CalPIF, this represents an extremely "healthy" system, one that cannot be mitigated if destroyed.

II. WILDLIFE MOVEMENT AND LANDSCAPE CONNECTIVITY IMPACTS ARE NOT ACCURATELY OR ADEQUATELY ANALYZED IN THE SSA

The ability to move across the landscape is essential for many species, especially those that occur as metapopulations. A "metapopulation" is a population that has a spatially discrete distribution, and for which at least one or more local populations has a non-trivial probability of extinction.[13] Desert tortoise, bighorn sheep, and Mojave fringe-toed lizards all exhibit a metapopulation structure. Maintaining the ability for these species to

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[9] *Id.*
[10] AFC, p. 5.6-4.
[11] Bendire's Thrasher, Burrowing Owl, Common Raven, Black-throated Sparrow, Ash-throated flycatcher, Phainopepla, Ladder-backed Woodpecker, LeConte's Thrasher. The SSA reports a "high" potential for an additional focal species, the Black-tailed gnatcatcher.
[12] *See* Figure 5-16 of CalPIF (California Partners in Flight). 2009. Version 1.0. The Desert Bird Conservation Plan: a Strategy for Protecting and Managing Desert Habitats and Associated Birds in California. California Partners in Flight. http://www.prbo.org/calpif/plans.html.
[13] McCullough DR. 1996. Introduction. Pages 1-10 in DR McCullough, editor. Metapopulations and Wildlife Conservation. Island Press, Washington (DC).

move across the landscape (i.e., connectivity) is the key determinant in the fate of each metapopulation, and ultimately the entire population.[14]

The SSA failed to analyze the significance of the Project's impact on the landscape-level connectivity necessary to maintain viable metapopulations. In my judgment, this is a fatal flaw in the biological analysis for the following three reasons.

First, Staff originally concluded the Project would hinder east-west movement for species such as the desert tortoise due to the Project's proximity to the Cady Mountains.[15] Staff has now concluded that the modified Project design will provide an east-west movement corridor along the northern boundary of the Project site—even though there has been ***no analysis to support this conclusion***.

A particular species' use of a corridor is dependent on many factors. The first is the particular attributes of the corridor itself. Some species avoid habitat edges, and will only use corridors with a wide band of habitat unscathed by edge effects. Other features such as length, bottlenecks (i.e., narrowings), gaps, and the presence of predators or aggressive competitors contribute to a particular corridor's viability.[16] The staff did not conduct an assessment of any of these features. Instead, it simply assumed additional space between the Project fence and the Cady Mountains would provide a viable corridor for motile species. Research studies have demonstrated *potential* mobility does not always translate into *realized* mobility.[17] For example, Diamond (1972, 1973) concluded that certain tropical forest birds were reluctant to even approach edges, much less fly across non-forest gaps. Diamond's study (and others that followed) demonstrated that just because an organism *can* move from one location to another, does not mean that it *will*. Consequently, reliance on particular species' *potential* mobility to support corridor use does not support staff's conclusion that Project impacts to east-west wildlife movement would be less than significant.

Unfortunately, the modified Project design does not ameliorate Project impacts. The area along the northern boundary of the new Project would possess many features that are likely to preclude or be hazardous to wildlife movement. These include the bottlenecks that would be present around rock outcrops and the unnatural levels of debris that would be collected in the numerous retention basins (which are located in the "corridor"). Species that are undeterred by these barriers might instead be deterred by Project noise, which is estimated to be intolerable to some species, and nearly continuous activity at the site due to SunCatcher maintenance. Any smaller animals (e.g., tortoises and lizards) that

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[14] Lidicker WZ Jr, WD Koenig. 1996. Responses of Terrestrial Vertebrates to Habitat Edges and Corridors. Pages 85-109 in DR McCullough, editor. Metapopulations and Wildlife Conservation. Island Press, Washington (DC).
[15] SA, p. C.2-94.
[16] Lidicker WZ Jr, WD Koenig. 1996. Responses of Terrestrial Vertebrates to Habitat Edges and Corridors. Pages 85-109 in DR McCullough, editor. Metapopulations and Wildlife Conservation. Island Press, Washington (DC).
[17] *See* studies cited in Lidicker WZ Jr, WD Koenig. 1996. Responses of Terrestrial Vertebrates to Habitat Edges and Corridors. Pages 85-109 in DR McCullough, editor. Metapopulations and Wildlife Conservation. Island Press, Washington (DC).

attempt the journey along the long northern fence line would be subject to heavy predation pressure from ravens, coyotes, and other predators that are known to use edges or that otherwise benefit from human disturbance (e.g., perching birds).[18]

Second, the SSA concluded Project fencing would result in a permanent barrier to north-south movement for the entire Project site. However, it concluded impacts to wildlife movement from construction and operation of the Project would be less than significant with mitigation even though it provided ***no mitigation*** for north-south movement, and no discussion of how this movement would be maintained after Project development.

Lastly, Staff's assessment of impacts—which was made without dedicated analysis—contradicts two studies that ***were based*** on dedicated analysis.[19] Based on these studies, in addition to the numerous issues I listed above, it is my professional opinion that the Project would have a significant unmitigated impact on wildlife movement. Furthermore, it is my professional opinion that the impact would be so significant that it would compromise the metapopulation dynamics necessary to maintain viable populations of several species.

a. The SSA Does Not Adequately Consider the Impact to Terrestrial Vertebrates From Fragmentation Caused by the Project

Even if wildlife corridors are utilized for dispersal to the extent expected, the functions provided by the corridors may not alleviate the adverse, *ecosystem-level* effects of an action. The SSA failed to predict, or even make an attempt to assess, the integrity of the resulting ecosystem if the Project was constructed. Edges generated by anthropogenic disturbance promote introduced plant and animal species, which may affect desert tortoises and other native species in adjacent areas.[20] Other potentially harmful activities that likely occur in greater numbers near human-induced edges include illegal dumping of garbage and toxic wastes; release of ill tortoises; vandalism, handling and harassing of tortoises; illegal collection of tortoises; and fire.[21] These numerous direct and indirect adverse effects may impact desert tortoise populations two miles or more away.[22]

Adverse effects from habitat edges and fragments are not limited to desert tortoises. Changes in broad patterns of resource patches can insidiously disrupt resource availability and resulting population functions in ways that would not become evident by examining merely local expressions of habitat conditions and occurrence of species. Individual components and forces of landscapes do not act in isolation; rather they are mutually determining. As a result, disruptions to populations and habitats alike can "unravel" ecological processes, biotic communities, and natural disturbance regimes.

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[18] 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.
[19] Hannah et. al 2009 and Spencer et al. 2010.
[20] Boarman WI, M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101.
[21] 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.
[22] *Id.*

Whereas the specific responses of most ecosystems that incur disturbances are difficult to predict, they need to be carefully considered when formulating impact analyses and mitigation. The SSA lacks these fundamental components.

In conclusion, the SSA provided a flawed impact assessment, primarily because it lacked a scientific basis for the predicted wildlife responses, and because it did not consider how the Project would change the synergistic interactions among species and their environment. These are accepted, fundamental requirements before a project of this magnitude can be considered.

III. THE SSA FAILS TO ADEQUATELY ANALYZE AND MITIGATE IMPACTS TO DESERT TORTOISE

The USGS has generated a model to predict desert tortoise habitat quality. The Project's Biological Assessment (BA) used the model to depict desert tortoise habitat potential in the Project region. The map that was presented in the BA shows a large swath of extremely high quality habitat (i.e., a score of 0.9 out of a possible 1.0) centered on the Project site. Although the model has limitations, the various survey data provided by the Applicant have validated the high quality desert tortoise habitat present on the Project site. Combined, the model and the Applicant's data indicate the Project would have a direct impact on at least 4,075 acres of extremely high quality desert tortoise habitat and an additional 2,140 acres of moderately suitable desert tortoise habitat. The USGS model shows few other large blocks of land with equivalently high quality habitat in the entire Project region.[23] Not only would the Project eliminate a considerable portion of this high quality habitat, but it would also **completely sever its connectivity**. An action of this magnitude would impede recovery of a species that is known to require landscape-level connectivity, and it could very easily lead to local extinctions. Given the scarcity of similar high quality habitat in the region, and given the SSA's failure to ensure impacts to extremely high quality habitat would be offset by compensatory mitigation, it is my professional opinion that the Project would have a significant, unmitigated direct impact on the desert tortoise.

Population Demographics and Health

The Applicant's 2010 surveys documented 104 individual tortoises, including 88 adults, 1 subadult, and 15 juveniles. Of these, only two showed some sign of disease or ill health. The SSA failed to consider the significance of these data in evaluating Project impacts and devising mitigation. The demographic data collected by the Applicant demonstrate tortoises are reproducing on the site and contributing to maintenance of the population. Despite development of two Federal recovery plans, desert tortoise populations continue to decline over much of the species' range. The Applicant's data do not enable assessment of a population trend (i.e., increasing or declining), but they can be used to estimate density. Specifically, the data indicate the Project site has a relatively high density of tortoises compared to many other areas in the region (including within

[23] Project BA.

designated critical habitat). Sites with a high density of tortoises, such as the Project site, may provide strong evidence that the Project supports source populations, which are critically important for the recolonization of areas following local extinctions, and for maintaining the overall population.

Desert tortoises are subject to several forms of disease. In some populations a relatively high proportion of tortoises are infected with disease, making disease one of the major threats to desert tortoise recovery. In some instances, translocation of diseased individuals has been implicated as the cause for decline in an otherwise healthy desert tortoise population. The absence of disease in the majority of the tortoises detected by the Applicant (i.e., < 2%), in conjunction with the demographic data, provides convincing evidence that the resident tortoise population is healthy and reproducing. The existence and importance of such a healthy population was not fully articulated in the SSA, nor has it been properly addressed in Staff's proposed mitigation.

a. The Project would contribute to an unmitigated, significant cumulative impact on desert tortoise

According to the SSA,

> "Urbanization/loss of habitat, deteriorating habitat quality from off-highway vehicles, invasion of non-native grasses and weeds, predation by ravens, collection, livestock grazing, and spread of an upper respiratory tract disease have all contributed to the decline of desert tortoise populations. In response to this decline, large expanses of desert tortoise critical habitat and numerous ACEC/DWMA areas have been identified or established within the WEMO planning area. Region-wide, the cumulative impacts of past, present, and foreseeable future large-scale habitat conversions to desert tortoise habitat and connectivity are ***cumulatively significant, even with these conservation efforts. Such effects can only be addressed through a regional and coordinated effort.*** Ongoing collaborative efforts by federal and State agencies to develop a Desert Renewable Energy Conservation Plan and BLM's Solar Energy Development Programmatic EIS provide an appropriate vehicle for such a regional mitigation approach."[24]

The Desert Renewable Energy Conservation Plan and BLM's Solar Energy Development Programmatic EIS have yet to be developed. Therefore, they cannot be relied on to provide a regional mitigation approach, and there is no basis for Staff to conclude the project's contribution to significant cumulative effects on desert tortoise will be less than significant.

[24] SSA, p. C.2-135. [emphasis added]

b. The Mitigation Measures are Not Adequately Developed

The SSA has accurately portrayed many of the hazards associated with translocating desert tortoises and has rightly concluded that moving tortoises off the site would "pose substantial effects to this species."[25] Even though the Staff Assessment ("SA") indicated that "Staff considers the translocation effort for desert tortoise to be the critical path for commencement of construction activities," the Applicant has yet to provide even a rudimentary translocation plan for public review.[26] The only information afforded since release of the SA is that "[t]he applicant has identified several potential translocation sites including areas north, east, and west of the project site. *Some* of these sites are areas less than 500 meters from the project boundary which would limit the need for disease testing and *may allow* some tortoises to maintain a portion of their home ranges after translocation."[27] The only substantive information that can be obtained from these statements is that tortoises will not be moved south, which ironically is where the nearest critical habitat for the species is located.

It is not possible for the public or interested agencies to evaluate the SSA's mitigation proposal for impacts to desert tortoise until the Applicant has provided a finalized version of the Draft Desert Tortoise Translocation Plan.[28] The problems associated with the Ft. Irwin translocation effort highlight the need for a well-crafted plan based on the best available science. However, the SSA lacks any information on specific translocation sites, the habitat suitability of those sites for tortoises, and whether the resident tortoise would be adversely affected by translocated individuals (or vice-versa). In addition, although the SSA indicates there should be monitoring associated with the translocation, it does not establish any monitoring standards or success criteria for adaptive management measures (e.g., if elevated levels of predation occur). A detailed translocation plan must be developed and thoroughly vetted before Staff can conclude it would be an effective means of salvaging tortoises off the Project site. At a minimum, the plan should contain:

1. An assessment of potential release sites, with special attention dedicated to evaluating the factors that limit the distribution and abundance of desert tortoises, as well as an appraisal of probable dispersal patterns.
2. An experimental, controlled trial, in which the initial translocation strategy is evaluated, then modified to improve the likelihood of success.
3. A detailed description of the monitoring and adaptive management measures that will be implemented after desert tortoises are released.

Project Fencing

Neither the Applicant nor Staff has explained how the Project would be fenced to prevent ingress of desert tortoises, yet allow egress of storm waters. At least one tortoise was

[25] SSA, p. C.2-3.
[26] SA/DEIS, p. C.2-65.
[27] SA, p. C.2-73. [emphasis added]
[28] SA/DEIS, p. C.2-66.

"lost" following the Ft. Irwin translocation project, apparently as a result of a wash carving out space beneath the fence lining. In addition, a recent press release issued by the National Park Service documented the performance of a pedestrian fence installed by the U.S. Army Corps of Engineers and U.S. Department of Homeland Security. Following a summer storm event, the fence failed several performance criteria related to hydrology despite the U.S. Border Control's Final Environmental Assessment, which had concluded the fence would "not impede the natural flow of water." The Ft. Irwin and National Park Service events highlight the problems associated with fencing in desert wash systems; the need for information on how the Applicant intends to mitigate flows that may impact fencing; and provision of a more rigorous monitoring and maintenance schedule for tortoise exclusion fencing.

IV. THE SSA FAILS TO ADEQUATELY ANALYZE AND MITIGATE IMPACTS TO GOLDEN EAGLE

a. The Description of the Affected Environment is Unreliable

Golden eagles are known to nest within a few miles of the project site and have been observed foraging over the Project area.[29] Information provided by the BLM and the Applicant indicates that up to six potential nesting sites occur within a 10-mile radius of the Project site.[30] To document potential nest sites for golden eagles, the Applicant conducted a helicopter survey for the species in March 2010. The survey detected approximately 22 stick nests including eight inactive, but potential golden eagle nests, and one active nest that contained an incubating adult golden eagle. The active nest is located approximately 3.5 miles east of the proposed project area.

The USFWS has established *minimum* inventory and monitoring efforts that "are essential components" to avoiding and minimizing disturbance and other kinds of take of golden eagles.[31] The USFWS reports "[t]hese field efforts are the mutual responsibility of agencies authorizing activities and their permittees."[32] I concur with the USFWS that inventory data are essential to evaluating the impacts of a proposed activity and for avoiding and minimizing take of eagles. Consequently, data that conform to the minimum inventory requirements specified by the USFWS need to be provided before the SSA's impact assessment and proposed mitigation measures can be fully evaluated.

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[29] SA/DEIS, p. C.2-4.
[30] SA/DEIS, p. C.2-31.
[31] Pagel JE, DM Whittington, GT Allen. 2010 Feb. Interim Golden Eagle inventory and monitoring protocols; and other recommendations. Division of Migratory Birds, United States Fish and Wildlife Service. p. 2.
[32] Pagel JE, DM Whittington, GT Allen. 2010 Feb. Interim Golden Eagle inventory and monitoring protocols; and other recommendations. Division of Migratory Birds, United States Fish and Wildlife Service. p. 2.

Research indicates golden eagles selectively use available habitat, and that they concentrate their foraging activities in select "core" areas.[33] In a study on spatial use and habitat selection of golden eagles in Idaho, Marzluff et al. (1997) concluded that there was substantial variation in home range size and habitat use among eagles, and that if such variation was ignored (by focusing on population averages), conservation strategies and biological descriptions will be inaccurate and rarely effective.[34] During the breeding season, eagles in Marzluff's study had home ranges as small as 480 acres, with 95% of the activity concentrated in core areas as small as 74 acres.[35] Home range size and behavior were a function of the types and configuration of prey habitat in the vicinity of the nest, and perhaps individual eagles.[36]

The results of this research have two important implications on the Project. First, in the absence of more appropriate empirical data, one must conclude Marzluff's results apply to the Project site, and thus the Project could eliminate a substantial amount of core habitat (perhaps all) used by at least one pair of breeding eagles. Second, whereas acquisition of compensation land may help conserve foraging habitat for *some* eagle(s), it may be of little consequence to *the* eagle(s) whose core habitat has been eliminated by the Project. This is important because not all eagles contribute equally to maintenance of the population.[37] For example, if all the suitable nest locations are fully-occupied, impacts leading to abandonment of a territory (either through destruction of the nest substrate or through not being re-occupied by either the original nesting pair or a new pair from the floater population) would likely have a significant negative impact to the area population.[38] Detrimental impacts to available prey base or intra-species competition would also contribute to stresses on the area population.[39]

I have the following additional comments related to Project impacts to golden eagles:

1. The SSA has not demonstrated that the Project would comply with the Bald and Golden Eagle Protection Act ("Eagle Act").
2. The compensatory mitigation plan recommended by Staff provides no provisions to ensure significant impacts to golden eagle foraging habitat would be mitigated to a level considered less than significant. Loss of core foraging habitat may result in nest failure and a violation of the Eagle Act.

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[33] Marzluff JM, ST Knick, MS Vekasy, LS Schueck, TJ Zarriello. 1997. Spatial use and habitat selection of golden eagles in southwestern Idaho. The Auk 114(4):673-687.
[34] Marzluff JM, ST Knick, MS Vekasy, LS Schueck, TJ Zarriello. 1997. Spatial use and habitat selection of golden eagles in southwestern Idaho. The Auk 114(4):673-687.
[35] Id.
[36] Id.
[37] US Fish and Wildlife Service, Division of Migratory Bird Management. 2009. Final Environmental Assessment, Proposal to Permit Take. Provided Under the Bald and Golden Eagle Protection Act. Washington: Dept. of Interior.
[38] US Fish and Wildlife Service, Division of Migratory Bird Management. 2009. Final Environmental Assessment, Proposal to Permit Take. Provided Under the Bald and Golden Eagle Protection Act. Washington: Dept. of Interior.
[39] US Fish and Wildlife Service, Division of Migratory Bird Management. 2009. Final Environmental Assessment, Proposal to Permit Take. Provided Under the Bald and Golden Eagle Protection Act. Washington: Dept. of Interior.

3. Condition of Certification BIO-20 requires that "[f]or each calendar year during which construction will occur an inventory shall be conducted to determine if golden eagle territories occur within one mile of the Project boundaries." The condition subsequently specifies the minimum data required for the inventory. The Applicant plans to initiate construction this calendar year (i.e., 2010). However, it did not provide the data required of Staff's condition. Therefore, it is unable to comply with the conditions set forth in BIO-20.
4. On behalf of the Applicant, Dr. Mock has provided testimony that "[a]ll open desert lands are potential foraging habitat for eagles, and an extensive agricultural area west of the site is likely preferred foraging habitat for eagles and other raptors in the project vicinity." The scientific literature, including the literature that accompanies the Final Environmental Assessment for take permits under the Eagle Act, contradict Dr. Mock's testimony.[40] Conversion of habitat to agricultural uses has negatively impacted golden eagles.[41] Golden eagles generally avoid agricultural areas, in part because they do not support the golden eagle's preferred prey species.[42] In addition, secondary poisoning from rodenticides used on agricultural fields is known to cause mortality in golden eagles and many other raptor species.

As a result of these issues, it is my professional opinion that the Project would have a potentially significant, unmitigated impact on golden eagles.

V. THE SSA FAILS TO ADEQUATELY ANALYZE IMPACTS TO MOJAVE FRINGE-TOED LIZARD

Staff conducted a reconnaissance survey of the Project site and believes the Applicant has underestimated the amount of habitat for the Mojave fringe-toed lizard.[43] Although Staff has attempted to provide a more accurate estimate of the amount of habitat that would be affected by the Project, the SSA was unable to provide a final estimate of habitat loss and direct impacts to Mojave fringe-toed lizard. Instead, it deferred a refined estimate of these impacts to Condition of Certification BIO-13. The condition requires the Project owner to provide a delineation of habitat for Mojave fringe-toed lizards to the CPM. The condition further requires the delineation to be prepared by an expert on the species' ecology, whose qualifications have been approved by the CPM. The SSA does not establish when the delineation would be conducted, nor a valid reason for its deferral. There are no verification measures built into the condition of certification to assure an accurate assessment of habitat loss and direct impacts to Mojave fringe-toed lizard before ground disturbance begins.

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[40] USFWS. 2009. Proposal to Permit Take as Provided Under the Bald and Golden Eagle Protection Act. Final Environmental Assessment.
[41] *Id.*
[42] Marzluff JM, ST Knick, MS Vekasy, LS Schueck, TJ Zarriello. 1997. Spatial use and habitat selection of golden eagles in southwestern Idaho. The Auk 114(4):673-687.
[43] SA/DEIS, p. C.2-29.

The SA concluded "[p]roject construction, including the SunCatchers, fences, and drainage structures would likely alter the aeolian transport of sand across the site to downwind habitat within the adjacent Pisgah Crater ACEC, immediately east of the project boundary, though available data are insufficient to quantify this potential impact."[44] Because Mojave fringe-toed lizards are dependent on aeolian sand, any Project-induced changes to sand transport would constitute a potentially significant impact.

The SSA concluded the project "could affect sand transport eastward into the adjacent Pisgah Crater ACEC, though available information indicates that this impact would be relatively minor and [*sic*] is insufficient to quantify this potential impact."[45] The SSA indicates Appendix A to the SSA provides a sand transport study, but no such study accompanies the document.[46] Despite the likelihood that the Project would have significant indirect impacts to Mojave fringe-toed lizard habitat in the adjacent Pisgah ACEC, the SSA does not require any compensation or other mitigation for the impacts.

Appendix A, which is referred to by the SSA, appears to be the "Geomorphic Assessment of Calico Solar Project Site" report prepared by PWA on 12 May 2010. That report concludes the Project could impact dunes off-site that receive their sediment from the site watershed, but such a determination would require more site-specific analysis that "was not conducted as a part of this study."[47] As a result, the environmental consequence of the Project on downwind dune habitat (which also provides habitat for sensitive plant species) remains unassessed, unmitigated, and potentially significant.

In addition to issues related to sand transport, the SA concluded the Project could have numerous indirect impacts to Mojave fringe-toed lizards and their habitat from compaction of soils; the introduction of exotic plant species; alterations to the existing hydrological conditions; alterations in the existing solar regime from shading; modification of prey base; and altered species composition. The placement of fencing and other structures would provide roosting opportunities for avian predators that target lizard prey. This has been shown to deplete lizard populations around the edges of human development.[48] Most importantly, the SA concluded large-scale land use conversion and disruption of native habitat, including drainages and desert scrub communities, would likely disrupt the ability of this species to effectively disperse from source populations and may result in the extirpation of "this" population.[49] In addition, Staff has concluded that the Project's contribution to a significant cumulative impact on Mojave fringe-toed lizard, even with Staff's recommended Condition of Certification BIO-13, would be considerable due to the net habitat loss and interruption of suitable breeding and dispersal habitat between occupied habitat to the east and west. Nonetheless, the SSA proposes no additional mitigation for the Project's cumulative

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[44] SA/DEIS, p. C.2-50.
[45] SSA, p. C.2-68.
[46] SSA, p. C.2-7.
[47] PWA, 2010 May 12. Draft Appendix A (Biology Report), p 21.
[48] Barrows CW, MF Allen, JT Rotenberry. 2006. Boundary processes between a desert sand dune community and an encroaching suburban landscape. Biological Conservation 131:486–494.
[49] SA/DEIS, p. C.2-61.

impact. Given the population dynamics exhibited by this species, including its reliance on a functioning metapopulation structure to persist, it is my professional opinion that the cumulative impacts scenario presented in the SSA would result in the extirpation of the Mojave fringe-toed lizard from the region.

VI. CRYPTOBIOTIC SOIL CRUSTS AND DESERT PAVEMENT

Cryptobiotic soil crusts—communities of cyanobacteria, lichens, and mosses—are found throughout the world's deserts. These crusts bind fine soil particles by linked cyanobacterial fibers, which protect the soil from wind erosion. Several studies have suggested that the presence of cryptobiotic crusts dramatically decreases wind and water erosion.[50] When disturbed, cryptobiotic crusts lose most of their protective qualities allowing mobilization of the underlying mineral soils.[51]

Desert pavement—a desert surface that is covered with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size—is also abundant throughout the world's deserts (most aeolian deflation zones are composed of desert pavement). Desert pavement is very stable and it protects the soil from wind and water erosion. However, underneath the desert pavement is a layer of extremely wind-erodable, wind-derived material, sometimes meters thick. As a result, anthropogenic disturbance to desert pavement or cryptobiotic crusts—such as the grading and other activities proposed by the Project applicant—is likely to have profound consequences.

a) The SSA Failed to Analyze the Significant Impacts from Vegetation Loss

Once the desert crust or pavement is removed (or damaged), sand may be blown several kilometers downwind, resulting in an area of indirect disturbance that can exceed the directly disturbed area by several-fold. For example, Okin et al. (2001) reported that 3,000 ha of land directly disturbed would be expected to indirectly disturb an additional 3,000 to 9,000 ha of land. The encroachment of blowing sand into adjacent shrublands has dramatic consequences for the landscape. Field observations indicate that blowing sand abrades plants, resulting in leaf stripping and damage to the cambium and therefore to the plant's ability to distribute and use water. Young plants are especially vulnerable to the effect of blowing sand as they lack woody tissue. This results in the suppression of revegetation in bare areas and the loss of vegetation on adjacent lands. Nitrogen-fixing microbial communities and cryptobiotic crusts are buried by sand, reducing inputs of nitrogen to the soil (Belnap et al. 1993; Evans and Belnap 1999).

The Project would involve site grading, which would destroy vegetation. In addition, the Project would involve brush trimming between every other row of SunCatchers (i.e., the power generation units). Schlesinger and Pilmanis (1998) have reviewed field experiments in which shrubs have been removed by cutting, herbicides, or fire. These

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[50] Okin GS, B Murray, WH Schlesinger. 2001. Degradation of sandy arid shrubland environments: observations, process modeling, and management implications. Journal of Arid Environments Vol. 47, No. 2, pp. 123–144.
[51] *Id.*

studies show variable rates of soil degradation, but in each case, "a loss of the local biogeochemical cycle associated with shrubs has allowed physical processes to disperse soil nutrients across the landscape." Thus, the progressive reduction in fertility acts in tandem with the mechanical action of sand to further decrease shrub cover, which, in turn, increases the susceptibility of the land to wind and water erosion. The permanent removal of suspension-sized particles from the soil by erosion results in a change of the soil texture, which may also reduce soil-binding properties, resulting in increased erodibility. Whether by wind or water, the fine particles and soil organic matter that are removed by erosion are key to the healthy functioning of soils because they increase soil nutrient content, soil porosity, water-holding capacity, and cation-exchange capacity. Because new vegetation growth is inhibited by blowing sand, the ability of vegetation to stem erosion is limited. This results in a negative feedback loop that ultimately results in severe land degradation.

VII. THE SSA FAILS TO ADEQUATELY ANALYZE IMPACTS TO SPECIAL-STATUS BAT SPECIES

The West Mojave Plan ("WMP") was created "to develop management strategies for the desert tortoise, Mojave ground squirrel and over 100 other sensitive plants and animals that would conserve those species throughout the Western Mojave Desert, while at the same time establishing a streamlined program for compliance with the regulatory requirements of FESA and CESA."[52] Included in the list of roughly 100 sensitive plants and animals governed by the WMP are 6 species of bats that require specific consideration.

No bat surveys have been conducted for the Project. However, the Townsend's big-eared bat is known to occur on the Project site, and several other bat species have been identified as having potential to occur.[53] Potential roost sites for bats occur in the Project area (i.e., railroad trestles, and rock outcroppings) and bats are known from the nearby Pisgah Craters.[54] In addition, the geologic map recently submitted by the Applicant depicts two mines (one of which is labeled "abandoned mine works") near the Project boundary.[55] The WMP identifies the potential for mines in the Project area to have significant (i.e., important) bat roosts. Despite this fact, none of the Applicant's biological resource maps show these mines, and the Applicant has not provided any information on how the Project might affect bat roosts that occur in the mines. Because bats are extremely susceptible to noise and other forms of human disturbance, and because viable roost sites are essential to maintaining bat populations, an assessment of Project impacts on bats must be provided.

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[52] Bureau of Land Management. 2005. Final environmental impact report and statement for the West Mojave Plan: a habitat conservation plan and California desert conservation area plan amendment. Moreno Valley (CA): U.S. Dept. of the Interior, Bureau of Land Management, California Desert District, Opening Letter.
[53] SA/DEIS, Biological Resources Table 1.
[54] SA/DEIS, p. C.2-93.
[55] URS. 2010 May 14. Field Reconnaissance Geologic Map, Calico Solar Project, Figure 4.

Under the WMP, take of bats and their roosting habitat is limited to sites harboring 10 or fewer bats.[56] The WMP does not permit the loss of significant roosts, and specific procedures must be followed for surveys and to allow for safe exit of bats.[57]

a. Survey Protocols Violate the West Mojave Plan

In order to mitigate adverse impacts on potential bat communities, the SSA has recommended the implementation of Bat Impact Avoidance and Minimization Measures ("BIO-25"), which includes pre-construction surveys in all areas of suitable bat habitat (i.e., rock outcrops and railroad trestles). The survey methods provided in BIO-25 do not mitigate potentially significant impacts to special-status bat species, and they do not correspond with the guidelines established by the WMP. Whereas the SSA requires roosting surveys to be conducted during the maternity season (1 March to 31 July), the WMP indicates that surveys must take place in both the summer and winter "to determine if bats utilize a potential roost for hibernation or for maternity colonies."[58] Additionally, the WMP specifies "surveys that indicate a roost is used in one of the seasons should be repeated during the other season to determine if bats use the roost for both functions."[59] Lastly, given the Applicant's proposal to start construction this year, there is no way for it to satisfy Staff's requirement that bat surveys be conducted during the maternity season (March through July).

b. Significance of Roosts Is Not Adequately Identified in the SSA

In discussing the required mitigation steps in the event that an active roost is located within Project boundaries, BIO-25 fails to set significant roost levels in accordance with the WMP. Under the WMP, all maternity and hibernation roosts of Townsend's big-eared bat and California leaf-nosed bat are considered significant if more than 10 individuals are present. Roosts of the other four bat species are considered significant at populations greater than 25.[60] Significant roosts may not be taken per the WMP, which must be incorporated into BIO-25 of the SSA. Specifically, the SSA contains ambiguous language on mitigation for an active maternity and/or hibernation roost on-site. It states, "[i]f active maternity roosts or hibernacula are found, the rock outcrop or trestle occupied by the roost shall be avoided (i.e., not removed) by the project, ***if feasible.***"[61] The mitigation measures must be modified so that an active, *significant* maternity and/or hibernation roost is completely avoided by all Project activities. Under the WMP, the presence of alternative maternity roosting sites in the area does not allow for disruption and/or take of "significant" roosts (as has been implied by the SSA), nor is there a provision for take of "significant" roosts if alternative roosting sites are available.

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[56] Bureau of Land Management. 2005. Final environmental impact report and statement for the West Mojave Plan: a habitat conservation plan and California desert conservation area plan amendment. Moreno Valley (CA): U.S. Dept. of the Interior, Bureau of Land Management, California Desert District, Chapter 2, p. 2-46.
[57] Id.
[58] Ibid., p. 2-80
[59] Ibid., p. 2-80
[60] WMP, p. C-79
[61] SSA, p. C.2-223.

c. Removal Measures are Inconsistent with WMP Guidelines and Protocol

Roosts that are not deemed significant by the thresholds discussed above qualify for incidental take following certain procedures outlined in the WMP. These apply to both non-significant maternity and hibernation roosts. The WMP recommends a temporary closing of roosts after the evening flight and entering the roost to remove any remaining bats. This process is to be repeated twice by a qualified biologist and in consultation with CDFG. The protocol for non-significant roost removal in BIO-25 must be modified to correspond with the WMP guidelines.

The timing of non-significant roost removals must also follow WMP protocol. BIO-25 states, "[i]f an active maternity roost is located in an area to be impacted by the project, and alternative roosting habitat is available, the demolition of the roost site must commence before maternity colonies form (i.e., prior to 1 March) or after young are flying (i.e., after 31 July)."[62] However, the WMP also prohibits disturbance or removal of non-significant roosts during winter hibernation seasons, which is absent from the timeframe included in the SSA. Per WMP guidelines, BIO-25 must include provisions to prevent roost disturbance or removal during both maternity and hibernation periods.

d. Impacts to Bat Species from Transmission Line Upgrades and Substation Construction are Not Adequately Analyzed

The Project is entirely dependent on the transmission line upgrades and substation construction proposed by the Applicant. Because these activities are part of the Project, the SSA must provide bat impact avoidance and minimization measures that apply to transmission line and substation upgrade activities.

The SSA notes the presence of potential bat habitat (i.e., mine shafts, rock outcrops, lava tubes, railroad trestles, bridges)[63] within the proposed transmission line route, and information provided by the Applicant states that the transmission line ROW runs east along the Mojave River, which represents potential riparian habitat for Townsend's big-eared bat. Significant roosts of this species have been recorded along the Mojave River.[64] A complete survey of all suitable bat habitat according to protocol established by the WMP must be conducted for any Project activities that occur in the WMP Area. The avoidance and mitigation measures established in the WMP must then be implemented if bat roosts are present.

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[62] DEIS, p. C.2-197
[63] DEIS, p. C.2-92
[64] Bureau of Land Management. 2005. Final environmental impact report and statement for the West Mojave Plan: a habitat conservation plan and California desert conservation area plan amendment. Moreno Valley (CA): U.S. Dept. of the Interior, Bureau of Land Management, California Desert District.

VIII. THE SSA FAILS TO ADEQUATELY ANALYZE ENVIRONMENTAL IMPACTS ASSOCIATED WITH THE REQUIRED TRANSMISSION UPGRADES

a. The Description of the Affected Environmental is Unreliable

The Project requires construction of approximately 67 miles of 500kV transmission line between the existing Pisgah and Lugo substations.[65] In addition, the existing Pisgah Substation would be relocated and expanded, and the Lugo Substation would be upgraded and expanded.[66] New telecommunication facilities would be installed between the Gale and Pisgah substations as well as between the Lugo and Pisgah substations. Although all these are reasonably foreseeable activities, the SSA does not depict them on a map or otherwise specify their boundaries.

The applicant conducted a reconnaissance-level habitat assessment to characterize the vegetation within the Pisgah-Lugo corridor and to determine potential habitats for sensitive species in 2007 and 2008.[67] To date, no surveys have been conducted along the Gale-Pisgah telecommunication corridor.[68]

The Pisgah-Lugo transmission corridor encompasses a wide range of terrain and elevation, and according to the Applicant, it crosses 17 native vegetation types (some of which are sensitive natural communities) and 3 non-native or disturbance-related vegetation types. The SA states the transmission corridor would cross through the Ord-Rodman Desert Wildlife Management Area (DWMA), the Pisgah Area of Critical Environmental Concern (ACEC), and the Upper Johnson Valley Yucca Rings ACEC.[69] Information provided by the Applicant suggests the transmission line would also pass through the Juniper Flats ACEC.[70]

Ten special-status plant and animal species were detected during the Applicant's reconnaissance-level surveys of the transmission corridor. However, numerous other special-status species have the potential to occur along the route. This was not articulated clearly in the SA, nor did the SA list all of the special-status species that might be affected by activities associated with the transmission line and substation upgrades. According to the Applicant, listed species with a "moderate" or "high" potential of being affected by the transmission line and substations upgrades include: Mojave tarplant (State Endangered), California red-legged frog (Federally Threatened), desert tortoise (State and Federally Threatened), southwestern willow flycatcher (State and Federally Endangered), and Mohave ground squirrel (State Threatened).

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[65] *See* AFC, Appendix EE: Environmental Summary Report for the Proposed Lugo-Pisgah 500kV Transmission Line and Substation Upgrades.
[66] SA/DEIS, p. C.2-117.
[67] SA/DEIS, p. C.2-113.
[68] *Id.*
[69] SA/DEIS, p. C.2-116.
[70] Applicant's response to CURE data request 395.

b. Impact Assessment and Mitigation is Inadequate

The SA concludes the transmission line and substation upgrades would create significant impacts to biological resources due to the permanent loss of habitat and the disturbance to sensitive plant and wildlife species during construction.[71] However, the SA further concluded mitigation is available and feasible, and would likely reduce most impacts to biological resources to less-than-significant levels under CEQA.[72] The SA does not provide sufficient information to assess whether transmission line and substation upgrade activities would comply with the West Mojave Plan.

The SA lacks support for the conclusion that mitigation is available and feasible, or that the proposed mitigation would likely reduce most impacts to biological resources to less-than-significant levels. The Upper Johnson Valley Yucca Rings ACEC contains a unique assemblage of ancient vegetation. Impacts to this feature would be significant and unmitigable.

White-margined beardtongue occurs along the transmission line route. This species has an extremely limited distribution in California, with most known occurrences in the immediate Project area. The continued existence of white-margined beardtongue in California is threatened by the Project. Because the species is known to occur along the transmission line route, upgrade activities would exacerbate the threat, and might not be mitigable.

The SA references "mitigation such as the measures described above" to justify its conclusion that mitigation to reduce impacts is available and feasible.[73] The mitigation measures described "above" were originally recommended by the Applicant in Appendix EE to the AFC.[74] The SA has demonstrated that some of these measures are actually *infeasible*. For example, the Applicant proposed relocation for impacts to white-margined beardtongue,[75] which the SA explicitly states is infeasible as mitigation.[76]

IX. THE SSA FAILS TO ADEQUATELY ANALYZE IMPACTS TO SPECIAL-STATUS PLANTS

The SSA lacks the information necessary to conduct a reliable assessment of Project impacts to special-status plant resources. This is primarily due to the Applicant's failure to conduct surveys during the summer/fall season or provide reliable data from surveys conducted during its 2007 and 2008 spring surveys. The SA did not contest this argument, and I believe Staff made considerable efforts to incorporate the Applicant's

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[71] SA/DEIS, p. C.2-122.
[72] *Id.*
[73] *Id.*
[74] SA/DEIS, p. C.2-119.
[75] AFC, Appendix EE, p. 21.
[76] SA/DEIS, p. C.2-119.

2010 survey data into the SSA. However, I am concerned the late submittal of these data has not given Staff adequate time to assess them or devise appropriate mitigation.

I have the following comments related to Project impacts to, and mitigation for, sensitive botanical resources:

1. Without reliable information on the species that occur—and as a result, the level and types of Project impacts on those species—the SSA cannot conclude proposed mitigation would reduce Project impacts to less than significant levels. A conclusion of this nature would rely on the presumption that all impacts can be mitigated to a less than significant level. Such a presumption is unrealistic for two reasons. First, it is difficult to predict the outcomes of surveys due to the new and unexpected discoveries that have been occurring in the desert (and thus the inability to pre-assign mitigation). Second, the flora of the Desert Floristic Province is poorly understood and therefore surveys may yield completely unexpected results that cannot be mitigated by standard conditions.
2. Small-flowered sand-verbena (*Tripterocalyx micranthus*) was reported on the Project site in the Applicant's Biological Resources Technical Report, though the locations were not mapped, nor was there an indication of numbers of plants or extent of distribution across the project site.[77] If valid, this report would be the first record of small-flowered sand-verbena in the central Mojave Desert. It was not relocated on the site during 2010 field surveys. Staff concluded the original report was apparently due to misidentification and that small-flowered sand verbena is unlikely to occur on the site. However, Staff further concluded that if small-flowered sand-verbena occurs on the Project site, impacts would be significant and would require mitigation. Staff provided little explanation for its conclusion that the species was unlikely to occur on the site, and based on my review of the literature, I do not think the possibility that it might occur should be discounted. The only means Staff has suggested for developing a more reliable conclusion on the species' occurrence is through "follow-up field surveys." The blooming period for the plant is reported to be from April to May, and therefore the Applicant's late season surveys would not be a sufficient means of searching for the plant before Project construction begins. As a result, Project impacts on the species would be potentially significant and unmitigated.
3. Many of the sub-categories in Section A of Staff's proposed Condition of Certification BIO-12 lack success criteria and rigor to ensure they are likely to succeed.
4. Section B of BIO-12 requires late-season surveys "to the extent feasible." However, the condition lacks a definition of what is considered feasible, or which party dictates feasibility.

[77] SA, p. C.2-32.

5. The compensatory mitigation described in Section D of BIO-12 lack feasibility and reasonable assurance that they would be commensurate with Project impacts.
6. The SSA requires mitigation for Project impacts to 3.3 acres of catclaw acacia or smoke tree habitat. Based on the map submitted by the Applicant, microphyllus tree species appear to be distributed along a cumulative total of at least two miles of desert wash. The SSA lacks an explanation of why impacts to a linear feature where converted into an area measurement for mitigation (which has resulted in mitigation not commensurate with Project impacts).
7. Staff concluded that "adverse impacts to small-flowered androstephium would be less-than-significant per CEQA due to numerous additional occurrences documented elsewhere in California in recent years, including new occurrences documented by the applicant on public lands to the west and east, including many in the Pisgah ACEC."[78] However, the SA noted that (a) a large percentage (85%) of the occurrences documented in the California Natural Diversity Database (82 occurrences as of Apr 2010) is threatened by development (solar energy projects and Fort Irwin expansion);[79] and (b) the Project could have a significant impact on downwind habitat within the Pisgah Crater ACEC.[80] In addition, the occurrence of over 1,500 small-flowered androstephium plants on the Project site during the 2010 plant surveys represents the single largest population of the species in California (based on records in the California Natural Diversity Database). These factors support the conclusion that the Project would have a potentially significant impact on small-flowered androstephium.

Compliance with the West Mojave Plan

The West Mojave Plan ("WMP") provides conservation measures to minimize and mitigate the take for each species for which take has been authorized. It does not appear that the Project complies with these conservation measures.

The WMP has established the allowable amount of incidental take of white-margined beardtongue for maintenance of existing facilities within the BLM utility corridor and on private land within the species' range. The authorized amount of incidental take is limited to 50 acres of occupied and *potential* habitat.[81] Additionally, the WMP calls for the conservation of all known occurrences of the species within washes south of the Cady

[78] SA/DEIS, p. C.2-51.
[79] SA/DEIS, p. C.2-22.
[80] SA/DEIS, p. C.2-50.
[81] Bureau of Land Management. 2005. Final environmental impact report and statement for the West Mojave Plan: a habitat conservation plan and California desert conservation area plan amendment. Moreno Valley (CA): U.S. Dept. of the Interior, Bureau of Land Management, California Desert District, Chapter 2, p. 2-51.

Mountains.[82] Due to limitations of the botanical field surveys, the SSA could not evaluate the total extent of habitat or numbers of white-margined beardtongue within the proposed Project area.[83] However, the SSA concluded white-margined beardtongue has the potential to occur anywhere in the lower elevation wash and sandfield vegetation.[84]

The WMP restricts the construction of windbreaks upwind of occupied Mojave fringe-toed lizard habitat.[85] The Project would be located directly upwind of occupied habitat within the Pisgah ACEC, which was specifically designated for conservation of the Mojave fringe-toed lizard.[86]

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[82] *Id.*
[83] SA/DEIS, p. C.2-49.
[84] SA/DEIS, p. C.2-25.
[85] Bureau of Land Management. 2005. Final environmental impact report and statement for the West Mojave Plan: a habitat conservation plan and California desert conservation area plan amendment. Moreno Valley (CA): U.S. Dept. of the Interior, Bureau of Land Management, California Desert District, Chapter 2, p. 2-92.
[86] SA/DEIS, p. C.7-10.

Declaration of Scott Cashen
Calico Solar Project

Docket 08-AFC-13

I, Scott Cashen, declare as follows:

1) I am an independent biological resources consultant. I have been operating my own consulting business for the past three 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 rebuttal testimony attached hereto and incorporated herein by reference, relating to the biological resource impacts of the Calico Solar Project.

4) I prepared the rebuttal testimony and maps 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 rebuttal testimony and maps 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 rebuttal testimony and maps, 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: 7-29-10 Signed: [signature]

At: Walnut Creek, CA

Calico Solar – 08-AFC-13
DECLARATION OF SERVICE

I, Bonnie Heeley, declare that on July 29, 2010, I served and filed copies of the attached Rebuttal Testimony of Scott Cashen on Behalf of California Unions for Reliable Energy on Biological Resources for the Calico Solar Project dated July 29, 2010. 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/calicosolar/CalicoSolar_POS.pdf. 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 electronically to all email addresses on the Proof of Service list; and by depositing in the U.S. mail at South San Francisco, CA, with first-class postage thereon fully prepaid and addressed as provided on the Proof of Service list to those addresses NOT marked "email preferred."

AND

By sending an original paper copy and one electronic copy, mailed and emailed respectively to:

CALIFORNIA ENERGY COMMISSION
Attn: Docket No. 08-AFC-13
1516 Ninth Street, MS 4
Sacramento, CA 95814-5512
docket@energy.state.us.ca.

I declare under penalty of perjury that the foregoing is true and correct. Executed at South San Francisco, CA, on July 29, 2010

_____/s/_____
Bonnie Heeley

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EXHIBIT 425

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In his 18 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

- Victorville 2 Solar-Gas Hybrid Power Project: Victorville, CA (338-acre natural gas and solar energy facility) – Review of CEQA equivalent documents and preparation of written documents.
- Avenal Energy Power Plant: Avenal, CA (148-acre natural gas facility) – Review of CEQA equivalent documents and preparation of written documents.
- Ivanpah Solar Electric Generating System: Ivanpah, CA (3700-acre solar facility) – Review of CEQA equivalent documents and preparation of written documents.
- Carrizo Energy Solar Farm: 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

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

- Surveyor - Pre-construction raptor and burrowing owl surveys *(various clients and locations)*
- Surveyor - Backcountry bird inventory *(National Park Service: Eagle, Alaska)*
- Lead surveyor - 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*

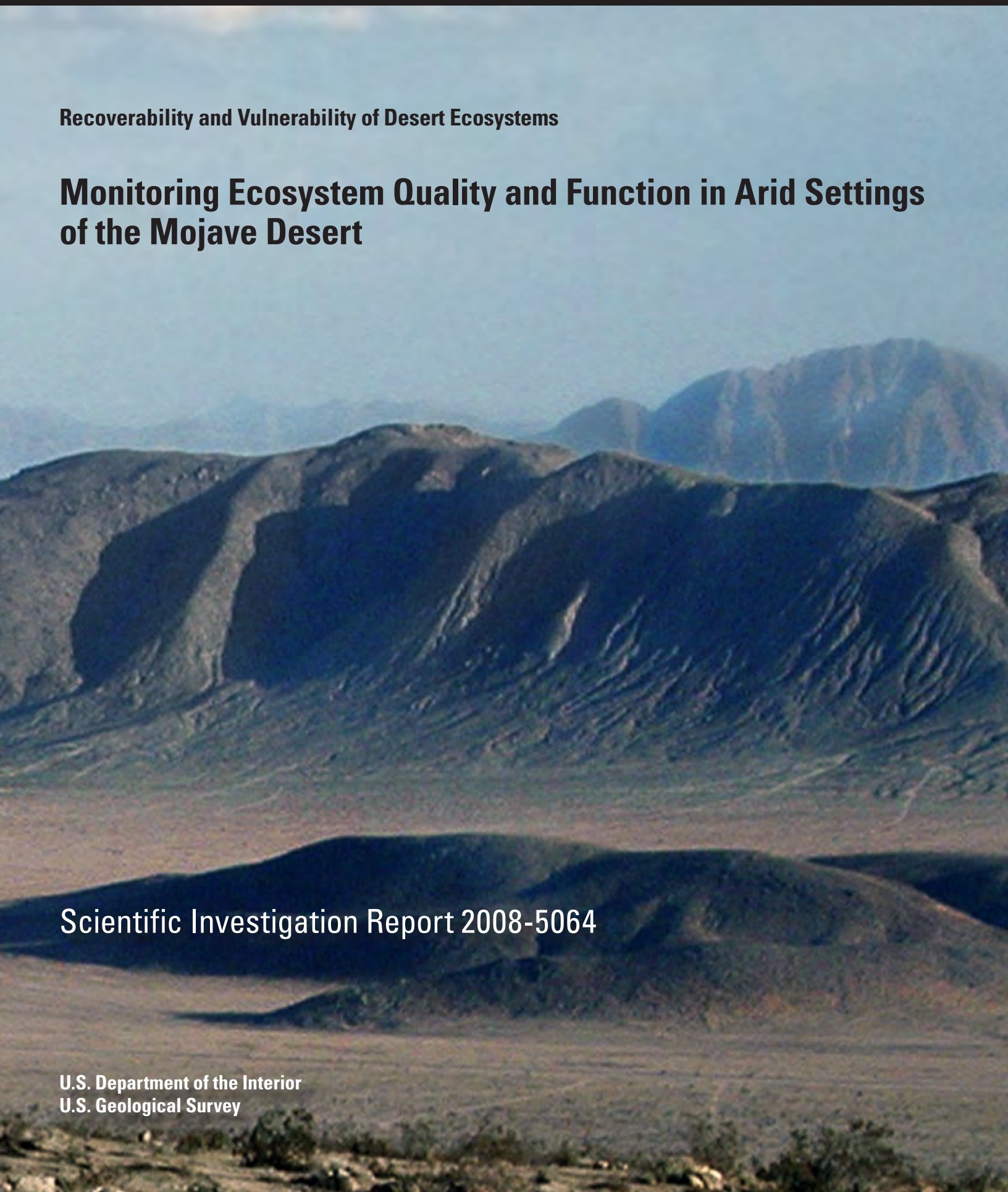
Land Committee Member – *Save Mt. Diablo*

TEACHING EXPERIENCE

Instructor: Wildlife Management, The Pennsylvania State University, 1998

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

EXHIBIT 426



Recoverability and Vulnerability of Desert Ecosystems

Monitoring Ecosystem Quality and Function in Arid Settings of the Mojave Desert

Scientific Investigation Report 2008-5064

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

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Monitoring Ecosystem Quality and Function in Arid Settings of the Mojave Desert

By Jayne Belnap, Robert H. Webb, Mark E. Miller, David M. Miller, Lesley A. DeFalco, Philip A. Medica, Matthew L. Brooks, Todd C. Esque, and Dave Bedford

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U.S. Department of the Interior
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U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

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Suggested citation:
Belnap, Jayne, Webb, R.H., Miller, D.M., Miller, M.E., DeFalco, L.A., Medica, P.A., Brooks, M.L., Esque, T.C., and Bedford, D.R., 2008, Monitoring ecosystem quality and function in arid settings of the Mojave Desert: U.S. Geological Survey Scientific Investigations Report 2008-5064, 119 p.

Produced in the Western Region, Menlo Park, California
Manuscript approved for publication, April 28, 2008.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
Area		
square meter (m2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km2)	247.1	acre
square centimeter (cm2)	0.001076	square foot (ft2)
square meter (m2)	10.76	square foot (ft2)
square centimeter (cm2)	0.1550	square inch (ft2)
hectare (ha)	0.003861	square mile (mi2)
square kilometer (km2)	0.3861	square mile (mi2)

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

$$°C=(°F-32)/1.8$$

Units and Nomenclature

In this report, we use metric units to describe all aspects of ecosystem attributes and function. Although we acknowledge that the common names of plants and animals vary considerably among lay persons and scientific observers, we use a consistent set of common names familiar to the authors and cite the appropriate Latin name for plants and animals on first mention in the text. Because the commonly used Latin names for plants and animals vary across the region and among scientists, we use the nomenclature presented in Hickman (1993) for plant species and the naming conventions in Banks and others (1987) for reptiles and small mammals.

Monitoring Ecosystem Quality and Function in Arid Settings of the Mojave Desert

Jayne Belnap, Robert H. Webb, Mark E. Miller, David M. Miller, Lesley A. DeFalco, Philip A. Medica, Matthew L. Brooks, Todd C. Esque, and Dave Bedford

Abstract

Monitoring ecosystem quality and function in the Mojave Desert is both a requirement of state and Federal government agencies and a means for determining potential long-term changes induced by climatic fluctuations and land use. Because it is not feasible to measure every attribute and process in the desert ecosystem, the choice of what to measure and where to measure it is the most important starting point of any monitoring program. In the Mojave Desert, ecosystem function is strongly influenced by both abiotic and biotic factors, and an understanding of the temporal and spatial variability induced by climate and landform development is needed to determine where site-specific measurements should be made. We review a wide variety of techniques for sampling, assessing, and measuring climatic variables, desert soils, biological soil crusts, annual and perennial vegetation, reptiles, and small mammals. The complete array of ecosystem attributes and processes that we describe are unlikely to be measured or monitored at any given location, but the array of possibilities allows for the development of specific monitoring protocols, which can be tailored to suit the needs of land-management agencies.

Figure 1. The Mojave Desert ecosystem occurs in southeastern California, western Arizona, southern Nevada, and the extreme southwestern corner of Utah. (Brown outline shows approximate area of the Mojave Desert.)

Introduction

The Mojave Desert covers 152,500 km^2 of the Basin and Range physiographic province of eastern California, southern Nevada, southwestern Utah, and northwest Arizona (fig.1). Resource managers in this diverse region are challenged with maintaining the integrity of a complex and varied ecosystem under the demands of resource extraction and multiple land uses. In particular, the pressures of off-highway vehicle recreation, military training, livestock grazing, and urban expansion have created a mosaic of intensive uses adjacent to relatively undisturbed landscapes. In addition, this ecosystem faces the additional stresses of increasing fire, invasion by non-native species, atmospheric deposition of pollutants, and fluctuations in temperature and precipitation. Monitoring of ecosystem quality and function is a requirement of state and Federal agencies—particularly the Bureau of Land Management, the National Park Service, and the U.S. Forest Service—as well as a means of determining potential long-term changes. Application of certain Federal laws, such as the Endangered Species Act, requires ecosystem monitoring as an integral part of recovery plans, and agencies with a mandate for ecosystem protection or sustainable use depend on monitoring protocols to assess the success of their mission.

This report presents conceptual ecological models that describe the structure and function of low-elevation, dryland ecosystems of the Mojave Desert. These models identify individual critical components of the ecosystem, their linkages to other components of the model, and how both natural and anthropogenic drivers affect these components and linkages. Such models are of great value in facilitating discussion among scientists, managers, and the public about how eco-

systems function and how ecosystem condition can best be monitored. We then discuss techniques for designing and conducting programs for monitoring these components and their linkages. We emphasize that the spatial variability induced by climate and landform development is critical to understanding ecosystem function, and these factors need to be considered when designing a site-specific monitoring program. Indeed, climatic variability is the single most important factor to be measured in any monitoring program, and the effect of geomorphic surface on ecosystem function is of sufficient magnitude to affect the interpretations that may be obtained from site-specific measurements. In addition, because there are far more components and processes to monitor than is financially feasible, we favor monitoring processes rather than attributes, with the knowledge that important, rare, or endangered species are likely to be specifically examined for long-term changes wherever these species occur.

The authors call on more than two centuries of collective experience to describe what has worked in the past, what the current recommendations are, and what might be available in the future to measure this unique and threatened desert. We cover what we consider to be the fundamental properties of the Mojave ecosystem that can be used to assess its status or to warn of impending problems, particularly emphasizing atmospheric and soil processes, vegetation productivity and quality, and small animal populations. Although we recognize the legal and scientific importance of endangered species, we do not focus on these and their often unique problems, choosing instead to discuss the habitat framework that encompasses them.

The Models

The Underpinnings of Ecosystem Sustainability: The Jenny-Chapin Model

In 1941, Hans Jenny proposed that five state factors—climate, organisms, relief (topography), parent material, and time since disturbance—determine soil and ecosystem processes. This model was later modified by Jenny (1980) and then expanded by Chapin and others (1996) to include four interactive controls that define ecosystem sustainability: climate, soil-resource supply, major functional groups of organisms, and disturbance regime. The state factors constrain the interactive controls and determine the “constraints of place” (Dale and others, 2000). For the purposes of this manual, we are using a modified version of this model adapted by Miller (2005; fig. 2).

An underlying assumption of the Jenny-Chapin model is that the maintenance of ecosystem health and integrity requires that the four interactive controls be conserved, as any large changes in them will result in a new ecosystem. For example, changes in the fire cycle or changes in the timing of rainfall can result in different plant species dominating a site. This, in turn, alters both below- and above-ground biota and most of the ecosystem processes associated with the biota. The resultant ecosystem, therefore, will have a different structure and function than the one preceding it.

The Mojave Desert General Conceptual Dryland Model

Our general Mojave Desert dryland conceptual model is presented in figure 3. This model is based on the concepts of the Jenny-Chapin model and then expanded to include the specifics of the Mojave Desert following the approach of Miller (2005). In this section, we discuss the main components of the Mojave Desert ecosystem, as outlined in the model.

Connectivity of Components and Process

Because arid systems are highly heterogeneous, they are often conceptualized as a mosaic of interconnected patches (Peters and Havstad, 2006). Patchiness can occur at all scales, from sub-millimeter patches (for example, soil aggregates versus pore space) to centimeter-sized patches (for example, root versus non-root areas) to meter-sized patches (for example, plant versus interspace) to the hillslope scale, landscape scale, and regional scale (figs. 2 and 3). As pattern and process are inherently linked in desert ecosystems, understanding the processes that form patterns and how patterns influence processes is needed to quantitatively and predictably understand and model ecosystems (Wu and Levin, 1994). As a healthy ecosystem can be defined as one in which the retention of soil, water, and nutrients is within the natural range of variation, and soil-resource patterning controls this retention, soil-resource patterning can be a useful indicator for monitoring programs (Herrick and Whitford, 1995; Ludwig and others, 1997; Havstad and others, 2000). This can be as simple as recording the size of spaces between plants, or as sophisticated as mapping the plants, interspace covers, and microtopography that can influence how materials (for example, water, plant litter, soil, seeds) move across the surface. For further discussion on this topic, see appendix A.

Regional Climate and Atmospheric Conditions

Climate

The diverse topography of the Mojave Desert was created by complex and active tectonics interacting with a wide variety of geologic formations (fig. 3). This topographic diversity strongly affects the climate of the region. On its west and southwest margins, the Mojave Desert is bounded by the Sierra Nevada, San Gabriel, and San Bernardino Mountains, all of which are fault-bounded margins of the Basin and Range physiographic province. These imposing mountains alter the prevailing westerly winds and intercept moisture derived from the Pacific Ocean, resulting in a rain shadow that creates the arid conditions on the lee side of the ranges. The Mojave

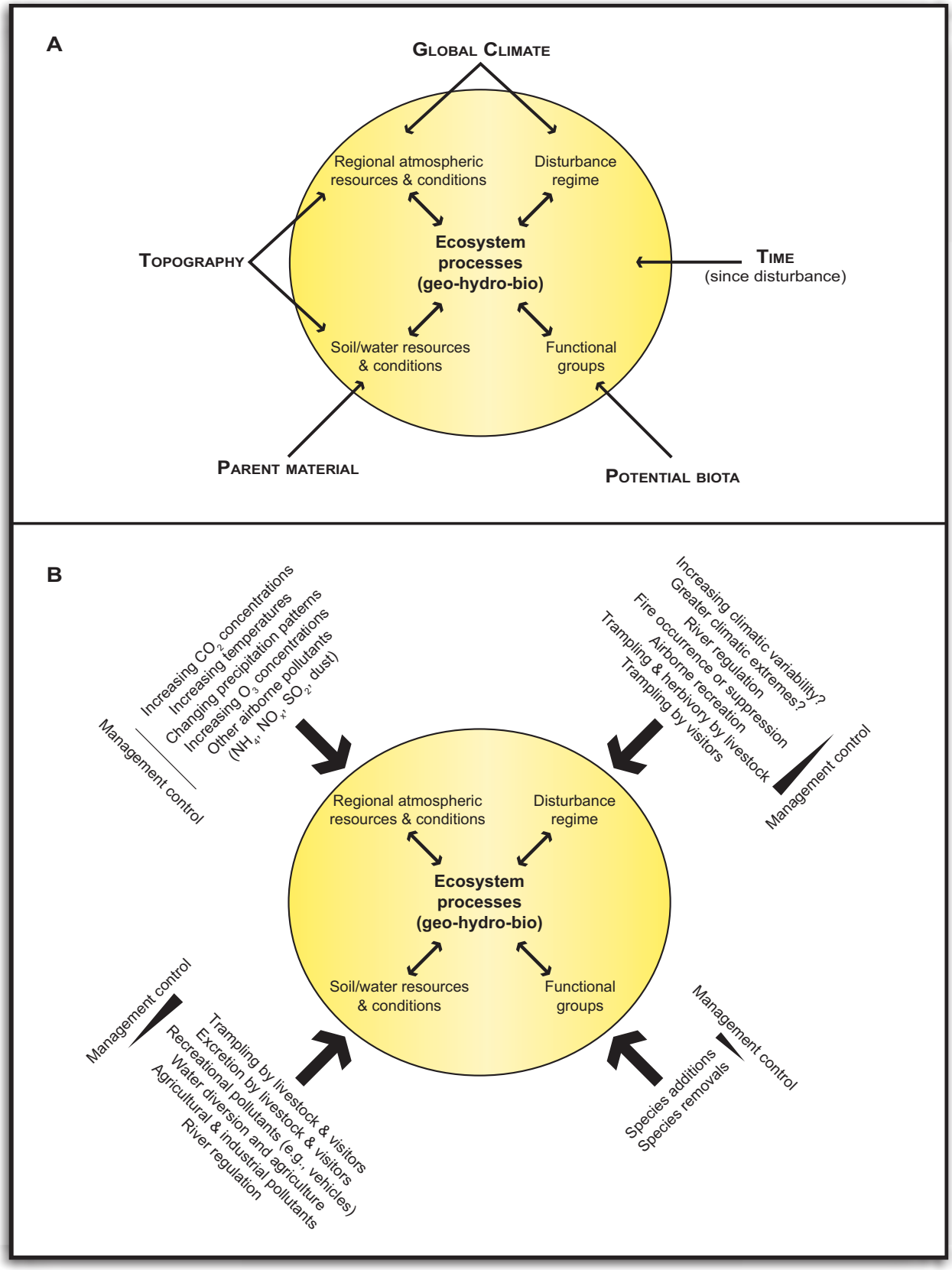

Figure 2. Modified version A, of the Jenny-Chapin model that serves as a general ecosystem model for the Mojave Desert (redrawn with permission from The American Naturalist and The University of Chicago Press; Chapin and others, 1996) and B, the array of stressors affecting Mojave Desert ecosystems arranged in the model in relation to their first-order effects. Complex, higher order effects occur as the four major controls interact through ecosystem processes. The circle represents the boundary of the ecosystem.

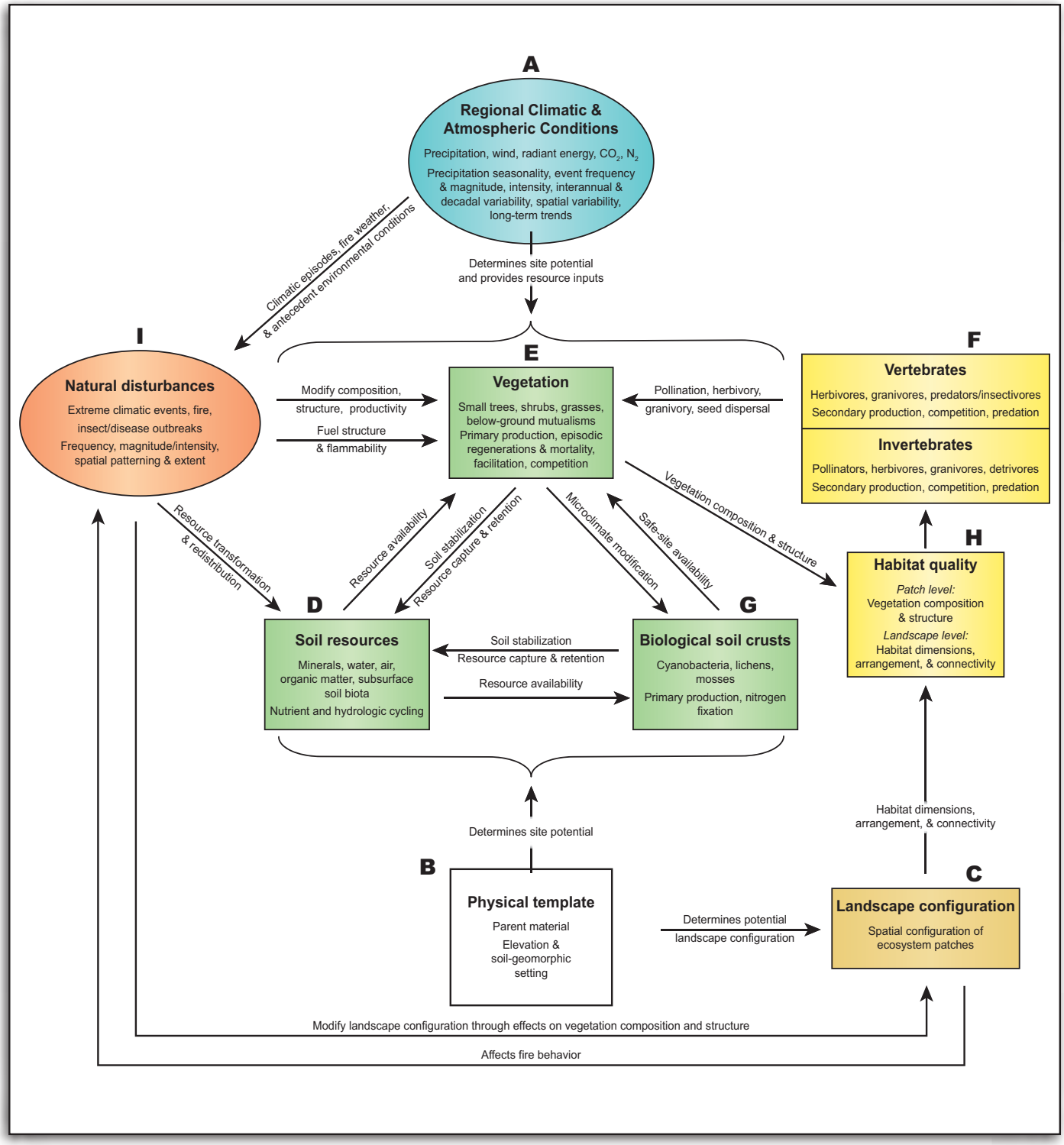

Figure 3. General conceptual model depicting the structure and functioning of dryland ecosystems. Ovals indicate major drivers of ecosystem change and temporal variability, as well as important attributes of drivers. Rectangles indicate major structural components and important processes. Arrows indicate functional relationships among components. Colored areas indicate drivers and dynamic ecosystem components that are subject to monitoring. The model is constrained by global climatic and atmospheric conditions, topography, parent material, potential biota, and time.

Desert is bounded on the northeast by the Colorado Plateau, which is a broad, mostly semiarid region rising above the general elevation of the southwestern deserts. The northern and southern boundaries of the Mojave Desert are transitional and largely caused by elevation changes. To the south the Mojave Desert grades into the Colorado Desert, to the southeast it grades into the Sonoran Desert, and to the north it transitions into the Great Basin Desert.

Most attributes and processes of dryland ecosystems, such as the Mojave Desert, are driven by the availability of water. Therefore, precipitation characteristics are critical in determining ecosystem function. The main characteristics of interest are event size, timing, reliability, intensity, and the total annual amount. The size of a given precipitation event determines the biotic response to the event. Most events in deserts are very small, with more than 85 percent of events less than 5 mm (Sala and Lauenroth, 1982). Whereas events of this size may stimulate microbial activity and nutrient transformation at the soil surface, larger events are required for a plant response or recharge of soil moisture at depth.

The timing, reliability, and intensity of precipitation are critical for determining how long soils stay moist, how long surface water is available, and what organisms will be active and able to utilize the moisture when it occurs. Throughout the desert, rainfall during May and June is very low; it is consistently less than 5 percent of the annual precipitation (Hereford and others, 2004). During the rest of the year, the timing of rainfall varies throughout the Mojave Desert. In the regions west of the 117th meridian of longitude, 70 percent of the climate stations record 82 percent of total precipitation falling during winter (October–April; Hereford and others, 2004, 2006). East of the 117th meridian, however, 90 percent of the climate stations document that summer–fall (July–September) precipitation accounts for 29 percent of the annual total, while winter precipitation accounts for only 66 percent of the annual total. Precipitation events during the winter months tend to be widespread, of relatively low intensity, and of relatively long duration. In addition, cool air temperatures result in low evaporation rates. Summer–fall precipitation generally results from either isolated or regional convective thunderstorms resulting from tropical cyclones and hurricanes that originate in the eastern North Pacific Ocean (Smith, 1986). These storms are typically accompanied by severe, localized, and unpredictable flash flooding. Although they constitute a large portion of the annual total for a given site, on average, many summers are totally dry. This is in contrast to deserts to the southeast of the Mojave (for example, the Sonoran and Chihuahuan), where summer–fall rainfall events are dependable. Summer–fall rainfall events occur when air temperatures are high, and thus the resultant soil moisture evaporates much more quickly compared to the same-sized events that occur in winter when air temperatures are lower.

Climate is also locally influenced by topography. Winter precipitation is strongly orographic (that is, related to changes in elevation due to mountains), increasing from approximately 100 mm at lower elevation sites to more than 500 mm near the tops of some Mojave Desert mountain ranges. Average temperature decreases approximately 6ºC for every 1,000-m increase in elevation (Ricklefs, 1990). Thus, topography directly influences the amount and timing of precipitation across large spatial gradients (basins and ranges) and more proximal elevation gradients (for example, on a single mountainside). The variation in temperature, combined with topography, results in high variability of potential evapotranspiration. Only a few studies have directly addressed the magnitude of climate variability over time in the Mojave Desert (fig. 4; Hereford and others, 2004; Hereford, in press). Huning (1978) found an overall decrease in precipitation from the 1940s—a period dominated by El Niño events—compared with the early 1970s. Average annual (calendar year) precipitation calculated from 52 climate stations in the region shows a range of 47–587 mm/yr, with a regional average of 149 mm/yr (Hereford and others, 2004). Regionally, the driest year was 1953, whereas 1941 and 1983 were two of the wettest years. Long-term annual precipitation varied substantially during the 20th century, with five precipitation regimes: 1893–1904 (early 20th century drought), 1905–1941 (above average), 1942–1975 (mid-century drought), 1976–1998 (above average), and 1998–2004 (early 21st century drought; Hereford, in press). The choice of limiting dates for these periods is subjective; for example, the mid-century dry

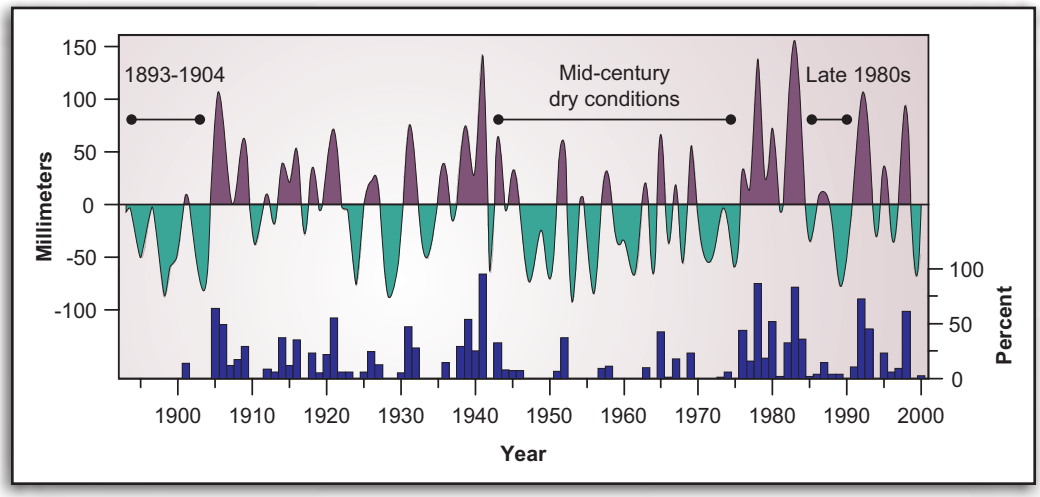

Figure 4. Average deviation of annual precipitation (that is, the average deviation from the mean of the reporting stations) and bar graph showing percent of stations having precipitation more than 68 percent of normal (modified from Hereford and others, 2004).

regime may have begun as late as 1946 and ended as early as the mid-1960s. Regardless of the exact dates, the mid-century drought intervenes between two wet periods, the latter of which was exceptional in terms of its effects on the Mojave Desert. The period from 1976 through 1998 was the wettest of the 20th century, broken only by a relatively brief, intense drought from 1989 through 1991 (Flint and Davies, 1997).

Climatic variability creates a complex framework for understanding past, current, and future features in the desert, such as plant viability, plant-animal interactions, soil moisture availability, and persistence of ephemeral and perennial streams. Superimposed on top of the background of climate variability are the short- and long-term effects of climate change. Based on past analogs and regional climate models that include increased atmospheric carbon dioxide (CO_2), scientists predict that drier conditions will prevail during the next few decades. The Pacific Decadal Oscillation (PDO) recently appeared to change phase (see http://topex-www.jpl.nasa.gov/science/pdo.html). The previous similar phase of the PDO occurred during the middle of the 20th century and was accompanied by prolonged dry conditions in the Southwest. By extrapolation, some climatologists predict future drought in the Southwest (Cole and others, 2002; Swetnam and Betancourt, 1998). Frequency of flooding, particularly in larger river systems, may decrease, and eolian activity in the Southwest may increase (Schmidt and Webb, 2001). Predictions for future climate include more intense, more frequent, and longer heat waves (Meehl and Tebaldi, 2004); increased temperature and decreased rainfall in both summer and winter (Thompson and others, 1998; Giorgi and others, 2001; Christensen and others, 2007); and winter warming, reduced snowpack, and more extreme winter storms (Leung and others, 2004). Although future climate trends are imperfectly predicted because climate systems are exceedingly complex, most studies agree that in 50 years it will be warmer and probably drier, accompanied by increased storm intensity. Isolating the effects of climate change from climate variability is an essential, but daunting, requirement in the management of desert ecosystems.

Data describing the temporal and spatial variability in climate are needed by resource managers for the purposes of interpreting temporal variations in resource conditions and assessing the spatial variation in ecosystem sensitivity to climatic episodes, natural disturbances, and land use practices. Despite the need for high-resolution data, climate monitoring is conducted only at a small number of point locations in the Mojave Desert. This is especially problematic in this region, as rainfall events, particularly summer thunderstorms, can be extremely localized (fig. 5). Because we will never obtain complete coverage, climate modeling will be an important tool in estimating the spatial and temporal variations in water and energy balances across landscapes. Coarse-scale climate extrapolations are readily available for this ecoregion. For example, Michaelson (*in* Thomas and others, 2004) provided a gridded climate extrapolation at 1-km spacing for the entire Mojave Desert.

The Physical Template: Geology, Geomorphology, and Soils

Geology

Parent material (fig. 3B) strongly influences the characteristics of the landscapes (fig. 3C) and soil (fig. 3D) derived from it and, consequently, patterns of plant distribution (fig. 3E) and animal distribution (fig. 3F). The most important effects are: (1) weathering rates, (2) chemical composition, and (3) texture (McDonald and others, 1995).

Weathering is the progressive fracturing of rocks by physical and chemical processes. This produces finer grained products with time, with the resultant particle size distribution, or soil texture, dependent on the original rock type. Parent materials

Figure 5. Summer monsoonal storms are more unpredictable than winter rainfall and typically deliver moisture in the Mojave Desert in small, isolated patches (U.S Geological Survey photograph by David M. Miller).

that are fine grained and/or composed of relatively reactive rock fragments, such as glassy volcanic rocks, weather most quickly to form clayey products in soils. In general, granitic rocks and some sedimentary rocks, such as shale and siltstone, weather faster than many other rocks but less fast than volcanic rocks. Sandstones weather to form a coarse-textured soil.

The chemical composition of the weathered rock particles is the primary control on the chemical composition of the resultant soil. Along with dust and weathering products, the mineralogy of the particles creates the starting materials for plants and soil biota to interact with. Limestone tends to create more fertile soils, for instance, whereas quartzite and sandstone create relatively sterile soils. In general, rocks with greater calcium, iron, and magnesium create more fertile soils. These rocks include limestone, marble, basalt, andesite, and mafic granitoids, such as diorite, gabbro, monzodiorite, and quartz diorite.

As soil texture and chemistry exert a strong control on local hydrology, plants, and animals, the rock type from which soils are derived can exert a strong control on community structure. A prime example is the alluvial material shed from granitic rocks that break down into grus (grain-by-grain disintegration). Soils composed of grus tend to exhibit weakly developed soil profiles because they are less stable than rockier soils and because pedogenic silt penetrates deeply into the profile. In general, these characteristics promote soil moisture conditions that are favorable for many plants and for biological soil crusts. In contrast, badlands composed of fine-grained, weakly consolidated materials erode so rapidly as to be practically devoid of plants.

Geomorphology

Geomorphic surfaces can be thought of as the surface characteristics of landforms in the desert, whether sand dunes, alluvial fans, or bajadas, and the surficial deposits are the near-surface interval of materials associated with those landforms (figs. 3B and C and 6; for information on mapping surficial geology, see appendix B). Of the many geomorphic environments in the desert, mountains and piedmonts cover the greatest area. Mountains are highly variable environments, as slope, aspect, and curvature, driven by both substrate materials and topography, can vary widely. Mountains have relatively high near-surface moisture stored locally in thin colluvial and alluvial sediment deposits that are underlain by eroded rock. They may also contain extensive water in the bedrock that flows downward toward the valley floors. At lower elevations, depositional surfaces are found that include alluvial fans, coalesced fans (termed bajadas), and various other landforms that, collectively, can be termed the piedmont. These are primarily depositional areas, where sediment eroded from the mountains accumulates over long time periods. Farther from the mountain front are other types of piedmont systems that are quite variable through the region and include such features as sand dunes, sand sheets, intermixed eolian sand and alluvial fans, and even wetlands (for example, Ash Meadows near Death Valley). Playas, stream systems, or, more rarely, perennial lakes generally occupy the valley floor.

Plant communities are highly variable on piedmonts in response to elevation gradients and to characteristics of geologic deposits. Surficial geologic deposits vary in soil texture (grain size distribution and packing), bulk density, and other factors. The grain size of deposits generally decreases from mountain front downward to distal piedmont, as do topographical features, such as channel incision and slope (Blair and McPherson, 1994). Superimposed on these textural and topographic patterns is the depositional history of a specific area, with features ranging from remnant fragments of very old piedmont deposits to actively depositing segments (fig. 7). The resulting patterns are crucial to ecosystems because they influence where, how much, and what type of soil is formed (McFadden and Knuepfer, 1990; McDonald and others, 1995).

Soils

Soils (fig. 3D) provide the basic foundation for most terrestrial life, because they provide structure and determine the availability of water and nutrients to soil biota (figs. 3D, F, and G) and plants (fig. 3E), which in turn, provide habitat and food (fig. 3H) for larger animals. The influence of soils on soil biota and plants is determined by the physical, chemical, biological, and depth characteristics of the soil. Even small differences in these characteristics can have relatively large effects on water and nutrient bio-availability, and thus biota (Comstock and Ehleringer, 1992; McAuliffe, 2003).

Soil formation, or pedogenesis, creates vertical variation on the landscape. Soils are mostly formed by the weathering of sediments within deposits. Because of the low rates of weathering and soil-forming processes in regions with low precipitation, the relative importance of parent material in determining soil properties increases with aridity (Jenny, 1941). In addition to this process, the accumulation of chemical deposition and the infiltration of eolian, fine-grained materials also contribute to pedogenesis (Pavich and Chadwick, 2003). Thus, the nature of the resultant soil depends on the physical and chemical properties of the bedrock from which the soil has weathered as well as the proximity to dust sources. The particle size distribution of the soil determines the quantity of nutrients and water and how tightly they are held in soil layers. For instance, sandy soils have large pore spaces and large particles that bear little electrical charge, which allows the rapid leaching of nutrients and water deeper into subsurface soils. In contrast, finer-grained soils, with higher silt and clay content, generally have small pore-size distributions and contain charged particles, enabling soil particles to bind nutrients and hold water higher in the soil profile.

Downward translocation of soil particles and nutrients occurs in more stable settings (for example, above the geomorphically active zones, such as washes) and results in a layered soil, with layers (horizons) varying in hydrologic and other properties. Thus, older deposits generally exhibit more

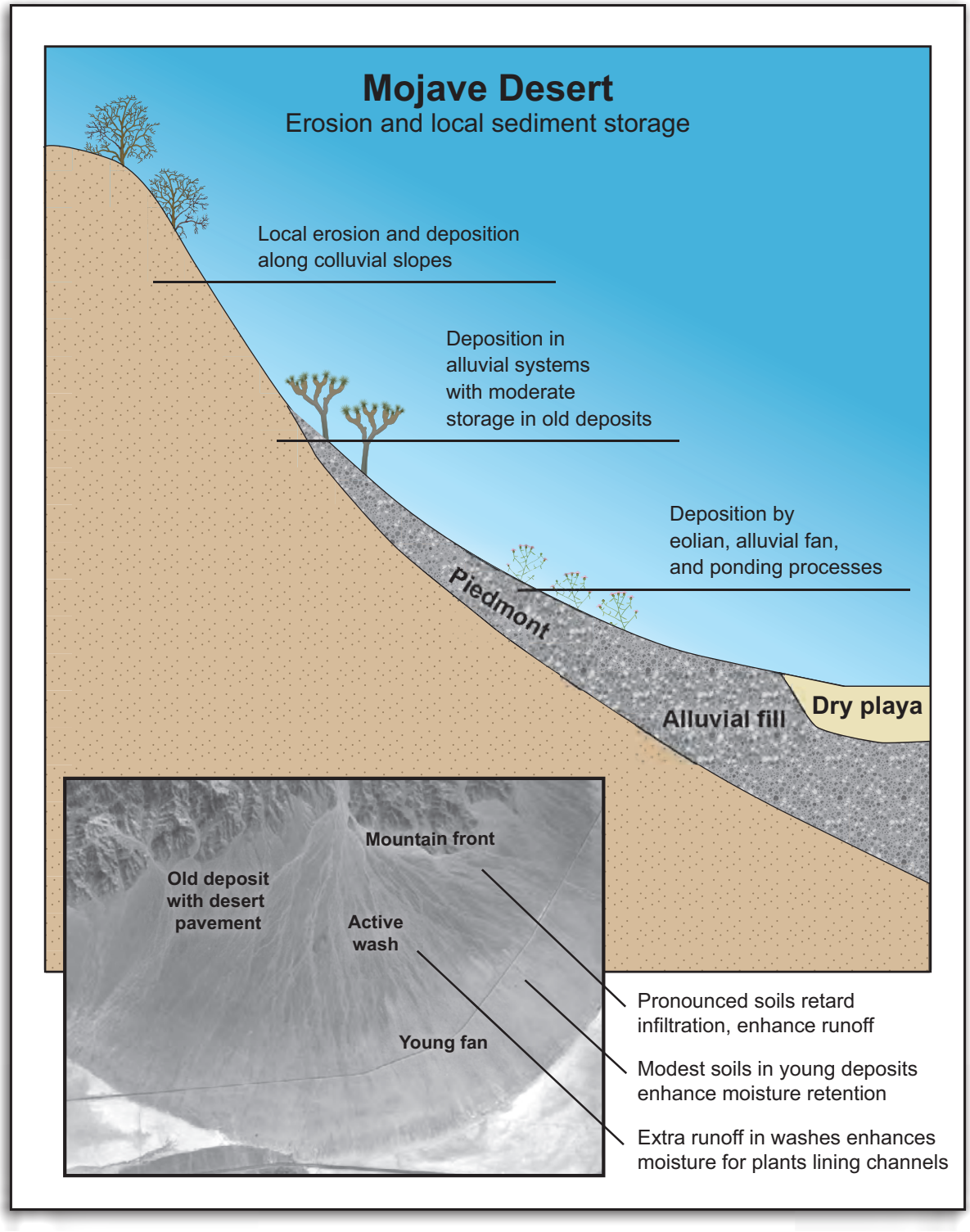

Figure 6. Processes operating on an elevation gradient representing desert mountain and alluvial systems in the Mojave Desert. The processes are partly related to elevation and climate, partly related to slope, and partly related to substrate; all of these factors have feedback loops to plants, animals, and moisture availability.

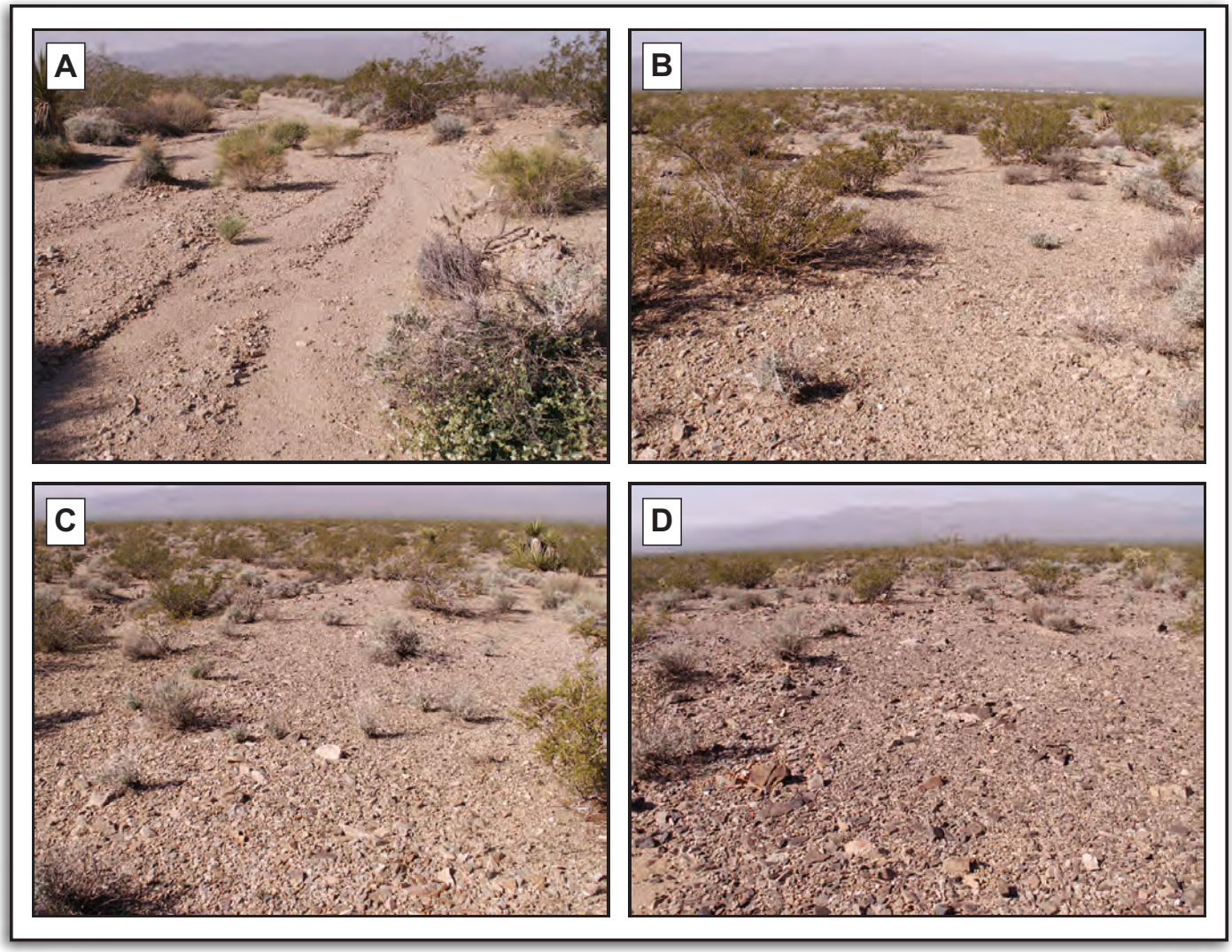

Figure 7. Photographs illustrating differences among ages of surficial deposits in the Mojave Desert. All photos from alluvial fans at about 900 m elevation, adjacent to the Providence Mountains. A, Active wash (Qya1) showing high albedo of frequently reworked channel surface, and *Hymenoclea salsola* (common cheesebush). Note the flowering *Encelia farinosa* (brittlebush) in middle distance and large *Larrea tridentata* (creosote bush) and *Yucca schidigera* (Mojave yucca) along the banks. B, Middle Holocene deposit (Qya3) showing darker surface with biotic soil crusts and tiny annual plants. A very weak pavement and *Ambrosia dumosa* (white bursage) and creosote bush are typical of this deposit. C, Early Holocene deposit (Qya4) showing weak pavement and desert varnish. Plants are similar to the mid-Holocene deposit, but slightly more sparse. D, Pleistocene deposit (Qia3) showing stronger varnish and pavement, and only rare annual plants. White bursage and creosote bush are sparse, and *Senna covesii* (desert senna), *Opuntia acanthocarpa* (staghorn cholla), and Mojave yucca are present (U.S. Geological Survey photographs by David M. Miller).

intense soil horizonation than younger surfaces (fig. 8). These older deposits are often capped with a silt layer filled with bubbles called a vesicular layer. As the vesicular layer is part of the surface, or A horizon, it is referred to as an Av horizon. Vesicular horizons restrict water infiltration, and as they get thicker through time, infiltration rates decrease.

The Av horizon is underlain by argillic (clay-rich) and calcic (calcium-carbonate cemented) horizons that can restrict water penetration and root growth due to their increased cohesion and high strength properties. Although this potentially decreases the amount of soil volume that can be explored by plant roots for water and nutrients, this layer also often perches and holds water, thus keeping it available to plant roots (Shreve, 1917; McAuliffe, 1994, 2003). Salts can accumulate in older soils in certain landscape settings, thus changing soil properties to favor plants with higher tolerances of soil salinity. Because of restricted water infiltration and salt accumulation, plant cover generally decreases with age of deposit within a given geologic setting (Hamerlynck and others, 2002). An exception is the low plant cover evident in many active washes, where unstable substrate and abrasion during floods reduce plant establishment and persistence. Unlike older geomorphic surfaces, young surfaces have little soil structure to restrict root elongation, have high infiltration rates, and generally are low in salinity. As a result of the progressive development of pedogenic soils, and the presence of deposits of varying ages in the piedmonts, the piedmont environment is a complex mosaic of areas with varying soil properties (fig. 9).

Concentrations of elements and carbon in soils is important in determining plant distribution and productivity. The soil elements essential for plant growth include nitrogen, phosphorus, potassium, magnesium, sodium, calcium and the micronutrients zinc, manganese, copper, and iron (Titus and others, 2002). The availability of a given nutrient is a function of many factors, including soil pH, the amount of acidic exudates from roots and other organisms in the soil, the concentrations of other nutrients in the soil, and soil temperature and moisture. Many studies have shown that, although water is generally the limiting factor for plant productivity, nutrients can quickly become limiting in wet years (Romney and others, 1973; Whitford, 2002). Some authors have suggested that nutrients and water are co-limiting in deserts (Hooper and Johnson, 1999). In addition, elevated levels or altered ratios of nutrients, particularly sodium, potassium, and phosphorus, may cause shifts in the species composition of annual and perennial species that can inhabit a particular geomorphic surface (Belnap and Phillips, 2001; Miller and others, 2001). Organic matter is also important in ecosystem processes, as soil food web organisms depend on soil organic matter for energy. Soils also contain enzymes excreted by microbes during decomposition (Sinsabaugh and others, 2002), and they can be used to measure the "health" of the decomposition cycle. Enzyme activity is also thought to be correlated with the relative availability of soil carbon and nitrogen.

There are other soil variables that also influence plants and soil biota. Soil depth is an important property, as it determines the volume of soil through which plant roots can extend to obtain water and nutrients. In addition, water in very shallow soils will evaporate more quickly than in deeper soils. Many desert fauna prefer specific soil depths at which they reside or burrow (Hafner, 1977; Whitford, 2002); if soils are

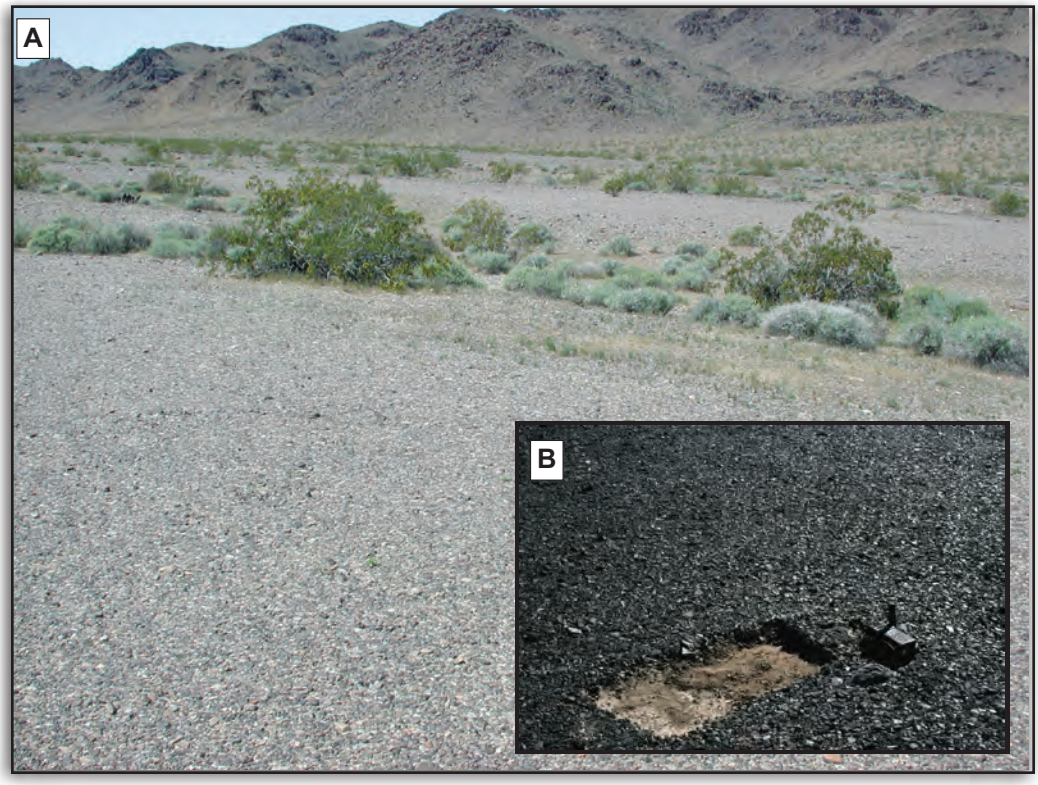

Figure 8. Photographs of desert pavements in the Mojave Desert. A, Desert pavement on a deposit with old soils, which is devoid of perennial plants except in dissected gullies, where soil horizons are disrupted. B, Well-developed desert pavement on a surface of late Pleistocene age. The lighter tan layer is the middle of the vesicular layer, or Av horizon, and the darker reddish unit underneath is the top of the argillic B horizon (U.S. Geological Survey photographs by David M. Miller).

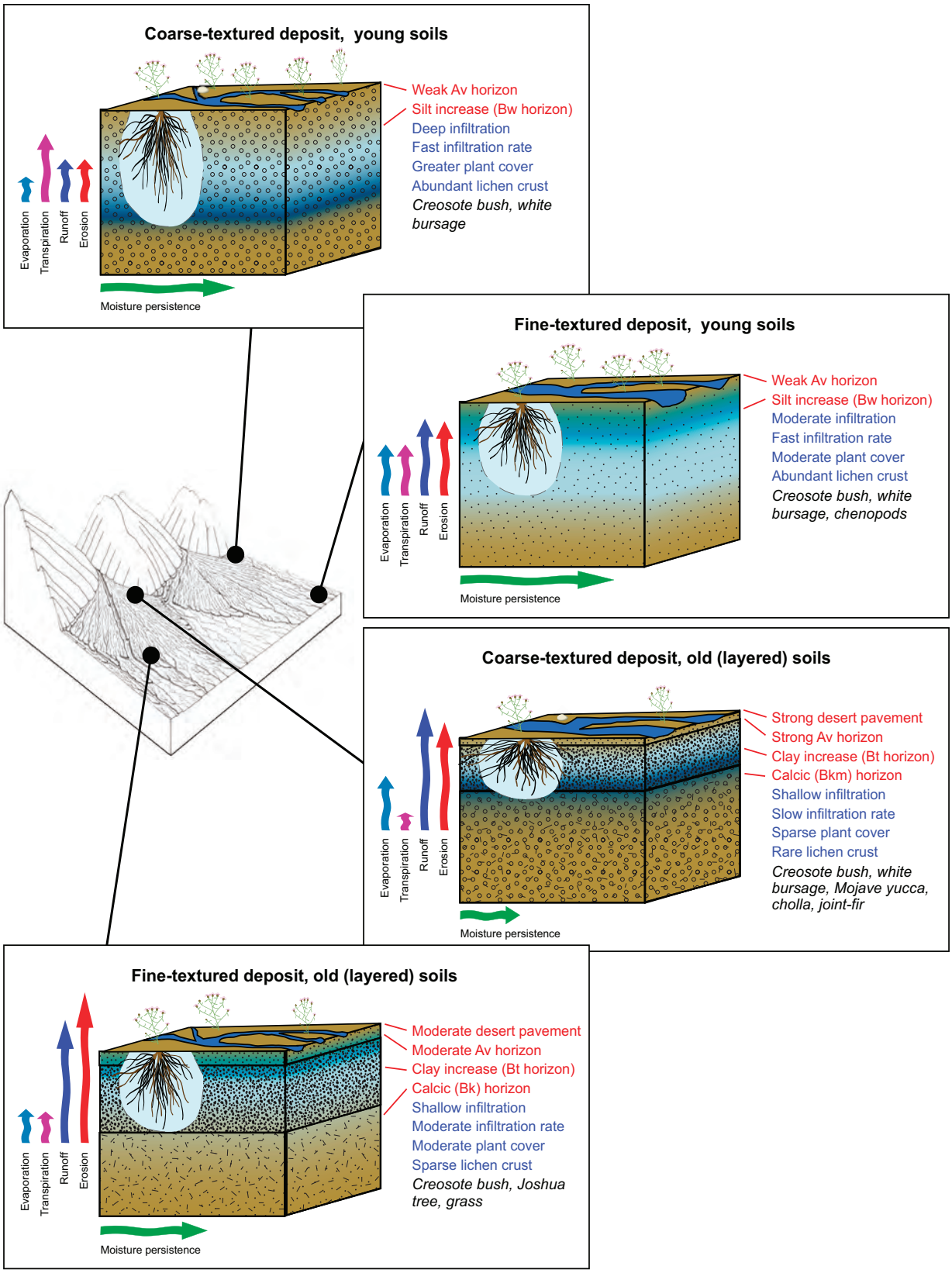

Figure 9. Soil-plant-water relationships for Mojave Desert piedmonts showing major processes and relative amounts and locations of soil moisture, overland flow, nutrient cycling, and functional vegetation. Varying soil properties exert strong control on surface and soil-water dynamics. Vegetation typical of a moderate-elevation bajada is given in italics. The size of the arrows indicates the relative rate or amount of the process indicated.

too shallow, those species will not be found at that site. Mineral crusts, also termed physical crusts, are present on many desert soils and help reduce wind erosion. However, they also decrease infiltration rates and dissolve when wet, thus offering little protection from water erosion. In addition, they generally form a smooth surface that makes lodging of wind-transported seeds more difficult, and their strength properties may inhibit plant seedling establishment (Sumner and Stewart, 1992). Surface roughness can determine the capture and retention of nutrient-rich dust particles and organic matter and affect local nutrient status.

Soil aggregate stability and structure are also important in determining soil function, as they influence soil stability, water infiltration, and nutrient cycling (Seybold and others, 1999). Most microbial activity occurs on the surface of soil aggregates, and thus it is where most nutrient transformations occur as well. Soil structure is also essential in conserving the pore space through which gases, water, and organisms move. Water infiltrates into the soil at different rates, depending on the pore space and moisture status of the soil. When rainfall intensity exceeds the ability of the soil to absorb the rainfall, or when a subsurface impediment to flow slows surface infiltration, runoff occurs. Although water moves downwards due to gravity, it can also move up or down through the root systems of plants and return to the soil at another depth, a process termed hydraulic redistribution (Ryel and others, 2003). Water can also move upwards in the soil due to vapor transport or capillary force when the soil is near saturation.

Soils provide habitat for animal burrows, and through their burrowing activities, animals alter soil texture, organic matter content, mineral availability, and soil moisture content, thus enhancing plant growth (Mielke, 1977; Inouye and others, 1997; Reichman and Seabloom, 2002; Titus and others, 2002; Wagner and others, 2004). Coppice mounds beneath *Larrea tridentata* (creosote bush) are common sites for rodent burrows (Titus and others, 2002), which are excavated into a generally finer-grained substrate created by the combination of bioturbation and eolian accumulation. Mounds associated with harvester ant colonies are a mix of surface and subsurface soil, in addition to large amounts of organic matter collected by the ants. Desert tortoises, larger mammals, lizards, and snakes all utilize burrows, and thus can also affect soil texture and chemistry.

Eolian Processes and Dustfall

Movement of soil particles (sand, silt and/or clay) by wind (fig. 10) is one of the dominant processes in dryland environments (Breshears and others, 2003). Soil movement affects ecosystem function through its effects on soil texture, depth, and chemistry. Such changes in soil characteristics can alter the plant species assemblage, density, and/or size in a given area. Inputs of sand onto existing soil surfaces increase water infiltration, dilute nutrient concentrations, reduce soil surface stability, and restrict the ability of the soils to hold nutrients and water in the soil profile (Breshears and others, 2003). Sand deposition causes plant burial, either partially or completely, favoring those plant species with the ability to adapt to rapid changes in the surrounding substrate. In addition, sand inputs can increase or decrease the ability of specific animal species to effectively burrow into the soil. The deposition of fine particles (silt and clay), which are generally rich in nutrients, can alter soil fertility, and thus plant community composition (Reynolds and others, 2001), including invasion patterns of non-native annual grasses (Miller and others, 2006). This input can also increase the water-holding capacity of soils, although if it is incorporated into an Av horizon, water infiltration can be restricted (as described above). As airborne dust collects and accumulates on leaves and stems of desert plants, a reduction in physiological performance may eventually reduce plant growth (Sharifi and others, 1997, 1999) and seedling establishment (D.R. Sandquist, oral commun.).

Many natural factors interact to determine rates of soil loss through eolian processes. Armoring of the soil surface is provided by rocks, physical and biological soil crusts, plants, and plant litter (van Donk and others, 2003; fig. 11). Well-armored soils are generally very stable. Soil texture is also very important in soil erodibility. Sand grains are large, and thus difficult to move, often blowing only short distances, whereas silt and clay particles can become entrained in the atmosphere and travel around the globe. Surfaces containing only silt and clay particles (for example, playas) are generally very stable, as physical crusting can rapidly armor the surface. However, input of sand particles, either as substrates are exposed or newly deposited by wind, will reduce the effectiveness of the armoring, as their high impact velocity can easily break through most physical crusting, dislodging the fine particles and allowing them to leave the site. Contrary to common belief, most desert surfaces are very stable and in the absence of disturbance, produce little sediment (Marticorena and others, 1997), although there are a few surface types (for example, playa margins, dry wash bottoms) that are inherently unstable. Because winds can more easily move silt and clay

Figure 10. Dust storm at U.S. Army National Training Center, Fort Irwin, California, illustrates the extremely large transport of topsoil in severely disturbed environments (U.S. Geological Survey photograph by Jayne Blenap).

than sand particles, loss of soil through wind erosion leaves behind a coarser textured soil with lower fertility and water-holding capacity.

Carbon and Nutrient Cycling

Carbon

In desert soils, there are two main sources of carbon: carbonate deposits and organic matter. Most carbonate deposits are formed when salt-bearing precipitation percolates down through the soil and the water evaporates, and the salts precipitate as carbonates. Carbonates are not considered a readily available form of carbon to either soil biota or plants; organic matter, on the other hand, is a readily available source of carbon. Most soil organic matter is derived from dead above- and below-ground plant material. Many models of above-ground plant materials assume that decomposition rates are mostly dependent on the quality of the litter (that is, how attractive is the litter to microorganisms and how easily can they decompose it). However, in desert ecosystems, there is little demonstrated relation between the quality of the litter and decomposition (Whitford, 2002), decomposition rates are often independent of temperature, and decomposition can occur in the absence of all biota (MacKay and others, 1994). Therefore, it is likely that most decomposition of above-ground litter is abiotically driven in deserts (Moorhead and Reynolds, 1989; Whitford, 2002). In contrast, decomposition of below-ground materials (such as plant roots) is biotically driven and highly dependent on the number and type of soil organisms present (Whitford, 2002). The activity, type, and abundance of these organisms are, in turn, affected by soil texture, chemistry, and structure, as well as climate and the quality of the litter available.

When soils are wetted, some soil carbon is lost due to abiotically driven outgassing. However, most carbon is lost from the soil through respiration by plant roots and surface and subsurface soil biota. Respiration rates are dependent on temperature, moisture, and on how much biomass is present to respire. Res-

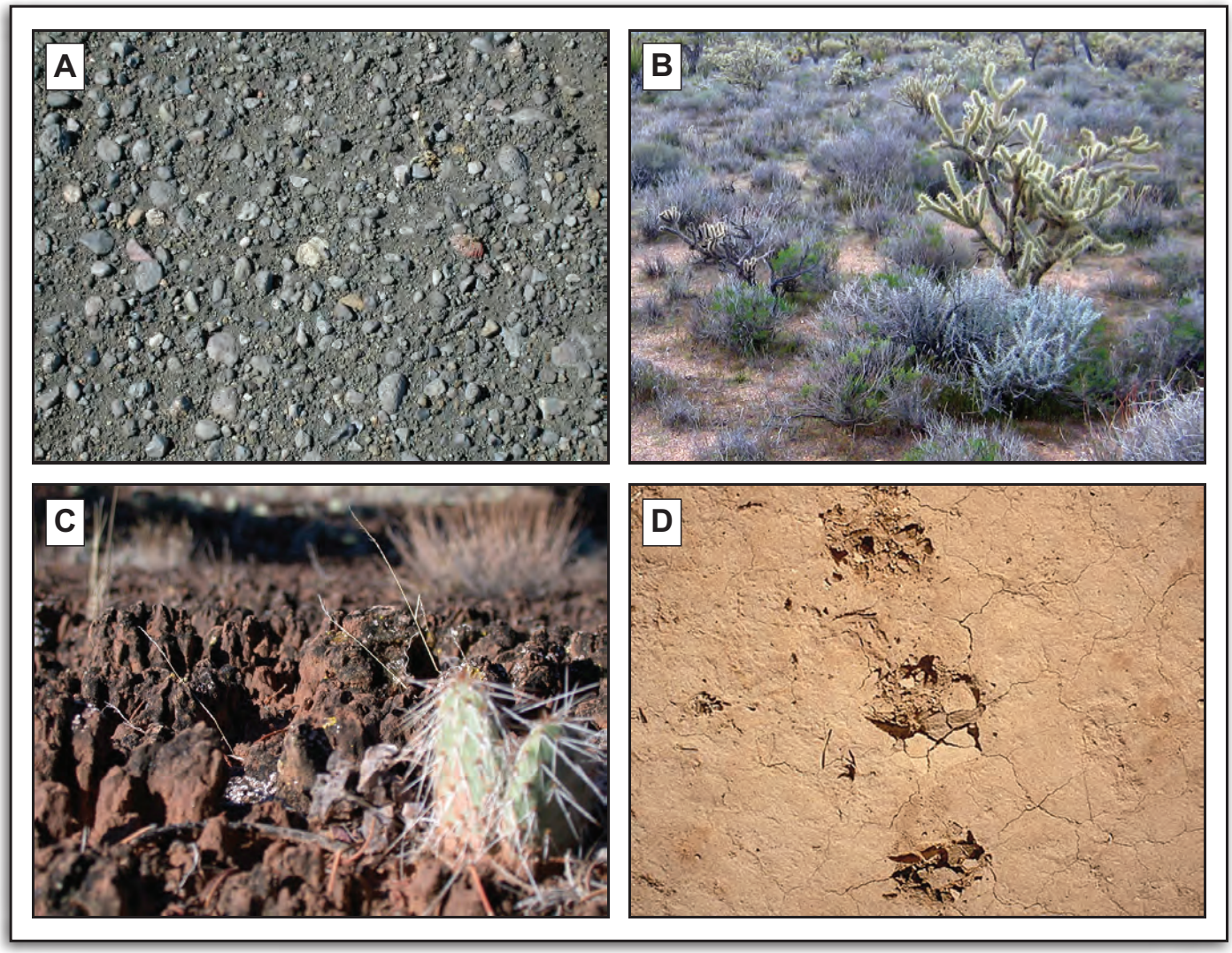

Figure 11. Soil stabilizers in aridlands include A, rocks, B, plants and plant litter, C, biological soil crusts, and D, physical and chemical crusts (U.S. Geological Survey photographs by Jayne Belnap).

piration rates in plants and soil biota increase with increasing temperature. While plants are always respiring, soil moisture is required for any measurable respiration from soil biota.

Nitrogen

Nitrogen, as it occurs in the atmosphere, is in a form not usable by vascular plants or other eukaryotic organisms. It must first be reduced or "fixed" by either lightning or prokaryotic organisms (for example, eubacteria and cyanobacteria). As rainstorms with lightning are infrequent in this region, lightning provides only a small amount of nitrogen to this system. Thus, the dominant source of nitrogen in the Mojave Desert is prokaryotes, and the dominant prokaryote is the cyanobacterium *Nostoc*. *Nostoc* occurs as a free-living organism or as part of the soil lichens *Collema* and *Peltula.* Heterotrophic bacteria, which occur in the root zones of plants, can also fix nitrogen, but reported values of nitrogen fixed by these organisms are extremely low. Some desert plants also have root nodules containing nitrogen -fixing bacteria (*Rhizobium* spp. or *Bradyrhizobium* spp.; Farnsworth and others, 1976; Whitford, 2002). However, the abundance of such plants is low in the Mojave Desert, and thus their contribution of nitrogen is limited.

Cyanobacteria and bacteria are physiologically active only when wet. Consequently, nitrogen fixation is primarily controlled by moisture, with temperature the next limiting factor (Belnap, 2003c). The nitrogen fixed by these organisms is often released into surrounding soils, where it is available for uptake by plants, other microbes, or to be reabsorbed by the fixing organism. Once nitrogen is fixed as ammonium (NH_4^+), it goes through several transformations mediated by soil microbes, producing multiple forms of nitrogen (NO, N_2O, and N_2). During each transformation, nitrogen-containing gases are released back into the atmosphere, and thus nitrogen is lost from the soil. The primary control on each step is the availability of the substrate to be converted and secondary controls are moisture and temperature. Therefore, nitrogen transformation rates are affected by soil disturbance and climate. Loss of nitrogen also occurs through ammonia (NH_3) volatilization, by leaching (Walvoord and others, 2003), or during rainstorms, where it is carried away in both runoff water and the sediment suspended in the water (Barger and others, 2006).

Phosphorus

Phosphorus can limit plant production in deserts (DeLucia and others, 1989; Schlesinger and others, 1989; Parker, 1995). The primary source of phosphorus is the weathering of primary minerals, such as apatite. Phosphorus inputs from the atmosphere (either as wet or dry deposition) are very low (Reheis, 1999).

In high-pH desert soils, phosphorus is relatively insoluble due to reactions with carbonates (for example, $CaCO_3$), iron oxide, or other compounds (Barber, 1995; Lajtha and Harrison, 1995). As a consequence, it is relatively unavailable for uptake by soil biota and plants (Barber, 1995; Marschner, 1995). Exudates of bacteria, fungi, cyanobacteria, and plant roots can increase phosphorus availability and uptake by dissolving some of these compounds (Lajtha and Harrison, 1995; Barrow and Osuna, 2002). For example, the emission of respiratory carbon dioxide (CO_2) by roots and soil biota results in the formation of carbonic acid (H_2CO_3) when CO_2 dissolves in water (Knight and others, 1989). The effectiveness of this mechanism for acidification and the enhancement of phosphorus availability is greater in cool moist soils than in warm dry soils because CO_2 solubility in water increases with decreasing temperatures above freezing (Krauskopf and Bird, 1995).

Potassium

Potassium is an essential nutrient for plants. Plants often require more potassium than is available in soils (Troeh and Thompson, 2005). Potassium is not easily leached from soils, even over long periods of time; thus potassium is fairly evenly distributed throughout the soil profile, especially in dryland regions where precipitation, and thus leaching potential, is limited (Troeh and Thompson, 2005).

Other Major Cations

Calcium concentrations in dryland soils are generally sufficiently high to not limit plant productivity. The high levels of calcium can have a profound influence on the availability of other nutrients. In addition to raising the pH of soils, excess calcium precipitates as calcium carbonate at the soil depth to which most precipitation infiltrates; this can create a solid layer (called caliche or calcrete) that impedes plant roots and water flow. Calcium compounds also react with other soil nutrients, such as phosphorus, magnesium, and micronutrients, reducing their solubility and bio-availability (Troeh and Thompson, 2005). Therefore, the ratio of calcium to other cations can influence plant productivity (Barber, 1995). Because carbon dioxide solubility in water (thus potential carbonic acid [H_2CO_3] formation) and calcium carbonate ($CaCO_3$) solubility both increase with decreasing temperatures (Krauskopf and Bird, 1995), adverse effects of calcium compounds on the bio-availability of other nutrients may decrease when soils are cold and wet.

Magnesium tends to be relatively easily weathered, and thus soils are depleted of magnesium faster than potassium or calcium. Magnesium interacts strongly with other cations, especially the monovalent potassium and sodium, due to the preferential adsorption of the polyvalent magnesium ion. Therefore, the ratio of magnesium, like the polyvalent calcium, to other cations can influence plant productivity (see Potassium section).

Sodium is considered a non-essential element, but it is beneficial in small amounts. Sodium levels in desert soils are almost always sufficient for plant growth. Sodium is the most easily leached cation. In deserts, salts (mostly sodium chloride [NaCl]) move upwards in soils due to capillary action when the soil surface is drier than underlying layers and form a white crust on the surface (Troeh and Thompson, 2005). Thus, much of the alkalinity of dryland soils is due to the presence of sodium. Many dryland plants have active mechanisms to handle excess soil sodium levels, such as extruding salt onto

the leaf surface or storing ions in cell vacuoles to prevent interference with processes in the cytoplasm (Whitford, 2002).

Micronutrients

Copper, iron, zinc, and manganese are all important to plants as well. However, coarse soils with high pH, which are typical in the Mojave Desert, have inherently low concentrations of bio-available micronutrients (Alloway and Tills, 1984). In addition, micronutrients often react with carbonate compounds in desert soils, resulting in low solubility and bio-availability similar to phosphorus. Interactions among the micronutrients themselves can also reduce their bio-availability (Day and Ludeke, 1993).

Low availability of the micronutrients can impact plant communities. Jarrell and Virginia (1989) postulated that copper may limit plant productivity in dryland regions. Copper deficiency has been linked to suppression of nitrogen fixation in vascular plant-*Rhizobium* associations (Cartwright and Hallsworth, 1970). Iron deficiencies are common in dryland regions and may limit plant productivity (Hunter and others, 1980; Wallace, 1989). Cramer and Nowak (1992) report that the addition of manganese stimulates growth in annual grasses, and others have noted that manganese deficiencies may limit plant productivity in drylands (Jaurequi and Reisenauer, 1982; Marschner, 1995). Bowker and others (2006) reported that manganese deficiency controls the distribution of the common nitrogen-fixing lichen *Collema tenax* in western North America. Zinc deficiency is also common throughout dryland regions of the globe and also can limit plant productivity (Jaurequi and Reisenauer, 1982; Jarrell and Virginia, 1989; Killingbeck, 1989; Marschner, 1995; Hacisalihoglu and Kochian, 2003).

Soil Biota

Soil biota (figs. 3D, F, and G) play a critical part in most ecosystem processes, including soil stabilization, nutrient cycling, and local hydrology. Because soil biota influence so many parts of the desert ecosystem, they are considered part of each of the four components of our general ecosystem conceptual model (fig. 3): soil resources (D), vegetation (E), biological soil crusts (G), and invertebrates (F). Most of the species diversity of any ecosystem occurs in the soils, but the species composition is poorly understood and difficult to elucidate. Functioning of soil processes depends on the soil biota present; the type and amount of inputs from above-ground biota; and soil structure, aeration, temperature, and moisture.

Soil Surface Biota: Biological Soil Crusts

Biological soil crusts (BSCs) are biotic communities composed of cyanobacteria, algae, microfungi, mosses, and lichens that occur on and within the upper few millimeters of the soil surface (Belnap and Lange, 2003; figs. 3G and 12). These diverse communities are characteristic of ecosystems where conditions limit the development of closed-canopy vascular plant communities or the development of thick layers of plant litter (Belnap and Lange, 2003). Almost all soil surfaces in the Mojave Desert are covered by a layer of cyanobacteria, with the dominant species being the large filamentous *Microcoleus vaginatus*. On more stable surfaces with finer-textured soils, the smaller cyanobacteria (for example, *Nostoc commune*) are common as well. In addition, more stable surfaces and soils at higher elevations also support lichens (for example, *Collema tenax, Placidium lachneum, Peltula richardsii)* and mosses (for example, *Syntrichia caninervis, S. ruralis*). In many areas, these crusts represent over 70 percent of the living ground cover (Belnap, 1997).

In addition to their major contributions to biological diversity, BSCs perform many other functions in dryland ecosystems. The presence and physiological activity of BSC organisms aggregate soil particles, thereby increasing soil stability and reducing the susceptibility of soil to erosion by wind and water (Williams and others, 1995 a, b). They roughen the soil surface, thus facilitating the capture and retention of wind-blown dust, which can be a significant source of mineral nutrients in dryland ecosystems (Belnap and Lange, 2003; Reynolds and others, 2001). BSCs similarly can enhance retention of windborne and waterborne organic matter and seeds (Belnap and Lange, 2003).

Figure 12. Patch of well-developed biological soil crust typical of the Mojave Desert (U.S. Geological Survey photograph by David M. Miller).

The hydrologic effects of BSCs are complex, as their effects on infiltration and runoff are very site specific. Regardless of crust or soil type, the presence of BSCs stabilizes soils and reduces water erosion. This stabilization is due to the above-ground structures of BSCs reducing raindrop impact and detachment of soil particles. In this function, cyanobacteria and algae are less effective than mosses and lichens. However, BSC organisms also can clog soil pores and inhibit infiltration. At higher elevations, soils frost heave, and the presence of BSCs roughens the soil surface. At these locations, the inhibition of infiltration from the presence of BSC organisms is more than offset by increased residence time of the water due to soil roughness, which increases infiltration. At low-elevation sites, however, BSCs do not always substantially increase soil surface roughness, and in these situations the presence of a well-developed soil crust can either decrease or increase infiltration, depending on specific site characteristics (Belnap, 2003a). Organic carbon produced by BSC organisms can contribute to the formation of stable soil aggregates that increase the ratio of macropores to micropores, and thus enhance infiltration. Strong soil features, such as the presence of a thick Av horizon or heavy shrink-swell clays, will override any effect of BSCs in terms of local hydrology.

In addition to enhancing soil stability and nutrient retention, BSCs also contribute to soil fertility. Mosses, cyanobacteria, green algae, and lichens are photosynthetic, and thus can be significant sources of carbon in dryland ecosystems, particularly in interspaces among vascular plants where soil crusts can attain 100 percent cover (Lange, 2003). Most cyanobacteria (for example, *Nostoc* and *Scytonema*) and cyanolichens (for example, *Collema*) are also capable of fixing atmospheric nitrogen into a mineral form that can be used by vascular plants (Evans and Lange, 2003). Consequently, BSCs can be the dominant source of nitrogen in many dryland regions (Evans and Ehleringer, 1993; Belnap, 2002). Soil organisms are significant sources of carbon for other soil biota, and they are more abundant and diverse under BSCs than under bare soils (Belnap, 2003b). BSCs also increase nutrient cycling rates of soil food webs through their effects on near-surface moisture availability, soil structure, soil aeration, and soil temperature, thus increasing soil nutrient availability (Belnap, 2003b).

BSCs also influence vascular plants. Where they roughen the soil surface, as when lichens and mosses are present or where soils frost heave, they increase the retention of seeds. Conversely, where they smooth the soil surface, as in very low elevations, they can increase the movement of seeds from the interspace to the nearest obstruction, such as a plant or rock. The effect of BSCs on plant germination is very species and site specific; research has shown them to suppress germination in some species and enhance germination in other species. They seem to consistently suppress the germination of large-seeded, non-native, annual grasses, such as *Bromus tectorum* (Belnap and Lange, 2003). Relative to plants growing in soils without BSCs, plants growing in association with BSCs consistently have greater biomass and greater nitrogen concentrations in tissues and usually have higher concentrations of the plant-essential nutrients potassium, magnesium, copper, and zinc (Harper and Belnap, 2001). In contrast, plants growing in soils with BSCs commonly have lower concentrations of phosphorus and iron than plants growing in soils without BSCs, suggesting that plants and BSCs may compete for these elements. Nutritional differences between plants grown in soils with and without BSCs are greatest in shallow-rooted herbaceous species, probably because they are rooted in near-surface soils that are most directly influenced by BSCs (Harper and Belnap, 2001). However, there are species-specific exceptions to these patterns (DeFalco and others, 2001). In addition, plants growing in crusted soils have a higher mycorrhizal infection rate than those growing in non-crusted soils, and thus have greater access to water and nutrients (see below; Pendleton and others, 1989).

Subsurface Soil Biota

Many thousands of tiny organisms, including bacteria, fungi, protozoa, nematodes, and microarthropods, comprise the subsurface soil biota (figs. 3D, F, and G; table 1). As these organisms are not photosynthetic, they depend for energy on the carbon contributed by biological soil crust organisms and plant litter or on predation on other soil biota. These organisms are critical in the breakdown of plant litter and roots in the soil and making the nutrients contained within these materials available to plants and other biota (Adl, 2003).

Because bacteria and fungi are very tolerant of harsh conditions, they are often the most important component for decomposition in deserts (Whitford, 2002). Bacteria thrive on readily decomposed substrates, such as fresh plant litter, fine roots, and compounds found near living roots. The species composition and abundance of bacteria vary with plant community composition. Because they are very small (1 μm), they cannot extend through the soil to find nutrients sufficient for their survival. Instead, those nutrients need to be in one small microregion. In addition, some nitrogen-fixing bacteria can colonize nodules that occur on the roots of particular plant species. These plants benefit by being able to directly absorb the fixed nitrogen.

Fungi, in contrast, tend to grow in threads that can be meters long, and thus nutrients found in one zone can be transported to another zone. Fungi can utilize recalcitrant litter, such as wood or large roots. Soil fungi also include mycorrhizal fungi, which colonize the roots of most desert plant species. These fungi can be very important in obtaining water, nitrogen, phosphorus, and zinc for plants due to their ability to expand into the soil zones beyond the reach of roots, and thus increase the soil volume being explored for water and nutrients. These fungi are especially important under adverse conditions. In addition, the presence of fungal hyphae winding through the soils also contributes to soil stability.

Larger soil microfauna include protozoa (ciliates, amoebae, and flagellates), nematodes, mites, and other microarthropods. They perform many important ecosystem functions, such as shredding large pieces of organic matter into smaller pieces,

Table 1. Soil organisms and their major functions.

Type of Soil Organism		Major Functions
Photosynthesizers	• Plants • Algae • Bacteria	**Capture energy** • Use solar energy to fix CO_2 • Add organic matter to soil (biomass such as dead cells, plant litter and secondary metabolites)
Decomposers	• Bacteria • Fungi	**Break down residue** • Immobilize (retain) nutrients in their biomass • Create new organic compounds (cell constituents, waste products) that are good sources of energy and nutrients for other organisms • Produce compounds that help bind soil into aggregates • Bind soil aggregates with fungal hyphae • Nitrifying and denitrifying bacteria convert forms of nitrogen • Compete with or inhibit disease-causing organisms
Mutualists	• Bacteria • Fungi	**Enhance plant growth** • Protect plant roots from disease-causing organisms • Some bacteria fix N_2 • Some fungi form mycorrhizal associations with roots and deliver nutrients (such as P) and water to the plant
Pathogens	• Bacteria • Fungi	**Promote disease** • Consume roots and other plant parts, causing disease
Parasites	• Nematodes • Microarthropods	• Parasatize nematodes or insects, including disease-causing organisms
Root-feeders	• Nematodes • Microarthropods (for example, cutworm, weevil larvae, and symphylans)	**Consume plant roots** • Potentially cause significant crop yield losses
Bacterial-feeders	• Protozoa • Nematodes	**Graze** • Release plant-available nitrogen (NH_4+) and other nutrients when feeding on bacteria • Control many root-feeding or disease-causing pests • Stimulate and control the activity of bacterial populations
Fungal-feeders	• Nematodes • Microarthropods	**Graze** • Release plant-available nitrogen (NH_4+) and other nutrients when feeding on fungi • Control many root-feeding or disease-causing pests • Stimulate and control the activity of fungal populations
Shredders	• Earthworms • Macroarthropods	**Break down residue and enhance soil structure** • Shred plant litter as they feed on bacteria and fungi • Provide habitat for bacteria in their guts and fecal pellets • Enhance soil structure as they produce fecal pellets and burrow
Higher-level predators	• Nematode-feeding nematodes • Larger arthropods, mice, voles, shrews, birds, other above-ground animals	**Control populations** • Control the populations of lower trophic-level predators • Larger organisms improve soil structure by burrowing and by passing soil through their guts • Larger organisms carry smaller organisms long distances

Adapted from the Natural Resources Conservation Service, http://soils.usda.gov/sqi/concepts/soil_biology/images/A-4.jpg.

making it more easily decomposed by bacteria and fungi. They stimulate microbial activity by grazing on them. They enhance soil aggregation through their fecal matter, while their burrows enhance penetration of water and gas into the soil. They stimulate species succession in the soil biota, and they can control plant pests (or be plant pests). All microarthropods prey on soil bacteria and fungi, as well as each other. Nematodes prey on bacteria, fungi, protozoa, microarthropods, plant roots, and other nematodes. When these animals eat each other, nutrients such as nitrogen are released into the surrounding soil. Soil microarthropods, especially nematodes and mites, have been shown to be sensitive indicators of ecosystem health in other arid ecosystems (Kay and others, 1999).

Vegetation

In terrestrial ecosystems, vegetation is the dominant functional type, as vegetation defines the productivity, habitat structure, and ecological processes within an ecosystem (fig. 3E). Plants convert carbon dioxide from the atmosphere into shoots, leaves and roots, and upon their decomposition, contribute carbon to soils (fig. 3D). Plant canopies and roots protect soils from erosion and mediate microhabitat conditions. They also provide fuels for fire and habitat for above- and below-ground fauna (figs. 3F, H, and I). The cover of native perennials, particularly the most common species, such as *Larrea tridentata* (creosote bush), *Ambrosia dumosa* (white bursage), and *Coleogyne ramosissima* (blackbrush), represents one of the most important signs of ecosystem health in the Mojave Desert. Plants are also effective indicators of biodiversity in arid ecosystems (de Soyza and others, 1998, 2000; Landsberg and Crowley, 2004).

The composition of Mojave Desert plant communities is influenced by the flora of the Sonoran and Colorado Deserts to the south and southeast and the flora of the Great Basin Desert to the north (Johnson, 1976; Rowlands, 1995). At the regional level, a high abundance of succulent plants that rely on summer precipitation (cacti, ocotillo, and members of the genera *Yucca, Agave,* and *Nolina*) can be found in the small portion of the Mojave (east and south) east of the 117th meridian, where summer rainfall is dependable (Rowlands, 1995). About 15 percent of these plants utilize the water-use-efficient C_4 or Crassulacean Acid Metabolism (CAM) photosynthetic pathways (Johnson, 1976). However, most of the Mojave Desert is dominated by winter rainfall, and consequently, 85 percent of the vascular flora utilize the C_3 photosynthetic pathway (Johnson, 1976) and have maximum growth during the spring months following winter rainfall. The most common perennial grasses in this desert also use the C_3 pathway, with the notable exception of the C_4 *Pleuraphis rigida* (big galleta grass). At the local scale, rainfall patterns interact with the soils and geomorphy to determine the distribution of plants, which, ultimately, governs the distribution and abundance of biota in desert systems (Juhren and others, 1956; Beatley, 1969, 1976; Schwinning and Sala, 2004).

Several classification systems for Mojave Desert perennial plant assemblages were developed in the mid 20th century (Johnson, 1976). Beatley (1976) proposed the first detailed classification system, describing 16 vegetation assemblages for the Nevada Test Site and vicinity in the northeastern Mojave and transition Great Basin deserts. She determined her assemblages based on almost a decade of work collected on 68 permanent vegetation plots. Ostler and others (2000), working in the same area as Beatley, defined 10 vegetation alliances and 20 associations using multivariate analyses of 1,508 observation points on the Nevada Test Site. In contrast, Sawyer and Keeler-Wolf (1995), in a manual of California vegetation, listed 26 assemblages that included either *L. tridentata* or *C. ramosissima*. Finally, Thomas and others (2004) defined 101 alliances in the Mojave Desert, ranging from those in riparian zones to those in arid settings, and provided a key to determining the alliance type from field-collected data. The concept of vegetation association and alliance has considerable elasticity, and a large amount of variation in species composition occurs within these vegetation units. The units described by Thomas and others (2004) are large, with low-resolution boundaries. Some of their units have explicit or implicit disturbance histories that drive the species composition (for example, wash assemblages).

The Mojave Desert is predominantly a shrubland with a large annual plant component and scattered, highly localized patches of perennial grasses and endemic plants. In general, the distribution of *Yucca brevifolia* (Joshua tree) and *Y. schidigera* (Mojave yucca) defines the broader extent of the Mojave Desert. The lowest elevations in the Mojave Desert have wet playas (salt flats) that support sparse vascular perennial vegetation (fig. 13). At the edges of the barren wet playas are salt scrub plant communities represented by *Distichlis* spp. (saltgrass), *Tessaria sericea* (arrowweed), and *Allenrolfea occidentalis* (pickle weed). *Prosopis glandulosa* (mesquite) stands occur near the margins of wet playas and the base of dune complexes, where they seasonally take advantage of both deep and shallow water tables.

Just above the lowest elevations are found the two most common species in the Mojave Desert: *L. tridentata* and *A. dumosa*. These species are shared with the southerly deserts and can be found in the medial piedmonts which cover much of the Mojave Desert. These two shrubs are often interspersed with a variety of cacti, such as *Echinocactus polycephalus* (cottontop cactus); semi-succulents, such as *Encelia farinosa* (brittlebush) and *Lycium andersonii* (wolfberry); as well as *Yucca schidigera* (Mojave yucca). The various saltbushes (*Atriplex canescens, A. confertifolia*), *Grayia spinosa* (spiny hopsage), *Krascheninnikovia lanata* (winterfat) and *Sarcobatus vermiculatus* (greasewood), shared with the Great Basin Desert, occur on gravelly soils at the base of piedmonts and sometimes the margins of dry playas at lower and middle elevations. The most common desert scrub community at intermediate elevations is dominated by *C. ramosissima* and *Artemisia tridentata* (big sagebrush) and provides an important transition with the Great Basin Desert. *C. ramosissima* can form near-monospecific stands on old deposits with

strongly developed soils. Although previously viewed as a species-depauperate vegetation type, recent studies indicate that blackbrush-dominated communities are as speciose as other desert scrub alliances (Brooks and others, 2004). Near the upper piedmonts, desert scrub alliances may border savannah grassland represented by perennial bunch grasses (for example, *Pleuraphis rigida, P. jamesii, Achnatherum hymenoides*) and scattered shrubs including *C. ramosissima* and *Y. brevifolia*. Above the blackbrush and sagebrush level, at the upper piedmont and the lower slopes of mountain ranges, is a sclerophyllus woodland characterized by the evergreen *Pinus* spp. (pinyon pine) and *Juniperus* spp. (juniper). These trees are interspersed with shrubs, such as *Purshia glandulosa* (bitterbrush) and *Cercocarpus montanus* (mountain mahogany). These woodlands occur at elevations above about 1,500 m and are transitional to the vegetation of the Basin and Range mountains, as well as to the Transverse Ranges and Sierra Nevada to the west. At higher elevations, the montane slopes are dominated by forests consisting of several different conifer species, such as *Abies concolor* (white fir), *Pinus flexilis* (limber pine), and *Picea englemannii* (spruce). These forests are highly variable in species composition.

Mojave Desert annual plants have been studied for decades, and research has focused on a broad diversity of topics, including soil seed reserves (Nelson and Chew, 1977; Guo and others, 1998, 1999), germination requirements (Went, 1948, 1949; Juhren and others, 1956; Beatley, 1974), microsite associations and environmental gradient (Nelson and Chew, 1977; Samson, 1986; Lichvar and others, 1998), population fluctuations in response to climatic variability (Beatley, 1974; Bowers, 1987; Webb and others, in press), physiology, growth and development (Went and Westergaard, 1949; Mooney and others, 1976), resource use and allocation (Williams and Bell, 1981; Bell and others, 1979; DeFalco and others, 2001, 2003), native versus non-native species compositions and interactions (Beatley, 1966; Brown and Minnich, 1986; Hunter, 1991; Brooks, 1999a, 1999b, in press), and competition and competitive abilities (DeFalco and others, 2003, 2007; Brooks, 2000). Desert annuals have also been integral to studies on the diet and foraging habits of the many herbivores that rely on them, such as heteromyid rodents (Beatley, 1969) and the desert tortoise (Esque, 1994; DeFalco, 1995). The timing and abundance of rainfall are enormously variable in the Mojave Desert, challenging our ability to predict annual plant productivity and species composition from year to year (fig. 14). Understanding variability by collecting data in multiple years of contrasting rainfall at sites that span a range of soil types is paramount to distinguishing natural fluctuations in native and non-native annual plant responses from those that signal a need for management action.

Annual Plants and Climatic Variability

The abundance and diversity of desert annuals are intimately tied to rain that falls from late autumn through early spring (Beatley, 1974), especially that occurring from late Sep-

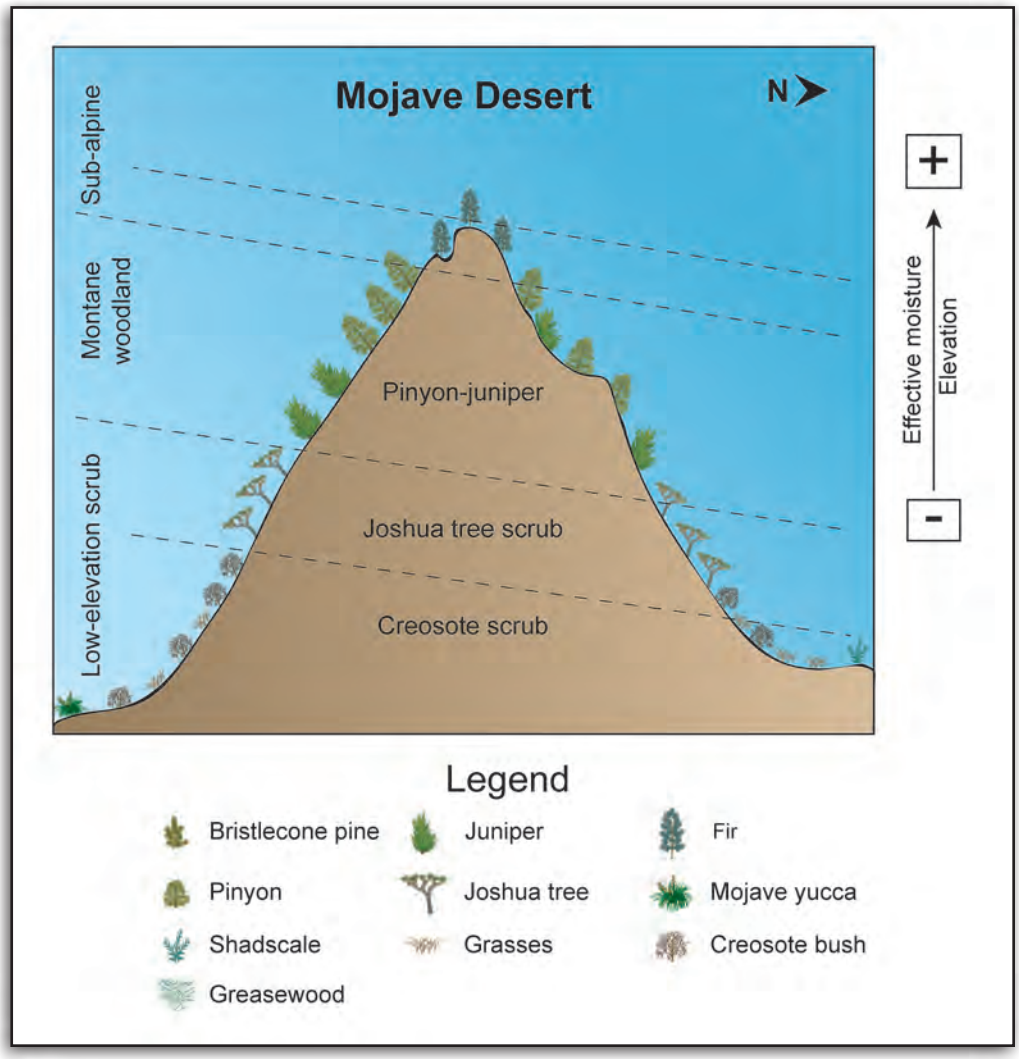

Figure 13. Vegetation zones in the Mojave Desert. As latitude increases, vegetation zones descend in elevation due to decreasing temperature and increasing available moisture. Plant cover is, in general, more dense northward and upward, except at very high elevations.

tember through December, which is needed to break seed dormancy and stimulate germination (Went, 1948; Beatley, 1967, 1969, 1974; Bowers, 1987; Hunter, 1991). On a regional scale, the above-average rainfall which generally occurs during an El Niño year stimulates the greatest amount of winter annual production in the Mojave Desert (Bowers, 2005a). Although most winter annual species senesce by late spring and early summer, occasional heavy monsoonal storms during July and August, which increase in importance to the east and south (Rowlands and others, 1982), can also stimulate a unique flora of summer annuals. Non-native *Bromus madritensis* ssp. *rubens* (red brome), an increasingly dominant species in annual plant communities (Brown and Minnich, 1986; Hunter, 1991), responds positively during wet rainfall years and has low numbers or is completely absent during drought periods (figs. 14 and 15). Revisitation of the undisturbed Beatley plot 3 in Rock Valley (DeFalco and others, unpub. data), censused from 1963 to 1975, 1987 to 1995, and 2000 to 2006, indicates that *B. madritensis* ssp. *rubens* has been continuously present. However, while *B. madritensis* ssp. *rubens* has the traits that allow it to outcompete native winter annual species (DeFalco and others, 2003), native population densities are not often negatively correlated with *B. madritensis* ssp. *rubens* densities (Beatley, 1966; Hunter, 1991). Thus, all annual species respond in complex ways to the timing, distribution, and amounts of winter precipitation.

Wet winters, such as the El Niño winter of 1997–1998, generally result in high densities of native and non-native annuals (Smith and others, 2000), leading to storage of propagules in seedbanks. Seeds of native desert species can remain dormant in the soil for years, which allows them to delay emergence when germination conditions are unfavorable (Cohen, 1966); the optimal conditions for breaking seed dormancy, germination, and plant growth vary among species and do not occur every year (Baskin and Baskin, 1998). Therefore, only a small number of the native seeds present in the soil may germinate and mature into adult plants each season, and the species composition of these standing annual plants can differ by more than 50 percent compared to the soil seedbank (M.L. Brooks, unpub. data). In contrast, *B. madritensis* ssp. *rubens* does not have seed dormancy (DeFalco and others, 2003), which makes it susceptible to extended periods of below-average rainfall that can result in dramatic seedling mortality. Seeds of natives and non-natives are also distributed unevenly across the landscape and the variable microsite conditions they experience introduce additional variability in germination and establishment success (Halvorson and Patten, 1975; Young and others, 1976; Reichman and Oberstein, 1977; Reichman, 1984; Price and Reichman, 1987; Price and Joyner, 1997; Guo, 1998; Esque, 2004). Consequently, seedbanks should be monitored in addition to above-ground plants and their productivity; not doing so underestimates the potential and true composition of the plant community.

Arthropods

Arthropods influence a diversity of trophic levels represented in the Mojave Desert through their role as pollinators, herbivores, predators, prey, vectors of disease, hosts and parasites, and decomposers (figs. 3D, F, and G). Macroinvertebrates are, by far, the most speciose animal group, with ants, termites, bees, and flies playing roles in pollination, seed predation, facilitation, decomposition, and bioturbation (MacMahon and others, 2000; Esque, 2004; Wagner and Jones, 2006). Arthropods that occur in soils and on the soil surface, such as ants, termites, and beetles, are critical in nutrient cycles. These organisms move large amounts of plant matter found on the soil surface into subsurface soils, accelerating the cycling of this plant material. In addition, nutrients released

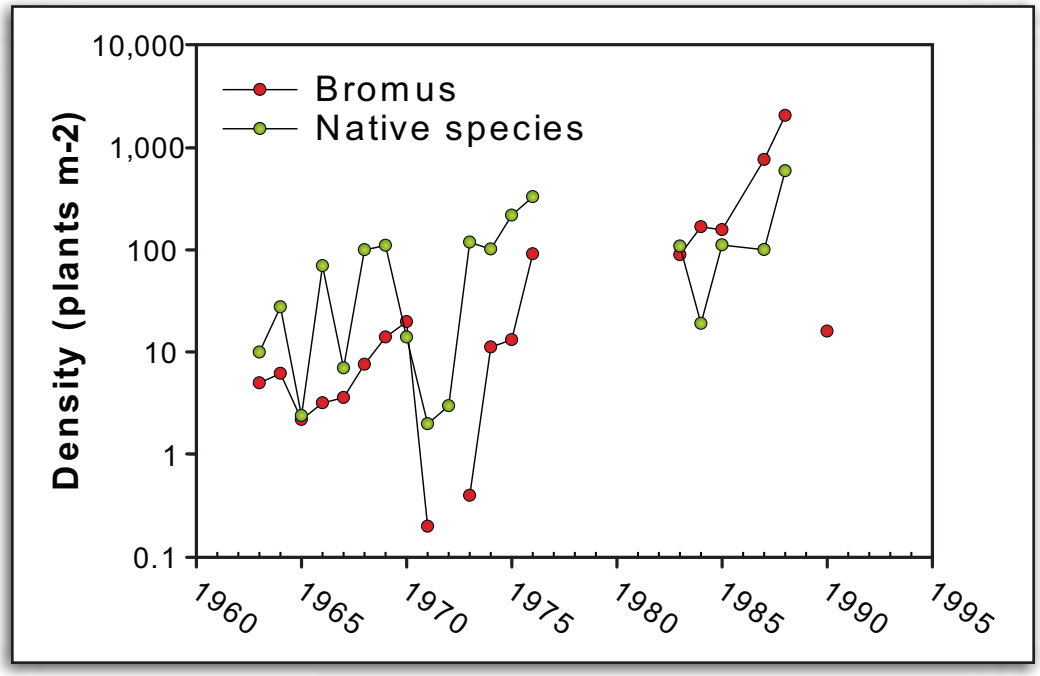

Figure 14. Mojave Desert annual grass populations fluctuate interannually as demonstrated across nearly three decades of censusing of the non-native annual grass *Bromus madritensis* ssp. *rubens* (red brome) and native species (adapted from Hunter, 1991). Census did not occur 1977 through 1982. Note the log10 scale of annual density: no individuals of *B. madritensis* occurred in 1972, no natives occurred in 1990, and no species germinated in the exceptionally dry year of 1989.

from plant material are less likely to be lost to the atmosphere through gaseous emissions, as temperatures at depth are less variable and gaseous exchange rates with the atmosphere are reduced. All burrowing arthropods also create macropores in the soil, increasing the infiltration of rain water (Whitford, 2002). Arthropods are concentrated around shrubs, as they are probably responding to higher levels of soil organic matter (Rundel and Gibson, 1996).

Ants and Termites

Probably the most well known of the arthropods are ants and termites. Termites are exclusively decomposers, feeding on wood, leaves, and soil organic matter and nesting 2 to 3 m below the soil surface. Thus, they are important in nutrient cycling and making nutrients available to vascular plants. In addition, building and maintenance of their nests require churning of the soil, which brings nutrient-rich soil to the surface and increases water infiltration, which stimulates other soil fauna. This creates nutrient-rich patches throughout the desert. However, termite numbers are low in the Mojave Desert, unlike many other deserts, and thus they are of only low or moderate ecological significance (Rundel and Gibson, 1996). In addition, they are relatively insensitive to vegetation change, making them less suitable than other soil variables as indicators of ecosystem health (Whitford, 2002).

Ants, on the other hand, are common throughout the Mojave Desert and are among the most abundant arthropods in deserts of the world. Ants are very flexible foragers, as they can be herbivores, granivores, farmers of fungi, or predators. They live in many diverse vegetation types and diverse places within those habitats, including soil and plants. They range widely and their prodigious numbers promote their success in deserts. They are highly socialized and together they function as a large organism, regulating temperature, humidity, and gases within the nest, reproducing and providing food to all parts of the "organism." This has required evolution of fairly sophisticated communication and the ability to transport materials from afar in a coordinated way. The females are the workers: they build the nest, collect the food, lay the eggs, and guard the nest. The males merely feed themselves and provide sperm; thus, they have lost the ability to evolve socially (Brian, 1978). Because ants can only travel a limited distance, the nest must occur in areas where resources are accessible, reliable, and sufficient. As ants collect materials and concentrate them at the nest, they also create fertile patches in the desert landscape, increasing organic matter, nitrogen, phosphorus and potassium in the vicinity of the nest (Wagner and others, 2004; Wagner and Jones, 2006).

Among the many ant species, harvester ants (for example, *Pogonomyrmex rugosus*; fig. 16) are the most studied, as they can have a large impact on vegetation dynamics. Observations on the distribution of ant colonies in time and space, and across thermal gradients, indicate that competition may shape ant community composition (Bernstein, 1974; Whitford, 1978; Davidson, 1980). Harvester ants regularly include seeds in their diets (MacMahon and others, 2000; Hölldobler and Wilson, 1994), and so their population size is greatest when seed drop occurs (Whitford, 2002). Seeds of specific species are often favored (Stradling, 1978), and harvester ants have been observed to collect from 33 to 100 percent of the seeds from these plant species and 9 to 26 percent of all available seeds (Crist and MacMahon, 1992). Seed harvesting by these ants can increase the diversity of seedbanks and plant production because ants consume the most common seeds and release rare plant species from competition (Brown and others, 1979). Although seed predation by ants has been emphasized in the literature, harvester ants are not always seed predators;

Figure 15. Non-native annuals, primarily *Bromus madritensis* ssp. *rubens* (red brome), in creosote bush-white bursage assemblages in the Mojave Desert are often restricted below shrub canopies in most years when average winter rainfall occurs (left). When above-average winter rainfall occurs, distribution of red brome can extend into the shrub interspaces such as in this blackbrush shrubland at the Nevada Test Site in southern Nevada (right) (U.S. Geological Survey photographs by Todd C. Esque).

worker ants sometimes disperse seeds by carrying seeds to the nest but not consuming them (Hölldobler and Wilson, 1994). Foraging can occur during the day and the night, depending on the species. Soil surface temperature, saturation deficits, and forage availability strongly affect foraging activity of harvester ants (Whitford, 2002). The main predators of ants are lizards, snakes, birds, and small mammals.

While Mojave Desert ants are likely to be good indicators of ecosystem health (Oliver and Beattie, 1996), much work is needed toward understanding the relations ants share with other taxa and whether they respond to environmental change similarly to other taxa. Nash and others (2004) did not consider ants to be good indicators of rangeland status in the Mojave Desert because it was not possible to discern a difference in the response of ant communities found in rangeland study sites that were ranked "fair" and "good." However, they were able to distinguish between "poor" and "fair" study sites. In contrast, ants in arid regions of Australia are routinely used as ecological indicators associated with diverse land uses (Andersen and Majer, 2004). It remains to be seen whether or not ants can be used as bioindicators in Mojave Desert communities.

Figure 16. Harvester ants (*Pogonomyrmex rugosus*) collect the fruits of many species of annual and perennial plants. Ants transfer fruits below ground where the seeds are usually removed, and the empty caryopses are discarded above ground near the nest entrance (U.S. Geological Survey photograph by Todd C. Esque).

Beetles

Darkling beetles (family Tenebrionidae) are very abundant in the Mojave Desert. There are about 50 species in this region, with *Eleodes obscura* generally the most abundant (Rundel and Gibson, 1996). Abundance of this beetle varies with habitat type, with the highest numbers found in *Larrea-Ambrosia* and *Grayia-Lycium* communities (Allred and others, 1963). Specific species prefer specific soil types, although overall abundance is higher on sandy soils. This is likely due to the poor conductance of heat through sand, resulting in substantially reduced soil temperatures at the shallow depths where they place their burrows (Crawford, 1988). In addition, the high water infiltrability of sands results in water accumulating below the burrow. Beetle density can be startlingly high, with estimates of 48,000 individuals per ha (Rundel and Gibson, 1996). Darkling beetles are active year round, although most activity occurs March–October, with activity peaking in August and September. Most species feed on plant litter found under plants, captured in small litter dams, or around ant mounds. These habitats also moderate the high heat of the day. The species composition and abundance of these beetles appear to be very similar among disparate deserts of the world (Whitford, 2002).

Other Arthropods

Many other species of arthropods occur in the Mojave Desert. Soil-dwelling arthropods include Orthoptera, isopods, millipedes, scorpions, solpugida, spiders, phalangida (daddy longlegs), centipedes, and mites, and all are ecologically important. Whereas phytophagous soil arthropods are dominated by weevils, foliage-dwelling arthropods are dominated by three orders: Lepidoptera (moths and butterflies), Coleoptera (weevils and leaf beetles), and Orthoptera (grasshoppers and crickets). Among all the insects, sap-feeders from the Homoptera and Hemiptera (bugs) and Thysanoptera (thrips) are the most abundant. Other insects, including mealybugs, treehoppers, leafhoppers, phyllids, beeflies, wasps, and ticks are also common and are ecologically important. Insects also have predators and parasitoids, including spiders, neropterans, hemipterans, and thrips. However, because of the difficulty of sampling these organisms and the limited background available for interpreting results, we will not include them in our discussion of monitoring.

Small Animals

Small animals are an important component in the Mojave Desert ecosystem, and they occur from the lowest to highest

elevations (fig. 3F). Within the northern Mojave Desert, in the vicinity of the Nevada Test Site, there are at least 34 species of reptiles (17 species of snakes, 16 lizards, and 1 tortoise), while the number of small mammal species is somewhat less (approximately 24 species of small mammals, excluding bats and rabbits; Wills and Ostler, 2001). There is a reduction of small mammal species with an increase in elevation and latitude and a similar, but less drastic, reduction in reptilian species. These animals are small individuals (mostly far less than 1 kg), but their combined biomass is formidable. Small animals churn (Whitford and Kay, 1999) and aerate soils, increasing water infiltration and bringing nutrient-rich soils to the surface. Daily activity patterns of small animals are varied, with the majority of the snakes and rodents being nocturnal and the majority of the lizards being diurnal. Most small animals reside within or near shrub cover to avoid predation. There is considerable variation in these animals' demographics. Some species of lizards (for example, side-blotched lizard [*Uta stansburiana*]; fig. 17) and small mammals (for example, Merriam's kangaroo rat [*Dipodomys merriami*]) exhibit nearly an annual turnover in their populations; their abundance increases after wet winters (Hirsch and others, 2002). Other small animals, such as the desert tortoise, can live multiple decades. Many of these small animals are prey for higher trophic levels of vertebrates.

Amphibians

Amphibians are unlikely desert dwellers, as they are intolerant of high temperatures and dehydrate quickly. In the Mojave Desert, the dominant amphibian species is the spadefoot (*Spea* and *Scaphiopus* spp.). These animals have a large protuberance on their back foot that facilitates digging. Their burrows are deep in the soil, where they can maintain body moisture. They produce only a small amount of urine, instead concentrating solutes and urea in their tissues, thus maintaining a favorable moisture gradient with the surrounding soils. In addition, they have thin, highly vascularized skin where most water uptake occurs (Gordon, 1982). Spadefoots can spend nearly a year buried in the soil, coming to the surface in response to large, intense, summer rainfall events, after which they feed and mate. They then bury themselves again, waiting for the next summer. While buried, their metabolism can drop to one-fifth of normal. However, individuals frequently die during the dormancy period due to insufficient fat stores or soil water. Another amphibian that is fairly widespread in parts of the Mojave Desert is the red-spotted toad (*Bufo punctatus*), which is a true toad, possessing small round parotid glands and horizontal or round pupils (Stebbins, 2003). Details for sampling amphibian populations is dealt with intensively in Heyer and others (1993), and the marking techniques by Ferner (2007). Many of the same sampling and marking techniques used to study amphibians are discussed in the section pertaining to lizards.

Reptiles

The number of reptilian species varies considerably between the major deserts of North America; the Mojave Desert has more species than the Great Basin, but fewer than the Sonoran or Chihuahuan Deserts (fig. 18).

The largest Mojave Desert reptile, the desert tortoise (*Gopherus agassizii*), is distributed throughout much of this desert at elevations below 1,200 m (Bury and others, 1994), with the population north and west of the Colorado River listed in 1990 by the Fish and Wildlife Service as threatened (fig. 19). The habitat selected by tortoises varies considerably between populations. The Sonoran population in Arizona generally inhabits rocky slopes, whereas the Mojave population inhabits primarily valley bottoms and foothills (Germano and others, 1994). The diet of the Mojave desert tortoise is primarily composed of ephemeral vegetation (Nagy and Medica, 1986; Esque, 1994; DeFalco, 1995; Avery, 1998), which is generally produced as a result of rains of 25 mm or more during the fall and winter (Beatley, 1974). Additionally, tortoises require free water for drinking, and after several continuous years of drought, a high mortality of adults has been observed (P.A. Medica, pers. observation; Longshore and others, 2003).

Figure 17. The side-blotched lizard (*Uta stansburiana*) is one of the smaller lizards found in the Mojave Desert and is prey for many other animals (U.S. Geological Survey photograph by Todd C. Esque).

A moderate number of lizard species are common within the Mojave Desert. Diurnal species include the side-blotched lizard (*Uta stansburiana*), western whiptail lizard (Cnemidophorus = *Aspidoscelis tigris*), zebra-tailed lizard (*Callisarus draconoides*), desert horned lizard (*Phrynosoma platyrhinos*), desert spiny lizard (*Sceloporus magister*), desert iguana (*Dipsosaurus dorsalis*), common chuckwalla (*Sauromalus ater*), Great Basin collared lizard (*Crotaphytus bicinctores*) and long-nosed leopard lizard (*Gambelia wislizenii*). There are only two common nocturnal lizards, the western banded gecko (*Coleonyx variagatus*) and the night lizard (*Xantusia vigilis*).

The highest species diversity of lizards is generally found in *Larrea-Ambrosia* communities (11 species). A moderate number of species are found in *Coleogyne* communities (8 species), *Grayia-Lycium* communities (7 species), *Atriplex-Kochia* communities (6 species) and disturbed communities dominated by *Salsola* (6 species). Only three species are commonly found in pinyon-juniper woodlands (Allred and others, 1963).

Most lizards are insectivores, feeding on larvae of ants, arachnids, termites, and other invertebrates. Some species are specialists, feeding primarily, but not exclusively, on ants (desert horned lizard, *Phrynosoma platyrhinos*) or termites (western whiptail lizard, Cnemidophorus = *Aspidoscelis tigris*), whereas others (long-nosed leopard lizard, *Gambelia wislizenii* and leopard lizards, *Crotaphytus wislizenii*) are omnivorous and feed on lizards, insects, and even the fruit of *Lycium andersonii* (wolfberry). The desert iguana (*Dipsosaurus dorsalis*) and common chuckwalla (*Sauromalus ater*) are almost exclusively herbivorous, feeding on flowers. The desert iguana feeds on those from *Larrea tridentata* (creosote bush) and *Abronia* spp. (sand verbena; P.A. Medica, pers. observation), and the common chuckwalla feeds on those from *Sphaeralcea* spp. (globe mallow; Sanborn, 1972). Some lizards are habitat specialists, with special adaptations, such as the specialized toes found on the Mojave fringe-toed lizard (*Uma scoparia*, fig. 20).

The most common and ubiquitous lizard in the Mojave Desert is the side-blotched lizard (*Uta stansburiana*). This lizard serves as a food item for many predatory species of vertebrates and even arachnids. Side-blotched lizards can occur in very high densities (80/ha; Turner and others, 1982) and are considered an annual species, as 75 to 80 percent of populations are replaced annually. There is a large amount of interannual co-variation with rainfall (Medica and others, 1994; Woodward, 1994), as high winter precipitation and the concomitant growth of annual vegetation and insect populations strongly increases reproduction in this lizard (Turner and others, 1974). Therefore, their population fluctuations often mirror short-term environmental change.

Figure 19. Desert tortoise (*Gopherus agassizii*) emerging from a burrow at Joshua Tree National Park (U.S. Geological Survey photograph by Todd C. Esque).

In contrast, many other lizard species are long-lived. Long-nosed leopard lizards (*Gambelii wislizenii*) live up to 10 years. Desert horned lizards (*Phrynosoma platyrhinos*) can live up to 6.5 years, the western whiptail lizard (*Cnemidophorus tigris*) can live up to 7.8 years (Medica and Turner, 1984), and the desert night lizard (*Xantusia vigilis*) can live up to 6 to 7 years (Zweifel and Lowe, 1966). In general, long-lived species require at least two seasons to become sexually mature. While the number, activity, and reproductive potential of the populations of the longer-lived species can vary greatly from year to year, they have demonstrated potential as indicators of environmen-

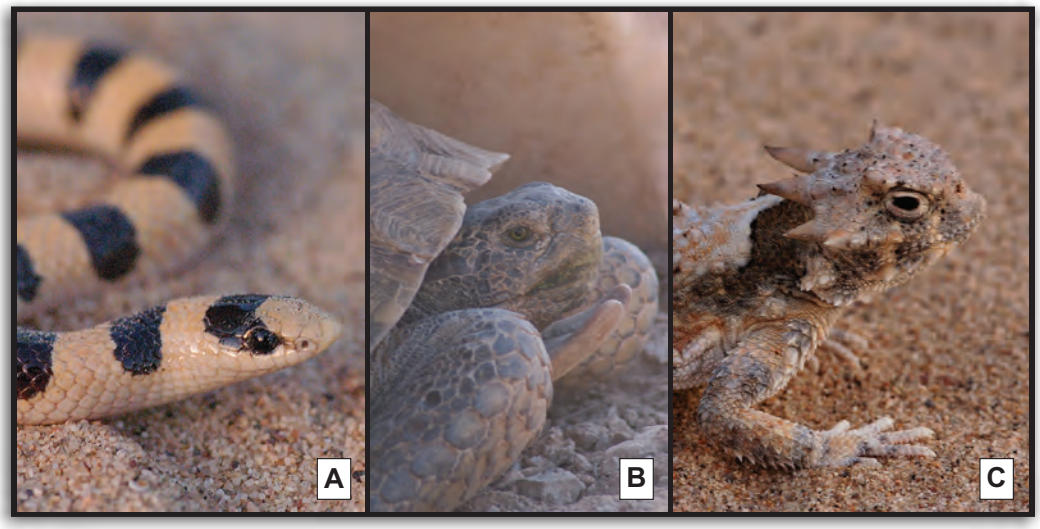

Figure 18. Common reptiles of the Mojave Desert. A, Shovel-nosed snake (*Chionactis occipitalis occipitalis*); B, Desert tortoise. (*Gopherus agassizii*); C, Horned lizard (*Phrynosoma platyrhinos*) (U.S. Geological Survey photographs by Todd C. Esque).

tal stress and disturbance (Medica, 1992; Medica and others, 1994).

There are many species of snakes in the Mojave Desert, and most are nocturnal. Many of these snakes are small and are known to feed on invertebrates and/or small lizards (for example, western blind snake [*Leptothyplops humilis*], ground snake [*Sonora semiannulata*], shovel-nosed snake [*Chionactis occipitalis*], and the night snake [*Hypsiglena torquata*]). The moderately sized snakes, such as the rattlesnake (*Crotalus* spp.), long-nosed snake (*Rhinocheilus lecontei*), and glossy snake (*Arizona elegans*), feed mainly on rodents and lizards. Other species may specialize in feeding on particular prey: the common king snake (*Lampropelus getulus*) feeds on snakes and rodents, and the lyre snake (*Trimorphodon biscutatus*) feeds primarily on lizards, bats and rodents. There are three diurnal species, the coachwhip (*Masticophis flagellum*), the gopher snake (*Pituophis melanolucus*) and the less common patch-nosed snake (*Salvadora hexelepus*), that feed on lizards, small mammals, and birds (Ernst and Ernst, 2003). There are at least two species of snakes that inhabit the southern portions of the Mojave Desert and are not found in the north. They include the rosy boa (*Lichanura roseofuscus*) and the diamondback rattlesnake (*Crotalus atrox*). Sampling records indicate that initial snake activity in the spring and early summer is highly dependent upon temperatures, as when daytime temperatures exceed 90°F (32°C) and nocturnal snake activity is greatly increased.

Small Mammals

A large proportion of the small mammals in the Mojave Desert belong to the family Heteromyidae (kangaroo rats and pocket mice), Cricetinae (white-footed mice, grasshopper mice, and wood rats), and bats. Besides the Heteromyids, the Sciuridae (ground squirrels and gophers) are most common. These small mammals subsist primarily on seeds, vegetation, roots, and insects. Their ability to survive under harsh conditions is tied to their nocturnal habit; their greatest activity times are when temperatures are cool. In addition, many have a variety of adaptations to economize water. Heteromyid rodents are able to survive without free water, and other species may be able to do so as well, but they have not been studied (Schmidt-Neilson, 1964; MacMillan and Hinds, 1983; French, 1993). Population numbers of small mammals vary widely among years as they respond to changes in their immediate environment. Their population numbers are closely tied to precipitation, and green forage is a cue to become reproductively active (Chew and Butterworth, 1964; Beatley, 1969). Differences in the distribution of two species of kangaroo rats along an elevational gradient reflects a dynamic interaction among primary productivity, driven by annual rainfall and the varying metabolic requirements of the two species (Price and others, 2000). Monitoring short-lived species, such as kangaroo rats, along such environmental gradients provide a sensitive indicator of a changing climate in the Mojave Desert.

Small mammals influence ecosystems in many important ways. Recent studies have shown that granivores may interact with seeds and each other in ways that affect multiple trophic levels both directly and indirectly (Mares and Rosenzweig, 1978; Brown and others, 1979; Galindo, 1986; Samson and others, 1992). As with ants and reptiles, they move large amounts of soil, bringing nutrients to the surface and creating macropores that significantly increase the amount of water infiltrating downwards. They are food for mammalian and avian predators. Plant-rodent interactions can be a significant mechanism in plant community change (Niering and others, 1963; Beatley, 1969; Chew and Chew, 1970; Soholt, 1973; Reichman, 1976; Price and Reichman, 1987; Brown and Heske, 1990; Kerley and others, 1997), as they are important in the dispersal and establishment of vascular plants as well as in the removal of seeds from the seedbank (Whitford, 2002; fig. 21). Small mammals are known to select seeds on the basis of size, burial depth, distribution (Reichman and Oberstein, 1977), and nutrient content (Kelrick and McMahon, 1985; Kelrick and others, 1986; Kerley and Erasmus, 1991; Crist and MacMahon, 1992). Heteromyids typically select the largest seeds available (Brown and others, 1979). Granivores may consume as much as 86 percent of seed production in the Chihuahuan Desert (Chew and Chew, 1970), 30 percent of the seeds of some plant species in the Mojave Desert (Soholt, 1973), and less than 1 percent of seeds in desert grasslands (Pulliam and Brand, 1975; Brown and others, 1979). Rodent populations in the Mojave Desert may be food-limited under some situations and, at these times, they may heavily impact seedbanks and vegetation (Soholt, 1973; Reichman, 1976). Unlike seeds buried in shallow caches, seeds that are transported to deep underground burrows are either eaten or forgotten, and thus ultimately removed from the seed pool (Reichman, 1975).

Figure 20. The Mojave fringe-toed lizard (*Uma scoparia*) is specially adapted for movement in its sand dune habitat at Kelso sand dunes in Mojave National Preserve. Note the fringes along the toe of the rear left leg (U.S. Geological Survey photograph by Todd C. Esque).

Rodents can also benefit plants (Reynolds and Glendening, 1949; Carroll and Janzen, 1973; McAdoo and others, 1983; McAuliffe, 1990; Vander Wall, 1990; Longland and others, 2001). Rodent manipulation of seeds in preparation for consumption and/or caching can increase viable seed numbers, spatial distributions, and establishment (Brown and Minnich, 1986; Price and Jenkins, 1986). Seeds placed in shallow caches, but not recovered, have higher germination rates than seeds germinating without rodent caching (Reichman, 1976; Vander Wall, 1990; Longland and others, 2001). In experiments, rodents, both diurnal and nocturnal, collected a larger percentage of seeds made available in trays than did ants (Brown and others, 1975). Dispersal of seeds of species, such as *Achnatherum hymenoides* (Indian ricegrass), *Pinus monophylla* (single-leaf pinyon pine), *Yucca brevifolia* (Joshua tree), *Coleogyne ramosissima* (blackbrush), and *Psorathamnus fremontii* (indigobush), have been documented for the Mojave Desert (Vander Wall, 1997; Longland and others, 2001; Esque, 2004). Rodents can also promote the establishment and success of the invasive species *Erodium cicutarium* (redstem filaree) and *Bromus madritensis* ssp. *rubens* (red brome) at their burrowing sites, due to continuous disturbance (Schiffman, 1994, 1997). Community relationships among granivores and ants of widely varying taxa can be more important than birds in affecting the abundance of seed resources (Pulliam and Brand, 1975).

Natural and Anthropogenic Disturbances in the Mojave Desert

Both natural and human disturbances in the Mojave Desert can result in ecosystem disruption (Lovich and Bainbridge, 1999; figs. 2 and 3I). Natural disturbances include extreme climatic events, fire, insect and disease outbreaks, and herbivory and trampling by wildlife. Human-related disturbance includes military training exercises, non-motorized recreation, off-road vehicle use, livestock grazing, mining, air pollution, and urbanization. Global atmospheric changes, invasive plants, and alterations of fire regimes result from an interaction of natural and human disturbance and will be discussed below.

Figure 21. Kangaroo rats (*Dipodomys* spp.) constantly move large numbers of desert plant seeds across the landscape. Although a portion of stored seeds is consumed as seed availability declines, other seeds are forgotten and germinate when soil moisture and temperature conditions are favorable (U.S. Geological Survey photograph by Todd C. Esque).

In addition to understanding the impacts of these disturbances on ecosystem structure and function, it is also critical to know the history of a site in order to understand current conditions. Legislation for homesteading, mining, grazing, and water use enacted more than a century ago has left a legacy in most of the Mojave Desert. The type and placement of infrastructure, such as roads, utility corridors, and water diversions, and all uses associated with public lands have resulted from the complex interplay of human values, social structure, survival, and the ecosystems in which these uses occurred.

Natural Disturbances

Natural disturbances are those events which occur within the natural range of conditions experienced by an ecosystem over time (fig. 3I). Natural disturbance regimes are important in altering the structure and function of ecosystems, and thus in determining their trajectories through space and time. Different disturbance types often interact with each other or act in sequence, and the synergistic effect can have consequences that are much larger than the consequences of a single event. For instance, wet periods often create high annual-plant biomass on landscapes, and when dried this high biomass can contribute to wildland fires. Interactions can also happen between natural and anthropogenic stressors. For instance, nitrogen deposition can lead to an increase in invasive annual grasses (Brooks, 2003; Allen and others, in press), which, in turn, may promote fire. Episodic, event-driven change is an important feature of many ecosystems (Holling, 1996; Scheffer and others, 2001) and is particularly characteristic of dryland ecosystems (Whitford, 2002).

Extreme Climatic Events

Severe climatic events have a strong influence on Mojave Desert ecosystems. These include very high or very low precipitation amounts or temperatures, hail and lightning storms and/or high winds. All these events can alter ecosystems in profound ways and set their trajectories for many years through the widespread mortality of plants and animals. An example is the effect of the 1989–91 drought on plant communities in the northern Mojave Desert. Before this period, 8 of the 16 plant communities monitored at the Nevada Test Site were dominated or co-dominated by *Grayia spinosa* (spiny hopsage). However, after the drought, surveys showed *G. spinosa* as co-dominant in only one community due to its extensive mortality (Webb and others, 2001). This mortality event will have huge impacts on the structure and function of

this ecosystem for many years to come. Consecutive extremely wet years can also change community composition and structure, as they often result in high recruitment and establishment of perennial plants and animals. Extremely wet years can also facilitate the invasion of non-native annual grasses. Highly erosive floods or large wind storms may redistribute soil resources and alter site conditions that can fundamentally change plant and animal communities.

Fire

Fire can have enduring effects on desert ecosystems, with one of the most significant being the alteration of vegetation composition and structure due to the selective injury or elimination of fire-intolerant life forms or age classes (Whelan, 1995). Specific effects of fire on vegetation structure vary in relation to fire-regime characteristics (frequency, intensity, seasonality, and spatial patterning) and the responses of different plant species. Variables that affect the occurrence of fire include elevation, seasonal precipitation, natural vegetation type, fuel flammability, the presence or absence of invasive plants, and proximity to roads (DeBano and others, 1998; fig. 22). When fuels are available in sufficient quantity, structure, and continuity, fire incidence varies with local weather conditions, such as humidity, wind direction and velocity, and air temperatures. Finally, an ignition source, such as "dry" lightning or human activities, is required (Swantek and others, 1999).

Because shrub canopy cover in Mojave Desert plant communities is generally low, large plant-free gaps exist, creating a lack of continuous fuel so that most low-elevation areas went centuries without fire in the past (Humphrey, 1974). Numerous studies have reported on fire in Mojave Desert plant communities that probably were not subject to fire previously (McLaughlin and Bowers, 1981; Brown and Minnich, 1986; Brooks and Pyke, 2001; Brooks and Esque, 2002; Brooks and Minnich, 2006). However, fire dynamics have changed, and wildfires have become more frequent in the past 30 years (Brooks and Esque, 2002; fig. 23), especially at middle elevations dominated by *Larrea tridentata* (creosote bush), *Yucca brevifolia* (Joshua tree), and *Coleogyne ramosissima* (blackbrush; Brooks and Matchett, 2006). This is partially due to the increased dominance by invasive annual grasses that accompanied the above-average rainfall during this same time period (Brooks, 1999a, 1999b; Brooks and others, 2004; Brooks and Matchett, 2006; Brooks and Minnich, 2006; fig. 24).

Owing to high winter rainfall, native annual plants also have a large role in landscape fuel accumulation that can lead to fires; following the record rainfall of the winter of 2004–05, some fires in the Southwest were fueled primarily by native annuals, such as *Plantago* spp.

Because of their propensity to increase fires, non-native grasses have caused changes in the composition and physical structure of many Mojave Desert plant communities, as most native plants are not fire-adapted (Young and others, 1969; Jackson, 1985; Mack, 1986; Billings, 1990; D'Antonio and Vitousek, 1992; Brooks, 2002; Brooks and Minnich, 2006). Once an area has burned and reburned, native species diversity and densities decline (Brooks, unpub. data), and thus there is less competition and more nutrients for the non-native grasses. Combined with the abundant seed sources often found in adjacent invaded areas, favorable conditions are created for dominance by alien grasses. As alien grasses become more

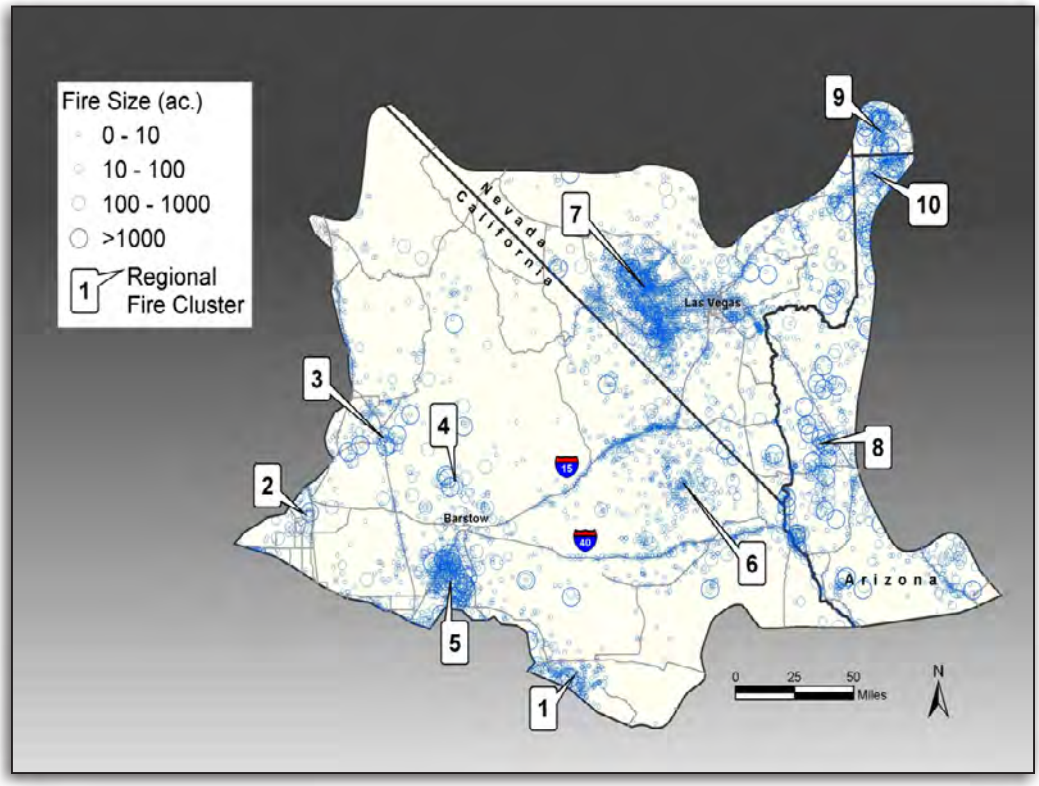

Figure 22. Spatial distribution of fires between 1980 and 1995 in the Bureau of Land Management California Desert District, and clusters of fire activity since the 1970s across the entire Mojave and Colorado Deserts. Major roads are included as geographic reference points (from Brooks and Esque, 2002).

abundant, the potential for fire increases, resulting in a positive feedback loop (D'Antonio and Vitousek, 1992).

Because most desert shrubs require extended periods without fire to re-establish, and grow slowly, fire is particularly destructive in shrub-dominated desert systems (Billings, 1990; Esque, 2004; Webb and others, 2003; Brooks and Minnich, 2006). As fire cycles are accelerated, opportunities for shrub establishment decrease. With the loss of perennial vegetation, important microclimates are lost, including those that provide conditions promoting germination and establishment of native plants and provide habitat for native animals. Repeated fire occurrence may be exacerbated by anthropogenic disturbances, such as atmospheric deposition of nutrients, which increases the production of non-native grasses (Brooks, 2003; Allen and others, in press), or an increase in precipitation due to climate change. Seedbanks can also change with fire (Esque, 2004), which impacts wildlife species of special concern (Esque and others, 2003; Brooks and Esque, 2002; Miller, 2005). Fire can create hydrophobic soils (Johansen and others, 2001; Miller, 2005) which, when combined with massive loss of vegetation cover, can allow for large losses of soil, nutrients, and organic matter. Wind erosion is often increased as well (Whicker and others, 2002; Miller, 2005). Soil movement is a risk wherever fires occur, but is a particular problem in habitats where vertebrates and invertebrates depend on free surface water (that is, springs, seeps, and riparian areas), as these features can be completely buried by siltation from burned areas. Fire also affects soil nutrients and nutrient cycling. Effects are variable, depending on the site and fire characteristics. Phosphorus and nitrogen availability can be increased temporarily (Raison, 1979; Blank and others, 1994; Miller, 2005), although this is highly variable from site to site. Nutrient stocks can also be depleted due to volatilization, ash, or soil erosion. Biota living at, or just under, the soil surface are often killed, thus slowing decomposition cycles and reducing soil nutrient availability. Depending on the severity of the fire, soil pH, cation exchange capacity, and infiltration rates can be affected as well.

Figure 24. Abundant alien annual grasses can cause high intensity fires, such as the one featured here engulfing an adult Joshua tree. Wildfires fueled by non-native annual grasses can cause catastrophic losses of native plant and animal species in Mojave Desert shrub assemblages (U.S. Geological Survey photograph by Todd C. Esque).

All of these factors change the biophysical environment of burned sites, creating openings for invasive species, suppressing the establishment of native plants, decreasing cover and forage for wildlife, changing nutrient availability and cycling, and, ultimately, changing the disturbance regimes and trajectories of these communities (fig. 25).

Insect and Disease Outbreaks

There is little information on the impact or role of insect and disease outbreaks in dryland ecosystems, unlike forests, where the effects of insects are a well-studied source of natural disturbance (for example, Veblen and others, 1991). Insect outbreaks are likely associated with drought conditions, which lower the resistance of vegetation to infection and affect the life cycles and dispersal patterns of the insect herbivores,

Figure 23. Disturbance caused by a single fire was sufficient to remove most woody perennial plant cover to the right of the road in this desert scrub plant community in Pakoon Basin, Mojave County, Arizona, 1989 (U.S. Geological Survey photograph by Todd C. Esque).

enabling them to infect plants (Swetnam and Betancourt, 1998; Logan and others, 2003; Miller, 2005). Hundreds of species of defoliating arthropods occur in the Mojave Desert (Rundel and Gibson, 1996), and thus it is likely that, under optimal conditions, they can have large impacts on the vegetation. For example, gelechiid moth larvae (*Chrysoesthia sexguttella*) consumed 40 to 80 percent of the leaves of *Lycium* spp. in 1971 in Rock Valley, Nevada, resulting in no fruits maturing on this species. These larvae are also attracted to *Ephedra* cones (Mormon tea) during pollen production. Outbreaks of the bark beetle pinyon ips (*Ips confuses*) in pinyon-juniper ecosystems are triggered by drought conditions that weaken host tree populations (Leatherman and Kondratieff, 2003; Miller 2005). Therefore, similar to fire, insect outbreaks can interact with climate to generate long-term changes in vegetation structure (Allen and Breshears, 1998; Miller, 2005). Insect- or pathogen-generated changes in vegetation structure can have multiple ecosystem-level consequences due to vegetation interactions with nutrient cycles, hydrologic processes, and geomorphic processes.

Herbivory and Trampling by Wildlife

Herbivory and trampling are also part of the natural disturbance regimes in the Mojave Desert. The effects of these disturbances depend on the characteristics of the ecosystem (for example, climatic conditions, soil properties, and vegetation structure and composition) in which they occur. However, given limited surface water and forage (Mack and Thompson, 1982; Grayson, 1994), and hunting by native peoples (Truett, 1996), it is unlikely that native ungulates were ever very abundant in this region. Thus, overall, herbivory and trampling by large ungulates were likely relatively minor disturbances in most dryland ecosystems prior to European settlement. However, herbivory by small mammals, such as gophers (*Thomomys* spp.), packrats (*Neotoma* spp.), mice (for example, *Peromyscus* and *Dipodomys* spp.), ground squirrels (*Ammospermophilis* spp., *Spermophilus* spp.), chipmunks (*Tamias* spp.), and rabbits (*Lepus* and *Sylvilagus* spp.) can be substantial, especially during drought years when they clip vegetation to access plant sap.

Anthropogenic Disturbance

There are a multitude of human-related disturbance types in the Mojave Desert that have a wide range of impacts on soils and ecosystem processes. In this discussion, we divide these disturbances into soil-disturbing activities, invasive plants, the alterations of fire regimes, urbanization, global atmospheric changes (including air pollutants), and the diversion of overland flow. The major types of disturbance, and recovery rates from these disturbance types, are presented in table 2.

Soil-Disturbing Activities

Although many land-use practices create severe disturbances in the Mojave Desert, those that disturb the soil surface (for example, military training, non-motorized recreation, off-road vehicles, livestock grazing, mining) create the largest direct and indirect ecosystem effects. These disturbances have several features in common: all increase soil compaction and vegetation loss while decreasing soil stability, nutrient cycling, and soil biotic activity. In this section, we will first discuss these common effects and then discuss the unique aspects of each disturbance type.

Soil Compaction

In its simplest sense, soil compaction results from the application of stress to the soil surface (fig. 26). In reality,

Figure 25. In alien annual grasslands, such as this example in Pakoon Basin, Arizona, *Bromus madritensis* ssp. *rubens* (red brome) and *B. tectorum* (cheatgrass) dominate the landscape in a former *Larrea tridentata* (creosote bush) and *Ambrosia dumosa* (white bursage) community that has burned multiple times in the past three decades (U.S. Geological Survey photograph by Todd C. Esque).

most disturbances impart a complex, three-dimensional stress field on soil, resulting in a normal stress that compacts the soil and a shear stress that dilates the soil (Webb, 1982). Depending upon the magnitude of the normal stress, maximum compaction typically occurs between 0.05 and 0.30 m depth, with the amount of compaction decreasing at greater depths. The amount of compaction that a soil can undergo is a function of particle size distribution, structure, and water content at the time of compaction (Webb, 1983). Poorly sorted soils (those containing a wide range of particle sizes), such as loamy sands and sandy loams, are compacted more readily than well-sorted soils (those with fairly uniform particle sizes), such as eolian sand or playas.

The amelioration of soil compaction is a complex process. Several factors affect recovery rates, especially the amount that bulk density increases with depth. Soil loosening occurs with freeze-thaw cycles, frost heaving, bioturbation, and the expansion and shrinking of clay minerals during wetting and drying (Webb, 2002). Therefore, loosening rates are heavily dependent on the clay content and mineralogy of the soil, the depth of water penetration, the frequency of wetting and drying cycles, and the depth of the compaction. Akram and Kemper (1979) applied both wetting and drying and freeze-thaw cycles to compacted soils and found that most of the change in infiltration rate, which is indicative of soil compaction, occurred during the first three cycles. Multiple freeze-thaw cycles reduce compaction in regions where severe freezing occurs (Orr, 1975; Brady and Weil, 1996), although such sites are rare in the Mojave Desert, and the loosening

Table 2. Summary of recovery rates for several metrics of ecosystem recovery on low-slope xerophytic sites in the Mojave Desert (from Webb and others, in press).

Metric of ecosystem recovery	Minimum recovery time (years)	Maximum recovery time (years)	Research needs
Visual appearance	20	>1,000	Visual recovery should be evaluated over a range of geomorphic surfaces and vegetation assemblages.
Biological soil crusts:			The interdependence of biological soil crust recovery and surficial particle size, soil nutrients, perennial plants, and climate should be evaluated.
cyanobacteria	20	50	
lichens/mosses	100	>1,000	
Surface soil compaction (0–60 mm)	70	140	Current data emphasizes sandy loams and loamy sands at intermediate elevations. The curvilinear trajectory may be a function of climatic fluctuations (wetting-drying cycles). Interrelation with plant recovery needs to be quantified.
Subsurface soil compaction (0.3–0.5 m)	unknown	>1,000	Little is known about recovery rates for subsurface compaction or whether they are important to overall recovery.
Annual vegetation	unknown	unknown	How does non-native vegetation affect recovery of native annual vegetation?
Total cover of perennial vegetation	20	80	A better understanding of recovery trajectories for different disturbances on different geomorphic surfaces is needed.
Density of perennial vegetation	unknown	>1,000	The processes leading to reduction in average plant size are unknown and affect recovery rates.
Cover and species composition of perennial vegetation	80	>1,000	This, the most important metric of recovery, allows comparison of natural recovery with active restoration. More information on key abiotic and biotic factors that control recovery is needed.
Biomass and productivity of perennial vegetation	unknown	unknown	Little is known about changes in biomass and productivity in the recovery process, or what key abiotic and biotic factors control recovery.
Arthropods	unknown	unknown	The linkage between arthropod populations and species composition changes in annual and perennial vegetation, or key abiotic or biotic factors, is needed.
Rodents	unknown	unknown	The linkage between rodent populations and species composition changes in annual and perennial vegetation, or key abiotic or biotic factors, is needed.
Reptiles	unknown	unknown	Population changes likely are linked to species composition changes in annual and perennial vegetation or key abiotic or biotic factors.

may occur only above 0.2 m (Blake and others, 1976; Larson and Allmaras, 1971; van Ouwerkerk, 1968). The effectiveness of freeze-thaw loosening depends on soil water content, texture, rate of frost penetration, and depth of compaction.

Bioturbation, ranging from roots penetrating the soil subsurface to insects or rodents burrowing, may be more important than physical processes in loosening compacted soil, especially in coarse-grained desert soils where clay content is low. The role of arthropods, particularly ants, in the dilation of compacted soils has not been studied. Observations indicate that rodent activity may increase in disturbed areas, particularly during or following overgrazing, but no work has been done to evaluate whether animals play a large role in the amelioration of compaction.

In the Mojave Desert, estimates of recovery time for compaction range from 80 to 130 years (Webb and Wilshire, 1980; Webb and others, 1986; Knapp, 1992; Webb, 2002; Webb and Thomas, 2003). A limited number of studies suggest that recovery below a depth of 0.3 m may be much slower than at shallower depths (Prose and Wilshire, 2000; Webb and others, in press) and may be so slow as to not be measurable. Bolling and Walker (2000) did not report any significant compaction recovery on roads that had been abandoned 5–88 years ago. However, they concluded that spatial heterogeneity among the roads they studied may have obscured any significant recovery trends, as they grouped measurements over a complicated array of geomorphic surfaces that likely respond differently to both the initial disturbance and subsequent recovery. Most general studies have assumed that a linear recovery model is an appropriate way to describe compaction recovery and have concluded that compaction amelioration is faster at higher-elevation sites, where freeze-thaw and wetting-and-drying cycles are more frequent than at lower elevation sites. However, as discussed above, the level of recovery needed for plant success is not known.

Soil Stability, Nutrient Availability, and Vegetation

Soil surface disturbance often compromises the stability of surface soils. The fibers in biological soil crusts that confer tensile strength to soil surfaces cannot withstand the shear stresses placed on them by trampling or vehicular traffic (Belnap and Eldridge, 2003). Other soil stabilizers are damaged or removed from the soil surface as well, including plants, plant litter, and rocks. Damage or complete destruction of these soil stabilizers leaves soil surfaces highly susceptible to erosion by wind and water (fig. 27). In addition, surface disturbances often kill plants, resulting in larger spaces between the plants. This allows more wind and water to reach the soil surface at a greater velocity, which, combined with greater water runoff due to soil compaction, increases the loss of soils. A decrease in soil fine particles (silts, clays) can be an indication that soil erosion is taking place. An increase in sand, especially the fine and medium fraction, can indicate deposition from a nearby area. Vegetation loss also alters the abundance, spacing, and species composition of the plant community. This, in turn, alters food and habitat availability for animals.

Figure 26. Soil compaction caused by military training exercises in the eastern Mojave Desert during World War II (U.S. National Archives photograph) .

Loss of plants and biological soil crust organisms decreases the contribution of nitrogen and organic matter to soils. Loss of pore space in the compacted soils restricts the amount of water and gases that can enter the soil, lowering the abundance, activity, mobility, and survival of soil biota (Brady and Weil, 1996). Combined, these factors all lead to less decomposition and nutrient transformations in disturbed soils. Thus, surface disturbance often leads to a reduction in soil fertility.

Recovery times of soil stability and fertility are dependent on the recovery time of plants, biological soil crusts, subsurface soil biota, and soil structure. These factors are dependent on dispersal rates of the organisms and climatic conditions. Soil biota are especially sensitive to climatic fluctuations. Soil organisms are metabolically active only when wet, and thus recovery time for them is almost completely dependent on the length of time the soil is sufficiently wet for activity. Recovery times also increase as the severity and size of the disturbed areas increase (Belnap and Eldridge, 2003), as much of the recolonization of soil biota must occur from the edges of the disturbance. Smaller organisms, such as cyanobacteria, bacteria, and fungi, colonize first, followed by other larger organisms, such as burrowing arthropods. In severely impacted areas in the very dry and hot regions of the Mojave Desert, full recovery of soil biota can take hundreds of years (Belnap and Warren, 2002).

More is known about recovery of perennial vegetation. Complete recovery of plant cover (irrespective of species composition) in the low elevations of the Mojave Desert is relatively slow (Vasek, 1980; Webb and Wilshire, 1980; Webb and others, 1988; Lovich and Bainbridge, 1999), but significant recovery in cover can occur in a few decades at some sites (Webb and others, 1988). Combined data from 127 sites show that, while road recovery follows a linear trajectory, recovery from other disturbance types follows a curvilinear relation, with 60 to 80 percent recovery in total perennial cover occurring in about 30 years (Webb and others, in press). However, the course of recovery is strongly affected by the species

present at a site, as well as disturbance type, soil properties, and climate. Short-lived species, such as *Encilia farinosa*, *E. virginensis,* and *E. frutescens* (various brittle bushes), *Gutierrezia* spp. (snakeweed), *Atriplex* spp. (salt bushes), and perennial grasses, including *Achnatherum hymenoides* (Indian ricegrass), *Pleuraphis rigida* (big galleta grass), and *Achnatherum speciosum* (needle-and-thread grass), are the first to establish in disturbed sites (Webb and Wilshire, 1980; Lathrop, 1983; Prose and others, 1987; Webb and others, 1988; Angerer and others, 1994; Lei, 1999). These species are eventually replaced by longer-lived species. It is not known if the classic concept of succession applies to the recovery of desert vegetation, as many of the changes in desert perennial plant communities are abiotically, not biotically, driven.

Plant community composition, on the other hand, recovers much more slowly than total cover. Because climatic variability results in large fluctuations in community composition and cover of undisturbed vegetation (Hereford and others, 2006; Webb and others, in press), recovery goals for perennial vegetation need to be based on a comparison with nearby undisturbed vegetation, rather than on the exact conditions before the beginning of disturbance (Webb and others, 1988). The presence of non-native annuals may reduce recovery rates of native plants due to competition (Brooks and others, 2004; DeFalco and others, 2007). The severity of soil disruption is also important to the course of vascular plant recovery. If resource patches that occur under shrubs are left intact, recovery of total cover is often accelerated (Wallace and others, 1980). If desert pavements are removed and the Av horizon is disrupted, the disturbed area may support higher plant biomass than undisturbed pavements (Gilewitch, 2004).

Soil compaction levels at the time of abandonment likely affect the reestablishment of plants (Webb and others, 1988). Although high levels of compaction appear to retard the establishment of native perennial desert plants (Adams and others, 1982; Prose and others, 1987; Webb and others, 1988; Prose and Wilshire, 2000), both native and non-native annuals are initially more numerous than in nearby undisturbed areas and recover much more quickly than the perennial vegetation (Hunter, 1995). Non-native annual grasses appear to have the greatest ability to grow on compacted soils, as they are usually the first to colonize such soils (Lathrop and Rowlands, 1983; Prose and Wilshire, 2000; fig. 28). That said, compaction can decrease the cover of native annuals; however, it can also increase their density (Adams and others, 1982).

Figure 27. Disruption of desert pavement in a motorcycle trail near Barstow, California. The contrast in surface color is due to removal of desert pavement and exposure of the underlying, finer-grained vesicular layer, or Av horizon (U.S. Geological Survey photograph by David M. Millller). .

Figure 28. In the Mojave Desert, non-native annual grasses often heavily colonize disturbed areas, especially where soils are somewhat compacted and a depression that collects water is formed (U.S. Geological Survey photograph by David M. Miller).

Figure 29. A, Cattle in the Ivanpah Valley of the Mojave Desert. B, Sheep near Ridgecrest in the western Mojave Desert (U.S. Geological Survey photographs by David M. Miller).

Effects of Specific Activities

Livestock Grazing

Livestock grazing is the most pervasive land use in the western United States (Fleischner, 1994), and, in general, grazing is thought to change ecosystem characteristics and create numerous disruptions of ecosystem function (fig. 29). In the Mojave Desert, soil compaction by domestic livestock can be especially high near watering areas (Webb and Stielstra, 1979; Avery, 1998; Brooks and others, 2006). As with all surface-disturbing activity, livestock grazing crushes biological soil crusts, reduces soil stability, and reduces nutrient inputs, while increasing the loss of soil, carbon, and nutrients from the ecosystems (Neff and others, 2005).

Livestock also consume plants, and often shift plant community species composition by decreasing the density of perennial grasses and the diversity of winter annuals, while increasing cover of unpalatable forbs and shrubs, such as *Larrea tridentata* (creosote bush; Avery, 1998). Livestock also disrupt the integrity of the soil surface, which often results in the invasion of non-native annual grasses. In addition, they damage plants as they seek shade. There is very little information on how grazing affects wildlife populations in the Mojave Desert.

Mining and Agriculture

Mining activities and agriculture have large impacts in the Mojave Desert, although in somewhat different parts of the landscape. Hard-rock mining usually impacts mountain ranges and their foothills, although deposition of tailings piles may bury vegetation on nearby alluvial fans and produce copious amounts of dust (fig. 30). Placer and gravel mining impact alluvial fans, typically in coarse-grained soils. In contrast, agricultural activities generally occur in low-relief areas with finer-grained soils. Mine spoils erode easily, and wind and water erosion can transport potentially toxic substances many miles from the source. We have no information on how mining activities affect wildlife populations.

In contrast, dust production from agricultural areas is a significant component of overall dust emissions in the Mojave Desert (Reynolds and others, 2003) and results in a loss of soil fertility from the source region. Native plants can take many decades to re-colonize abandoned fields, and if nitrogen was added to the soil as fertilizer, or if nitrogen-fixing plants (for example, alfalfa) were planted, non-native annual plants (*Salsola tragus* [tumbleweed], *Brassica* spp. [mustards], *Bromus* spp. [brome grasses], *Schismus* spp. [schismus grasses], and *Erodium cicutarium* [redstem filaree]) can outcompete native vegetation for many years and prevent their reestablishment (Carpenter, 1983; Carpenter and others, 1986).

Military Activities

Military training and testing exercises often involve extensive use of vehicles or troops on the ground, resulting in soil churning and compaction, removal of soil surface protectors, loss of perennial vegetation, and disruption of wildlife populations. Although these ecological impacts are similar to

Figure 30. Dust emissions from a mining operation in the Mojave Desert of southern Nevada (U.S. Geological Survey photograph by David M. Miller).

other land uses, military training may involve very large areas, such as whole valley bottoms, and occur over longer time periods. Moreover, military training exercises may involve more extensive mechanical manipulation, such as blading, than other land uses in the Mojave Desert. Removal of surface soils, in particular, is one potential effect that could significantly slow recovery of abandoned military sites (Steiger and Webb, 2000; Kade and Warren, 2002). Use of the Mojave Desert for military training and testing exercises is increasing, particularly as greater emphasis is being placed on training in desert regions (fig. 31).

The Mojave Desert has a long legacy of use for military training, beginning with General George S. Patton and the need to train for the North African campaign in World War II (Howard, 1985; Bischoff, 2000). Military camps were constructed throughout the desert and then abandoned. Tanks and other vehicles left many miles of tracks. The effects of these military exercises during World War II and in 1964 are still evident in the central Mojave Desert (Prose, 1985; Prose and Metzger, 1985; Prose and others, 1987; Steiger and Webb, 2000; Prose and Wilshire, 2000; Belnap and Warren, 2002). Some areas have recovered, whereas others have not, providing an opportunity to document which site factors affect recovery rates of soils, crusts, and perennial vegetation (Wells, 1961; Webb and Wilshire, 1980; Webb and others, 1988; Webb and Thomas, 2003).

Disruption of desert pavement is still apparent 55 years after these exercises, and total biomass of biological soil crusts has only recovered 46 to 65 percent in tank tracks, even when the tank made only a few passes (Belnap and Warren, 2002). Disruption of desert wash systems is another effect of military training and requires significant time for recovery (Nichols and Bierman, 2001). Total recovery of perennial vegetation cover (without considering species composition) occurs about 80 years following these disturbances (fig. 32). Recovery of species composition ranges from less than a century for assemblages on young geomorphic surfaces to thousands of years in blackbrush assemblages that occur on older geomorphic surfaces. The trajectory of recovery may depend on the history of climate following disturbance. Rates of change are expected to be higher during wet periods than during drought periods, although severe droughts may cause high mortality in ruderal species, allowing longer-lived species to assume dominance.

Off-road Vehicle Use and Roads

Off-road vehicle use, particularly in open areas, causes significant environmental degradation (fig. 33). Soil compaction increases as a function of the number of passes, with the largest changes occurring during the initial passes (Davidson and Fox, 1974; Wilshire and Nakata, 1976; Webb, 1982, 1983; Lei, 2004). Hillclimbs, a favorite use of motorcycles and four-wheel drive vehicles, cause compaction and soil disruption on steep slopes, and water erosion on slopes can be 10–20 times greater than on disturbed, level ground (Iverson, 1980; Iverson and others, 1981). The increased runoff and sediment yield that result from these activities can have significant

Figure 31. A, Tank involved in a military training exercise in the Mojave Desert, 1964. B, The streets of Camp Iron Mountain, a World War II training facility abandoned in 1944, were still highly visible in this 2001 aerial photograph (copyrighted photographs by D.V. Prose, used with permission).

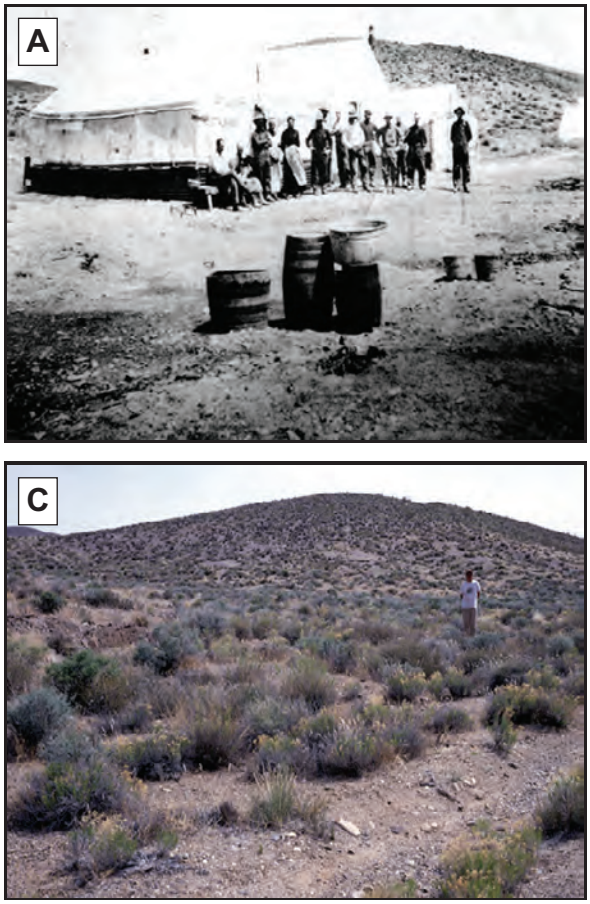

Figure 32. Recovery of perennial vegetation at Harrisburg townsite, Panamint Mountains, Death Valley National Park. A, In 1908 before abandonment (Death Valley National Monument photograph) ; B, in 1984 (U.S. Geological Survey photograph by Robert H. Webb); C, in 1999 (U.S. Geological Survey photograph by Robert H. Webb).

effects downstream, including high dust production. Shrubs are often killed, and late-successional communities replaced by ruderal species, such as *Hymenoclea salsola* (cheesebush) and *Chrysothamnus nauseosus* (rabbitbrush; Avery, 1998). Increasing density of off-road vehicle tracks is correlated with decreased cover and diversity of standing vegetation and decreased density and species richness of the soil seedbank (Matchett and others, 2004). One study reported that biomass of an invasive non-native grass (*Schismus* spp.) was higher within off-road vehicle tracks compared to adjacent untracked areas (Brooks, in press). A dated review of off-road vehicle effects in the Mojave Desert was done by Webb and Wilshire (1983). There is almost no data on how off-road vehicles affect wildlife populations.

Much less is known regarding the effects of roads in the Mojave Desert (Brooks and Lair, in press). The few previous studies that described road effects in this region primarily compared conditions in an actual roadbed with those in a control area located away from the study road. The studies showed that plants (Frenkel, 1970; Johnson and others, 1975; Vasek and others, 1975b), rodents (Garland and Bradley, 1984; Starr, 2002), arthropods (Lightfoot and Whitford, 1991), and tortoises (Nicholson, 1978; Berry and Turner, 1984; Boarman and others, 1997, Berry and others, 2006) are affected by roads. Two studies report that biomass of non-native annual plants is significantly correlated with density of dirt roads (Gelbard and Belnap, 2003; Brooks and Berry, 2006), and another showed that biomass of the invasive Sahara mustard (*Brassica tournefortii*) was higher along dirt roads than areas away from roads (Brooks, in press). Effects of roads on Mojave Desert bird communities have not been described.

Figure 33. Motorcyclist on hillclimb in Dove Spring Canyon, western Mojave Desert (U.S. Geological Survey photograph by David M. Miller).

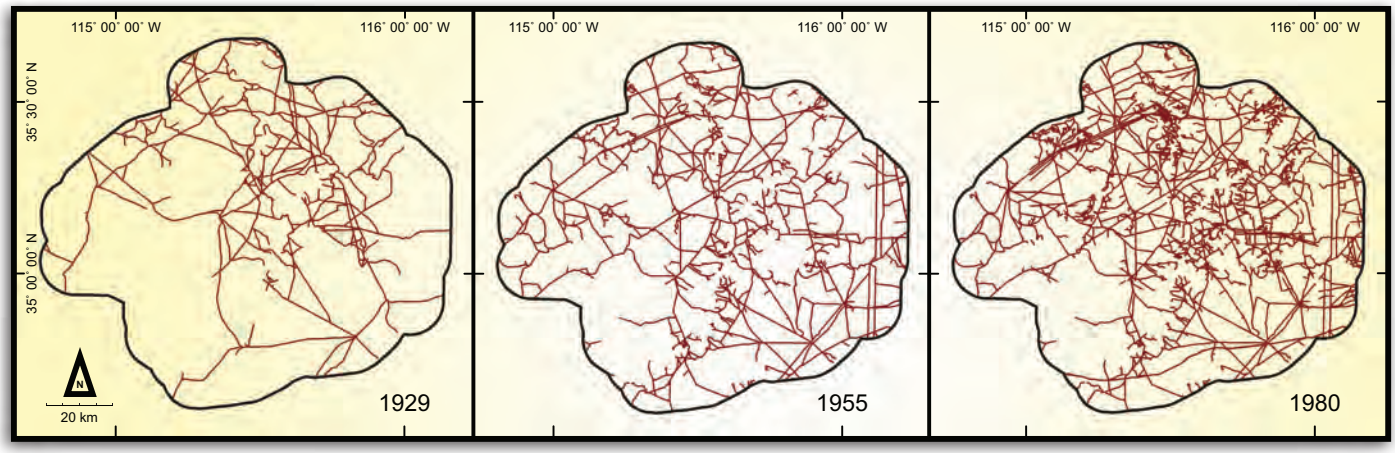

Figure 34. Road proliferation in the Mojave National Preserve from 1929 to 1980 (from Vogel and Hughson, in press).

Fugitive dust from roads has not been studied, despite the fact that it clearly is an issue. Additionally, traffic on main thoroughfares, such as Interstate-15, Interstate-40, and major state highways, create an almost impenetrable barrier for animals attempting to cross, fragmenting their habitat. Although these data indicate that roads can have significant ecological effects, most of these studies only looked at the effect within the roads themselves and in the immediate corridors and did not evaluate gradients of effects away from the road (Brooks and Lair, in press). Therefore, we have almost no data on how widespread road impacts are in the Mojave Desert. The number of roads has increased dramatically in the Mojave Desert (Vogel and Hughson, in press; fig. 34), and there is no data on how this habitat fragmentation has affected animal populations, or on the possible multiplicative effects as road density increases.

Recovery of abandoned roadbeds has been studied by numerous people. It has been primarily these studies and studies of ghost town roads that have been used to estimate recovery of vegetation and compaction in this region. As discussed in the sections above, the time needed for recovery of compacted roadbed soils ranges from 80 to 130 years (Webb and Wilshire, 1980; Webb and others, 1986; Knapp, 1992; Prose and Wilshire, 2000; Webb, 2002; Webb and Thomas, 2003), although Bolling and Walker (2000) did not find any recovery after 88 years. The recovery rate of vegetation is hugely variable, depending on site characteristics and whether total cover or species composition is being measured. We have no information on recovery of animal populations from the impacts of roads.

Hiking and Mountain Biking

Although long known to contribute to ecosystem damage, the impact of recreational activities, such as hiking and mountain biking, have been little studied in the Mojave Desert. Lei (2004) compared the effects of hiking, mountain biking, motorcycle traffic, and vehicle use on a desert soil in Kyle Canyon of southern Nevada. Two studies (Webb, 1983; Lei, 2004) evaluated the effects of trampling and vehicle use. It was found that one vehicle pass causes the equivalent amount of soil compaction as ten passes by a human on foot (Lei, 2004). Hiking and mountain biking have less effects than motorcycle or vehicle use, but available information suggests that these activities can, with sufficiently heavy use, create the same amount of surficial soil compaction as off-road vehicles. There is no known information on the impact of dispersed hiking and biking on soils, plants, or wildlife populations.

Other Anthropogenic Disturbances

Urbanization

Urbanization is perhaps the greatest single threat to the Mojave ecosystem (fig. 35). Roads, paved and unpaved, proliferate around urban areas, fragment wildlife habitat, and cause habitat alteration. Proliferation of vegetation along roads attracts wildlife, leading to high mortality rates when wildlife attempts to cross (T.C. Esque, oral commun.; fig. 36). Unpaved roads are a major source of fugitive dust in desert ecosystems (Campbell, 1972), disrupt surface water flow, and act as a conduit for invasive plants (Gelbard and Belnap, 2003; Brooks and Berry, 2006; Brooks, in press; Brooks and Lair, in press). The abandonment of subdivisions following the initial phase of development may cause many years of elevated dust production. Completed subdivisions extend the urban environment into the desert, introducing dogs and cats as domestic or feral predators of native wildlife, increasing vehicle access to the desert, and increasing noise levels. The increase in dumps and litter is unsightly and has the potential to damage animal populations, either by consumption by wildlife of indigestible material, trapping of rodents in containers, ensnaring of birds in plastic, or the attraction and resource subsidy of predators (for example, ravens), which then increases predation pressure on their prey (for example, baby tortoises). Lights cause the death of millions of desert insects attracted to them. The disturbance associated with urban areas allows for the expansion of non-native plant and animal species into areas where they previously had not become established.

Figure 35. The sprawling nature of cities such as Las Vegas, Nevada, introduce multiple impacts to ecosystem quality and function in the Mojave Desert (U.S. Geological Survey photograph by David M. Miller).

Introduction of Non-native Species

Although relatively few non-native species have become established in the Mojave Desert compared to other more mesic ecosystems (Brooks and Esque, 2002), their ecological effects have been highly significant (figs. 15 and 37). *Bromus madritensis* ssp. *rubens* (red brome), *Bromus tectorum* (cheatgrass), *Schismus* spp. (schismus grasses), and *Erodium cicutarium* (filaree) appear to compete effectively with native annuals for soil nitrogen and moisture in the Mojave Desert (Brooks, 2000, 2003; DeFalco and others, 2003). After germination, these non-native annual plants initiate vegetative growth earlier than most native species (Jennings, 2001), and established seedlings may inhibit the subsequent germination of other annual plant seeds (Inouye, 1980, 1991). *B. madritensis* ssp. *rubens*, in particular, can even impact the growth of mature Mojave Desert shrubs, such as *Larrea tridentata* (creosote bush), and the perennial grasses *Pleuraphis rigida* (big galleta grass) and *Achnatherum hymenoides* (Indian ricegrass). The intensity of this impact on perennials depends on the timing of *B. madritensis* ssp. *rubens* establishment; earlier winter germination and growth of *B. madritensis* ssp. *rubens* has a greater impact than those established in spring (DeFalco and others, 2007). These impacts can result in major changes in the composition of plant communities (Bock and others, 1986).

Plant litter created by non-native annual grasses decomposes more slowly than that of native annuals (Brooks, 1999b) due to the higher fiber content in non-native species (DeFalco, 1995), and thus accumulates over successive years. Thick plant litter may impede germination of plant seeds by shading the soil surface, intercepting water that otherwise would infiltrate into the soil, and suspending seeds above and out of contact with soil surfaces (Facelli and Pickett, 1991). Some have suggested that non-native species, which can occur at high densities, could affect the mobility of desert rodents and reptiles (Cowles, 1977). In addition, sit-and-wait predators, such as lizards, have a difficult time sighting their prey from their observation points under shrubs, as the view is often obscured by non-native annual grasses (T.C. Esque, pers. observation).

Figure 36. Roadside enhancement of perennial vegetation, mostly *Larrea tridentata* (creosote bush), along Highway 127 between Baker, California and the Dumont Dunes, eastern Mojave Desert (U.S. Geological Survey photograph by David M. Miller).

Figure 37. Non-native annual vegetation, primarily *Bromus madritensis* ssp. *rubens* (red brome), as an understory to *Larrea tridentata* (creosote bush). Note the pieces of creosote bush branches on the ground that resulted from pruning by rabbits (U.S. Geological Survey photograph by Jayne Belnap).

As previously discussed, persistent plant litter contributed by non-native annual grasses has accelerated fire cycles, heavily impacting non-fire-adapted native plants in the Mojave Desert (Brooks, 1999a, 1999b, 1999c; Brooks and Esque, 2002; Brooks and Matchett, 2006; Brooks and Minnich, 2006; Howard, 2006) and elsewhere (D'Antonio and Vitousek, 1992; Brooks and others, 2004). In addition, many invasive plant species possess physiological traits that enable them to benefit from aspects of global change, such as increased atmospheric carbon dioxide and warmer minimum temperatures during winter and at night (Alward and others, 1999; Dukes and Mooney, 1999; Smith and others, 2000).

Atmospheric Changes

Many aspects of the Earth's atmosphere are expected to change in the near future (Houghton and others, 2001). These include increasing levels of atmospheric carbon dioxide, increasing soil and air temperatures, increasing aridity (Seager and others, 2007), and altered precipitation patterns. In addition, more extreme wind, precipitation, and temperature events than occurred in the past are expected in the future. This will have many impacts on different aspects of Mojave Desert ecosystems. Elevated temperatures and an increase in the frequency of small precipitation events have been shown to kill mosses, lichens, and cyanobacteria (Belnap and others, 2006, 2007). Changes in the global atmosphere are expected to affect the physiological processes and competitive relationships of vascular plants, including enhancement of non-native annual grasses (Alward and others, 1999; Smith and others, 2000) and their competitive effects on native species (DeFalco, 2003), nutrient cycles, hydrologic processes, and disturbance regimes, all of which have the potential to greatly alter the structure and functioning of dryland ecosystems, including the sensitivity of these systems to anthropogenic stressors (for example, Ehleringer and others, 1999; Smith and others, 2000; Weltzin and others, 2003). Despite modeling efforts, there is great uncertainty about how global atmospheric changes will affect precipitation patterns in particular regions, such as the Mojave Desert. Uncertainty regarding how different atmospheric factors will change, and the ecological outcomes of this change, greatly compounds the challenges of managing and monitoring these ecosystems.

Air Quality

Although the Mojave Desert may appear to be a remote area with superb air quality, much of the region experiences high levels of air pollutants, especially areas downwind of urban zones (for example, the Los Angeles basin and Las Vegas) or fossil-fueled power plants (Allen and others, 1992). The pollutants of particular concern in the Mojave Desert are ozone, sulphur dioxide, nitrogenous compounds, particulates, and various organic compounds (Allen and others, 1992). Acid rain does not appear to be an issue in deserts, as desert soils have a high pH, and thus neutralize raindrop acidity (Bytnerowicz, 2003).

Ozone and sulphur dioxide are generated by the burning of fossil fuels, whether from vehicles or power plants. Both compounds can directly damage vascular plants and other organisms (Thompson and others, 1984; Olszyk and others, 1987; Bytnerowicz and others, 1988; Gonzalez-Coloma and others, 1988; Temple, 1989). In contrast, other major pollutants, such as nitrogenous compounds, can alter many aspects of ecosystem function through the fertilization of soils (Asner and others, 1997; Brooks, 2003; Fenn and others, 2003, Galloway and others, 2003; Allen and others, in press). As desert soils are low in most nutrients, this may be perceived as a benefit. However, fertilization can present a large threat to desert ecosystems. The structure of desert plant communities is often based on the ability of individual plant species to exploit soil nutrients in different ways. As some nutrients are more limiting to the growth of some plants than others, depending on soil and plant characteristics, increases in soil nutrient levels can alter the competitive relationships between plants, and thus change the composition of plant communities (Allen and others, 1992). For instance, annual plants are better able than perennial plants to utilize nitrogen, and thus increased soil nitrogen gives annual plants an advantage (Mun and Whitford, 1998). Because the most problematic non-native desert plants are annuals, additional soil nutrients may exacerbate the problem of invasion (Brooks, 2003; DeFalco and others, 2003; Fenn and others, 2003). Similarly, higher levels of soil nutrients can alter soil biota, and thus decomposition and nutrient transformation rates.

Particulates are another type of air pollution of special concern in deserts. Because plant cover and rainfall are sparse, and soil surface stabilizers (rocks, biological and physical soil crusts) are easily disturbed by vehicles, livestock, and other human activities, levels of airborne particulates can be very high. Dust storms reduce the highly valued clarity of the desert air, often obscuring distant vistas. Drastically reduced visibility on highways can result in severe vehicle accidents. Dust reduces photosynthesis and growth in plants. Dust can scratch the cuticles of insects, leading to their death (Sharifi and others, 1997, 1999). Dust is also a human health hazard, as it carries soil pathogens that can cause diseases, such as Valley Fever (Reynolds and others, 2001), and fine particulates lodge easily in human lungs, potentially leading to lung cancer or other respiratory ailments.

Hundreds of other compounds also pollute the air in this region, including a huge variety of organic compounds released during the application of herbicides or fertilizers, or when fuels, such as wood, coal, and gas, are incompletely burned. Release of metals, such as lead from combustion of leaded gasoline, arsenic, metalloids, and the fallout of human-produced radioactive elements, such as cesium and plutonium, have an unknown effect on ecosystem and human quality and health; scientists know very little about the effects of these compounds, because they are difficult to sample accurately and expensive to analyze. Some species, such as the desert

tortoise, may bioaccumulate some or all of these substances, notably metals and metalloids, during their life spans. Thus, it may be helpful to focus resource monitoring protocols on the distribution of these substances, as well as their long-term effects on the environment (Berry and others, 2006).

Diversion of Overland Flow

Thousands of miles of linear features, such as roads, railroads, and pipelines, crisscross the Mojave Desert. Most of these are located mid-slope or at the toes of alluvial fans, disrupting or blocking water channels and overland flow from reaching the downslope vegetation. As a result, water collects above the feature and flows off the feature, accumulating along its margins, resulting in increased productivity of the vegetation that is directly adjacent to the feature (reviewed by Brooks and Lair, in press). However, vegetation below the feature can be deprived of water and this effect can be seen for 500 m or more below the diversion (Schlesinger and others, 1989). This deprivation can lead to altered plant community composition and spacing, thus affecting animal habitat and food sources. Soil moisture is decreased, along with the activity times of soil biota. This results in slower nutrient transformations, and thus lower soil fertility.

Philosophies and Strategies for Monitoring in the Mojave Desert

Why is Monitoring Needed?

Land management agencies have multiple mandates for managing use in Federal lands in the Mojave Desert. Congressional mandates include the General Mining Act of 1872, the Taylor Grazing Act of 1934 (amended several times), the Endangered Species Act of 1973 (amended in 1988), the Federal Land Policy and Management Act of 1976, the National Environmental Policy Act of 1969, and the California Desert Protection Act of 1994. These laws, combined with the Federal Water Pollution Control Act Amendments of 1972 (as amended in 1977, this became the Clean Water Act), the Clean Air Act of 1990 (amended in 1997), various laws protecting archaeological and cultural resources (especially the National Historic Preservation Act of 1966), and laws protecting Native American lands and resources, provide much of the legal basis for land management in the Mojave Desert. These mandates and the regulations specified for the Department of Defense, Department of Energy, Bureau of Land Management, and National Park Service underscore the responsibility to manage public lands in a fashion that does not threaten basic ecosystem quality or integrity. This goal is becoming ever more difficult to reach as the demands on public lands increase from many different user groups.

Although there are many definitions of ecosystem quality and integrity, all include the idea that soil, water, and nutrients should not be lost or accumulate at an accelerated rate, that species are sustained, that ecosystem processes are balanced and sustained, and that the potential of the landscape be conserved (Noon, 2003). In order to meet their mandates, managers need to understand the condition of their resources, the natural disturbance and climate regimes, the impacts of different stressors and altered disturbance regimes on these resources, and the effectiveness and unintended consequences of corrective management actions. Therefore, monitoring programs generally have one or more of the following goals: (1) determine status and/or trends in the condition of ecosystems and the species contained within them; (2) contribute to the understanding of ecosystem dynamics and response to stressors; (3) provide early warning of undesired changes to the ecosystems and species so as to trigger management action; (4) evaluate the effects of a management effort; and (5) meet legal mandates, such as the Endangered Species Act. A successful monitoring program depends on its goals being well defined from the beginning, as many aspects of the program (for example, sampling design, measured variables) will later be defined in terms of the monitoring goals.

It should be noted that to be most effective for land managers, monitoring programs should provide insight into the cause-and-effect relations between environmental stressors, management actions, and ecosystem response. Without this linkage, there will be little information pertaining to when a management action is required to rectify undesirable conditions. There is also value in incorporating measures that are both retrospective (seeking to understand effects after they occur) and prospective (predictive or stress-oriented to detect effects before they occur or become serious). However, finding prospective measures is difficult, as few cause-effect relations are well understood (National Research Council, 1995).

Monitoring Ecosystem Attributes and Processes

Although the monitoring of species and/or populations provides one level of information to managers, the monitoring of explicit ecosystem processes provides a very different and valuable perspective. Thus, most monitoring programs generally consist of monitoring both ecosystem components and processes. There are many attributes and processes that are the basis of ecosystems, and their healthy functioning is vital to the conservation and preservation of that ecosystem. A good example of an important ecosystem attribute is total cover of perennial vegetation. An example of an important process is nitrogen cycling or fire frequency. The distinction between attributes and processes may be blurred in many cases; for example, ant populations are an attribute, but they are also integral to the process of bioturbation. Soil compaction is both a process and a state described by soil pore space.

The benefit of attribute monitoring is that biological and physical attributes are combined as indicators of the functional status of rangeland integrity. Thus, the multitude of direct measures of site integrity and status of ecological

processes, which are difficult or expensive to measure due to the complexity of the processes and their interrelationships, are reduced to a manageable effort. Moreover, the focus is on biotic and abiotic processes that reflect on the functioning of the ecosystem, as opposed to tabulation of a specific component of the ecosystem (for example, bird populations) without cognizance of its trend or the broad array of potential forces for change.

Because the success of most biota depends on the proper functioning of ecosystem processes, such as decomposition, nutrient cycling, and hydrologic cycles, these processes are important to consider when designing a monitoring program (Coleman and Crossley, 1996). In addition, observing dysfunction in a process is often anticipatory of other changes likely to occur. For instance, increased wind erosion or decreased decomposition rates may presage a decrease in soil fertility at a given site before the decline is manifest in the plant community. Monitoring of the physical structure of an ecosystem can also be valuable in understanding and/or predicting changes in species or populations. Physical structure (for example, the height, width, and distribution patterns of plants) has been shown to heavily influence the availability of habitat and food for biota. Although it would be optimal to monitor all species and processes, such an endeavor will never be logistically or monetarily possible. Therefore, in most general monitoring programs, some subset of the measures of species, processes, and physical structures is desirable. In addition, many programs include the monitoring of special species of concern (for example, desert tortoise).

In assessing rangeland status, Pellant and others (2000) developed a guide for interpreting indicators based on three broad ecosystem attributes: (1) soil/site stability, defined as the capacity to limit redistribution and loss of soil resources by wind and water; (2) hydrologic function, defined as the capacity of the site to capture, store, and safely release water from rainfall, run-on, and snowmelt, to resist a reduction in this capacity, and to recover this capacity following degradation; and (3) integrity of the biotic community, defined as the capacity of the site to support characteristic functional and structural communities in the context of normal variability, to resist loss of this function and structure due to disturbance, and to recover following disturbance. This guide is based on the premise that ecological processes functioning within a normal range of variation will support specific plant and animal communities.

"Vital Signs," or Indicator, Approach

As ecosystems are complicated entities with numerous components and interacting processes, they are difficult and expensive to monitor in their entirety. For this reason, many monitoring programs utilize indicators of ecosystem or population condition, rather than measuring the specific processes or species themselves (National Park Service, undated). Many agencies have developed indicators for their monitoring programs, and there are many lists of potential indicators and the criteria that should be considered for choosing indicators for a specific site when developing a monitoring program. Unfortunately, many indicators address specific and localized impacts, such as those created by campsites and trails. However, the need for monitoring many other aspects of ecosystems or ecosystem condition, including areas of diffuse impact, will require developing new and different indicators. Therefore, it is useful to understand the process of indicator selection and testing so monitoring plans can be tailored to the specific needs of the landscapes to be monitored.

The selection of indicators is a fairly straightforward process. First, the ecosystem to be monitored, its processes, and the real and potential stressors on that ecosystem need to be identified. A list of potential indicators is then constructed using three primary methods: (1) performing a literature search on the ecosystems and stressors of concern, (2) interviewing local experts, and (3) determining what changes occur in an ecosystem of interest when non-impacted areas are compared to areas where the stressors of interest have been applied—those variables that differ between compared sites become potential indicators.

Once a list of potential indicators is compiled, the indicators are entered into a matrix that evaluates the suitability of each indicator (table 3). The matrix is constructed by creating a column for each suitability factor and a row for each potential indicator. This matrix includes both required and desirable characteristics of indicators. Indicators are ranked from 1–5 according to how well they meet the characteristics. Required characteristics include: (1) response to the stressors of interest is reliable and measurable, (2) measuring the indicators has no or low impact, (3) measurements are repeatable through time and with different personnel, and (4) indicators have high ecological relevance. Indicators that do not meet all required characteristics are rejected. Those potential indicators that are not rejected are then ranked according to desirable characteristics, which include: (1) a quick response to stressors and management actions taken to mitigate the impacts, so that the efficacy of management actions can be determined in a short time frame; (2) minimal spatial, temporal, and climatic variability, which allows the effects of the stressor to be clearly distinguished from natural variability; (3) ease of sampling; (4) large temporal sampling window to allow flexible scheduling of fewer personnel; (5) cost effectiveness; (6) short training time; (7) availability of baseline data; (8) components that respond over a range of stressor intensity, which allows impacts to be detected while still relatively slight; (9) integrative measures that reflect multiple processes, populations, or gradients; and (10) inclusion of components that anticipate larger, impending changes in the ecosystem. If indicators show no response to impacts until a large decline in resource condition occurs, impacts may be impossible or difficult to repair. The numerical rankings are then added to produce a short list of potential indicators.

After the list of potential indicators is narrowed to a short list, making certain to consider indicators from different scales (for example, plot to landscape), further research is then needed to demonstrate that these indicators truly repre-

Table 3. Characteristics of good indicators of ecosystem condition. Note that there are those characteristics that are required (left hand side of matrix) and those that are desirable (right hand side of matrix).

Potential indicators	Required characteristics				Desired characteristics					
	Reliable, quick, and measurable response to visitor impacts and management actions	Non-destructive to measure	Repeatable with different personnel	Ecological relevancy; indicative of significant adverse effects	Relatively quick recovery response to management actions	Independent as possible from other environmental variables	Ease of sampling	Ability to be sampled at any season	Cost effectiveness	Short training time required for sampling personnel
Soil stability										
Biological soil crusts										
Vegetation cover										
Etc.										

sent the ecologically relevant processes or populations they are intended to represent. This step is absolutely essential in choosing indicators and should not be skipped, even though the exercise of definitively linking indicators to their target can be expensive and time-consuming. Once it is established that the indicators meet the intention of the program, protocols are developed for measuring them, these protocols are field tested, and the final monitoring program is designed. An important aspect of indicator selection is maintaining flexibility at all stages of the process. During testing, selected indicators need to be freely added or dropped based on experience gained in the field. During field testing of chosen indicators, measurement methods may be changed several times until they are adequately modified to meet monitoring needs.

Available funding generally dictates the number of indicators used for a given monitoring program, and funding typically is limited. Given this constraint, managers have several choices: (1) monitor more indicators at fewer sites, which limits the geographic area to which the results can be extrapolated; (2) monitor fewer indicators at more sites, which provides less information about each site and increases the risk that subtle shifts with potentially large ecosystem impacts may be missed, but allows results to be extrapolated to a larger area; or (3) monitor using a tiered program in which some indicators are monitored more frequently than others. For instance, factors that change quickly with stress (for example, vegetation cover) could be measured annually, while monitoring factors slow to change (for example, soil compaction) could be monitored every five years. This approach can offer a great deal of flexibility to a monitoring program and facilitate measurements at more sites more often.

Once indicators are chosen, triggers for management action, or standards, need to be defined for each indicator. Standards are based on a combination of data obtained from research, management goals, and professional judgment. Standards should be specific, quantifiable, and generally attainable. Standards define the desired condition of a given resource and so should not necessarily be based on current conditions.

Standards are an important tool for achieving management goals. The level at which they are set is generally based on the importance of a variable to ecosystem functioning and the indicator's resiliency and resistance to disturbance. For example, little deviation from normal may be tolerated in variables that are essential for healthy ecosystem functioning and have very slow recovery times, whereas more tolerance for impacts may be shown for indicators less crucial to the overall system functioning or with short recovery times. Standards also tend to be more lax in areas of high visitation, relative to areas of low visitation, reflecting both the higher use of the area, the higher incidence of impacts, and the reduced ability of management to control such impacts. Because standards reflect the desired future condition of the resource, not necessarily the current condition of the resource, they may be set at levels, such that the areas are currently out of compliance. As a result, immediate management action to correct this condition would be triggered.

It is also important that standards not allow ecosystems to cross a threshold from one stable state to another stable state. Thresholds are defined as the point past which, when the stressors driving change are stopped, the system fails to recover back to its original state. Such a transition is not easily reversed without significant inputs of resources (National Research Council, 1994). For example, in Chihuahuan Desert grasslands, reduction below a threshold value of 20 percent shrub cover heralds the local extinction of banner tailed kangaroo rats (*Dipodomys spectabilis*; Krogh and others, 2002). In the Mojave Desert, the invasion of annual grasses has pushed many grassland ecosystems over a threshold where accelerated fire cycles prevent the reestablishment of perennial plants. Expensive restoration measures (for example, non-native plant control, soil ripping, or reseeding) may be necessary to restore ecosystems once they have passed a threshold (Pellant and others, 2000). Furthermore, when ecosystem degradation extends beyond specific thresholds, the changes may be irreversible (Whitford and others, 1995).

Measurement and Site Selection

Criteria for site selection are as varied as the issues being addressed by the monitoring program. Therefore, the intent and goals of the monitoring program must be clearly stated in the design and execution of the program. The most important program decisions are whether (1) to monitor the status of ecosystems, the trends in ecosystems, or both; (2) the program will provide managers with information as to why the observed changes are occurring, as well as when and what management actions are needed; (3) measures will be qualitative, quantitative, or a mixture of both; (4) the program will measure the natural background of change, focusing mostly on undisturbed sites, or will include disturbed sites; and (5) all ecosystems will be targeted or whether the program will be limited to specific ecosystems, such as ones that are dominant, at high risk, and/or of special interest. Together, these decisions dictate what, where, and how often sampling is required.

One of the biggest trade-offs faced by designers of monitoring programs is the vast landscape that is to be monitored in light of the amount of funds that are available. To further exacerbate the trade-offs, climate variability is high and components of the desert ecosystems, whether plants or animals, can have significant lag times between the application of a stressor (for example, drought) and the response. Therefore, if the monitoring program is to document only the status of ecosystems, it may be sufficient to visit sites on a rotating basis (for example, every five years). However, if the documentation of trends is desired or if the program's intent is to explain the cause of the observed trends, sites are best visited annually. This will likely require a tiered sampling program as discussed above.

Climate

Documenting climatic conditions is basic to most monitoring programs. The placement of climate stations (fig. 38) is

a decision that should be based on where current stations exist in relationship to the climatic zones where the study plots or other areas of interest reside. At a minimum, each precipitation-temperature zone should be represented by some level of climate monitoring. Data from these stations can then be modeled and extrapolated to represent areas that are not monitored. However, where vegetation or process studies are located, it is strongly suggested that air temperatures and precipitation be monitored on site.

Monitoring of climate should include at least daily maximum and minimum air temperatures and precipitation at multiple locations. However, this information is much more valuable if measurements are taken hourly. Given new advances in technology (for example, Hobo event recorders), this is now feasible for a minimum price. Additional data that is of value, particularly if potential or actual evapotranspiration is wanted, are relative humidity, solar radiation, and wind speed and direction.

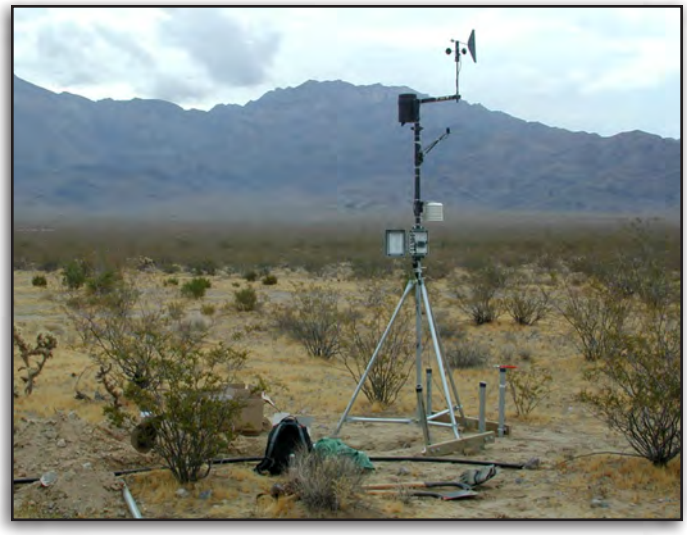

Figure 38. A climate station in the Mojave Desert simultaneously measures multiple meteorological parameters, including rainfall, temperature, wind speed and direction, and solar radiation (U.S. Geological Survey photograph by Richard Reynolds).

Air Quality and Dustfall

Monitoring of wet and dry deposition is both costly and time consuming, and thus aerosol deposition generally is not monitored by local land managers except as part of a larger network or for specific, short-term research questions. The National Atmospheric Deposition network (http://nadp.sws.uiuc.edu) currently operates stations at many sites across the United States, including two in the Mojave Desert (Joshua Tree and Death Valley National Parks). However, these stations only measure wet deposition, including nitrogen (inorganic, nitrate, ammonium), magnesium, sodium, calcium, potassium, chloride, sulfate, and pH. Unfortunately, this network ignores the large amount of dry deposition that occurs in deserts. The National Park Service has a network of sites that measures some aspects of dry deposition, including nitrogen, ozone, sulfur, and particulates; Joshua Tree National Park has one of these stations. Data from these stations can be obtained at http://www.nps.gov.

Dust inputs are fairly straightforward to measure (fig. 39; for measuring dust output, see Soil Stability section below). It is best if the collection devices are co-located with climate stations that are recording at least precipitation and, more optimally, wind speed and direction as well. Wind direction and speed are needed if any extrapolation of the data to other areas or modeling of sediment production is desired. The simplest dustfall collectors are angel food cake pans placed 2 m above the ground and filled with marbles. Their rims are covered with sticky materials to discourage birds from perching on them. Dust sticks to the marbles and is then washed down below the marbles when it rains. (Due to limited rainfall and high evaporation rates, the pans do not fill with water). Pans are emptied every six months by carefully brushing and washing off the marbles and the bottom of the pan. If you want seasonal data, you will need more than one pan, as dust amounts are generally small (2 to 3 g). The water is evaporated from the samples, which are then weighed. This type of

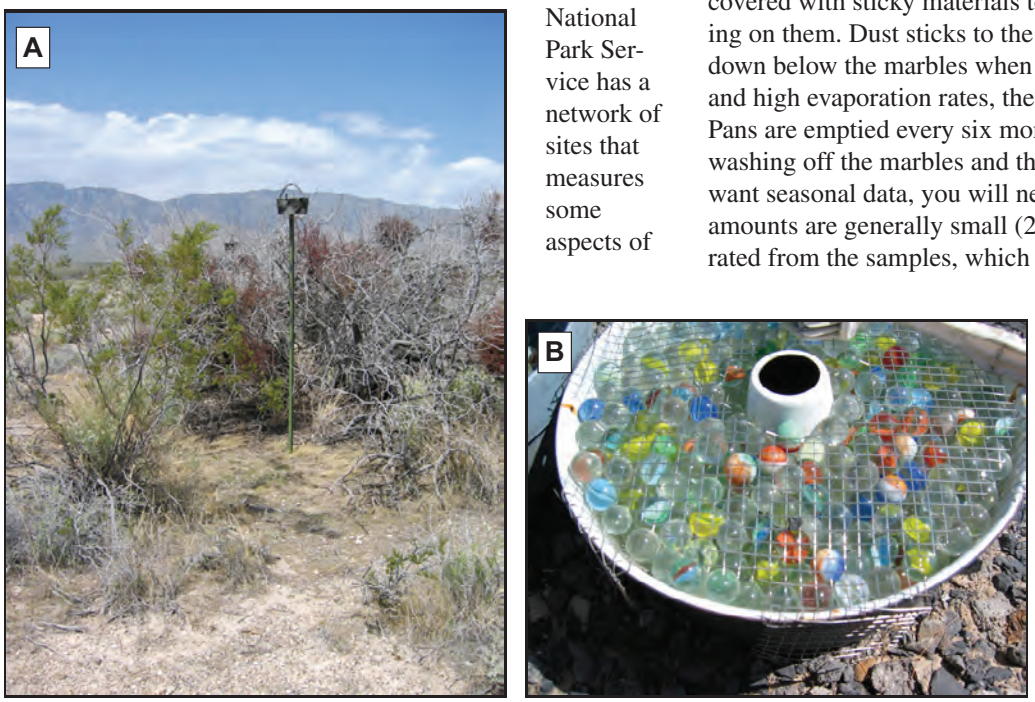

Figure 39. Dustfall traps in the Mojave Desert. A, Dustfall trap installed on the east side of the Sheep Range. B, Close-up of a dustfall trap showing marbles in an angel-food cake pan used to collect dust for analysis (U.S. Geological Survey photographs by Marith Reheis).

collector, along with extensive data from the Mojave Desert from a network of such collectors, can be seen at http://esp.cr.usgs.gov/info/sw/clim-met/. Data from an extensive dust trap system throughout the Mojave can bee seen at http://pubs.usgs.gov/of/2003/ofr-03-138/ofr_03_138_508.pdf.

Soils

Soil properties are highly variable across even small distances. Therefore, characterizing soil requires either a high number of replicates (~5 to 10), or a smaller number of replicates made up of multiple subsamples (for example, 2 to 5 samples, each made up of 30 composite sub-samples). Depth of sample collection depends on the soil property being measured. Because Mojave Desert soils are often rocky and have indurated subsurface horizons, sample depth should be kept as shallow as possible without compromising the goal of the data collection. In general, because most plant roots occur in the top 20 to 30 cm of soil, sampling for soil nutrients and/or soil food web activity is most often restricted to the top 10 to 20 cm of soil. On the other hand, depth profiles for soil texture may be important to determining hydraulic properties and moisture-holding capacities.

Soil depth is an important indicator of a number of ecosystem-related processes, particularly water-holding capacity. Unfortunately, this indicator is not appropriate for either rocky soils, cohesive soils, or soils on old geomorphic surfaces where indurated subsurface horizons will impede insertion of depth probes. If the issue is rocky soils, the only option is to either use a large auger (bigger than the buried rocks) or collect all soils and rock within a given area and estimate the volume of soil per area (see Soil Texture section). Measuring the depth to the caliche layer can be very informative, although where soils are very rocky, again, either a large auger will be needed, or a hole will have to be dug. To measure soil depth in soils without issues such as rocks (for example, sandy soils), a thin, pointed, metal pole that has a handle and has distance from the pointed bottom marked at 1 or 5 cm intervals is inserted (often pounded) into the soil along a transect. At least 10 randomly spaced probes are inserted around the entire plot. At each measuring point, the probe is pushed straight into the soil until some obstruction prevents the probe from going any deeper. If soil depths are highly variable, the number of sampling points should be increased to at least 30.

Soil Texture

Soil texture (the distribution of different particle sizes in the soil) is an important descriptor of surface and subsurface soil properties. Soil particles are classified according to size. Although there are several different classification systems, most scientists use the following diameter categories: particles greater than or equal to 0.002 mm (2 μm) are clay, particles 0.002 mm to less than 0.063 mm are considered silt, and particles from 0.063 mm to less than 2 mm are considered sand. Gravel consists of particles greater than or equal to 2 mm, and the terms stones, cobbles, and boulders are used with a variety of size definitions to describe the largest size fractions.

Particles larger than 128 mm are often measured by one of two techniques: point counts (Wolman, 1954) are done by stretching a tape measure across the soil surface and, at a fixed interval, the size of the intercepted particle is measured and tallied into size classes. The total number of particles measured should range from 100 to 400, depending upon the range in particle size. Each size group is then weighed and a volume for weight transformation used (Kellerhals and Bray, 1971a, 1971b; Rice and Church, 1996). Alternatively, a pit of known volume is excavated, particles are segregated by size into classes, and the groups are weighed. This method requires either an estimation of bulk density or collection of the total weight of all material removed from the pit.

A sieve analysis is used to obtain the particle size distributions of the moderately sized soil particles (0.063–128 mm; Klute, 1986). Sieves with different mesh sizes are commercially available, and soils can be sieved by hand with a mechanical shaker or an ultrasonic vibrator. The initial sample weights and analysis times vary with the method used, the sieve diameter, and the particle-size distribution of the sample. If particles larger than 128 mm are measured separately, a proportion of this size fraction is required to combine the results from point counts or direct measurement with sieve data. The volume of the soil fraction remaining on the sieve is calculated and used to determine the proportion of the soil volume that the given fraction represents. The fraction passing through the 0.063 mm sieve (also known as “pan leavings”) is further analyzed for silt and clay percentages.

A variety of techniques are used to measure the distribution of silt and clay particles. All of these methods use some variation of measuring the velocity of particles falling through water (Klute, 1986). The simplest method uses a hydrometer to measure changes in fluid density with time. A disaggregated and dispersed soil sample is introduced into a graduated cylinder filled with deionized water, and the change in the fluid density is measured at fixed time intervals corresponding to when the various sizes are expected to have fallen through the water column. The more sophisticated pipette method extracts a sample of the fluid at fixed time intervals for gravimetric measurement. Other methods use gamma rays or optical properties to estimate the amount of silt and clay in suspension as a function of time. As each soil analysis technique is different, it is important to stay with one technique throughout the sampling time.

Soil Nutrients

Soil nutrients are highly variable, both spatially and temporally, and thus many subsamples are required to adequately characterize a site. Because most plant roots occur in the top 20 to 30 cm of soil, and because soil nutrients at 20 to 30 cm are highly correlated with nutrients at 0 to 10 or 0 to 20 cm, most sampling for soil nutrients is done at 0 to 10 or 0 to 20 cm.

Many soil nutrients are often used for monitoring change or recovery. These usually include nitrogen, phosphorus, and carbon, but may also include major cations (for example, potassium, calcium, magnesium, sodium) and micronutrients. Although cations and micronutrients are very important in understanding the functioning of desert ecosystems, they are seldom used to detect changes in sites, as little is known about what is "normal" for these elements. An exception to this is in burned areas or where subsurface soils have been brought to the surface (for example, due to mining activities), where both cations and micronutrients can change dramatically.

Nutrient analyses are traditionally done on the soil fraction larger than 2 mm, and thus once soils are collected for analysis they are either sieved first or sent directly to a soil analysis lab. Selection of a soil lab must be done with care, as most are equipped to handle agricultural soils with low pH and high organic matter. Therefore, their extraction techniques need to be modified to handle the high pH and low organic matter of desert soils. For a complete site characterization, the most important data to collect is soil texture, pH, organic matter, electrical conductivity, total nitrogen, calcium carbonate ($CaCO_3$, or an estimate of the buffering capacity of the soil), bio-available phosphorus, exchangeable cations, and bio-available micronutrients. If possible, obtaining data on total concentrations of phosphorus, cations and micronutrients using Inductively Coupled Plasma Emission Spectrometry (ICP-ES) is also valuable, as it indicates the total pool of the nutrients in the soil. If funding is limiting, the minimum analyses should include soil texture, total nitrogen, calcium carbonate, and bio-available phosphorus and cations. The amount of soil required for analyses is about 100 g for soil pH and salinity, and 50 g for all other types of chemical analyses.

Nitrogen

There are three types of nitrogen analyses commonly included in monitoring programs: (1) total nitrogen, using the Kjeldahl method of analysis (Bremner, 1960); (2) bio-available nitrogen (nitrate and ammonium), using resin or potassium chloride extractions (Sparks and others, 1996); or (3) actual or potential mineralization (Haney and others, 2004). Total nitrogen measures all nitrogen in the soil, regardless of its form and whether or not it is bio-available. This measure is fairly constant through time. Nitrate and ammonium are the two forms of nitrogen most utilized by biota, and thus their levels indicate how much nitrogen is readily available for uptake. Consequently, it can be a more sensitive measure than total nitrogen. However, transformations between these two nitrogen pools occur continuously. Therefore, they can only be used for monitoring if measured repeatedly and under similar conditions or in comparison with a nearby reference area with similar climate, soil texture, and landscape position. In addition, potassium chloride extraction needs to be done in the field.

The most common nitrogen transformation measure used in monitoring programs is actual or potential nitrogen mineralization. Potential nitrogen mineralization is a laboratory measure. Soils are analyzed for nitrate and ammonium, incubated under ideal conditions for a set period of time (weeks to months), and then re-analyzed to examine changes in the two pools. Actual mineralization rates are done in the field. Soils are collected, a subset is extracted in the field for ammonium and nitrate concentrations (and analyzed in the lab afterwards), and the rest of the soil is then re-inserted into the soil. After incubation for a set time, the re-inserted soils are collected, extracted in the field, and analyzed again for nitrate and ammonium (Haney and others, 2004). Pre- and post-incubation pool sizes are then compared. Positive numbers indicate net mineralization (an increase in plant-available nitrogen), whereas negative numbers indicate net immobilization due to microbial uptake (a decrease in plant-available nitrogen).

Nitrogen inputs can also be measured as part of a monitoring program, although this is much more difficult than measuring pools of soil nitrogen. Most present-day inputs to Mojave soils are likely from the cyanobacteria and/or lichens in biological soil crusts, although even these inputs are low. Deposition of nitrogen due to human activities can also be significant in some parts of the Mojave. Measuring nitrogen inputs in these ecosystems, therefore, requires assessment of nitrogen fixation by microbes and inputs from atmospheric deposition. Measuring microbial fixation is generally done by incubating the sample under a 10 percent acetylene atmosphere in the light, under known temperature and moisture conditions (in the field or the laboratory), for up to six hours. Subsamples of the gaseous headspace are then injected into a gas chromatograph and the amount of ethylene evolved is measured as a surrogate for nitrogen fixation (this is based on the fact that the nitrogenase enzyme preferentially reduces the acetylene rather than the atmospheric nitrogen gas). Ethylene amounts are then converted to nitrogen units, using a multiplier of three (this number appears accurate for lichens; however, the correct number for soil cyanobacteria is under discussion; Belnap, 2003c).

Atmospheric deposition is measured in several ways. The simplest is a passive collector, which does not require power, but collects only ambient deposition (see dustfall traps in the Air Quality and Dustfall section). This means collected amounts are often low and timing of deposition cannot be determined. More sophisticated collectors can separate wet and dry deposition, collect an enhanced volume of air using a vacuum system, as well as determine the time of deposition.

Nitrogen losses are also difficult to measure. Gaseous losses need to be measured with some form of closed chamber system where gases are collected and analyzed with a gas analyzer (in the laboratory or field). These systems are expensive, are generally restricted to one-point-in-time assessments (although very expensive, continuously monitoring systems are available), and are high maintenance. Leaching losses are also difficult to assess, as there needs to be some sort of collecting device inserted at depth in the soil from which nitrogen-containing water can be collected. Nitrogen losses due to wind erosion are straightforward to measure (see wind erosion in the Eolian Processes and Dustfall section). Losses due to

water erosion are, again, difficult to measure, as both the water and sediment contained in the water need to be collected and analyzed. Therefore, most measures of nitrogen inputs and losses are not generally part of a monitoring program.

All is not lost, however. In addition to total soil nitrogen, soil nitrogen isotopes can be used as an indicator of the balance between gains and losses of nitrogen from an ecosystem. Therefore, isotopes can be an excellent integrated measure of the disruption or recovery of nitrogen cycles. However, the collection of the samples has to be done carefully, as only areas with the same soil moisture availability can be compared. Therefore, comparisons can only be made among areas of similar climate and soil texture (and thus landscape position, as soil texture can change downslope due to the movement of fine soil particles). If the disturbance is only at the surface, with little subsurface effects, comparisons can be made of the surface (0 to 1 cm) and subsurface (4 to 6 cm) soils at the same site, assuming soil characteristics do not change with depth. Under these conditions, a reference site is not needed. For isotope analyses, soils are collected as for other nutrients (depth of soil collection will depend on what part of the soil is of interest), and 1 g is sent to a laboratory for analysis on a mass spectrophotometer.

Phosphorus

Although total phosphorus is often high in desert soils, its interaction with other soil elements often makes it unavailable to plants and soil organisms (Lajtha and Schlesinger, 1988). Therefore, while total phosphorus (using Inductively Coupled Plasma Emission Spectrometry [ICP-ES]; Sparks and others, 1996) is of interest, it should be combined with other measures, including bio-available phosphorus and either calcium carbonate or the acid-neutralizing capacity (ANP; a combined measure of calcium carbonate [$CaCO_3$] and oxides of zinc, manganese, iron, and magnesium, which all buffer soil acidity) of the soil. Bio-available phosphorus is most often determined by extracting soils with sodium bicarbonates or resin strips (Olsen and others, 1954). The ANP of the soil is usually done by measuring the amount of hydrochloric acid required to obtain a neutral pH of the tested soil (Allison and Moodie, 1965). Calcium carbonate is generally determined gasometrically with a Chittick apparatus and is reported as percent calcium carbonate equivalent (Dreimanis, 1962).

Organic Matter

Organic matter is generally very low in deserts and can be highly variable across small areas (Whitford, 2002). Soil organic matter occurs in many forms that range in their ease of decomposition. Therefore, there are many levels of precision at which soil organic matter can be measured. For total organic matter, the soil is weighed, heated to combust the organic matter (Sparks and others, 1996), and then reweighed to determine mass loss. Distinguishing the different fractions of organic matter that have different rates of decomposition is more elaborate and is only done in specialized laboratories.

Cations and Micronutrients

Cations and micronutrients are critical for plant growth. However, we know very little about how these nutrients change with season or disturbance in desert soils. The one exception is sodium. This element can increase dramatically after the invasion of salt-tolerant plants (for example, *Tamarix* spp.[salt cedar], *Atriplex* spp. [salt bush], *Halogeton glomeratus* [salt lover], *Distichlis spicata* [salt grass]). In general, however, the use of cations or micronutrients in a monitoring program requires the use of reference areas or sampling needs to take place under similar conditions throughout a long time period. When cations are sampled, total concentrations are obtained using Inductively Coupled Plasma Emission Spectrometry (ICP-ES), and exchangeable levels are obtained using extraction with ammonium acetate (Sparks and others, 1996). Available (as opposed to exchangeable) potassium is extracted with sodium bicarbonate (Schoenau and Karamonos, 1993). Although micronutrients can be limiting in deserts (Bowker and others, 2005), these are not often included in a monitoring program, as little is known about their natural abundance or controls on this abundance. Bio-available levels of these nutrients are determined after extraction with diethylenetriaminepentaacetic acid (Leita and others, 1999). It is important to request that all these extractions be done at a pH similar to that of the soil being tested, as most laboratories generally use a pH of 7.

Soil Stability and Compaction

Soil stability and compaction can be measured using both indirect and direct measures. The most common indirect methods include measurements of protective ground covers, soil aggregate stability, and/or erosion using bridges or pins. Direct measures include collecting and quantifying soils moved by wind and/or water.

Indirect Measures

Protective ground covers include rocks, plants, plant litter, and biological and physical soil crusts. These parameters are measured using line transects or quadrats, as discussed in the biological crust/ground cover and vascular plant sections below. Another measure of soil stability is aggregate stability, which can be measured either quantitatively in the lab, or qualitatively in the field using a soil stability test kit (Herrick and others, 2001; fig. 40). Quantitative assessments require specialized field collection and laboratory equipment, and thus are seldom included in monitoring programs. In contrast, the soil stability test kit is quick and easy to use in the field. It requires collecting a small (20 mm) soil surface fragment and placing it into a basket constructed from 25-mm PVC pipe with window screen glued to the bottom. Although 18 samples are usually collected per site, high variability may require more samples. The baskets containing the soil are slowly lowered into a 10-mm container of distilled water. The time it takes to lose 50 percent of its structure is recorded. If, after five minutes,

there is no loss of structure, the baskets are slowly raised and lowered three times, and left to soak again. Class ratings are then assigned; fragments which are highly prone to erosion fall into the lower classes, and those less prone to erosion fall into higher classes. These kits can be easily constructed or can be purchased commercially (Herrick and others, 2001).

Another indirect measure of soil erosion is an erosion bridge, which consists of two short posts placed about 15 cm apart and protruding from the ground by about 5 cm. A line is tautly stretched between the two posts and secured on both ends to a permanently marked position. To measure soil loss or deposition, a ruler is placed between the two posts, and the distance to the ground measured at predetermined intervals, staying away from the posts (fig. 41). An increase in the distance to the ground indicates a loss of soil, whereas a decrease in the distance indicates deposition. This method is heavily used to monitor the impacts of trails, particularly on hillslopes, but its utility on general undisturbed hillslopes is questionable, because it does not readily account for spatial variability. This technique has limited value in areas where soils freeze or in soils with high amounts of shrink-swell clays, as soils can heave upwards during these events.

Direct Measures

Wind Erosion

Soil loss due to wind erosion accounts for the greatest amount of soil loss in dryland regions (Breshears and others, 2003). Soil loss by wind is most commonly measured by using Big Spring Number Eight (BSNE) collection boxes (fig. 42). These boxes allow air to flow through them without allowing dust or sand to escape (Fryrear, 1995). They are generally placed 15, 50, and 100 cm above the ground (although these heights would be different in areas with tall shrubs) on a pole that allows them to swing freely. The buckets have vanes that enable them to face the wind, regardless of direction. These boxes generally need to be emptied every 3 to 6 months, unless the measured surfaces are highly erodible. Collected sediment is weighed. If texture or chemical analyses are desired, the sediment can then be sieved and sent in for analysis.

Water Erosion

Directly measuring soil loss because of water erosion is much more difficult. There are several qualitative indicators that can be measured, including number of rills, plants on pedestals, gullies, litter dams, and water flow patterns (Pellant and others, 2000). While these are useful indicators of condition, they are mostly qualitative and it is difficult or impossible to compare results from year to year. These features can be measured quantitatively (marking individual spots and carefully delineating where measures are taken), although it is hard to relate changes in these features directly to soil lost through water erosion. There are only two quantitative measures that are generally feasible for monitoring applications. The first is the installation of silt fences (like those used at construction sites) at the bottom of the area of interest (Robichaud, 2002). These fences (fig. 43) retain whatever sediment is moving off the area, which can then be collected and weighed. To install the fences, a 0.15-m deep, 0.30-m wide trench is dug along the bottom edge of the plot. The bottom of the silt fence material (Amoco 2130, about 1 m wide), is placed in the trench. The lower 0.30 m of the mesh is used to line the bottom of the trench, the uphill side of the trench, and part of the uphill slope. The bottom of the trench is then refilled. A 305-mm band of aluminum flashing is placed over the filled trench,

Figure 40. Soil stability test kit (U.S. Geological Survey photograph by Jayne Belnap).

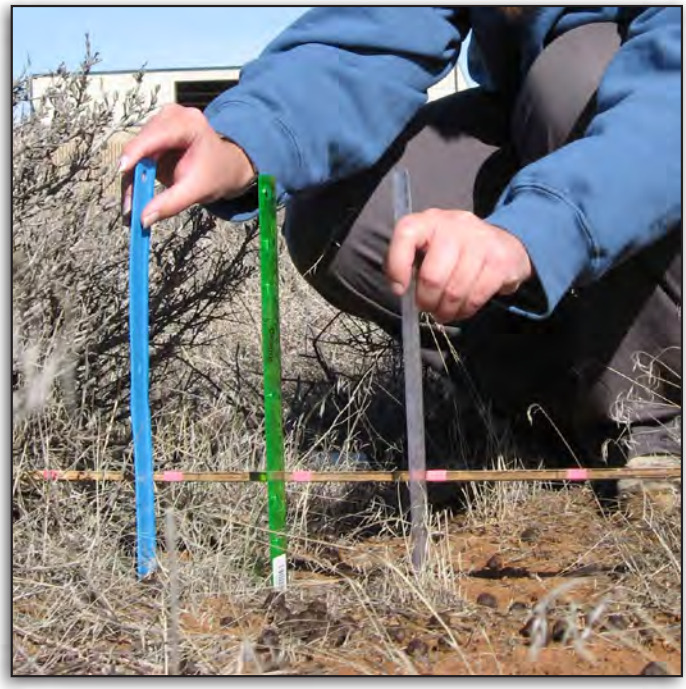

Figure 41. Soil erosion bridge (U.S. Geological Survey photograph by Jayne Belnap).

Figure 42. A Big Spring Number Eight (BSNE) measures soil lost due to wind erosion (U.S. Geological Survey photograph by Jayne Belnap).

and the 0.30-m bottom of the silt fencing is then folded back downhill over the flashing. The upper edge of the fencing is then attached to metal T-posts placed at a minimum of 1 m intervals along the downhill side of the trench. (If placed in a channel, the T-posts are more closely spaced). If the watershed area contributing to the silt fence is not defined by topography, it needs to be defined with some type of edging. For this, a trench is dug to outline the sides and top of the plot, and edging (for example, galvanized steel flashing, plastic garden edging, wood) is placed in the trench. The trench is then backfilled. A tipping rain-gauge bucket and Hobo event recorder should also be installed at the site, so that there is a record of the timing and intensity of rain events to correlate with amounts of soil movement.

Figure 43. A silt fence is established along linear disturbance features, such as this unpaved road, to collect soil lost by water erosion (U.S. Geological Survey photograph by Jayne Belnap)..

Soil Surface Roughness

Soil surface roughness is created by rocks, biological soil crusts, and plant litter. There are four ways generally used to measure soil roughness. The first uses a chain from the jewelry section at any store (fig. 44). Links need to be small (about 1 mm or less long) and the chain highly flexible. The chain is laid across the area of interest, with care taken that each link of the chain is in close contact with all the soil irregularities. Soil surface roughness is then defined as the difference between the chain length it takes to cover rough ground versus the length that would be required if the ground was flat.

The second method for measuring soil surface roughness is using a pin box. This is basically a board with holes drilled in it, such that pins hanging downwards are held snugly in place (fig. 45). The board is placed on supports hammered into the surface of interest. The pins are then pushed down to meet, but not penetrate, the soil surface. The standard deviation of the different measures between the pins is used as a measure of roughness. The advantage of these two techniques is that they are cheap and easy. The disadvantage is that they give only a two-dimensional view of surface roughness.

The third method uses a laser that scans back and forth across a small area, while the fourth uses cameras from several angles. These two methods are superior in that they give a three-dimensional picture of the soil surface. However, they are expensive, time consuming, and are, at this point, mostly restricted to small surface areas. However, the field is moving rapidly forward and is likely to be extremely useful in the future.

Soil Compaction

By definition, soil compaction is the decrease in pore volume within a soil mass, resulting in an increase in bulk density (Johnson and Sallberg, 1960). The density increase caused by

Figure 44. A jewelry chain is used to measure soil roughness (U.S. Geological Survey photograph by Jayne Belnap).

Figure 45. A box with moveable pins is used to measure soil surface roughness (U.S. Geological Survey photograph by Jayne Belnap).

soil compaction changes other soil properties, most notably the size distribution and continuity of pores (thus influencing the infiltration rate of water and gases), and strength characteristics. Numerous methods have been developed for measuring soil compaction and its effects (Freitag, 1971). Here we consider soil density and strength properties, and we discuss infiltration properties in the next section.

Bulk Density and Moisture Content

Soil bulk density is measured using a variety of techniques (Klute, 1986) For fine-grained soils, use of a core sampler is the preferred technique (fig. 46). The most common core sampler (figs. 46A and B) consists of a 57-mm diameter cylinder equipped with a wedge cutting tip and designed to collect intact samples. Narrow-diameter core samplers, which are designed for homogeneous, fine-grained agricultural soils, are more difficult to use in the Mojave Desert. Most samplers collect from the 0–6 cm depth—with the potential for splitting depth into 3-cm increments (0–3 cm and 3–6 cm)—although some core devices sample a slightly deeper depth range of 0–10 cm (Prose and Metzger, 1985). The sampler is carefully inserted into the soil either using a coaxial hammer or a hand-held sledge hammer; this insertion technique, which works best on soils wet at or near field capacity, must be done carefully to avoid soil dilation and inaccurate bulk densities. A minimum of 10 bulk density samples are recommended for each site. Another choice, especially in rocky soils, is to dig a small hole and drive a small object of known volume (for example, a socket) into the soil at the appropriate depth from the side of the hole.

Coarse-grained soils, with gravel content greater than about 15 percent by weight, pose a large problem for measurement of bulk density. The simplest technique involves collection of a sample from a shallow depression, lining the hole with plastic, and measuring the amount of water that fills the excavated volume (fig. 46C). Although this technique is useful for soils with considerable gravel contents, the error is large unless the rim of the depression is perfectly level. Methods are available for measuring the volume of an excavation,

Figure 46. Soil bulk density samplers. A, Soil corer for fine-grained soils and, B, the accompanying tools. C, Balloon sampler for coarse-grained soils (U.S. Geological Survey photographs by Robert H. Webb).

including inflating a water-filled balloon into the depression or filling the depression with a known-volume substance, such as well-sorted sand or other spherical solids (Johnson and Sallberg, 1960). Gravel content affects the representative volume that must be sampled in gravelly soils; at gravel contents greater than 54 percent, that volume must be between 5 and 50 L (Vincent and Chadwick, 1994).

All bulk densities are calculated as dry weight (g/cm^3); thus, moisture contents are required on all samples. This is obtained by weighing samples before and after drying. Certain applications of density data, such as estimation of hydraulic properties, may require knowledge of particle size distributions, especially the clay, silt, sand, and gravel fractions, and therefore provision should be made for particle-size analysis, either on bulk density samples or a separately collected sample.

Figure 47. An automated soil compactor is used for compacting soils at specific bulk densities by varying the hammer weight, the number of hammer blows, and the hammer height. A pot that is prepared for a compaction experiment (white PVC pipe) is secured to the rotating table and the hammer (here, in the lowered position) blows are delivered to each soil layer (U.S. Geological Survey photograph by Robert H. Webb).

Proctor Compaction Tests

The Proctor compaction test is used for analysis of soils to determine the moisture content of engineered fill soil at their maximum density (Klute, 1986). This test is useful for management purposes because it can distinguish whether soils are vulnerable or invulnerable to compaction, and the moisture contents at which soils are most vulnerable (Webb, 1983, 2002).

Proctor tests are conducted in a laboratory using the method specified in the ASTM International standards. The standard test uses a steel or aluminum mold, 102 mm in diameter, in which the sample is placed. The soil to be tested is sieved to remove particles larger than 19 mm. A sample of known weight and gravimetric moisture content is then placed in the mold and compacted in three layers using either a manual hammer or an automated machine (fig. 47). A total of 25 blows are administered for each layer, moving the hammer head to achieve uniformity of compaction. Bulk density is calculated by measuring the volume of soil after completion of the test.

Typical Proctor compaction curves are shown in figure 48. A “zero voids curve” constrains the possible bulk density to values beneath the curve. A minimum of 4, and up to 8, water contents are analyzed per compaction curve. The curve generally has two maxima, one at dry or near-dry conditions, and one that is at, or just below, field capacity (see section on Infiltration Rates). For Mojave Desert soils, the most important point is when soils are dry, because this is typically when soils are most vulnerable to compaction. Other points are empirically distributed between dry and field capacity, and at least one point is wetter than field capacity to constrain the curve. Maximum bulk densities achieved using Proctor compaction tests are greater than field-measured densities, even from roads, because in the field the surface of disturbed soils has generally dilated.

Soil Strength

Soil strength is measured using a variety of devices that range from rudimentary to sophisticated. In this discussion, we limit soil strength tests to field measurements, although laboratory tests, such as triaxial shear, can be used as well. Soil strength can be measured as an index (penetration depth), as shear-stress resistance, and as penetration resistance. In all cases, a downward pressure is applied, and in the case of shear-stress resistance, a rotational shear stress is applied as well. Soil strength is strongly controlled by soil texture, particularly silt and clay content, and soils are classified as cohesive (silt- and clay-rich) or non-cohesive (sand-rich) on the basis of these contents. All measurements of soil strength are sensitive to moisture content (Greacen, 1960), and thus measurements must be reported in conjunction with gravimetric or volumetric water contents.

Penetration depth is the mean depth to which a 30°, 920-mm^2 cone penetrometer (known as a “geostick”; fig. 49A) can be pushed into the soil surface (Wilshire and Nakata, 1976). This depth can be used as an index of compaction recovery

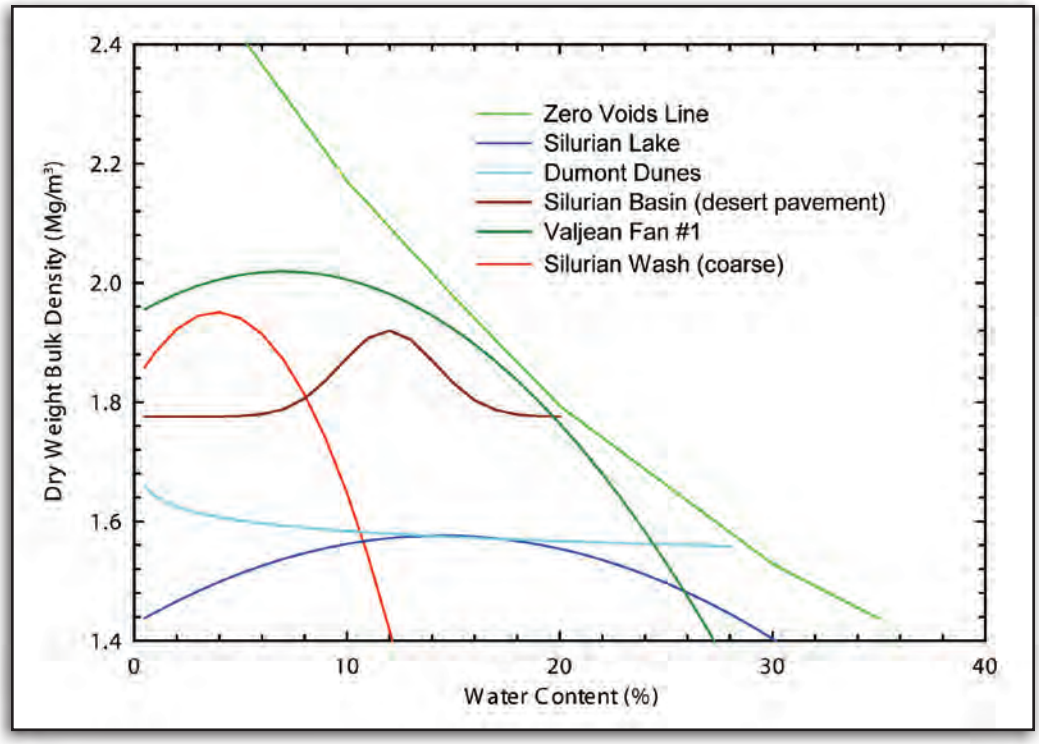

Figure 48. Proctor compaction curves for a variety of Mojave Desert soil types.

(Webb, 2002) or as a monitoring technique (Wilshire and Nakata, 1976). Of the variety of soil strength measurement techniques, penetration depth is least sensitive to soil gravel content, which inhibits measurement of the other, more fundamental, soil properties, such as bulk density (Webb, 1983; Webb and others, 1986). The downward pressure exerted on the penetrometer at insertion is the body weight of the operator, which means that the device is sensitive to operator variability. This, combined with sensitivity to moisture content, strongly suggests that penetration depth should be indexed, either to maximum compaction (for example, a nearby heavily compacted road) and an undisturbed condition, or over a range of soils. We recommend at least 70 penetration depths as the minimum sample for this technique.

Several penetrometers (figs. 49B–D), described as static cone penetrometers (Herrick and Jones, 2002), measure the penetration resistance as a cone is pushed through a soil column. The standard method for penetration resistance involves application of downward pressure at levels just high enough to slowly push the cone downward into the soil at a constant velocity. In practice, these penetrometers are pushed down by an operator. Maintaining a constant velocity is difficult, as subsoils vary in strength. For highly compacted and dry soils, these devices may not be able to penetrate past 3–5 cm depth. The so-called Corps of Engineers penetrometer (figs. 49B and 49C) measures only the maximum pressure required to penetrate to a fixed depth (Karafiath and Nowatzki, 1978). Other devices record the penetration resistance as a function of

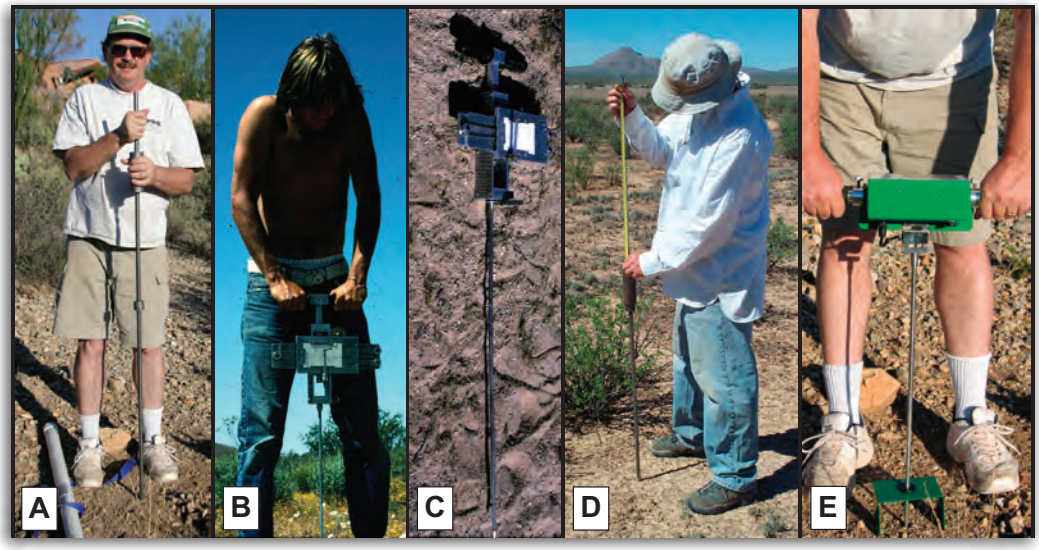

Figure 49. Soil cone penetrometers. A, The geostick, a device that measures cone penetration under the body weight of the operator. B, U.S. Army Corps of Engineers penetrometer, an analog device that has been linked to theoretical models of soil strength. C, Close-up of device shown in B. D, Dynamic-cone penetrometer. E, Automated recording penetrometer (U.S. Geological Survey photographs by Robert H. Webb).

depth, either with analog springs (Carter, 1967) or load cells with distance sensors (Klute, 1986).

Our preferred tool is a dynamic-cone penetrometer (fig. 49D) that was recently developed for field monitoring of soil strength (Herrick and Jones, 2002). Unlike the other penetrometers, which require an operator to apply downward pressure, a weight is dropped a fixed number of times on the cone-bearing shaft, pounding the cone into the soil. This avoids many of the problems associated with those pushed into the soil by the operator. The results from the dynamic-cone penetrometer can be expressed either as the cumulative pressure (number of drops) required to penetrate a fixed distance, or as the depth penetrated with each drop or with a specific number of drops. As with the static cone penetrometers, we recommend a minimum of 25 repetitions of this technique to get an accurate mean value for penetration resistance, and because the measurement is sensitive to soil moisture, indexing or calibration is required.

Pocket penetrometers are used to measure the resistance of the soil surface. They have a small, blunt tip instead of a cone, and were designed for turf in golf courses. Use for measuring subsurface soil strength is not recommended, because its size and tip adds to the measurement variability. However, they can be very useful for measuring the strength of surface physical or biological soil crusts. Because most pocket penetrometers have very stiff springs designed for turf, they do not work in weak or thin soil crusts. For these crusts, one can use testers designed for fruit (fig. 50), which are available across a range of forces (for example, grape, peach, apple). The strength of the crust will determine which fruit tester should be used.

Shear resistance is a soil property of high importance to trafficability (Karafiath and Nowatzki, 1978), and monitoring of shear resistance may provide important insights into changes that result from trampling. Shear resistance is perhaps more important in cohesive soils, because non-cohesive soils, particularly well-sorted sands, shear easily whether disturbed or undisturbed. Shear stress may be most useful in evaluating the impacts of physical soil crusts, which can develop following disturbance of soil with significant silt and clay content. Many devices are used to measure shear resistance, and all involve a spring-loaded device that has a disk with a variety of roughness elements that range from smooth metal to steel vanes (fig. 51). A constant normal stress is applied, followed by shear stress, until soil failure occurs. The torvane shear device is hand-held and has vanes that are inserted into the soil and twisted. Thus, the measure obtained is the force that causes the soil to fail at 0–2 cm. One of the limitations of all these devices is that the surface being measured has to be broken in order to be measured. Thus, the true shear resistance of an intact surface is underestimated; instead, the shear resistance of the pieces of soil between the vanes is being measured. In addition, the spatial variability of shear properties appears to be larger than for penetration depth or resistance. Measurements with shear-stress devices should be made over a range of normal pressures.

Figure 50. Fruit testers used to measure the strength of thin soil crusts (both physical and biological) (U.S. Geological Survey photograph by Jayne Belnap).

Figure 51. Hand-held torvane shear device measures shear stress of physical soil crust or subsurface soil horizons. Because of its small sampling area, repeated measures yield high variability (U.S. Geological Survey photograph by Jayne Belnap).

Soil Moisture

Soil moisture is affected by a variety of physical and biological processes, creating a large number of possible measurement techniques. The choice of an appropriate technique for monitoring of soil moisture depends on whether moisture content is all that is needed, or whether rates of change in moisture content are required.

The simplest measurement of soil moisture is achieved by weighing samples of a set volume before and after drying. The standard method calls for drying in an oven at 100ºC for 24 hours, but to minimize "baking" of clay minerals and a loss of structural water from clay minerals, we recommend drying at about 60ºC for 48 hours. Soil moisture contents can be expressed either as gravimetric contents (g/cm^3) or, if bulk density is known, as volumetric content (cm^3/cm^3). Laboratory drying of samples is the only way to calibrate other soil moisture measurement devices.

As soil moisture decreases from saturation, the matric potential, or the pressure required to extract moisture from the soil, increases. Figure 52 shows the relation between moisture content and matric potential for a sandy loam, a typical desert soil. This relation, called the characteristic curve, is useful for several assessments of soil status, including pore size distributions, water-holding capacity, and infiltration rates. Characteristic curves can be measured several ways, but the most common technique involves placement of soil samples—intact or disturbed—on a pressure-plate apparatus mounted in a pressure chamber. The pressure plate is a porous ceramic plate with drainage to the outside of the pressure chamber. As air pressure is increased within the chamber, water is forced from the soil through the pressure plate. After a sufficient period of equilibration has elapsed, the soil moisture content is measured for the specific applied pressure (matric potential).

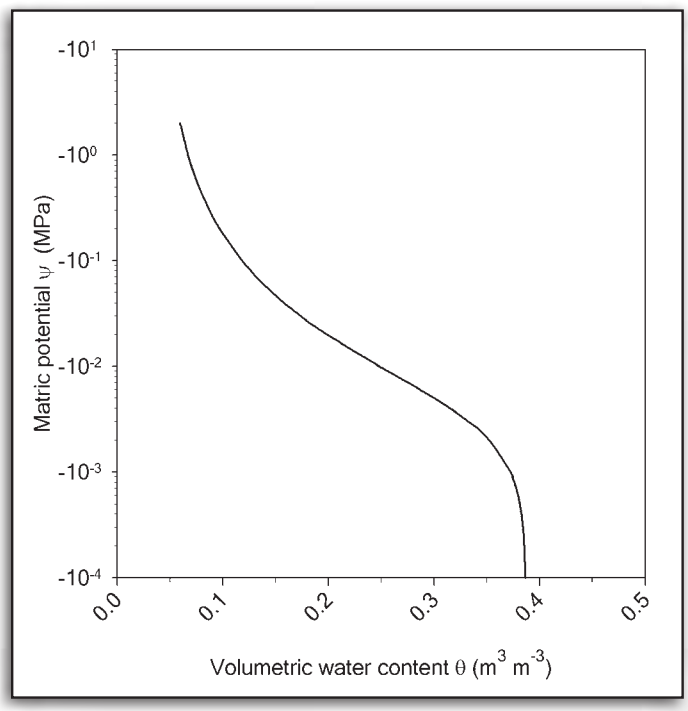

Figure 52. The relation between moisture content and matric potential for a sandy loam, a typical desert soil. This relation, called the characteristic curve, is useful for several assessments of soil status, including pore size distributions, water-holding capacity, and infiltration rates. Figure courtesy of M. Duniway, derived from the computer program ROSETTA (see Infiltration Rates; Schaap and others, 2001).

In situ measurement of soil moisture involves either direct measurement of the matric potential, measurement of heat dissipation as affected by soil humidity, or direct measurement of humidity. Tensiometers use porous ceramic media to measure low matric potentials (> -1 bar). Because these matric potentials are close to saturation, tensiometers seldom are useful for monitoring moisture contents of desert soils. They are useful for estimating wetting-front propagation during infiltration, but they cannot be deployed for significant time periods when desert soils are dry. Heat dissipation probes measure the ability of the soil to absorb heat generated in thin wires; this ability is related to the relative humidity of the gas within soil pores, which is related to soil moisture content.

Time-domain reflectometry (TDR) is a recently developed technique for using the dielectric properties of soils to measure moisture content (Klute, 1986). This technique covers the widest useful range in soil moisture content, from near-saturated to near-dry conditions. Because the TDR probe consists of parallel rods, it can be installed for long time periods and used for long-term monitoring, unlike other methods for measurement of soil moisture. However, data from times of very low soil moisture are much less accurate than at other soil moisture levels. Thermocouple psychrometers (Klute, 1986) remain a useful device for in situ measurement of very high matric potentials (> -15 bars). All of these devices can be used for real-time soil moisture monitoring, but all share two critical problems: (1) they must be deployed through destructive manipulation of the soil, and (2) all are too expensive to effectively capture spatial variability in soil moisture.

Ground-penetrating radar (GPR) used to estimate soil moisture can partially overcome these two problems. When used in a borehole setting (Rucker and Ferré, 2003), GPR can detect the vertical water-content profile of a soil column. This method can determine the average moisture content over a relatively large area, but it has the disadvantage that manual operation is required, and thus continuous measures through time cannot be made. Other methods still in use for estimating soil-moisture properties include those that use gamma-ray radiation sources, neutron probes, and electrical conductance (Klute, 1986). Because of its ability to measure a wide range of soil moisture contents, as well as its ability to continuously measure for long time periods, we recommend TDR for monitoring of soil moisture in the Mojave Desert, while recognizing that the other techniques have greater usefulness for specific applications.

Infiltration Rates

Infiltration rates can be measured using a wide variety of field and laboratory techniques (Klute,1986). Infiltration rate is defined as the rate of water movement into a soil surface, and soil hydraulic conductivities—both saturated and unsaturated—control these rates. Hydraulic conductivities strongly relate to soil texture and bulk density (pore space), as well as to the distribution of pore sizes, soil cracks, and voids left by animal burrows and roots. The presence of large amounts of gravel pose a particular problem to measurement of hydraulic conductivity, and laboratory measurements of infiltration rates typically are made on the soil fractions larger than 2 mm. The "available water content" of soils may be greatly overestimated if gravel content is not considered (Cousin and others, 2003). Saturated conductivities decrease with increases in the volume of large rock fragments, and methods have been developed for correction of conductivities measured on fractions less than 2 mm for rock volume (Mehuys and others, 1975; Dunn and Mehuys, 1984).

The most common method for measuring infiltration rates is the use of either single- or double-ring infiltrometers (Haise and others, 1956; fig. 53). Ring infiltrometers estimate saturated conductivity only, and installation of these devices in gravelly soil can introduce considerable disturbance, which affects infiltration rates. Double-ring devices, where the outer ring is not measured but helps to minimize lateral flow from the inner ring, is the preferred technique for fine-grained soils. Because saturated conductivity is more spatially variable than other soil properties (Webb, 1983), a minimum of 10–20 repetitions is recommended. Recently, construction of in situ basins, either lined with berms or concrete banks, have been used to measure infiltration rates over a larger area and with less disturbance than the ring-infiltrometer technique.

Tension infiltrometers (fig. 54) provide a less invasive technique for measurement of unsaturated hydraulic conductivities (Ankeny and others, 1988; Perroux and White, 1988). A porous disk (available in various sizes and tensions) of known hydraulic properties is attached to a water reservoir, and the disk is placed on the soil surface. A layer of well-sorted sand typically helps establish hydraulic contact between the disk and the surface of the soil. These devices can be used to measure hydraulic conductivity over a range of matric potentials to help define the unsaturated conductivity versus moisture content curve. This may be very useful for evaluating the hydrological effects of low levels of soil compaction where only the largest soil pores are affected, and where the effect on infiltration rates may be greatest at the lowest matric potentials. However, these instruments can measure only a very small surface area, and thus capturing the variability of a

Figure 53. Double-ring infiltrometer being used in the western Mojave Desert (U.S. Geological Survey photograph by David M. Miller).

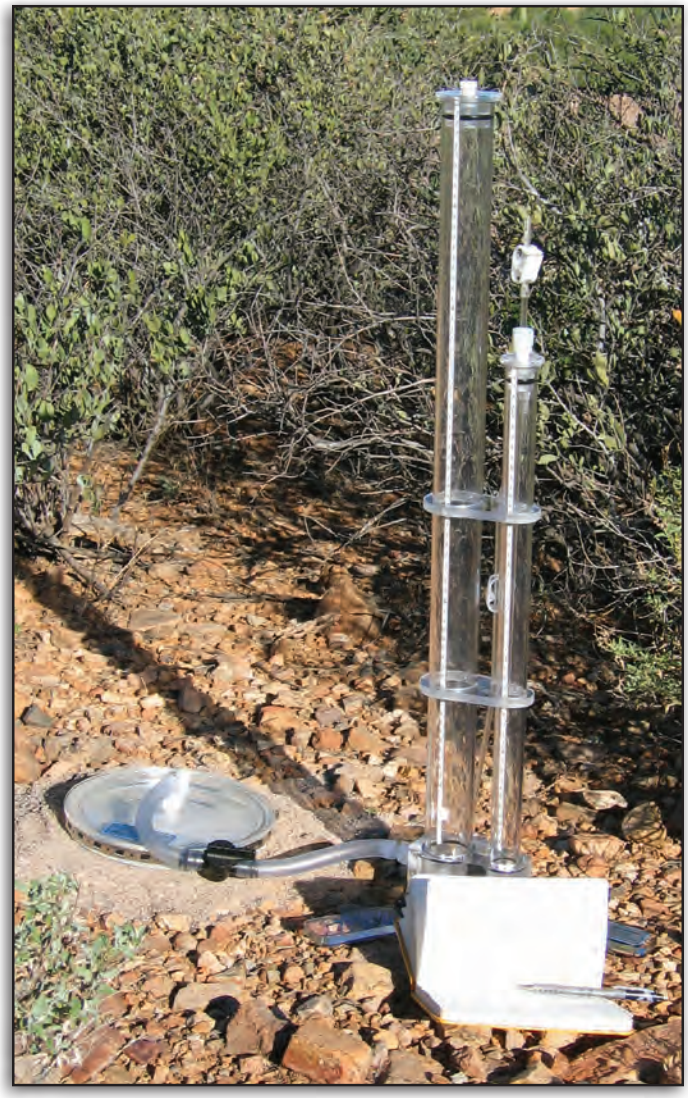

Figure 54. Tension infiltrometer in use in the Silurian Valley (U.S. Geological Survey photograph by David M. Miller).

site is time consuming. In addition, the pore size of the soil must be closely matched with the tension of the instrument. These instruments can be automated with a datalogger so that other monitoring activities can take place while they run. However, as they only measure unsaturated conductivity, ring infiltrometers or other devices are required for measures of saturated conductivity.

Rainfall simulators provide one of the best field techniques for estimating infiltration rates (Iverson, 1980), although this method is intensive and expensive. The advantage of rainfall simulation is that it does not disturb the soil, unlike ring infiltrometers, and infiltration is averaged over a large area (typically greater than 1 m^2), unlike with a tension permeameter. Most rainfall simulators use a nozzle that is designed to simulate the variability of natural raindrops. Water is applied at a specified intensity to simulate the physical crusting that can occur in disturbed soils. If measurement of saturated hydraulic conductivity is the goal, the intensity must be higher, and can be adjusted with nozzle pressure. Rain is directed over a plot that is cordoned off with metal flashing to contain and direct runoff to a point of outflow where it can be measured. Collected water, and the sediment in the water, is measured. Carbon and nutrient contents of the runoff water and sediments can be measured as well. Like in situ basins, this measurement is made over a larger soil area, thereby minimizing some of the spatial variability in hydraulic properties.

Laboratory analyses of either disturbed or undisturbed samples also can be used to measure saturated and unsaturated hydraulic conductivities. Manual techniques can be as simple as using drainage between a soil column and a lower elevation water chamber, or as complicated as using a centrifuge to rapidly apply pressure to a sample for fast drainage. These techniques generally are expensive and only useful if soil moisture properties must be accurately measured for small samples. Alternatively, soil hydraulic properties have been determined for a wide variety of soils, and statistical relations have been developed that allow estimation of these properties from soil particle size distributions and bulk density (Van Genuchten, 1980). A computer program (Rosetta) that performs these calculations is available from the USDA Agricultural Research Service (http://www.ars.usda.gov/Services/docs.htm?docid=8953; Schaap and others, 2001).

Perennial Vegetation

Perennial plants have been monitored in the desert Southwest for more than 100 years, and the techniques are well established in the scientific literature. Phytoecological measurements are an essential part of evaluation of ecosystem sustainability (de Soyza and others, 2000) and should be included in any significant monitoring program for the Mojave Desert. Readers are particularly referred to Mueller-Dombois and Ellenberg (1974), Bonham and others (1997), Elzinga and Evenden (1997), and Elzinga and others (1998) for more specific information on how to measure perennial vegetation. Here, we focus on the many nuances of measuring perennial plants that may affect a monitoring strategy for the Mojave Desert.

Perennial Vegetation Types in the Mojave Desert

Definition of assemblage, association, or alliance type is the first step towards establishing monitoring of perennial vegetation in the Mojave Desert. We recommend use of the classification technique presented in appendix B of Thomas and others (2004) to determine the type of alliance that is present at a site where long-term monitoring will occur. In addition, the NatureServe Web site (http://www.natureserve.org/explorer) can be used to determine vegetation alliances for the Mojave Desert. However, we recognize that assemblage-level definitions are also possible for Mojave Desert vegetation.

Plot Types

Permanent Plots

Establishment of permanent vegetation plots has been long used in the Mojave Desert to assess the factors that affect the distribution and long-term stability of perennial vegetation (Beatley, 1980; Cody, 2000; Webb and others, 2003, in press). The most difficult questions to be addressed concerning the establishment of new permanent plots is determining where on the landscape to place them, how many plots are required to adequately represent a patch of vegetation, and how often the plots are to be re-measured.

Beatley (1980) used the approach of multiple plots within a given vegetation assemblage, spread over the elevation range of the Nevada Test site, and established 68 permanent plots in 1963 to be re-measured every 10 years for woody perennial plants and every year for herbaceous perennials. In contrast, Cody (2000) reports results from only one plot that was intensively monitored for 15 years.

Once a monitoring strategy for a vegetation assemblage has been developed, permanent plots should be located using aerial photography or remote sensing. The geomorphic surface underlying the new plot should be reasonably homogeneous, as evaluated with photography, and no apparent trends in perennial vegetation should be present. Rills, gullies, and small washes can affect the pattern of perennial vegetation, and these geomorphic features should either be eliminated from the area of the plot or explicitly included as part of the sampling design (that is, include monitoring plots with, and others without, these geomorphic features to evaluate their impacts). Considerable variation in plot area and shape is possible and depends on whether just the plot is marked or whether the plot is part of a larger exclosure. We prefer marking permanent plots with fence posts at corners or edges, and marking transects with rebar placed a minimum of 0.3 m into the ground to allow long-term repeated measurements.

Random Plots

Establishment of permanent vegetation plots forces a statistical design of repeated measures, which may or may not be a desirable strategy, depending upon the goal of monitoring. Random monitoring of unmarked plots is a useful technique for one-time comparisons of status or recovery and can provide useful data in conjunction with measurement of permanent plots. By placing plant transects randomly, one can employ a different set of statistical techniques to evaluate change, although these techniques are less robust than repeated measures of one plot. As with establishment of permanent plots, use of aerial photography to locate random plots is an important component of site selection, both to avoid areas with problematic variability and to precisely locate measurement sites in the assemblage type of interest.

Point relevés have long been used observationally to quickly collect large amounts of data on species composition of perennial vegetation, and can be permanent or random plots. The primary data supporting two vegetation maps of the Mojave Desert relied on a combination of point relevés and other plant observations as the primary data for statistical extrapolation (Ostler and others, 2000; Thomas and others, 2004). Relevés are most useful for rapid acquisition of large amounts of data for mapping or other site characterization work. As applied by Thomas and others (2004), a circular plot of 1,000 m^2 was established by placing two tapes perpendicular over a center point; each area measured was 35.6 m diameter. Visual estimates of the cover of each species within the circular plot were then made. Readers are directed to Mueller-Dombois and Ellenberg (1974) for more information on relevés.

McAuliffe (1990) proposed the log-series survey method for quickly estimating cover and density of desert vegetation. Circular plots of areas ranging between 250 and 1,000 m^2 are established, and individuals of each species are assigned to classes of density and cover based on a logarithm of base-2 scale. This method, which bridges the gaps between relevés, quadrats, and line-sampling techniques, is particularly well suited to rapid measurement of density and cover on a one-time basis.

Figure 55. Belt transects at Skidoo townsite, Death Valley National Park. The number of plants between the lines, which are 2 m apart, is counted to obtain density, and the transect lines are used for line intercepts. Alternatively, two diameters and a height can be measured for all plants with bases between the lines, allowing calculation of density, cover, and biomass using regression equations (U.S. Geological Survey photograph by Jayne Belnap).

If a general survey for a large area is desired, a step point-intercept transect (modified from Evans and Love, 1957) is often the most cost-effective method. A compass point or focal point on the horizon is identified. The observer walks in a straight line towards the point, without looking at the ground. Points are located after a predetermined number of steps (generally 2 to 4) are taken, at which point a walking stick, rod, or pin flag is touched to the ground (without looking at the ground) to mark the point. To characterize an area, at least 300 points are measured.

Sampling Techniques within Plots

Line Sampling

There are many types of line sampling techniques that can be used. The point-quarter method of Cottam and Curtis (1956) has been used to assess grazing impacts (Webb and Stielstra, 1979) and recovery from disturbance (Wells, 1961). This method consists of stretching a single line (or parallel lines) for a predetermined distance and establishing either a regular sampling interval (for example, every 10 m) or random sampling locations. At each sampling location, an imaginary line perpendicular to the sampling line creates four quadrants. The distance to the nearest plant in each quadrant is measured, and each plant is measured for two diameters (maximum and minimum) and height. The results of the point-quarter method can be used to estimate density, cover, and biomass of perennial vegetation, but usually insufficient numbers of plants are measured, because the method is inefficient in terms of use of available sampling space. A more common use of this method is for the random selection of individual plants for measurements other than density and cover (for example, random selection for isotopic analyses).

The line intercept and belt transect methods—alone or in combination—have long been used to measure density and cover of perennial vegetation (fig. 55). The line intercept method measures cover and species composition based on coverage by a one-dimensional intercept method. A line is stretched tightly parallel to the soil surface, and the starting and ending points of the perennial canopies intercepted are recorded for each species encountered. The total length of the line that overlaps perennial canopy is divided by the total transect line and multiplied by 100 percent to obtain percent canopy cover. Cover may be absolute—in which only the individual with the tallest parts are measured (Webb and others, 1988)—or relative—in which cover of all overlapping canopies are measured (Beatley, 1980). The length of line required to adequately measure cover depends, in part, on whether the cover of uncommon species at the site is required. Usually, 200–400 m of line intercepts are used (usually as multiple

lines). A one-dimensional map of the plot can also be made if the transect ends are marked and intercepts are recorded. Beatley (1980) used line intercepts combined with maximum height measurements (using the average height of the plant) in her 68 permanent plots on the Nevada Test Site.

Belt transects are more commonly used for shrub and seedling measurements, because both density and cover can be obtained, and a wider area is sampled along a given line (Vasek and others, 1975a, 1975b; Webb and others, 1988). A belt consisting of two parallel transect tapes is placed on the landscape a fixed distance apart. Although a separation of 2 m is convenient for most Mojave Desert shrub assemblages, wider separations are sometimes used if accurate data on uncommon species is desired, or if tree species are measured. All plants within a fixed polygon (for example, 2 × 2 m) are counted, and the presence of the basal stem between the tapes is the criterion for whether an individual is in or out of the transect. Definition of an individual can be a problem with many species in the Mojave Desert, especially *Coleogyne ramosissima* (blackbrush) and *Ephedra nevadensis* (Mormon tea). Cover can be obtained either by using the bounding tapes as line intercepts or by measuring one or two diameters of each shrub that is encountered. The latter measurements are typically made with a height measurement in order to estimate biomass (see Biomass Estimation: Direct and Indirect).

Hunter (1994) developed a hybrid belt transect method that serves as the basis for permanent plots on the Nevada Test Site. He stretched a line transect between marked fence posts and established a 2-m wide belt transect, 1 m on each side of the primary line. For each shrub within the 2-m width, he recorded the position along the main tape and the distance from the tape (negative to the left, positive to the right). After establishing the position in this reproducible way, he measured two diameter measurements (at the widest diameter and at a 90º angle from ground to plant at the widest diameter) and the maximum height to estimate biomass. This method is perhaps the best way of measuring a permanent plot, because it yields more information than the line intercept method of Beatley (1980), but is less intensive than full mapping of plant diameters.

Quadrat Sampling Techniques

Quadrat sampling techniques are less commonly used in the Mojave Desert, but are extremely useful in high-density shrubs, which are encountered in certain blackbrush or big sagebrush assemblages, and to measure ground cover (see Measurement Techniques for Ground Cover). For areas with large shrubs, quadrat frames are generally at least 1 m^2 in area. Carpenter and others (1986) used a 4-m^2 quadrat in areas with low-density perennial vegetation. For grasslands or smaller shrubs, ¼-m^2 quadrats are commonly used. One problem with the larger quadrats is that sampling requires trampling within the plot, which will impact ground covers, especially biological soil crusts, with repeated visits. In this situation, personnel should be required to stay on designated trails. Placement of the quadrats can be determined in many ways. The three most common ways include: (1) Establishing a line transect in the area to be measured and developing a grid from this line. Random numbers are created to describe the distance along the line and from the line for placement of the quadrat frame. Density and cover are then estimated as in a belt transect as described above, or visually estimated. (2) Placing the quadrat at random points along the line. (3) Placing the quadrat at regular intervals along the line.

Some species (for example, *Yucca brevifolia* [Joshua tree]) are poorly measured with most line, belt, or quadrat techniques. One means of estimating density and cover of these species is to establish plots up to 1 ha in size around the smaller-area plots designed for more common shrubs. Comanor and Clark (2000) used a circular area 1,000 m^2 for their permanent plots to study *Y. brevifolia* growth. For columnar species like *Y. brevifolia* and *Carnegiea gigantean* (saguaro), heights are measured using a telescoping rod—usually a converted stadia rod—with a horizontal bar on the top. The bar is lowered onto the highest point to obtain the heights of the plants, which are then averaged. This type of approach is particularly suited to cacti or other species that occur on the landscape in low densities. Trails to the target plants need to be designated to reduce trampling of ground covers.

Mapping Techniques

The oldest plots for measurement of desert vegetation in the United States, at the Desert Laboratory in Tucson, Arizona, are irregularly shaped mapped plots of varying size (Goldberg and Turner, 1986; Bowers, 2005b). The typical plot at the Desert Laboratory is 100 m^2, similar to the Beatley (1980) plots on the Nevada Test Site, but much larger plots (800 m^2) are also present at the Desert Laboratory, including nested plots for studies of *Carnegiea gigantean* (saguaro). Initial mapping used a grid of strings stretched over the plot; more recently, surveying instruments were used to outline shrub canopies. Cody (2000) used the grid technique to map perennial vegetation on his plot in the Mojave Desert. Mapping perennial vegetation can be extremely labor-intensive, but can be the optimal way to answer some questions (for example, determining the distance from wash channels on plant distribution and productivity, documenting the spatial relationship among different plant species). In addition, GIS software is required to depict and analyze vegetation characteristics on these plots. The use of modern surveying equipment (total stations) has greatly reduced the time required for mapping vegetation.

Monitoring of Invasive Plants

Monitoring for new invaders can be made more effective through the use of predictive models linking landscape features with likely pathways of invasion; however the data on the presence/absence of species necessary to develop these models are rarely available (Brooks and Klinger, in press).

If species lists are available, search areas can be prioritized based on the life history characteristics of the species present. In most cases, species occurrence data or comprehensive lists are not available, and monitoring plans need to be based solely on general invasion theory (Brooks and Klinger, in press). The basic guidelines suggest that invasions are most likely to occur near propagule sources and/or where resources for plant growth are most readily available (Brooks, 2007). In desert regions, these invasion pathways include roadsides, railroads, and utility rights-of-way (Brooks and Pyke, 2001; Brooks and Berry, 2006). They also include focused areas of disturbance to which invaders may disperse over long distances, such as livestock corrals or watering sites, mines, camping areas, off-road vehicle and military staging areas, and old townsites (Brooks and Pyke, 2001). Because these areas are extensive, monitoring should also be extensive, necessitating rapid assessment techniques, such as visual surveys of a given area (for example, between mile markers along a roadside) for a given amount of time (for example, a constrained-time search). Because the vast majority of invaders in the Mojave Desert are annual species (Kemp and Brooks, 1998; Brooks and Esque, 2002), surveys must be conducted during the active growing and flowering season (typically March-April for winter annuals and June-September for summer annuals). A common way of measuring the extent of an invasion from a known point source (for example, the edge of a road) is to evaluate the cover and/or density of the invasive plant at the edge of the heavily invaded area, and then at distances that double each preceding distance interval (for example, 1 m, 2 m, 4 m, 8 m, 16 m, and so on). This can be done either along a line transect or using a quadrat frame. When testing the hypothesis that the expected vector of spread is, in fact, facilitating spread, then one or more additional sampling transects should be established in random directions to serve as controls for hypothesis testing. Monitoring to determine the ecological effects of invaders can be done concurrently by measuring additional ecological variables within each sampling plot. For example, native annual plant community abundance and diversity can be measured in response to increased abundance of the invader as it spreads into new areas (for example, caused by competition; Brooks, 2000).

Spatial and Temporal Variability and Sampling Intervals

Proper sampling design for monitoring of perennial vegetation requires a plan for coverage of both spatial and temporal variability. Tests of statistical inference require replicate sampling, which would suggest that a minimum of three permanent plots should be established for each vegetation unit that is monitored. However, no previous permanent plot design in the Mojave Desert has used a replicate-sampling approach; although Beatley (1980) established 68 permanent plots, they were not explicitly established as replicates and instead are essentially 68 sites that represent independent vegetation assemblages. Cody (2000) used only one site but applied a repeated-measure statistical design.

The frequency of monitoring requires a tradeoff between maximum data acquisition and minimum site disturbance. Although proper evaluation of annual changes—particularly primary production—would require annual or seasonal visitation, trampling associated with monitoring access could affect soil compaction, disrupt seedbanks, damage biological soil crusts, and have inadvertent negative effects on perennial vegetation. Cody (2000) re-measured his single plot annually for 15 years with unknown sampler-access effects. The Beatley plots were re-measured for perennial vegetation only three times between 1963 and 2002 (Webb and others, 2003), but herbaceous perennials and other ecosystem attributes were sampled at least annually from 1963 through 1970 with uncertain consequences.

One possible solution would be to develop multiple replicate plots that are measured on an alternating basis, but for which at least one plot is measured annually. This sampling strategy would involve a high initial investment in time to create the array of plots but could ensure long-term viability of the monitoring program by minimizing sampler impacts. Even with this design, care would need to be taken during sampling to not disrupt ground covers. In addition, the sampling array would have to be carefully designed to avoid confounding effects that could arise from a variety of factors, including variation in geomorphic surface, soil subsurface properties, and land-use history.

Measurement Techniques for Perennial Vegetation

Phytoecological Measures

Numerous possible phytoecological measures have been used to evaluate ecosystem status, sustainability, and stability. Ranging from largely qualitative information on species composition to quantitative measurements of plant physiology, these measures can be easily acquired or can require an extensive research commitment. Our focus here is on discussing phytoecological measures that are appropriate for monitoring of the Mojave Desert ecosystem. While we briefly discuss isotopic and physiological techniques that have application to plant vigor, we will concentrate on measures that can reasonably be accomplished by a competent staff with limited monitoring resources. Readers are urged to consult Rundel and Gibson (1996) and Whitford (2002) for more information on the ecological processes that affect perennial vegetation in the North American deserts.

Biomass Estimation: Direct and Indirect

Biomass—whether above-ground, below-ground, or total—is one of the most important measures of the status and vigor of perennial plants. Biomass is usually expressed in dry mass per unit area. Direct estimation of biomass is accom-

plished by harvesting the plants, drying the plant parts, and weighing them. Typically, above-ground biomass, also known as standing crop biomass, is measured, because obtaining sufficient quantities of roots of perennial plants for measurement is extremely difficult and time consuming. Because of its deleterious effects on plant assemblages, direct estimation of biomass cannot be used in permanent plots.

An indirect measure of biomass uses measurements of plant volume to determine a regression equation between plant volume and biomass, which is then used to estimate biomass in plots (appendix C). Several regression equations for indirectly estimating plant biomass are available for the Mojave Desert (Romney and others, 1973; Bureau of Land Management, 1980). Development of these equations is based on an assumption concerning the geometric shape of shrubs—some shrubs, such as *Ambrosia dumosa* (white bursage), are assumed to be hemispherical, whereas others, such as *Larrea tridentata* (creosote bush) are assumed to be inverted cones, truncated at the base or intact. Before indirect volume estimates are made, the shape of the species being measured should be determined from the regression equations. The extant regression equations relating biomass to shrub shape and volume are mostly unpublished and are given in appendix C.

Primary Production

Primary production is an extremely important but difficult-to-measure attribute of perennial plant assemblages in the Mojave Desert. Because water availability controls the flow of energy through this type of ecosystem (Noy-Meir, 1973), primary productivity is intimately linked to precipitation and temperature monitoring. Webb and others (1978, 1983) define above-ground net primary production (ANPP) and its relation to water-use efficiency in a variety of biomes, including the Mojave Desert. Lane and Stone (1983) and Lane and others (1984) present a quantitative model linking soil moisture and ANPP, using data from the Nevada Test Site as an example. Turner and Randall (1989) discuss ANPP for the Nevada Test Site and report a precipitation threshold of 26 mm for annual plants and 21 mm for perennial plants (roughly in agreement with Beatley, 1974). Hamerlynck and others (2002) showed that gross production is related to geomorphic surface characteristics that control available soil moisture.

Measurements of ANPP generally involve destructive sampling of new-growth twigs and leaves (Turner and Randall, 1989). ANPP can also be calculated using biomass regression equations applied to old-growth volumes versus new-growth volumes; however, this technique involves considerable uncertainty and requires numerous assumptions about allometric growth relations among years. In a hybridization of destructive sampling and allometry, DeFalco and others (2007) marked two culms per perennial grass and four terminal twigs per shrub and followed the growth over time. Parallel measures were collected on other plants, but these were harvested, dried and weighed to develop the culm- and twig-level regression equations for calculating changes in productivity through time. Use of season-long leaf area index (LAI) measurements may be another way to non-destructively estimate ANPP. Lane and others (1984) provide a rudimentary water-balance model for estimating ANPP from precipitation and soil characteristics.

Plant Vigor

A large variety of techniques are available for measurement of plant vigor. The definition varies, but generally plant vigor is measured at the end of a growing season and represents the cumulative growth in a manner similar to ANPP. Vigor measurements can reflect both environmental variability and site-specific conditions and are usually conducted as a comparison of management treatment versus a control. For example, for *Coleogyne ramosissima* (blackbrush), twig growth essentially doubled as precipitation doubled, and twig growth was 1.9 times larger on deep soils than shallow soils under the same amount of precipitation (Provenza and others, 1983). Critical ratios of essential elements in plant tissue—such as nitrogen and phosphorus—are another useful metric of plant vigor that have been tested in many ecosystems, including arid systems (Drenovsky and Richards, 2004), although not specifically in the Mojave Desert. Carbon isotopes in plant tissue can be used to determine water stress in C_3 plants (Ehleringer and Cooper, 1988), but should be compared to a control plant of the same species from soils with the same texture. Nitrogen isotopic ratios can also be used to determine the status of nitrogen cycles in the soil: a lower number indicates that plants are growing in soils where nitrogen inputs exceed nitrogen losses.

Phenology and Seed Production

Phenology, or observations of the dates of leaf-growth start, flowering, and fruiting, is an important measure of plant productivity and vigor (Beatley, 1976; McGinnies, 1980; Turner and Randall, 1987). In light of current trends toward an increase in growing season length, which is also starting sooner, attributable to overall climatic warming in the Southwest, annual collection of phenological observations should be an integral part of a monitoring program in the Mojave Desert. Desert annuals and perennials are highly responsive to either winter or summer rains (Ackerman and Bamberg, 1974), and differential species response could be used to assess the effects of future shifts in the relative amounts of winter and summer precipitation as predicted in some general circulation models. Beatley (1974) presented an elaborate model of rainfall and phenology for the northeastern Mojave Desert, which could be used to integrate climatic and phenological observations.

Seed production, an extension of the more typical set of phenological observations, is extremely difficult to quantify and is labor intensive. However, seed production may also be sensitive to climatic change because, as spring temperatures rise, the possibility exists that the period during which flowering and fruiting can occur may be telescoped down to a narrower time period. For shrubs and some perennial grasses,

small, fine-mesh bags can be secured to flowering branches or culms, and the mature seed collected and counted when it falls from the plant. Seed production should be expressed as a proportion of productivity (called reproductive effort; Harper and Ogden, 1970) and as indicated in the Primary Production section above (see DeFalco and others, 2007). Net seed production—the amount of viable seed produced minus the amount taken by seed predators—can also be roughly approximated with seedbank measurements (see Seedbank section).

Seedbank

Seedbanks are typically sampled after seeds have matured and fallen to the ground from the parent plant, but not before an after-ripening period, which is generally the period of prolonged high temperatures in July–August. For desert annuals, plants generally senesce with the onset of high spring and summer temperatures, which causes resources to be focused toward seed maturation and abscission from the plant. Seeds of some desert species require after-ripening so that physiological and physical changes in the seed embryo and seed coat can prepare it for the dormant phase and subsequent germination when conditions become favorable again. Perennial species typically have at least a magnitude lower seed densities and greater spatial variability than annual species and are therefore more challenging to sample. Care also needs to be taken when quantifying seedbanks in the Mojave Desert so that soils are sampled before significant late-fall/early-winter rainfall stimulates germination.

The distribution of seeds across the landscape is tremendously variable in the Mojave Desert, and the sampling design must account for this variability, as well as detect low abundances of rare species. Seed distributions in soil tend to be related to microtopography (Price and Reichman, 1987), thus seed collection locations are often stratified by canopy cover, irrespective of species (that is, beneath shrub canopy versus in the open spaces between shrubs; Esque, 2004). Other conditions that may contribute to spatial variability and that should be considered for stratification include shrub hummocks versus washes, and sites of varying soil ages or textures.

Sampling for annual species begins by collecting surface soil using a tin canister or soil tin pressed firmly into the ground, usually within the top 30 mm, where seeds are found (Nelson and Chew, 1977; Ferrandis and others, 2001), and sliding a metal plaster knife underneath. Size of soil tins and the number of tins collected from one sampling point vary, but care should be taken to account for the variability of arid shrubland systems. For example, in a study examining the role of granivores, wildfire, and precipitation on the annual plant seedbank, Esque (2004) selected sampling points beneath both randomly selected shrubs and adjacent bare soil areas; then, at each point, four sampling tins were collected and pooled to obtain a single representative sample for each sample point. In the pooled samples, soil aggregations were crushed, litter and rocks (> 1 cm diameter) were removed, and the remaining soil was thoroughly mixed. A soil volume of 120 cm^3 (measured to a depth of 3 mm) was used for each germination trial for a rough estimate of 40 cm^2 of surface area. This can be multiplied by 250 to provide an estimate of the number of seeds/m^2.

Because perennial seed densities in the soil are typically much lower than annual seed densities, sampling with small soil tins may not capture the rare occurrence of perennials. A metal frame ranging in size from 10 × 10 cm to 25 × 25 cm may be pressed in the ground to a depth of 3 cm and the soil collected within the frame to ensure perennial seeds are sampled more appropriately. However, consideration should be taken when developing more complex designs, as the larger volume of soil will require more space in the greenhouse (and a heavy duty truck to carry tons of soil!) if a grow-out method is used (see below). An alternative method for sampling perennial seeds is vacuuming the surface soil to a depth of 2 cm using a modified leaf blower (DeFalco and others, 2005: 2 × 2 m quadrats were vacuumed and grown out in the greenhouse successfully, and quadrats of this size captured many of the perennial species present at the site).

Soil seedbank is determined by subjecting soils to four phases of moisture and chemical wetting in a greenhouse. These phases include two wetting phases with tap water, a third wetting phase with the addition of a 0.01 M solution of potassium nitrate (KNO_3; Mayer and Poljakoff-Mayber, 1982), and a fourth wetting phase with the addition of a 6.5×10^{-4} M solution of gibberellic acid (T.C. Esque and others, unpub. data). The addition of these chemicals is known to trigger the germination of some types of seeds (Mayer and Poljakoff-Mayber, 1982; Baskin and Baskin, 1998). The treatments include 50 ml of the solutions per treatment pot. Soil samples are kept damp with additional tap water, but not to the point of soil moisture draining off. Seedlings that germinate from each wetting cycle are identified, counted, and removed from pots. Pots are dried between each wetting treatment (approximately 3 to 4 weeks) to simulate the annual dry seasons, and thus break down seed dormancy agents so that all seeds will germinate. Seedlings are identified based on cotyledon shape, size, and surface characteristics (T.C. Esque and others, unpub. data, for photographic reference of Mojave Desert species).

This seedbank assay methodology is not foolproof, and can fail to detect some seeds, possibly due to their stringent germination requirements. A random subsample of assays from multiple sites in the Mojave Desert and adjacent ecoregions indicates that assays conducted during any given year detect an average of 87 to 91 percent of seeds present in the samples (Draper and Brooks, unpub. data, 2002–2004). Samples run back through the assay process a second and a third consecutive year detect an additional 7 to 8 percent and 2 to 4 percent, respectively, of the seeds present in the samples.

Measurement Techniques for Desert Annuals

Density and Production

Annual plant abundance is often characterized as number of individuals per unit area (density) or shoot biomass per

unit area (production). Density and production are typically sampled when annual production peaks (April–May); however, phenologies of winter annuals vary by up to four weeks, so multiple sampling times may be necessary to capture differences in peak abundance by species. Quadrats are typically placed completely at random within a study area, stratified between disparate habitats (for example, beneath shrub canopy versus in the interspace), or placed at intervals along a randomly placed perennial line intercept or belt transect (see Perennial Vegetation). The efficiency of sampling, using different quadrat sizes (for example, 0.10 m^2 versus 1 m^2) and quadrat number, should be determined in pilot sampling before much investment is made. Quadrat size should be based on: (1) objective of study; (2) travel, set-up, and measuring time; (3) spatial distribution of plants; (4) edge effects; and (5) sampling impacts to the study (Elzinga and Evenden, 1997; Elzinga and others, 1998). While small quadrats allow for numerous replicates that can be rapidly sampled, a larger quadrat size may be necessary to capture small, widely spaced or rare annuals in years of low rainfall. After an initial number of randomly placed quadrats are sampled, and the mean and standard deviation calculated, a calculation can be made to determine if further sampling is necessary based on the adequacy of sampling techniques (that is, when a sufficient quadrat number is determined and when variances between plot numbers become stable; Bowers and others, 1995; Zar, 1997). Those seeking additional detail about appropriate sampling units and sampling design should consult Elzinga and others (1998).

Species Composition

The number of species present within a quadrat and the frequency of quadrats occupied by each species can provide valuable information on species dominance, competitive interactions, and local species extinctions. The number of species can vary considerably among different sized quadrats and does not scale linearly (for example, species-area curves). Therefore, quadrat size should be determined in pilot sampling and kept constant among the study areas that are being compared. Species richness (number of species) and species evenness (frequency of occurrence) are used to calculate species diversity. Discussion about the calculation of species diversity indices, and their uses and pitfalls, can be found in Bowers and others (1995).

Cover

Annual plant cover can be estimated directly or indirectly at the same time density and species composition are assessed on quadrats. Cover is often related to production, and so cover and production are measured simultaneously only for establishing the correlation between the two; once established, cover takes less time than collecting, drying and weighing plants for production. Cover is directly measured as the number of grid demarcations on a quadrat that contain annual plants, or, similarly, by counting the number of 1 cm^2 grid squares with annual plants on a transparency held above the plant canopy. Indirect, ocular estimations of cover, using percent-cover classes, are less precise but allow rapid assessment for numerous quadrats. However, if multiple observers conduct the estimates, it is important to standardize ocular estimations of plant cover and validate the estimates against the actual cover measurements from a suitable number of plots.

Measurement Techniques for Ground Cover (Including Biological Soil Crusts)

Ground cover includes rocks, plant litter, live plant bases, animal feces, bare ground, and physical and biological soil crusts. These factors can be assessed in as many ways as vegetation is measured. In the Mojave Desert, where lichens and mosses tend to occur in widely spaced patches, there are two common ways to assess ground cover. Regardless of the measurement method chosen, one of the first decisions to be made is how ground cover will be defined: will only the top layer of ground cover be recorded, or will all layers of ground cover be recorded? For instance, a thin layer of plant litter may be on top of a moss, and one needs to decide if one or both will be recorded. At each point, whatever ground cover the rod hits is recorded in predefined categories described below. Whether or not the ground cover point is under the canopy of a shrub or is in the interspace can be recorded as well. This provides information both on vascular plant cover, as well as the distribution patterns in relationship to plants for the different ground covers.

Ground cover is often measured using a point-hit frame. The frame is small (fig. 56) and is gridded off with wires to form cells 5 × 5 cm, creating cross points. The size and shape of the frame depends on the questions being asked by the monitoring program. Percent cover is calculated by dividing the sum of hits for each category by the total number of hits and then multiplying by 100. Quadrat frames can also be used, with crust cover estimated by cover classes or absolute cover. We find this technique only works with highly trained personnel.

The frames can be used in several ways to characterize ground cover at a site: (1) Stops are made every 1 to 5 m along three 50 to 100 m transect lines, depending on the variability in cover types. (If vascular plants are being measured, the length of line is generally determined by the vascular plant requirements, although the stops for ground cover variables may be more frequent, depending on the patchiness of the site.) At each cross of the wires, a pin flag is lowered to the ground surface, and whatever ground cover the pin flag encounters is recorded. Whether or not the quadrat is under the canopy of a vascular plant, in the interspace, or in both is recorded. (2) Interspaces and areas under plant canopies (often by plant species) are sampled separately. The results from the frames are multiplied by the proportion of interspace and plant canopy (usually obtained by a step-point intercept) to obtain values for the site. This combination of techniques is often the fastest way to characterize a site. (3) For specific studies on

the community dynamics of soil crust organisms, a line-intercept transect is employed. The technique used is the same as that for vascular plants, but lines are generally much shorter, as this method is very time-consuming. The advantage to this method is that information is collected on the spatial distribution of ground covers.

Lichens and Mosses

Lichens and mosses should be recorded by species if possible, as the more detailed the information that is collected, the more can be determined about trends at the site. If the species is not known, there are several choices: (1) Record each different lichen and moss as a unique number, take a voucher from outside the plot, and have the species identified by an expert. (2) Record hits as either lichen or moss (mosses can be easily distinguished from lichens by moistening them: mosses will immediately turn green or brown, whereas lichens will not change color). This approach will give you information on nitrogen inputs (the black gelatinous lichens fix nitrogen) and carbon fixation (mosses fix more carbon per unit surface area than lichens). (3) Classify lichens into two classes: a) black gelatinous lichens that swell upon wetting, and b) plate lichens (black, brown, or colored, that don't swell with wetting); and classify mosses in two classes: a) short mosses or b) tall mosses (Eldridge and Rosentreter, 1999). This gives you information about nitrogen and carbon fixation, as well as effects on seed germination (tall mosses can prevent seed germination). If this latter option is chosen, these categories need to be carefully and clearly defined before the monitoring is started.

Cyanobacteria and Physical Crusts

Cyanobacterial crusts are divided into two classes, light and dark, which reflects the biomass of organisms in the surface soils. Soils with very low cyanobacterial biomass can be difficult to distinguish from soils with no cyanobacteria. If the soil surface looks bare, tap it lightly with a pin flag. If you do not penetrate the soil surface, or if the pin flag goes through the surface leaving a distinct hole, you have either a physical or biological soil crust. Pick up a small piece of surface soil and look for hanging fibers (fig. 57). If you do not see them, record this hit as a physical crust. If you see them, record this hit as light cyanobacteria. If you do not see them, you can either (1) record the hit as bare ground or physical crust or (2) collect the soil and analyze it for chlorophyll (see Measurement of Cyanobacterial Biomass and UV-protective Pigments). Dark cyanobacterial hits are recorded if the soil surface is darker than underlying soils and the soil is slightly roughened but no lichens or mosses are visible. If desired, the amount of cyanobacteria present can be determined by chlorophyll analysis.

Translucent rocks embedded in the soil surface almost always have hypolithic cyanobacteria and green algae living underneath them, unless the rock protrudes more than 3–5 cm into the soil. The presence of these organisms is indicated by a bright green band around the edge or along the bottom of the rock. These can be recorded as a separate cyanobacterial class if they are of interest.

Bare Soil

Bare soil is any loose soil not covered with any other identifiable ground covers. (This does not include soil that has a few loose sand grains on the surface, as other ground covers are generally present as well). Bare soil can also be subdivided into soils that have been disturbed by animals (bioturbation) and those that have been disturbed by other factors (for example, water). Soil that has been previously disturbed by an animal but is crusted together with cyanobacteria can also be recorded as bioturbation/cyanobacteria. It should be remembered that there is very little bare soil in the desert, except in washes that run frequently or in recently disturbed areas.

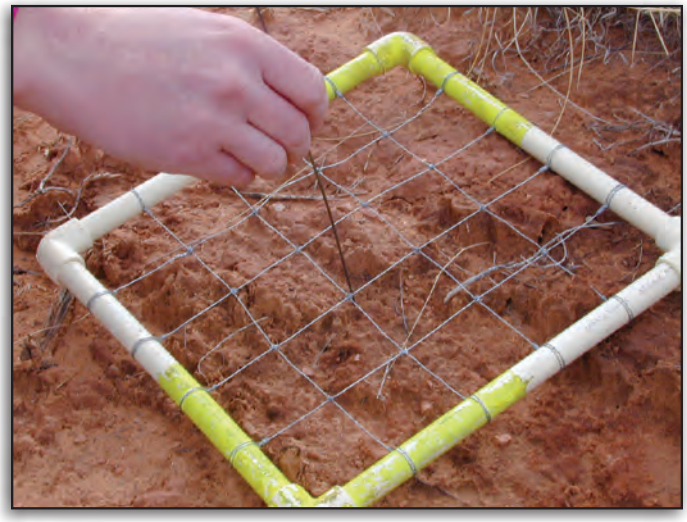

Figure 56. Removable frame for sampling cover of biological soil crusts (U.S. Geological Survey photograph by Jayne Belnap).

Figure 57. Cyanobacterial filaments hanging down from a piece of surface soil (U.S. Geological Survey photograph by Jayne Belnap).

Rocks

It is useful to classify rocks into size classes to provide information on their resistance to movement by wind and water. Small (1–5 mm at their largest diameter) are moveable by wind; medium (5–50 mm) and small rocks are moveable by water; and large (greater than 50 mm) are unlikely to be moved by physical forces other than debris flows. If interested in true cyanobacterial cover at a site, translucent rocks should be recorded as a separate category from other rocks.

Attached and Unattached

LitterThis category includes dead organic material (plant and animal) that is unattached to the soil surface, and thus easily moved by wind or water, and litter that is attached to the surface of the soil, such that no crust organisms live beneath it nor is it easily moved. Depending on the monitoring objectives, it is often best to distinguish between these two litter types.

Live Plant Base

Live plant bases are recorded whenever the pin flag hits where a live plant stem penetrates the soil surface, as they constitute ground cover.

Measurement of Cyanobacterial Biomass and UV-protective Pigments

Cyanobacterial biomass cannot be assessed in the field, but requires an estimate of chlorophyll *a* in the lab. To collect samples for this analysis, it is essential that all living or recently deceased plant material is avoided, as it often contains chlorophyll as well. Therefore, after carefully brushing away all plant litter, the top 5 mm of soil is collected using a paint scraper modified by bending the edges up so they are 5 mm high, or test tubes marked to indicate the proper insertion depth. Keeping the depth of collection constant is critical so that results can be expressed on a surface area basis and because some analyses (that is, high pressure liquid chromatography, or HPLC) are based on sample volume. Samples are taken randomly by throwing a small object in the general area to determine where the sample will be taken, or along a line transect at predesignated intervals. At each stop, the soil is carefully scooped up, again making certain to hold the depth constant. At least 25 subsamples should be taken to characterize a 50-m line. These can be composited to reduce variability and the number of samples needed. If composites are made, collect at least five subsamples into a single container and mix them thoroughly for consistency. One gram is needed for the chlorophyll analysis. Analysis is done using either a fluorimeter or HPLC after extraction with acetone (Karsten and Garcia-Pichel, 1996).

The advantage of HPLC analysis is that one also obtains measures of accessory pigments in the cyanobacteria, lichens and/or mosses. These UV-protective pigments are an excellent way to assess the physiological state of these organisms, as pigment production requires high amounts of water, carbon and sometimes nitrogen. When an organism is stressed, it must first allocate carbon and/or nitrogen to repair and maintain the structures needed for carbon and/or nitrogen fixation. Therefore, production of UV-protective pigments only occurs once these basic needs are met. However, these pigments are necessary to prevent damage and/or death, as UV exposure can quickly lead to severe damage or death (Bowker and others, 2002). Thus, higher pigment levels indicate favorable conditions (for example, wet cool conditions, fertilization by atmospheric nitrogen deposition). When lower UV pigments are detected, it indicates that the organism is under stress (for example, summers with long periods between rainfall; small, frequent rainfall events, disturbance). Typically, scytonemin, myxoxanthophyll, canthoxanthin, echinenone, and carotene are analyzed. Because pigment concentrations are sensitive to climate, a reference site must be used, unless it is the impact of climate change that is being monitored.

Other measures can also be made of soil crusts. These include nitrogen fixation and carbon fixation. Measuring nitrogen fixation requires expensive equipment and extensive expertise (see Nitrogen section). The same is true when measuring photosynthesis, respiration and/or the “health” of the photosynthetic machinery. These require a gas-exchange system, which measures changes in carbon dioxide concentrations in small specialized chambers, or a portable fluorimeter. For any of these measures, it needs to be decided whether to measure the potential of the organisms (done under optimal conditions in the lab) or actual levels of fixation in the field. Field measures need to be done repeatedly, as photosynthetic and nitrogen fixation rates vary widely with environmental conditions experienced by the organisms before and during the analyses.

Subsurface Soil Bacteria, Fungi, Protozoa, and Fauna

The analysis of soil biota is expensive. In addition, environmental conditions must be carefully controlled, unless a reference area is being used. If funds are limited but the monitoring of subsurface organisms is desired, previous studies have indicated that nematodes may be the most responsive to disturbance in deserts (Freckman and others, 1975; Mankau and others, 1973; Freckman and Mankau, 1986; J. Belnap, unpub. data).

If possible, it is best to collect samples for soil biota analysis at the same time as soils are collected for chemistry, and in the same way. Splits of the same soil can be sent for both types of analyses so that you also have data on soil nutrients as well as soil biota. In contrast to soil elemental analyses, however, soil food-web samples need to be bagged immediately in plastic to preserve the soil moisture, kept cool, and shipped overnight above ice (so they are cold, but not frozen). Identification of these organisms requires specialized

microscopes and expertise, and thus is generally done by a professional lab. Samples should be approximately 100 to 200 g (2 cups in volume) to analyze for active and total bacteria and fungi, protozoa, and nematodes.

Soil microarthropods are larger than other soil biota, and collecting them with a small soil corer will result in many organisms being damaged. Therefore, soil microarthropods are best collected with a trowel and with minimal soil disturbance or stirring. Samples are much larger than for other soil biota (about 1 kg), although 30 subsamples are still recommended per sample, with three to five samples per site. These samples, unlike those for microbial analysis, can be stored and shipped at room temperature, although they still need to be bagged to preserve soil moisture and shipped immediately. As with the smaller food web organisms, identification of these organisms is difficult and requires expertise (Moldenke, 1994). Invertebrates are generally identified to the family, genera or functional group level, as identification to species is extremely difficult.

Enyzmes

There are many enzymes secreted by soil biota that can be assayed in soils, with the most common being seven glycosidases, nine aminopeptidases and three aminohydrolases, as well as alkaline phosphatase, sulfatase, acetyl esterase, phenol oxidase, and peroxidase. These enzymes break down lignin, cellulose, and proteins. Therefore, which enzymes are assayed for depends on the monitoring question, and an expert in this field should be consulted. Aminopeptidase, aminohydrolase and peroxidase levels are high in desert soils, and thus are often measured. Potential enzyme activity should be assayed at the ambient soil pH, and rates calculated per gram of soil organic matter or per gram of soil. While soils are easily collected by resource staff, extractions and analyses need to be done by qualified personnel, using a spectrophotometer and fluorimeter in the laboratory.

Decomposition

Above-ground Decomposition

In deserts, the main drivers of above-ground decomposition are abiotic (UV, wind), and thus are generally outside the control of land managers. This, combined with the difficulty of measuring this variable, has meant that above-ground decomposition rates are seldom included in a monitoring program. However, if this measure is desired, native plant material should be placed on top of the ground (either a known weight or complete coverage of a known surface area) in a bag that has a wide-gap mesh on top (for example, plastic bird netting) and a smaller mesh (< 5 mm) on the bottom. The top mesh layer prevents material from being lost through wind or water, and the bottom layer facilitates picking up the litter for reweighing, and the large gaps do not prevent animal access. Disappearance of above-ground litter can be a good measure of termite, beetle, or ant activity, all of which can be disrupted by human-related disturbance. To prevent loss by UV, which can account for up to 85 percent of above-ground decomposition in deserts (Whitford, 2002), the plant material also should be shaded, unless loss by UV is to be measured. Loss rates can then be assessed annually by reweighing.

Below-ground Decomposition

In contrast to above-ground decomposition, below-ground decomposition is biotically controlled and can be easily disrupted by disturbance. In addition, it is much more straightforward to measure. There are three main methods: decomposition cloths, wooden strips, or litter bags. Decomposition cloths (fig. 58) are cotton cloths of a standard thread/in^2 construction. These ~100 mm-wide strips have been used to measure relative decomposition rates in ecosystems around the world (Harrison and others, 1988). Generally, three replicate strips are carefully inserted into the ground, making certain to keep them unwrinkled, to the desired depth (generally 20–30 cm). Cloths are replaced monthly or bimonthly, depending on loss rates. After collection, cloths are cut into pieces spanning the soil depths of interest (such as 0–5 cm, 5–10 cm, 10–15 cm, 15–20 cm). These are then placed in a tensiometer that measures the strength of the cloth, as greater decomposition results in lower cloth strength. Tensiometers can be found in universities with textile departments. Similarly, wood strips (tongue depressors, toothpicks, balsa wood strips) are weighed, inserted into the ground and reweighed after a specified amount of time. These are best used in very rocky soils where decomposition cloths cannot be used. All these methods have the advantages of not restricting access by any soil fauna. However, as with any such method, they represent a concentration of resources not otherwise found in desert soils. Thus, they may attract a higher concentration of organisms than is generally found in these soils, and lead to an over estimation of decomposition rates. They are excellent in establishing the time of year when decomposition is most active. This information can be used to design sampling protocols if soil food webs are going to be measured. In addition, the cotton or wood strips can be placed in bags with mesh sizes to restrict or allow access by different types of organisms (for example, microbes versus small soil fauna [mites] versus large fauna [termites]). In this way, one can determine the degree to which the different types of organisms influence decomposition rates. Fumigated cloths can also be used to restrict microbial populations.

Litter bags are mesh bags filled with litter and/or plant roots collected on-site (Wardle and Lavelle, 1997). Green plant material is collected, dried, weighed, and placed in the bags. As with the cotton strips, different mesh sizes can be used to exclude or allow access by organisms of interest to determine levels of consumption by the different functional groups. Five to ten bags are buried at each of the desired depths (for example, 5 and 15 cm) under a plant canopy or in the plant interspaces. Bags are weighed and replaced every 6 to 12 months, depending on loss rates. Litter bags can be problem-

atic in deserts, as they increase the time litter is moist, thus causing overestimation of decomposition rates. They require disturbance to insert, and can also restrict access by soil fauna in undesirable ways, thus causing underestimation of decomposition rates.

Arthropods

Entomologists first implemented the use of pitfall trapping of animals in an attempt to secure samples of insects (Greenslade, 1964). Pitfall traps can be constructed using any cans; at the Nevada Test site, "cement test cans" with a steel insert were used. A 1-cm lip made sample removal easy, as did removable bottoms. The can is buried in the soil to the rim and covered with a lid when inactive. When the trap is set, the lid can just be removed, or set up on legs to create shade and thus attract the arthropods (Turner and Medica, 1977). The cans are placed in a grid within replicated study plots (for example, four 8.5-ha study plots with 400 pitfall traps in a 15-m grid pattern each). Pitfall traps can also capture a sizable number of lizards and small snakes, who may eat some of the captured invertebrates. Thus, the traps need to be actively emptied.

A set of standardized protocols is being used on a global basis to inventory and analyze ant communities. This set is called the Ants of the Leaf Litter (ALL) protocol (Agosti and Alonso, 2000; Alonso and Agosti, 2000). The ALL protocol uses three methods: (1) pitfall trap arrays, (2) leaf litter sampling on standardized plots, and (3) general collecting throughout sampling sites. The pitfall traps are similar to those described above: cans, buried in the ground, in a grid pattern. The part of the protocol using leaf litter has limited applicability in the Mojave Desert, as leaf litter is fairly rare in many vegetation communities. Therefore, we suggest using the relevant portions of this protocol in habitats with significant leaf litter and adding bait stations to the protocol for the remainder of the desert. The results of standardized protocols can be used in comparison with data from other sites where the ALL protocol is used. In addition to the ALL protocol, we suggest using bait stations to provide additional information on the dominance of ant species at sampling sites.

Reptiles

Techniques for Monitoring Reptiles

Monitoring of Mojave Desert populations of reptiles is of significant importance to both the Federal and state land management agencies, as well as state wildlife agencies. The U.S. Fish and Wildlife Service is mandated to monitor the status of the Mojave Desert population of the desert tortoise (*Gopherus agassizii*), the largest reptile that inhabits the Mojave Desert, as it is listed as threatened north and west of the Colorado River (U.S. Fish and Wildlife Service, 1994; Tracy and others, 2003). Some reptilian species are short lived (1–2 years for side-blotched lizard [*Uta stansburiana*]; Turner and others, 1970), and their population fluctuations mirror short-term environmental changes. Other species, such as leopard lizards (*Gambelii wislizenii*) and horned lizards (*Phrynosoma platyrhinos*), can live 8 to 10 yrs (Medica and Turner, 1984), and their behavior and population dynamics vary greatly from year to year in both activity and reproductive potential. Reptiles have demonstrated potential as indicators of environmental stress and disturbance (Medica, 1992; Medica and others, 1994), and may play an important role in future habitat monitoring as indicators of environmental health.

Monitoring Mojave Desert populations of reptiles can be accomplished through a number of sampling techniques, varying from measures of relative abundance to detailed population enumeration using mark-recapture methods. The type of information desired defines the intensity of the methodology required and the stringency with which the data is collected. Abundances of lizards and snakes can vary dramatically by year, season, month, week, or even day, depending upon the climatic conditions that exist at the time of sampling. Such variation needs to be accounted for in the planning and design of a sampling program.

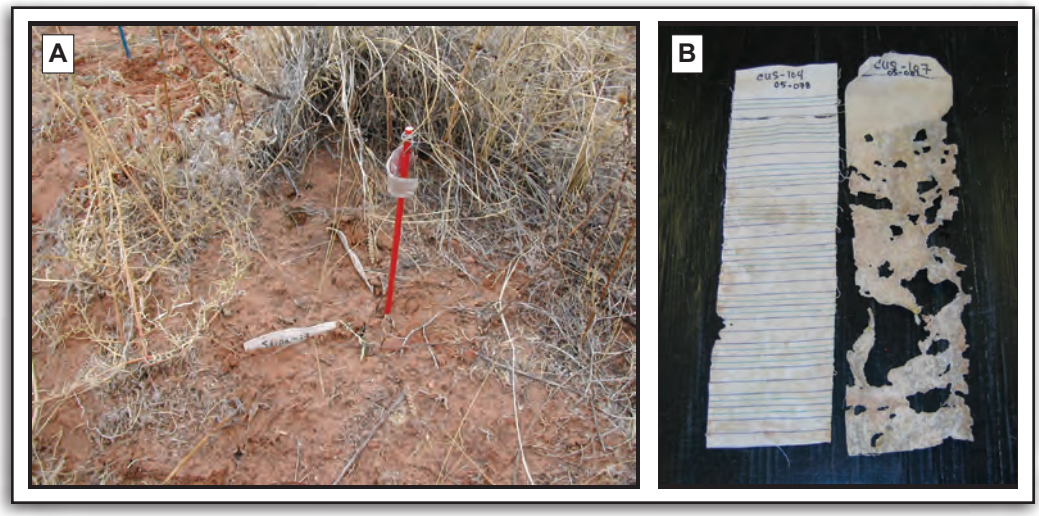

Figure 58. Decomposition cloths for measuring decomposition rates. A, Installation of a decomposition cloth. B, Examples of extracted decomposition cloth. The cloth on the left has had little decomposition compared to the one on the right (U.S. Geological Survey photographs by Jayne Belnap).

Much of the methodology for assessing populations of reptiles comes from extensive studies in Rock Valley reported by Turner (1977), and elsewhere on the Nevada Test Site (Medica, 1992; Medica and others, 1994; Woodward, 1995). Reptilian sampling can be divided into several sampling methodologies, which can vary by taxa. The following discussion describes the various trapping methods and sampling techniques that have been used successfully within the Mojave Desert. All have occurred within permanent 9-ha fenced plots that have been gridded so that animal locations can be mapped. When more than simple indices of relative abundance or species richness are attempted using transect data, adequate tests using the line-distance sampling technique need to be tested. It is necessary to use known densities of lizards in enclosed populations to evaluate and calibrate the technique, and to determine the ability to inventory all observed specimens in order to estimate density.

Night-driving Surveys

Sampling snake populations by driving at night on paved roads for a specified distance in the arid southwest habitats was popularized by Klauber (1939). Night-driving surveys continue to be a viable methodology for determining species distribution, occurrence, and relative abundance in various habitats. Mendelson and Jennings (1992) used night-driving techniques to evaluate changes in relative abundance in a desert grassland community over a 30-year period. Little else has been done to evaluate snake species composition changes using this technique. Seasonal variation in snake abundance following rainfall periods has been documented by Reynolds (1982). Night driving has proven to be a successful technique for conducting mark-recapture studies of the nocturnal western banded gecko (*Coleonyx vigilis*), and the desert night lizard, (*Xantusia vigilis;* B.D. Hardenbrook and P.A. Medica, pers. observation).

Pitfall Traps and Drift Fences

In the early 1950s, Fitch (1982) sampled populations of amphibians and reptiles using pitfall traps at the Kansas Natural History Reserve. In the early 1960s, several research projects were initiated at the Nevada Test Site using arrays of pitfall traps—one by Brigham Young University and the University of California Laboratory of Nuclear Medicine and Radiation Biology (UCLA/LNRB) in conjunction with the Federal Government's nuclear testing program "Sedan" (Allred and others, 1963). An additional research project was initiated in Rock Valley between 1962 and 1964 by UCLA/LNRB to evaluate the effects of gamma irradiation on natural populations of plants and animals (French, 1964). Using these techniques, pitfall traps are placed in a grid pattern within replicated permanent plots (in Rock Valley, the same traps for arthropods were also used for reptiles). Traps should be run daily to insure that no mortality occurs. Larger snakes and lizards might easily escape these traps, although occasionally can be found in the traps (for example, gopher snake [*Pituophis melanoleucus*], sidewinder [*Crotalus cerastes*] and long-nosed leopard lizard [*Gambelia wislizenii*]). The nocturnal lizard desert banded gecko (*Coleonyx variegatus*) can also be caught using pitfall traps; however, efforts to recapture marked individuals has proven to be difficult.

Drift fences, in combination with pitfall traps, have become increasingly more successful in capturing reptiles in more mesic habitats, as was proven in Kansas (Fitch, 1982). More recently, this method has proven to be highly successful in coastal southern California (R. Fisher, oral commun.) and has been used with a moderate degree of success in the Mojave Desert at Fort Irwin (Morafka, 1993) and Twentynine Palms (Hirsch and others, 2002). The physical characterization of pitfall trapping and drift fence arrays are numerous and well illustrated for assessing: (1) amphibians (Corn, 1994); (2) lizards, snakes, and small mammals (Hirsch and others, 2002); (3) lizards and small snakes (Medica and others, 1971); and (4) amphibians and reptiles (Campbell and Christman, 1982; Vogt and Hine, 1982; Corn and Bury, 1990). The pitfall-trap/drift-fence technique is an excellent way to document species diversity from one place to another or one habitat type to another. This method can provide evidence of rare or relatively uncommon species, which may possibly be more numerous than cursory sampling might indicate. In order to understand patterns in trapping success, species richness, and relative abundance, environmental conditions during the sampling should be recorded, as these conditions can cause species and numbers to vary greatly. During a drought year (1970) drift fence trapping for snakes in Rock Valley was unsuccessful (P.A. Medica, pers. observation). Relative abundance provided by pitfall trap/drift fence sampling should not be construed as density. Population densities are more accurately estimated by mark-recapture sampling techniques.

Mark-recapture

An excellent summary of population estimation techniques was given by White and others (1982), who stated that "interest in estimating the size of populations has had a long history. The crudest methods date back at least at the 17th century and probably long before that." The basic premise to all mark-recapture sampling techniques is based upon the initial assumption that there are no births, deaths, immigration, or emigration, and thus there exists a "closed population." For the most part this basic premise is violated by most researchers' experimental design, which results in high variance when statistical rigor is applied to the data.

The most efficacious method for capturing lizards in mark-recapture studies is by noosing species in the genera *Uta, Urosaurus, Uma, Aspidoscelis* (= *Cnemidophorus*), *Callisaurus, Dipsosaurus, Sceloperus, Gambelia,* and *Crotaphytus*. Horned lizards (*Phrynosoma*) are easily captured by hand, and geckos (*Coleonyx*) and night lizards (*Xantusia*) either by evening road collecting or pitfall traps. A cautionary note about *Coleonyx*—the ability to recapture individuals using pitfall traps without drift fences can be very low (P.A. Medica, pers. observation).

In the Mojave Desert, the classical study of desert tortoises conducted by Woodbury and Hardy (1948) on the Beaver Dam Slope of southern Utah used branding techniques to permanently mark individuals. Notching of marginal scutes, the placement of epoxied numbers written on card stock attached to depressions in costal scutes, painted numbers or dots to signify individual animals, and the use of PIT tags (Passive Integrated Transponders) all have been used to identify desert tortoises. Additional marking techniques for other reptiles include: toe clipping; painting patterns or numbers on the body or base of the tail of lizards; clipping the ventral caudal or abdominal scutes on snakes; and placement of a PIT tag under the skin, into muscle or into the abdominal cavity of all reptiles. If individual recognition is necessary, individually distinct numbers or patterns have been used in order to expedite sampling after the initial permanent marking phase is completed.

When considering studying Mojave Desert saurian populations, the mark-recapture technique works well. The standard technique has been toe-clipping. Numbering front foot toes left to right in the order of 1, 9, 4, 7, and 2 provides the capability of numbering every numeral in between by clipping toes that are never adjacent to each other, and no more than two toes per foot (fig. 59). The long toe on each hind foot was specifically given the number 900 or 9,000; we normally avoided clipping these long toes (Medica and others, 1971; Hunter and Medica, 1989). The numbering system designated the right rear foot in the thousands, the left rear foot in the hundreds, the right front foot in the tens, and the left front foot in ones.

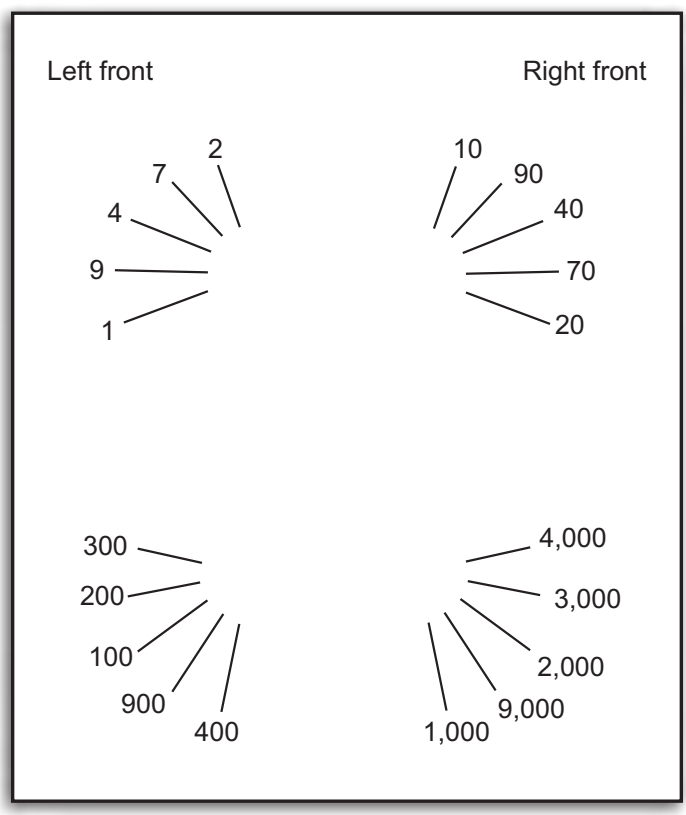

Figure 59. Lizard toe numbering system (Medica and others, 1971).

Considerations for Specific Species

Side-blotched Lizards

Side-blotched lizards (*Uta stansburiana*) have been sampled in a manner similar to that described by Tinkle (1967). Two to four people walk back and forth systematically within a defined study area. When a lizard is observed, a numbered marker is dropped at the location and the lizard is noosed (over 95 percent of adult side-blotched lizards are successfully noosed). After capture, the lizards are placed in numbered plastic vials. The location, vial number, and marker number are recorded so that the lizard can later be returned to the spot where it was captured. Then the vial with the lizard inside is placed upside down in a sack containing 20 such vials. Empty vials are placed with the lid facing upward. Sampling continues until the entire plot has been searched. All side-blotched lizards are weighed to the nearest 0.01 g, measured to the nearest mm, palpated to determine reproductive status (whether they possess eggs or yolk follicles and the size and number), toe-clipped if not already marked, and painted with a distinctive paint pattern for easy recognition in subsequent sampling periods. After all of the lizards have been processed they are released at the point of capture and the numbered markers retrieved.

Sampling should be done for one week during each of the months of March and April. The spring density (as of March 1) is taken as the total roster of all different individuals registered. Densities of side-blotched lizards can also be effectively estimated indirectly by capture-recapture analysis, assuming that a chain of four or five consecutive samples is utilized (Turner and others, 1970).

As would be expected, the percentage of the total population enumerated over a period of time increases rapidly at first, and then declines as more individuals are registered. With stable weather conditions and uniform sampling effort, the percentage of the side-blotched lizard population (P) can be approximated by the following equation:

$$P = 1 - e^{-ßt}, \qquad (2)$$

where t is the number of samples and ß an exponent depending on the number of workers involved and the local environment. When four people were working four 1.44-ha plots in Rock Valley in 1970, ß was estimated at about 0.65. The majority of *Uta* in Nevada rarely survive beyond three years with approximately 70 percent of the population replaced annually (Turner and others, 1970). The maximal life span of side-blotched lizards in Rock Valley is about 58 months (Medica and Turner, 1984).

Juvenile lizards should be inventoried and marked during the months of July and August, using pitfall traps in combi-

nation with noosing. Each week, the hatchlings captured are painted with a different colored tail dot. If a painted hatchling is seen, the location is recorded. The goal is to enumerate as many hatchlings as possible so that survivorship can be determined the following spring. Survivorship has been estimated simply as the fraction of the total number of juveniles marked in July and August recovered during the ensuing spring. In Rock Valley, juvenile survival was estimated as 0.24 from 1966 through 1967, whereas from 1967 through 1968 survival was 0.192 (Turner and others, 1970).

Whiptail Lizards

Density of whiptail lizards (*Cnemidophorus* = *Aspidoscelis tigris*) can be estimated using mark-recapture techniques. The period of above-ground activity of adult whiptail lizards is generally compressed into about four months (late April to early August; Turner and others, 1969b). Not all animals are active throughout this period. Females generally become active a few weeks later in the season than males, there is a dilution effect as the season advances, and not all of the population is active at any one time (Tanner and Jorgensen, 1963). Therefore, most estimation work for this species should take place during May and June, although records should be accumulated throughout the summer as opportunities arise. In general, whiptail lizards are distributed fairly evenly, and thus the best survey technique is to have people walking grid lines from 7.5 to 15 m apart. When a whiptail is seen, all searchers converge on the animal and the lizard is noosed. Processing the animals is similar to that of side-blotched lizards, except that larger plastic vials are used to hold the animals in the field. The paint patterns are also different—whiptail lizards are painted with rings at the base of the tail instead of dorsal body patterns. The rings are painted on the dorsal and lateral sides of the tail and are visible from the side. Rings are painted in sets of three colors. The most proximal ring indicates sex; males are either white or blue, females are either pink or yellow. Using the above four colors, plus green, there are 25 possible combinations, totaling 100 possible patterns. Green is used as the proximal color when all of the 100 other patterns have been used, and can denote either sex. The more distal rings may be any combination of colors, which will distinguish individuals. Lizards painted in this manner are generally recognizable for 3 to 4 weeks.

Spring densities have been most successfully estimated by capture-recapture analysis (Turner and others, 1969b). The most reliable approach for density estimations is to consider any animals registered in a given year (except the young-of-the-year marked in August and September) as a single cohort. All individuals registered in the ensuing year (except for one-year-olds and young-of-the-year) constitute the second sample (n), and recaptures (r) are simply those animals originally registered the previous year. Each pair of consecutive years is analyzed separately, and the capture-recapture history of each individual assessed independently of events in any but the two years in question. This procedure may seem cumbersome, but it is more reliable than capture analyses based on short-term samples.

Spring densities can also be done by direct enumeration when the area being censused is fenced and the registry for a given year is predicated on data available from that year as well as several subsequent years. Such minimum registries have always been less than the corresponding capture-recapture estimates. In the absence of these conditions, capture-recapture analyses of the sort described above would be more reliable.

Simple counts, or counts along line transects (Degenhardt, 1966; Pianka 1970) are inadequate measures of true density. In fact, because of day-to-day variations in success, such counts are probably not safe estimators of relative abundance. In Rock Valley, four people, walking at an interval of 7.5 m within a fenced 9-ha plot, detected only about 1/3 of the marked whiptail lizard population (Medica and others, 1971). There can be 5- to 10-fold differences in success at different times, even though the observers are following essentially the same procedures.

Leopard and Horned Lizards

Collections of leopard lizards (*Gambelia wislizenii*) and horned lizards (*Phrynosoma platyrhinos*) are made at all times of the spring and summer as opportunities arise. Paint patterns used are similar to those used with side-blotched lizards, whereas all other procedures are similar to those employed with whiptail lizards. Minimal spring densities of leopard lizards and horned lizards have been determined by direct enumeration, in a manner similar to that employed with whiptails (Turner and others, 1969b; Medica and others, 1973).

Desert Tortoise

Desert tortoises are generally marked by notching the shell with a three-cornered file, and populations followed using mark-recapture. When conducted on a long-term basis, trends in density of desert tortoise can be documented, although determining the cause of population fluctuations over long periods of time becomes problematic. With study plots that are unfenced, the statistical analysis of the traditional 30-day initial marking period with a 30-day recapture period within 1-mi^2 plots results in a large error. Attempts have been made to reduce the variance in population estimation by making plots smaller (for example, 1 km^2 or 1 ha^2) as was recommended by the U.S. Fish and Wildlife Service recovery plan (1994), thus increasing the ability to sample plots in a shorter period of time. Reducing the interval between the marking phase and the recapture phase when sampling desert tortoises also greatly reduces the possibility of immigration and emigration, and also achieves closer to 100 percent coverage of the plot. Subsequently, researchers have experimented with combinations of line-distance transects and 1-ha^2 plots in an attempt to develop methodology for range-wide desert tortoise monitoring (P.S. Corn and P.A. Medica, unpub. data).

In 2001, the U.S. Fish and Wildlife Service initiated range-wide monitoring using the line-distance sampling technique developed by Buckland and others (1993) and field tested in Nevada by Anderson and others (2001). With this technique, individuals walk a line of known distance and observe tortoises along that line. When a tortoise is observed, the perpendicular distance from the line to the object is measured. The technique requires that all tortoises intersected by the line are observed and counted. With desert tortoises, it is also important to get an estimate of those individuals that are not above ground. This sampling methodology shall hopefully enable researchers to monitor the population trends over time by developing baseline population density estimates and reducing the variance error in sampling. Subsequently, monitoring desert tortoise populations may occur at 3- to 5-year intervals, once the baseline has been determined. Definitive techniques used in desert tortoise line-distance sampling evolved between 2001 and 2003 and appear in a final report that summarizes the range-wide sampling conducted throughout the Mojave Desert by the U.S. Fish and Wildlife Service (2006).

Small Mammals

Techniques for monitoring small-mammal populations within desert habitat have evolved greatly over the course of the past century. Early studies in southwestern North America on kangaroo rats (*Dipodomys* spp.; Vorhies and Taylor, 1922) and pack rats (*Neotoma* spp.; Vorhies and Taylor, 1940) pertained to the economic impacts of rodents upon food reserves and grazing. Collections for voucher specimens normally were conducted using snap traps and the traplines run early in the morning to retrieve specimens (Grinnell, 1937; Hall, 1946, 1962). Since that time, many sampling techniques, with variations in trapping arrays to account for species distributions, movements, population dynamics, and habitat preferences, have been developed. The objectives of small-mammal monitoring need to be well defined before deciding upon a sampling technique (Wilson and others, 1996). Choosing the proper trapping array, as well as the type of trap, needed for each species of rodent can be very important. For example, trapping whitetail antelope squirrels (*Ammospermophilus leucurus*) during mid-day requires open mesh traps with shaded covers to minimize temperature stress. Based upon sampling conducted in southern Nevada, the best time to sample for small mammals is generally spring and early summer (late April-early June), if the goal is to obtain the greatest number of species and the spring density of adult animals. The season in which sampling occurs is important, based upon the ecology of the species being sampled (for example, if trapping is conducted too early in the spring when nighttime temperatures are low, few little pocket mice [*Perognathus longimembris*] will be captured). Likewise, in some portions of southern Nevada, Ord kangaroo rats (*Dipodomys ordii*) appear to be more susceptible to trapping in fall rather than in spring and summer—whether this characteristic is more than a localized occurrence is not well documented. If much variation in elevation enters into the sampling scheme, then lower elevation sites should be trapped first. Many of the specific details with illustrations for marking and monitoring small mammal populations are described in great detail in Wilson and others (1996). Additionally, the American Society of Mammalogists (Gannon and others, 2007) has revised their guidelines for the use of wild mammals in research.

Snap Traps

Snap traps are often best for studies of species composition and richness, as well as knowledge of species distribution (Sedivec and Whidden, 2007). Use of these traps is particularly important when closer examination of the mammal is required, such as in studies of food habits where stomach contents are analyzed or studies of the age structure of a population as determined by examining the curvature of the eye lens. If destructive collection is necessary and voucher museum specimens are to be preserved, tissues from internal organs can be frozen (for example, liver, heart or kidney for DNA analysis; Riddle and Honeycutt, 1990; Yates, 1996). If collection of internal tissue is unnecessary, live-trapping methods are preferred. Genetic samples can be collected from ear and/or toe clippings (Dubach, 1986) and/or blood samples from the suborbital sinus (Mech and Hallett, 2001).

Live Traps for Nocturnal Small Mammals

Live trapping techniques vary widely, depending on the questions being asked and the number of traps and personnel available. Trapping needs to occur for a minimum of three consecutive nights (French and others, 1974). French (1964) estimated that 81 percent of the small-mammal population is captured on the first night, 13 percent more on the second night, and 5 percent on the third night. No more than 2 percent remained untrapped after three consecutive nights of trapping, although this can vary among sites.

Sherman live traps (7.6 × 8.9 × 30.5 cm) are used for the capture of small mammals. Trap stations are placed either in a grid (for example, a 12 × 12-m grid at 15-m intervals with two traps per station is standard) or along a line, again with two traps per station (O'Farrell and others, 1977). Traps are typically baited in late afternoon with a combination of rolled oats and bird seed, and remain baited until shortly after sunrise on the succeeding morning. Traps are typically oriented north-south and placed under a sheet metal (half-round) trap cover to prevent overheating by direct sunlight, or placed on the west side of shrubs when set in the late afternoon if trap covers are not used. The trap covers can prolong the time allowed to service the traps in the early morning by an hour or more in the event that a large number of animals are captured.

Many variations in the standard grid design have subsequently been developed in order to refine the ability to

estimate density or to recapture all animals known or believed to occur on a designated plot. For example, the monitoring of small mammals in adjacent burned and unburned areas has been done using a 6 × 6-m staked grid with trap stations at 15-m intervals (total area sampled 0.56 ha^2). Two live traps with trap covers were placed at each staked location. A second method was also tried: four transect lines, spaced 15 m apart, extended 225 m into both the burned and unburned habitats. The total area sampled, using live trapping, was 1.44 ha^2. Two live traps and trap covers were placed at each of 32 stations per line (16 stations in each of the burned and unburned habitats). A comprehensive comparison and analysis of sampling procedures was published by White and others (1982) and Kendall and Pollock (2001).

Handling and Marking Small Mammals

Many small mammals are capable of inflicting a painful bite. Depending upon the experience of the handler, emptying traps can become problematic. Thus, wearing cloth gardening gloves is recommended, as they give the handler an ability to grasp animals gently while still affording adequate control and protection. Some mammalogists prefer to use a plastic bag to empty the trap into and subsequently capture the animal, while others do not. Some biologists simply insert 3 to 4 fingers into the trap and force the rodent into the palm of their hand and then grab it and pull it out of the trap in one smooth motion.

For monitoring individuals, such as in mark-recapture studies, each mammal is permanently marked using either numbered ear tags, clipped toes, or PIT tags that can be inserted subcutaneously. However, because ear tags may fall out or be torn from the ears, marking by toe clipping or PIT tagging are the preferred methods. No more than one toe should be clipped per foot. If the study is short-term (that is, 3 to 4 days in duration), marking a longitudinal stripe on the belly hair using indelible markers with different colors each day has worked well (P.A. Medica and T.C. Esque, pers. observation). After capture and marking, sex, reproductive condition, and grid location are recorded. Each animal is then weighed to the nearest gram using a Pesola spring scale, which weighs to 300 g. Scales with the capacity to weigh animals in the 5 to 10 kg range should be kept handy in the event that mammals, such as squirrels, chipmunks, rabbits, or weasels, are captured. Densities are estimated using the formula developed by Seber (1973).

Special Considerations for Diurnal Species

Ground Squirrels and Antelope Squirrels

Ground squirrels occur in most major habitats in the Mojave Desert. At the lower elevations, the whitetail antelope squirrel (*Ammospermophilus leucurus*) and the roundtail ground squirrel (*Spermophilus tereticaudus*) are locally abundant. At higher elevations, the rock squirrel (*Spermophilus variegatus*) and the cliff chipmunk (*Eutamias dorsalis*) are present. Squirrel trapping on permanent plots should be conducted at least once a year (preferably in the spring) to determine the size and age distribution of the population. The "Tomahawk" live trap #102 (12.7 × 12.7 × 40.6 cm), constructed of wire fabric with a single door at one end, is the most effective. Traps should be opened in early morning (about 8:00 AM) and should remain open until late afternoon (about 4:00 PM), or possibly later, depending upon the activity of the species being sought. Traps should be checked at one- or two-hour intervals throughout the day and closed after 4:00 PM, or at the end of the sampling period, until the next morning. Trap shades constructed of 30.48 × 30.38 × 0.48 cm masonite should be used to block the sun and positioned appropriately, as the position of the sun changes throughout the day. This will insure that animals do not perish from exposure to direct sunlight, especially at mid-day.

Squirrels can be toe-clipped, as described for nocturnal small mammals, or PIT tagged (Schooley and others, 1993). Captured animals should be sexed, aged, and weighed, and released at the point of capture. Density estimates can be analyzed using the same methods described above and densities with statistical limits determined.

Jackrabbits and Desert Cottontail Sampling

Numerous methods have been used to estimate the density of jackrabbits (*Lepus californicus*) and cottontails (*Sylvilagus audubonii*). Pellet group counts, using quadrats, is not an effective method (W.H. Conley, oral commun.). Hunter (1987) has shown that jackrabbits make special use of disturbed sites in dry weather and might repopulate larger areas during favorable (for example, wetter) seasons. In late summer or early fall, transect lines walked by one or two observers are effective for surveying rabbits. As described by Whitford (1973), observers walk a predetermined distance; when a rabbit is noted, the distance and direction of the rabbit from the observers is estimated and recorded.

Landscape and Regional Scale Monitoring

Ground measurement of permanent vegetation plots surpasses any type of imaging in accuracy, but necessarily has limited spatial scope. Therefore, many monitoring programs utilize some type of imagery to document changes at the landscape or regional scale. Repeat photography has been used worldwide to document and analyze changes in landscapes (Rodgers and others, 1984). More than 500 studies show repeat photography is an excellent means of documenting many aspects of long-term ecological and landscape change and complements other techniques (fig. 60). Aerial photography has been used to study landscape changes since it first became available in the late 1920s. However, it does not cover earlier times when many of the changes began, and its resolution generally does not allow assessment of changes in species composition. High altitude airplanes can provide imagery with high spectral resolution but low spatial resolution. Multi-

spectral satellite imagery is an excellent way to monitor and evaluate ecosystem change, as it provides widespread spatial coverage and collects visible and non-visible spectral data. However, it can provide only limited information on changes in species composition and is only available after 1974.

Repeat Ground-based Oblique Photography

Methods and Equipment Used for Repeat Photography

Proper interpretation and analysis of repeat photography requires an understanding of the equipment and film that the original photographers used and then employing comparable equipment to take the photo match. During and since the period encompassed by the original photography used in many studies, both cameras and film have radically evolved. Pioneer photographers invariably used large-format cameras (100 × 125 mm images or larger), some capable of taking images as large as 180 × 356 mm on glass plates designed for stereographic images on 203 × 254 mm media. Before about the turn of the 20th century, lenses did not have shutters; to expose the negative, the lens cap was removed and then replaced after a timed period. Later photographers used medium-format cameras (60 × 70 mm, or slightly larger images) equipped with flexible roll film. Cameras using the 35-mm film format gradually gained favor with photographers in the middle of the 20th century. The result is a large variation in the resolution of the original images, as well as differences in the captured visible spectrum.

The first useful images of the southwestern United States were on glass-plate negatives. This medium, which was unwieldy and fragile, nonetheless created images with high detail and minimal distortion. Flexible, translucent roll film was developed in 1889 to lower the weight of negatives as well as to provide a medium for creating enlargements. Whether glass plates or roll film was used, the photographic media was orthochromatic, and these blue-sensitive emulsions, when properly exposed for typical landscapes, severely over-exposed the sky. As a result, the images look significantly different from modern panchromatic black-and-white films.

By the early 20th century, cameras became smaller as films gained resolution and reliability. Most photographers from this time period used medium- and large-format cameras, usually with a film size of no larger than 100 × 125 mm. The earliest films were cellulose-nitrate based, a flammable substance that created a fire hazard for tightly rolled films. Photographic manufacturers started to replace nitrate film with cellulose acetate film in the 1920s. Color film was introduced in the 1920s, although the first color films were unstable and faded; development of Kodachrome films in the mid-20th century provided a stable and archival color film, if stored properly. Polyester-based films, introduced in the 1960s, are the predominant type in use today.

To replicate historical views, we recommend the use of medium-format (60 × 90 mm) and large-format (100 × 125 mm, aka 4 × 5) cameras, equipped with a variety of lenses. These formats provide higher film resolution than typical 35-mm camera systems and are more comparable with historical cameras. Most medium-format cameras use roll film, which makes them very convenient, whereas large format cameras use 100 × 125 mm sheet film. We suggest that each replicated view be documented with black-and-white negative, color positive, and color negative films. Filters, typically Wratten Yellow 8, may be used with black-and-white film as a haze filter to increase contrast and bring out background scenery. Color film, not used by most of the original photographers, primarily adds current information for future interpretation of changes. Film should be stored in acid-free media in an environment with controlled temperature and humidity.

At present, digital cameras may be a potential replacement for film cameras. Digital photography offers several advantages, including no cost for film, immediate evaluation of composition and lighting, and the potential for immediate printing of the match view for in-field analysis. On the other hand, digital photography cannot be considered to be archival at the present time, owing to lack of archival digital media—CDs may only have a reasonable life-expectancy of decades—and the likelihood of technology transfer to a different medium in the future. High-quality digital cameras currently equal the resolution of a good 35-mm camera, and will undoubtedly soon equal the quality of a medium- and large-format film camera. Large format digital cameras are currently expensive and not a reasonable alternative to film, but digital camera technology is rapidly evolving and will likely become a viable option in the future.

Repeat photography offers some technical difficulties in closely occupying the original camera position, making an acceptable match, and then assessing changes (Rodgers and others, 1984). In the field, it is essential to relocate the original camera position as accurately as possible. Sometimes this is difficult owing to landscape changes, obstruction of the view by vegetation growth, lack of background features, or loss of the original camera station due to road or other construction. When possible, duplication of lighting, shadows, and condition of perennial vegetation as depicted in the original photograph is desirable; however, logistics of repeat photography for many sites are not amenable to even duplication of the original seasons for many photographs, although this usually is not a major limitation. Camera stations are documented using hand-held global-positioning-system devices (latitude, longitude, elevation, and estimated position error), the geometry of the view (camera height, azimuth, and tilt), the camera settings (shutter speed, f-stop, and film type; Hall, 2002a, 2002b), and date and time. It is also useful to record general atmospheric conditions (hazy, cloudy, etc.).

Sources of Historical Photography

Historical photographs can be obtained from many archives and private individuals. The following archives are particularly good sources of historical photographs of the Mojave Desert: the Bancroft Library, University of California

at Berkeley; the Arizona Historical Society, Tucson; Special Collections and the Homer Shantz Collection, University of Arizona, Tucson; Cline Library, Special Collections and Archives, Northern Arizona University, Flagstaff; the Museum of Vertebrate Ecology, University of California at Berkeley; the National Geographic Society, Washington, D.C.; the Southwest Museum in Los Angeles; the Marriott Library, University of Utah, Salt Lake City; the Huntington Library, San Marino. Table 4 lists Web sites and archives where historical photography of the Mojave Desert can be obtained.

Several Federal government archives have extensive photographic archives. These include the U.S. Geological Survey (USGS) Photographic Library in Denver, Colorado; the National Archives and Records Administration in College Park, Maryland; the Bureau of Land Management; and the National Park Service Historic Graphic Collection, Harpers Ferry Center, Harpers Ferry, West Virginia.

Image Analysis

Repeat photography has been used to extract qualitative and quantitative data on landscape changes. The most powerful uses involve large numbers of photographs with extraction of simple qualitative or quantitative data on either presence-absence of features or count statistics of readily interpretable features. Examples of applications include estimating mortality and recruitment rates of perennial vegetation (Bowers and others, 1995), documenting the occurrence of debris flows (Webb and others, 1999), calculating the probability of debris-flow occurrence (Griffiths and others, 2004), and documenting large-scale changes in landscapes (Turner and others, 2003; Webb and others, 2004). Use of repeat photography in association with permanent plots is particularly useful for qualitatively verifying plot data and extending change detection over the larger landscape (Webb and others, 2003).

The oblique ground images generally used for repeat photography present a challenge to using computers for change analysis. If digital analysis is desired, the best imagery would have little information in the foreground and most of the information on slopes facing the camera. Although rubber-sheet rectification has been applied to downward-looking repeat photography (Webb and others, 1999), the most appropriate analysis would appear to be relative change between images.

Table 4. Archives and Web sites from which historical photography of the Mojave Desert can be obtained.

Archive or repository	URL for web access
Arizona Historical Foundation	None
Bancroft Library	http://sunsite.berkeley.edu/CalHeritage/
Death Valley National Park	None
Desert Laboratory Repeat Photography	http://geography.wr.usgs.gov/mojave/time-series/
Harold Wright Collection	none
National Archives and Record Service	http://www.archives.gov/research_room/arc/
Nevada Historical Society	http://dmla.clan.lib.nv.us/docs/museums/reno/his-soc.htm
Nevada State Historical Society	http://dmla.clan.lib.nv.us/docs/museums/lv/vegas.htm
Northern Arizona University Cline Library	http://www.nau.edu/library/speccoll/index.html
Shantz Collection (University of Arizona Herbarium)	None
Southwest Museum/Autry National Center	http://www.autrynationalcenter.org/collections/
University of Wisconsin: Golda Meier Library	http://www.uwm.edu/Libraries/special/
U.S. Geological Survey Photographic Library	http://libraryphoto.cr.usgs.gov/
Smithsonian Institution	http://www.siris.si.edu/
Denver Public Library	http://photoswest.org/presearch.html
Online Archive of California (searches multiple archives)	http://www.oac.cdlib.org/
Bureau of Land Management	http://www.photos.blm.gov/his_imsearch.html
Harpers Ferry Center, National Park Service	http://data2.itc.nps.gov/hafe/hfc/npsphoto2.cfm
Arizona Archives Online (searches multiple archives)	http://aao.lib.asu.edu/index.html
Library of Congress American Memory Project (searches multiple archives)	http://lcweb2.loc.gov/ammem/browse/

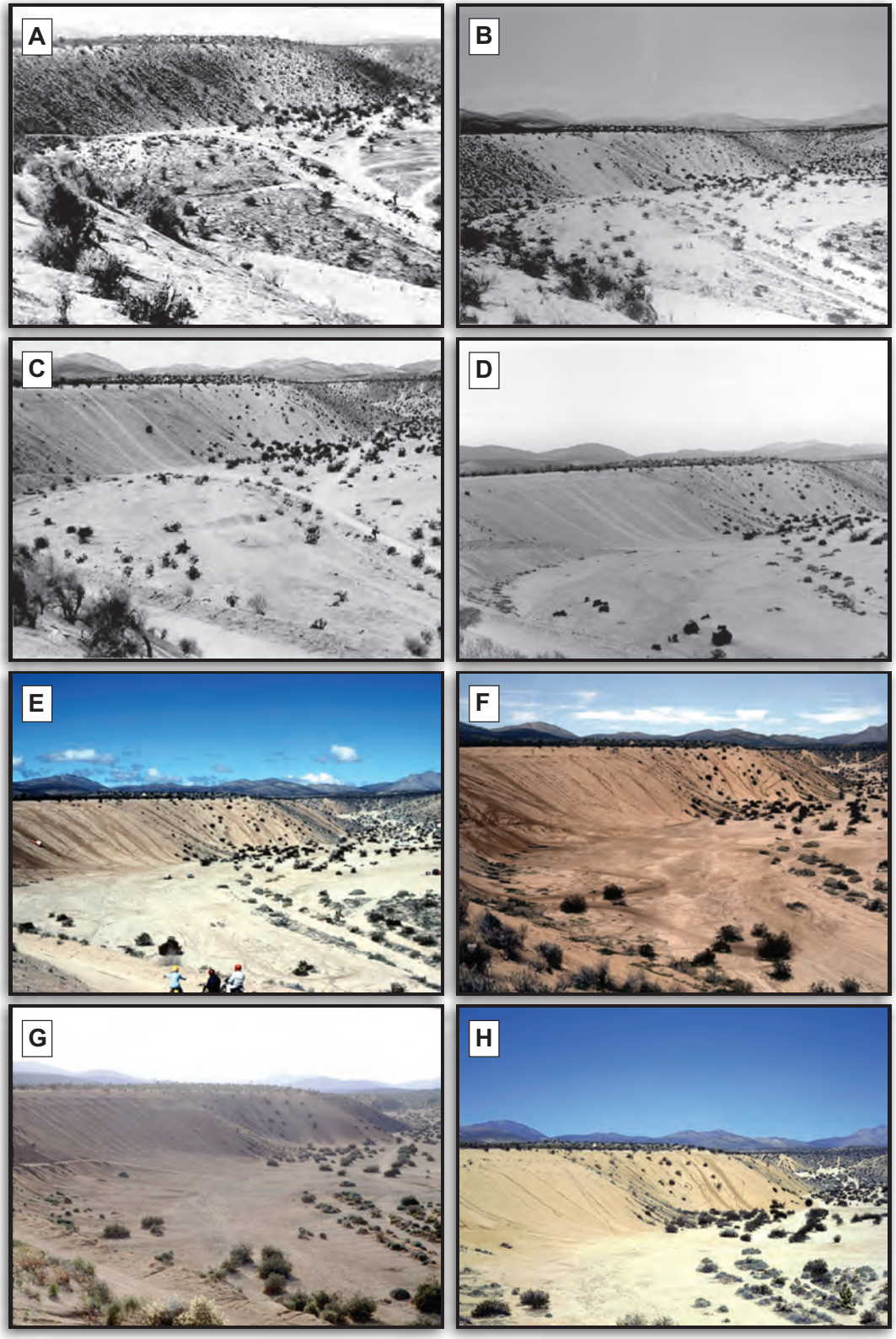

Figure 60. An example of repeat photography in the Mojave Desert. A, In 1968, Dove Spring Canyon, in the western Mojave Desert, had limited off-road vehicle use in the general location of the Los Angeles Aqueduct corridor (Bureau of Land Management photograph). This photograph shows hillslopes relatively undisturbed but with initial hillclimbs. Changes in the landscape are documented in subsequent photographs: B, 1970 (Bureau of Land Management photograph); C, 1972 (Bureau of Land Management photograph); D, 1976 (U.S. Geological Survey photograph by R. Webb); E, 1978 (U.S. Geological Survey photograph by R. Webb); F, 1983 (U.S. Geological Survey photograph by R. Webb); G, 1992 (photograph by H.W. Wilshire); H, 1999 (U.S. Geological Survey photograph by R. Webb).

Because percentage change is strongly affected by the distance of an object into the view, repeat photography with a large foreground component cannot be easily analyzed using digital image processing, but requires manual evaluation.

Airborne Remote Sensing

Aerial Mapping Photography

Aerial photography is used to assess a variety of landscape elements and changes and is the standard tool for geologic, soil, and vegetation mappers. This data is extremely useful for change detection (fig. 61) and particularly to document recovery from disturbance or other long-term changes, such as channel narrowing in washes (Hereford and others, 2006). From its humble beginnings during the early 20th century with oblique aerial images, vertical aerial mapping photography of high quality became commonly available over large areas in the 1930s. Commissioned by the Soil Conservation Service (now the Natural Resources Conservation Service), early black-and-white photographs generally were taken over either agricultural areas or high-value rangelands, and the imagery is stored at the National Archives and Records Service in College Park, Maryland.

Depending upon location, aerial photography may be available for every decade of the 20th century after 1940. These aerial photographs are available in color, black-and-white, and color infrared formats from a wide variety of Federal government agencies or private archives. The USGS has developed the National Aerial Photography Program (NAPP), which supplies aerial photography taken by a consortium of agencies. The program, which began in 1987, provides cloud-free photography for the entire United States at a scale of 1:40,000 per 229 × 229 mm image taken on a period of 5 to 7 year cycles. Larger and smaller scale imagery is also available from the Earth Resources Observation and Science (EROS) data center of the USGS, although the images are currently only available as digital scans, not as photographic prints. The Bureau of Land Management and National Forest Service are better sources for photographic prints that are superior for stereoscopic analysis.

Digital orthophoto quarter quadrangles (DOQQs) are aerial photographs that have been scanned and rectified to eliminate distortions and sized to one quarter of a standard USGS 7.5 minute quadrangle map. DOQQs interact with other data sets, such as topographic maps, and are extremely useful for digitizing of field data that are needed in a spatially referenced framework, as for GIS applications. For the southwestern United States, the aerial photography used to create the 1:24,000 DOQQs was taken between 1993 and 1995 and provides a baseline of 1-m resolution imagery for monitoring purposes. Large shrubs, such as *Larrea tridentata* (creosote bush), can typically be resolved in these images. Of the private archives holding aerial photography, the Fairchild Aerial Photography collection at Whittier College in Whittier, California, is one of the largest, containing 500,000 images taken between 1927 and 1965 (*web.whittier.edu/fairchild/home.html*). Finally, private companies frequently operate in regions of the United States, flying contract aerial imagery for government agencies or commercial companies.

Aerial photographs can be used directly to qualitatively assess changes or used

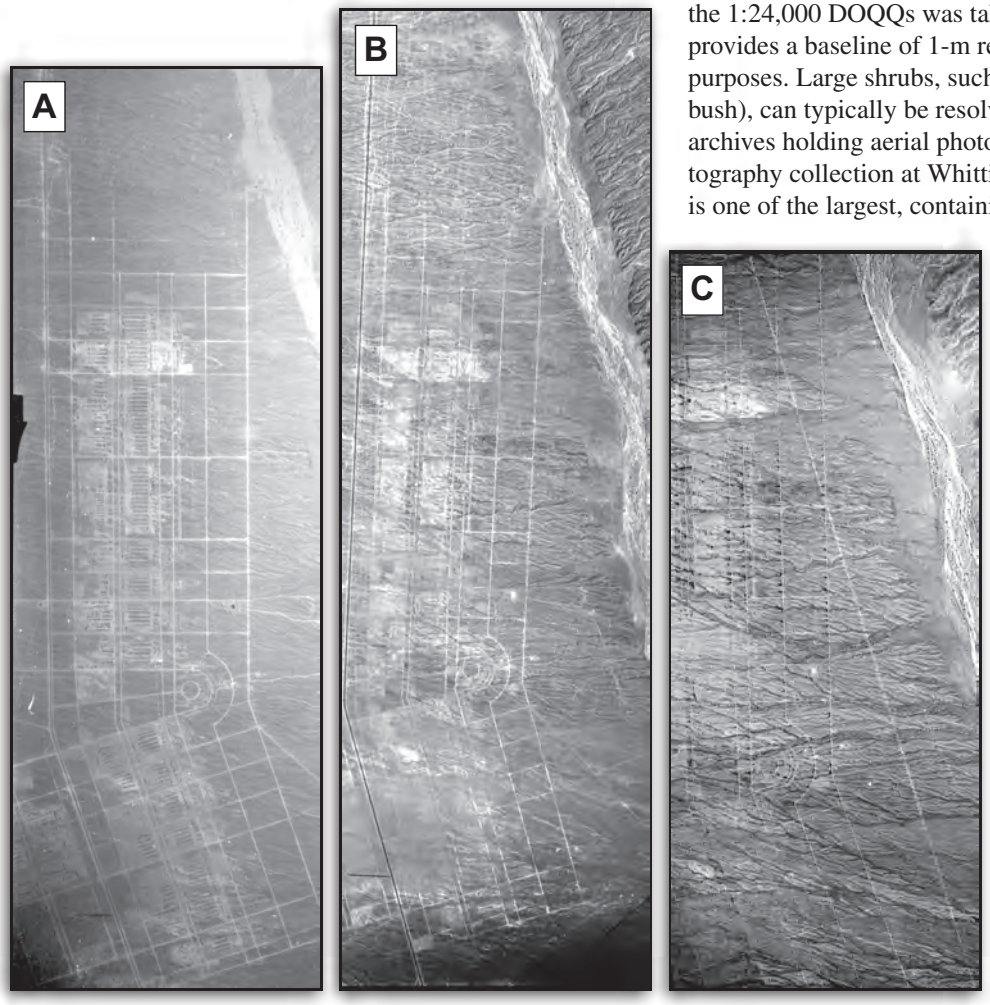

Figure 61. Aerial photographs of Camp Ibis, a World War II training camp northwest of Needles, California. A, April 1943, shortly before the camp was abandoned (U.S. Army Map Service photograph); B, April 1953 (U.S. Geological Survey photograph); C, April 1982 (U.S. Geological Survey photograph).

quantitatively to map features of interest. These photographs contain considerable distortion, particularly on their edges, and photogrammetric techniques are necessary to remove this distortion and to make aerial photography directly compatible with maps. Several image-processing software packages provide the capability of the simplest form of rectification, informally called "rubber sheeting." Control points are identified on an image, and computer software is used to digitally stretch the image to a best fit of the control points. More sophisticated rectification, as used on DOQQs, involves careful calculations using data on the camera focal length and other characteristics, the photograph's fiducial marks on all four sides, and control points within the image to rectify the view. Alternatively, features mapped on aerial photographs can be readily digitized by "heads up" methods on DOQQs to remove distortion. The most sophisticated software can create digital elevation models (DEMs) from overlapping aerial photography, allowing extraction of quantitative data from the imagery.

Use of aerial photography should be an integral part of a monitoring program in the Mojave Desert, but use of photography requires careful planning. Low-level photography flights or balloon (fig. 62) and kite photography may be necessary to get sufficient resolution for desert plants, and use of ground-surveyed targets typically is required to perform high-quality rectifications. Careful planning for data acquisition should focus on the expected use and accuracy of the data acquired from aerial photographs, particularly if historical imagery taken with cameras of unknown characteristics are compared with recently obtained imagery.

Aircraft-borne Multispectral Scanners

NASA has developed several imagers that are flown on specialized aircraft, including color infrared, MASTER thermal infrared, and multispectral scanners. Of these, the most useful is the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) developed in 1987. AVIRIS uses 224 continuous spectrum channels, making it the spectral sensor with the largest detection range. This device has an 18-m pixel and is particularly useful for identifying soil major cation chemistry, clay mineralogy, and vegetation. AVIRIS has also been used to evaluate vegetation change and the effects of grazing (for example, Harris and others, 2003). Although AVIRIS is a useful tool for site-specific studies where substrate characterization, in particular, is a necessary component of a monitoring program, it is extremely expensive.

Satellite-based Remote Sensing

For regional information, data obtained from remote sensing provides consistent information over large areas and provides valuable temporal and geospatial perspectives on ecosystem changes. In particular, remote sensing provides retrospective data that can be used to study past effects of land use or climatic variation, validate long-term site conditions of potential permanent monitoring points, and improve the ability to scale up plot information to larger areas.

The rapid increase in the number of different types of remote-sensing platforms and sensors in the last few decades

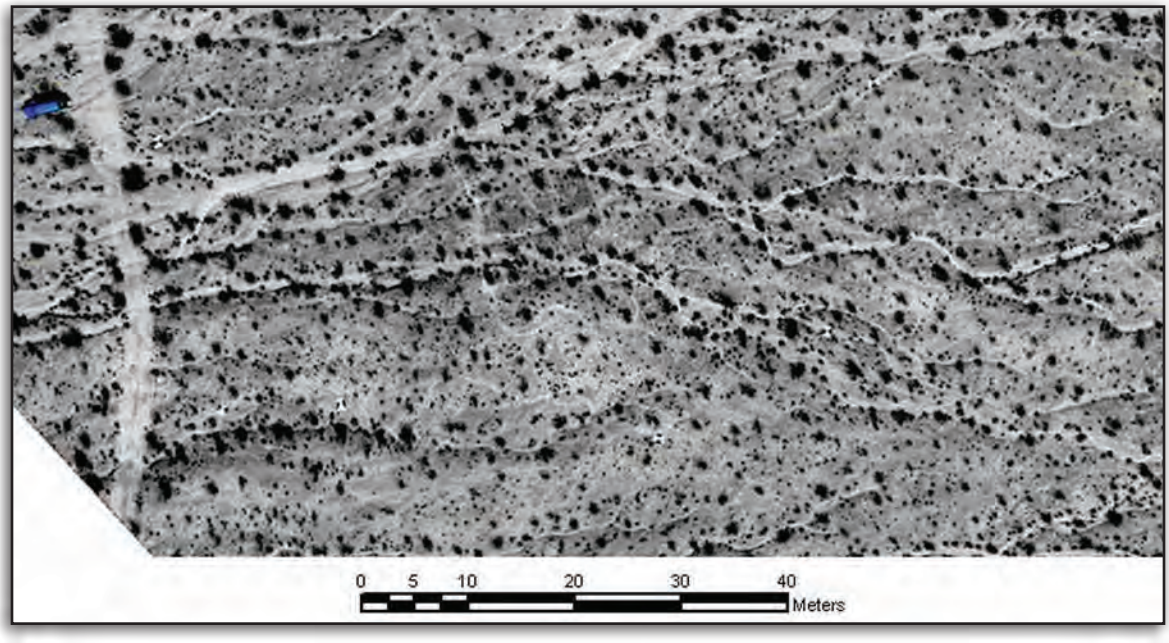

Figure 62. Piedmont photo-mosaic (taken by balloon, Mojave National Preserve) depicting soil and plant patterns. Bright green plants are *Larrea tridentata* (creosote bush); pale and smaller plants are *Ambrosia dumosa* (white bursage). Pale lines running right to left are stream channels (downhill to left); broad pale line is a dirt road with blue vehicle parked next to it. Note the larger *L. tridentata* adjacent to channels. Detailed plot studies have demonstrated that plant pattern varies with age of deposit and associated soils (S. Robinson, U.S. Geological Survey, unpub. data).

makes any review of remote sensing beyond the scope of this report. Here, we focus on the types of remotely sensed data that are most likely to be used to monitor long-term ecosystem quality and change over the continental United States. This imagery either is visual (color or black and white) or multispectral. We do not discuss radar platforms, although these clearly have significant applications for topographic mapping or change detection, or imagery from spy satellites, which may be declassified and available for certain regions. The information presented in this section is gleaned from Web pages for the National Aeronautics and Space Administration (NASA) (http://www.nasa.gov), the Jet Propulsion Laboratory (http://www.jpl.nasa.gov), the USGS (http://www.usgs.gov), or the National Oceanic and Atmospheric Administration (http://www.noaa.gov).

Although photographs were taken by TIROS-1 in 1960 and during the Apollo missions of the 1960s and early 1970s, satellite remote sensing began with the launch of the Landsat-1 satellite in 1972 (fig. 63). Landsat-1 had a multispectral scanner capable of recording four spectral frequencies at an 80-m resolution and one panchromatic band at 40-m resolution. With the launch of Landsat-4 in 1982, the Thematic Mapper (TM), a multispectral scanning radiometer, was introduced with seven spectral bands and a 30-m resolution. Currently, Landsat-7, launched in 1999, is the most advanced satellite in this series of remote-sensing platforms, with the Enhanced Thematic Mapper Plus (ETM+) multispectral scanner with a highest resolution of 15 m (panchromatic) and 30 m (most spectral bands) over a 185-km swath width.

The North American Land Classification (NALC) imagery is a standardized set of Landsat imagery that is used for change detection or long-term assessment of site conditions (U.S. Environmental Protection Agency, 1993). This data, when used with more recent data (such as Landsat TM data), can be used to assess time-series of changes on a watershed or larger scale at 60-m resolution (Jones and others, 2001; Kepner and others, 2002). In the late 1990s, Landsat TM data were analyzed to produce the National Land Cover Data (NLCD), which provides 21 classes of land cover as determined consistently throughout the United States (http://landcover.usgs.gov). Although many land-classification types have been extracted for more humid regions, application to the Mojave Desert may be problematic, owing to the low vegetation cover. This method seems to be particularly well suited to identifying severely disturbed areas in the landscape (W.H. Kepner, U.S. Environmental Protection Agency, oral commun.).

Privately owned satellites provide very detailed, if very expensive, satellite imagery. Satellite Pour l'Observation de la Terre (SPOT), a satellite owned by France, began in 1978. SPOT data has 10-m resolution panchromatic and 30-m multispectral imagery. Several privately owned satellites with high resolution have been launched in the last decade. IKONOS 1, launched in September, 1999, has a 1-m resolution with its panchromatic camera and 4-m resolution with its 4-channel multispectral scanner. Quickbird, launched in 2001 (http://www.digitalglobe.com), has a resolution of about 0.60 m for panchromatic imagery and

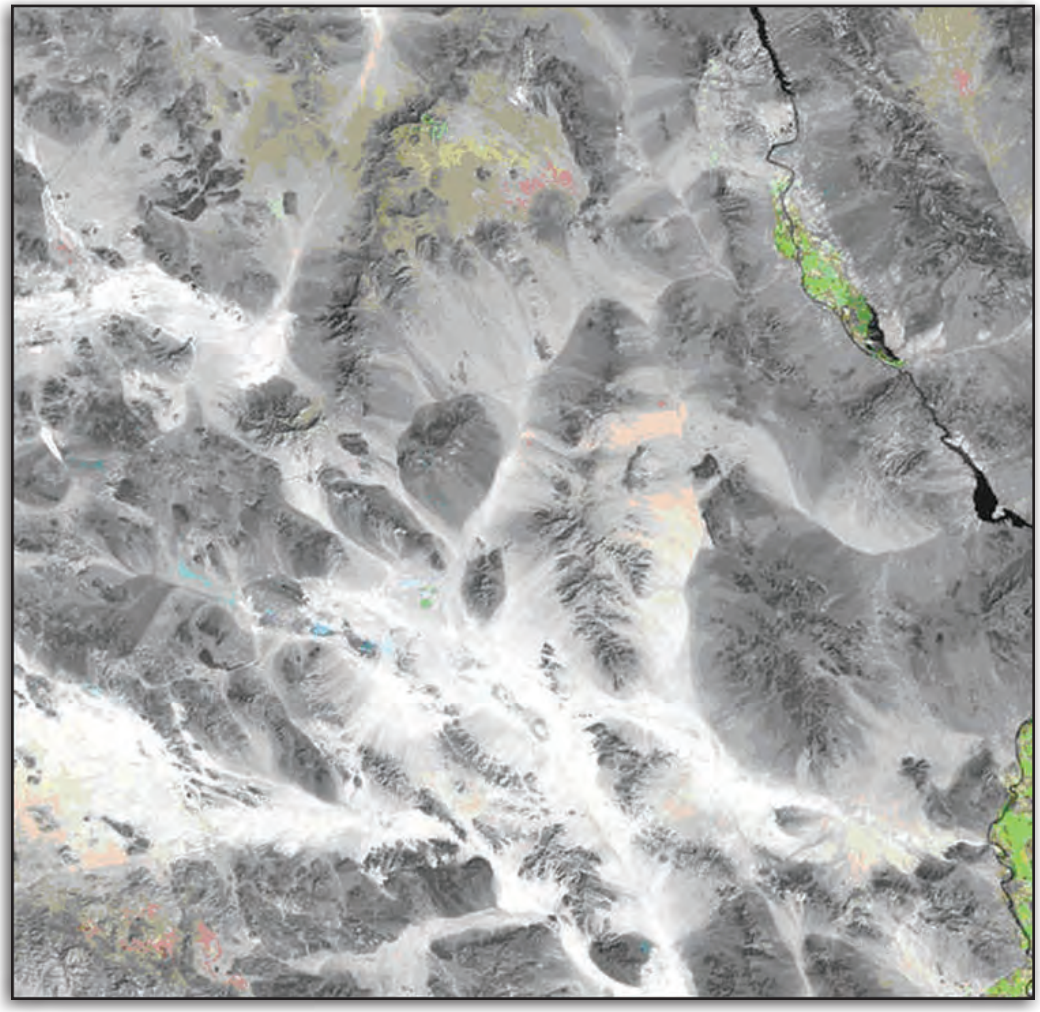

Figure 63. Landsat Thematic Mapper (TM) image of part of the Mojave Desert ecoregion taken in 1997. The Colorado River appears on the right; Lake Mohave is at the top, and the Palo Verde Valley near Blythe, California, is at lower right. The Colorado River Aqueduct is shown crossing the center of the view from right to left (U.S. Geological Survey photograph).

2.4 m for multispectral imagery. This platform, in particular, has the desirable characteristics of sub-meter resolution, quick response, and large frame imagery, and is being increasingly used for large-scale monitoring efforts.

Two other satellite platforms provide lower resolution data that are extremely useful for monitoring of vegetation status. In 1999, NASA launched the Earth Observing System (EOS) satellite named Terra; a second satellite called EOS-Aqua was launched in 2002. These satellites have Moderate Resolution Imaging Spectroradiometers (MODIS) as primary instruments designed to monitor vegetation (fig. 64). When both satellites operate in concert, daily imagery is obtained, and the principal products are 16-day averages at a resolution of 250 m. The Advanced Very High Resolution Radiometer (AVHRR) is a satellite-based platform for relatively low resolution (1.1 km^2 per pixel) launched in 1978. AVHRR data are especially well suited for large-scale analyses of vegetation change (Zhou and others, 2001) but may have little ability to resolve changes in regions like the Mojave Desert, where vegetation biomass is low. Advanced Spaceborne Thermal Emission Radiometer (ASTER) imagery (http://asterweb.jpl.nasa.gov/) is free and presents several bands in the thermal infrared spectrum at 90-m resolution; it is useful for identifying broad vegetation patterns and large-scale geomorphic change.

Satellite imagery is useful for several applications related to monitoring of the Mojave Desert. While sensing of perennial and annual vegetation cover remains difficult, new approaches are yielding positive results. Perennial plant cover may be successfully modeled with a combination of MODIS and TM data (Wallace and others, 2008), and annual plant production during good rainfall years can be detected with TM, yielding information on spatial variability of rainfall (P. Chavez, USGS, pers. commun.) and plant response. Change detection has been used to document the expansion of development in Clark County of southern Nevada (W.H. Kepner, U.S. Environmental Protection Agency, written commun.). Ikonos imagery has been used in the vicinity of Palm Springs, California to map eolian sand distributions where endangered species may live (C. Barrows, oral commun.). As the high-resolution commercial data become more readily available, satellite-based remotely sensed data will increasingly be used to scale plot information to regional scales, and therefore play a large role in monitoring of change in the Mojave Desert.

Comparison of Landscape-scale Monitoring Techniques

The four landscape-scale monitoring techniques discussed in this section—land-based repeat photography, aircraft-based aerial photography, aircraft-based remote sensing, and satellite-based remote sensing—offer significantly different options. Satellite-based remote sensing provides a consistent data set for large landscape areas, making it the best value for regional monitoring. Satellite-based remote sensing has significant limitations,

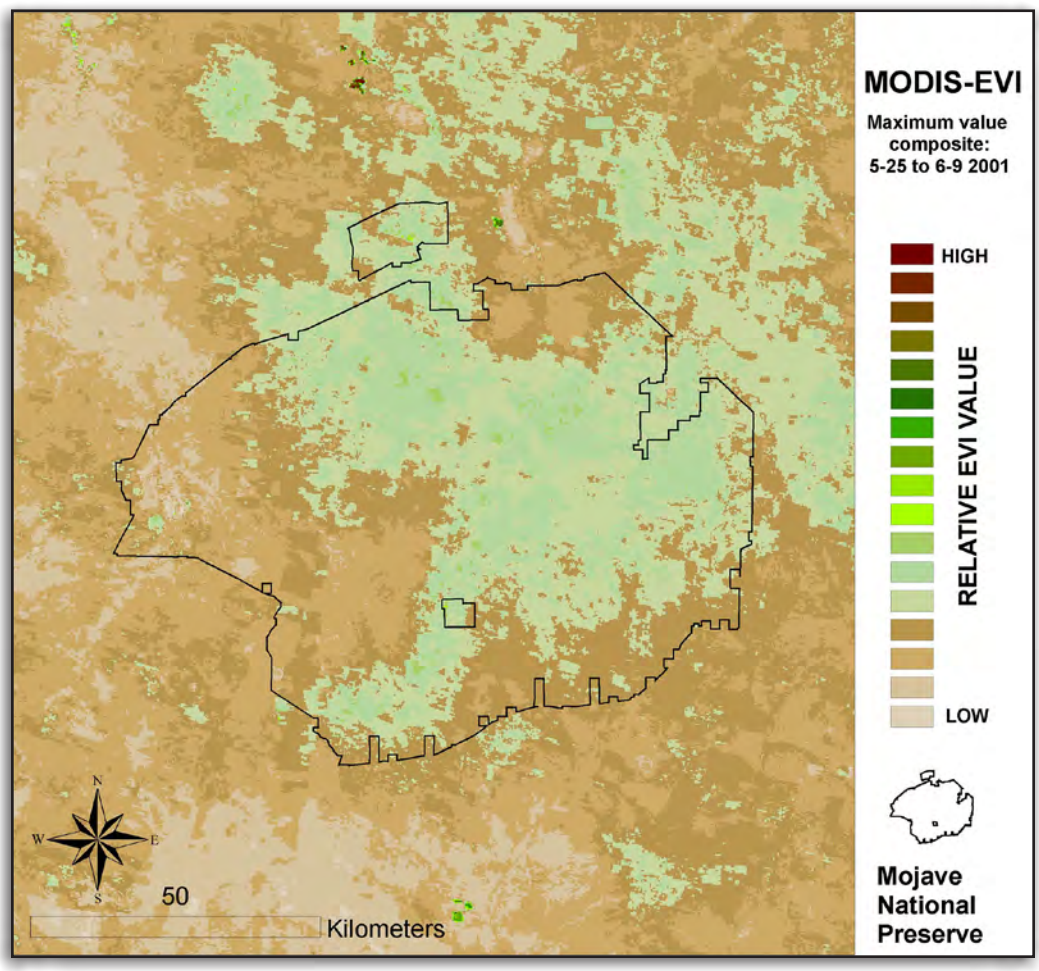

Figure 64. Moderate Resolution Imaging Spectroradiometers (MODIS) image showing the Enhanced Vegetation Index (EVI), a multispectral representation that reflects vegetation cover (Wallace and others, unpub. data), composited over the period of May 25 to June 9, 2001, for the Mojave National Preserve. High EVI values indicate greater vegetation cover of annuals and perennials (from Wallace and others, 2008).

including a relatively short (30-year) record that precludes significant retrospective analysis, general lack of ability for species-specific monitoring except for large plants or monospecific stands, and an ever-evolving technology that is not necessarily backward compatible. Future changes in remote-sensing technology will undoubtedly improve this monitoring technique and increase its relevance to site-specific monitoring. Aircraft-based remote sensing tends to be the most expensive, but this platform can provide extremely valuable one-time data, whether it is AVIRIS data for detailed, site-specific study or Lidar (Light Detection and Ranging; http://www.csc.noaa.gov/products/sccoasts/html/tutlid.htm) data for high-resolution topography.

Aerial mapping photography is particularly useful when registered or rectified to remove distortion and provide a uniform scale. This readily available form of imagery should be considered an important first step in establishing plot-level monitoring, because aerial photography, particularly when used to develop time series, can identify past disturbances or other factors that may enhance or diminish the relevance of a specific site to a monitoring program. Likewise, repeat photography is very useful when historical photography is available. Although this technique is superior to the others for documenting species-specific changes—particularly subtle ones—over long time periods, the limited amount of historical photography makes this technique less useful in many areas. However, a search for historical photography might be a useful starting point when planning a monitoring program. The Quickbird satellite-based imagery platform may eventually replace aerial photography, particularly if its resolution continues to improve.

The ideal monitoring program would utilize most, if not all, of these techniques for maximum effectiveness. Because repeat photography is superior at documenting antecedent conditions and long-term change, this technique is invaluable for establishing monitoring locations, as well as setting an agenda for those attributes and processes that would be more likely to change in the future. Aerial mapping photography is invaluable for delineating geomorphic surfaces, mapping vegetation, validating sites for large-scale land-use effects, and for determining representation of a site to the broader landscape. Finally, the various remotely sensed ecosystem characteristics, whether through aircraft- or satellite-borne sensors, should be an integral part of most monitoring programs in the Mojave Desert.

Acknowledgments

The authors thank the many individuals who have helped with ongoing monitoring and research in the Mojave Desert. These individuals include Diane Boyer, Sara Scoles, Sue Phillips, Peter Griffiths, Dustin Haines, Marilyn Murov, David Bedford, Kevin Schmidt, Sara Robinson, and Elizabeth Deliso. Raymond Turner helped start widespread repeat photography in the Mojave Desert, and Dominic Oldershaw has helped to perfect the technique, particularly as it is applied to the Mojave Desert. John Steiger helped with our discussion of the legal basis for land management in the Mojave Desert. Katie Coulson and Tina Kister helped to prepare the manuscript. We thank numerous people for critically reviewing this manuscript. This work was funded by the Research on the DOI Landscape (in the Western Region) and the Priority Ecosystem Science's Recovery and Vulnerability of Desert Ecosystems program of the USGS.

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Appendix A: Trigger-Transfer-Reserve-Pulse

The trigger-transfer-reserve-pulse (TTRP) framework (Ludwig and others, 1997) is a useful framework for understanding how resource patterning affects ecosystem processes and how these components and processes are connected in drylands (fig. A1). "Triggers" are events, such as rain, that elicit a response from the ecosystem. "Transfer" is the vertical or horizontal movement of materials (for example, water, nutrients, soil) across the landscape in response to the trigger. In deserts, this is generally done by wind and water. Transfer patterns vary naturally among different ecosystems (figs. A2 and A3). Transferred resources are either retained by the receiving patch (the reserve) or leave the system. The retained resources, when triggered by an event, respond with a resource pulse (for example, microbial activity, germination of vascular plants). This framework emphasizes that landscape components are connected by the transfer of materials and highlights feedback processes that regulate and maintain landscape function. Because of the integral connection between plants and soils, any changes in the distribution of one will affect the other. Understanding the distribution of ecosystem components and their connections is essential to the design and implementation of an effective monitoring program. Whereas the example below uses rainfall as the trigger, similar scenarios can be constructed for other triggers.

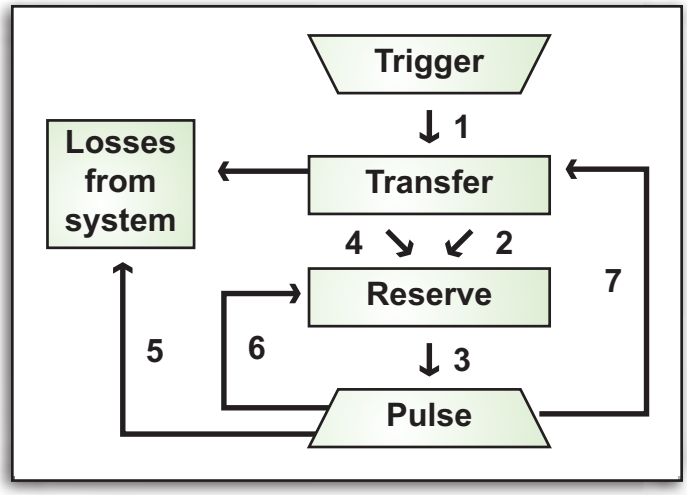

Figure A1. A conceptual framework representing sequences of landscape ecological and hydrological processes and feedback loops. Examples of processes are (1) rainstorm; (2) infiltration, capture, and retention or storage; (3) plant germination, nutrient mineralization, and uptake processes; (4) soil loss, runoff into streams, rill flow, and erosion; (5) herbivory, leaching, fire, harvesting, and deep drainage; (6) biomass increase, nutrient availability, and organic matter cycling; and (7) physical obstruction/absorption processes (adapted from Belnap and others, 2005).

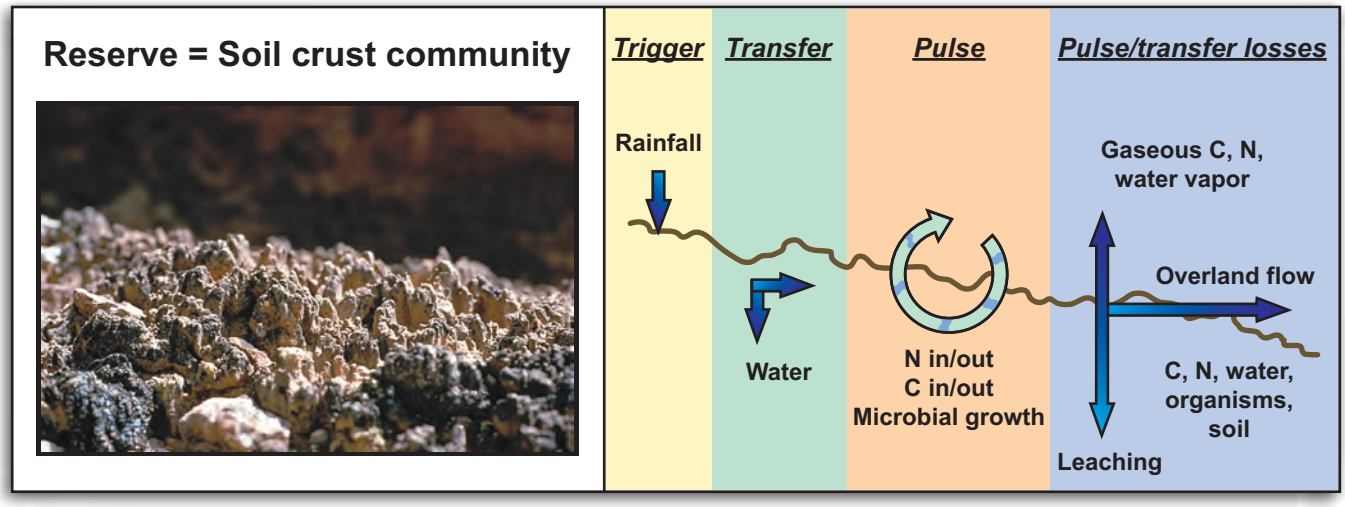

Figure A2. Trigger-transfer-reserve-pulse (TTRP) model applied to the plant interspace. The trigger is precipitation, and the reserve is the soil biotic community. Pulses discussed here include nitrogen (N) and carbon (C) dynamics. Transfer and losses include water, carbon, nitrogen, organisms, and soil (adapted from Belnap and others, 2005).

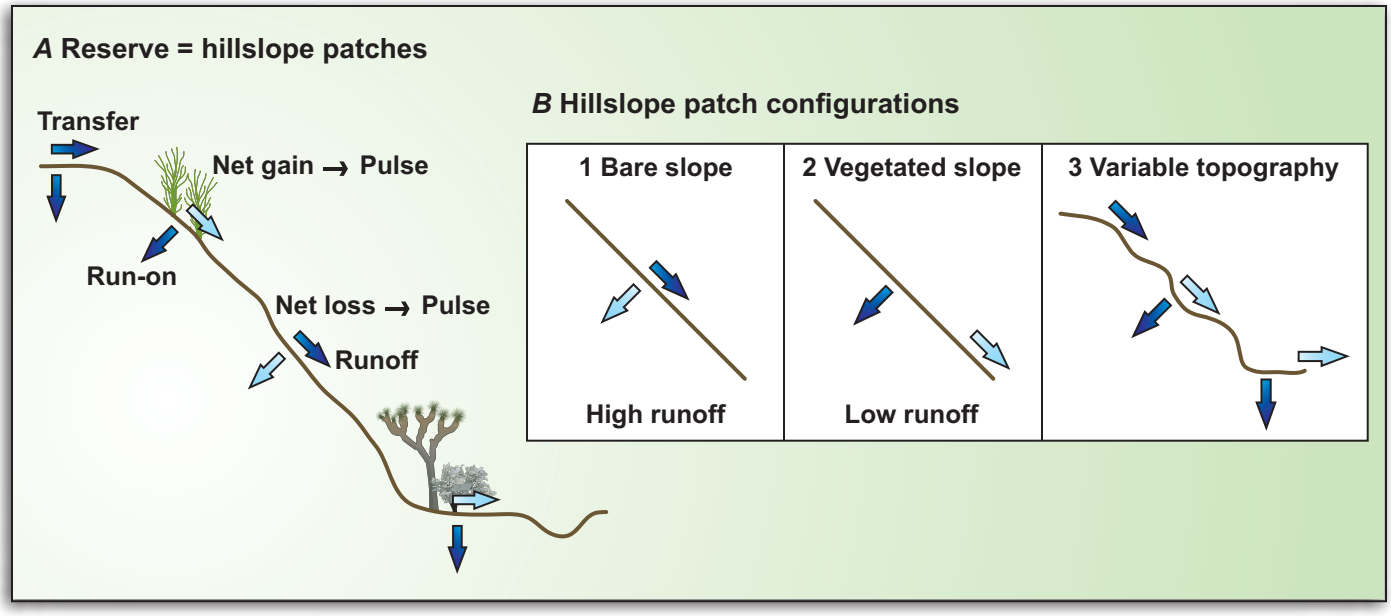

Figure A3. A, Stylized depiction of a desert hillslope including vegetated and non-vegetated patches arrayed along a topographical gradient from ridge top to valley bottom. Vegetated patches and topographic depressions have greater capacity to absorb rainfall, leading to greater pulses of microbial activity and less runoff when compared to plant interspaces. B, Hypothesized effect of hillslope patch configuration on hydrologic and material retention. Bare slopes have (1) little capacity to absorb water and nutrients in comparison with vegetated hillslopes (2), and those with variable topography (3), including topographic flats or depressions. Since topographic depressions and vegetated areas increase retention, hillslope patch configuration may influence overall retention. As runoff volume and material redistribution increase (with increasing storm intensity), the effects of patch configuration on hillslope retention may become more pronounced. Dark blue arrows indicate more water movement, while light blue arrows indicate less.

Example of the Trigger-Transfer-Reserve-Pulse Model at the Local and Hillslope Scale, Using Rainfall as the Trigger

Example of Reserves: Plant Interspaces, Plant Islands, and Hillslopes

Plant interspace patches are generally covered by biological soil crusts, which mediate most gas, nutrient and water inputs to, and losses from, desert soils. Other factors, such as rocks, plant litter, ant mounds and surface roughness, also influence processes in the interspace patch. In wet years, the interspace patch supports a significant cover of annual plants. Plant island patches in the Mojave Desert generally show increased water availability, infiltration, organic matter, soil biota, and faunal abundance when compared to the plant interspace soils (for example, Jackson and Caldwell, 1993; Smith and others, 1995; Breshears and others, 1998; Schlesinger and Pilmanis, 1998; Breshears and Barnes, 1999; Cross and Schlesinger, 1999; Dunkerley, 2000; Bolling and Walker, 2002; Bhark and Small, 2003). The pattern (spacing, density, composition) of plant patches in arid ecosystems has been linked to the mechanisms by which water is redistributed from the interspace to the plant island patches (for example, Sanchez and Puigdefabregas, 1994; Puigdefabregas and Sanchez, 1996; HilleRisLambers and others, 2001; Wilcox and others, 2003). At the hillslope scale, a given area can be envisioned as a series of plant and interspace patches. At this scale, more organic matter, nutrients, and microbial biomass occur in valley bottoms relative to ridge tops (Gallardo and Schlesinger, 1992).

Example of Resource Transfer: Horizontal and Vertical Movement of Water, Sediments, and Nutrients

The interplay between the intensity of the trigger (for example, wind or precipitation) and site characteristics (for example, the arrangement of plant interspaces and islands; topographic position; aspect and slope, soil hydraulic conductivity; and the presence, structure, and arrangement of ground surface cover) will determine whether materials are absorbed by the receiving patch or transferred downslope (Tongway and Ludwig, 1997; Puigdefabregas and others, 1999). The arrangement of plants can differentially affect water flow velocity and direction (fig. A3). Stems can deflect flow and soils under shrubs often have greater water and nutrient absorption than interspace soils (Abrahams and Parsons, 1994). During wet years, annual plants that occur in plant interspaces slow the transfer of water and sediment. When rainfall rates exceed interspace or plant island infiltration rates, the resultant overland flow horizontally redistributes water, sediment, and nutrients. Losses are determined by interspace characteristics. For

example, smooth and thin cyanobacterial soil crusts will allow more nutrients, sediment, and water to be transferred from the interspace soils than rough and thick lichen soil crusts. Nutrients lost from a given patch can provide a resource subsidy for receiving patches or be lost to downslope intermittent washes. Retention is concentrated in "run-on" patches—generally mounds around plant bases and topographic depressions, depending on the scale being measured.

There are other avenues of water and nutrient loss. The dominant loss pathway for water is evaporation, and rates for a given area are influenced by the amount, arrangement and cover of plant patches, as well as ground cover of interspace patches. Evaporation is lower under lichen soil crusts than cyanobacterial soil crusts (George and others, 2003). Soils shaded by plants will dry more slowly than soils in full sun. In wetter years, both subsurface patch connectivity and vertical losses may be greater. Downward leaching of carbon and nitrogen is thought to be very low in deserts, but may be substantial in coarse-textured soils, especially after low-intensity synoptic storms accompanied by high infiltration rates (Walvoord and others, 2003). Soil erosion by wind can lead to substantial loss of soil fertility (Neff and others, 2005).

Example of a Pulse Response to the Trigger: Carbon and Nitrogen Dynamics

Because microbial activity can occur only when soils are sufficiently wet, local and hillslope patch structure interacts with incoming rainfall to create a mosaic of microbial activity. Microbial respiration begins immediately upon wetting and across a range of temperatures, whereas photosynthesis requires light and optimal temperatures (Lange, 2003). Thus, precipitation that occurs at night, in small events, and/or when soil temperatures are high, often results in carbon losses for soil autotrophs (Jeffries and others, 1993). Wetting of dry soils also kills up to ½ of the soil microbial biomass through osmolysis (Kieft and others, 1987), releasing microbial carbon and nitrogen that stimulates a pulse of microbial activity (for example, Marumoto and others, 1982). Rapid increases in microbial biomass (Kieft and others, 1987) and microbial process rate (for example, nitrogen mineralization, nitrification) occur with wetting (Davidson and others, 1993; Fisher and Whitford, 1995). Longer time periods between wetting events result in greater microbial activity once soils are wetted than when times between wetting events are shorter, because resource availability increases over time as organic matter photo-degrades (Moorhead and Callaghan, 1994), atmospheric deposition results in a buildup of nitrogen, phosphorus, and other nutrients on the soil surface (Verrecchia and others, 1995), and microbes die.

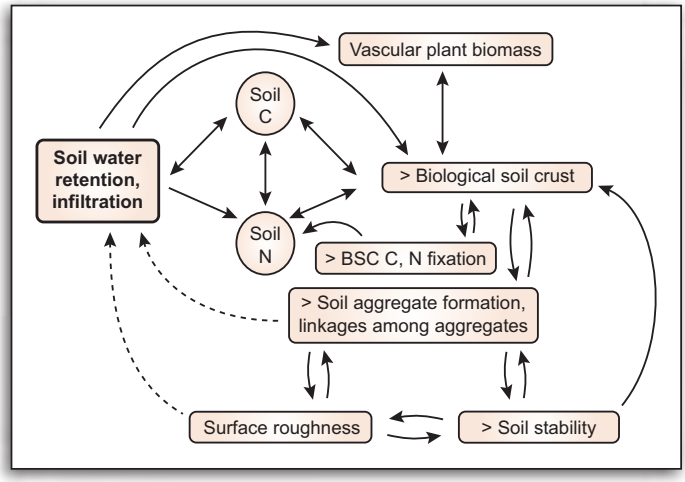

Figure A4. Many feedbacks that occur in deserts influence the effect of moisture pulses on multiple scales, including those of the plant interspace patch, plant patch, and hillslope patch. The solid lines represent linkages that have been explicitly studied; the dotted arrows represent connections that require further study.

Potential carbon and nitrogen mineralization rates are generally higher in vegetated patch reserves than interspace patch reserves, given the higher soil organic matter found there (Kieft and others, 1998; Burke and others, 1999). Spatial variation in microbial processes at the hillslope and landscape scale is expected to be highest in summer due to differential evaporation rates among the patches; the variable influence of aspect, slope, vegetation; and the localized nature of short high-intensity rains. This will create greater disparity between gaining (positive carbon and nitrogen balance) and losing (negative carbon and nitrogen balance) patches in hot summer months compared to winter months. During wet years, increased water availability can create carbon and nitrogen limitations (Mummey and others, 1997).

Losses of carbon and nitrogen also vary according to season and patch type, as these processes are dependent on soil temperature and moisture. In all deserts, the rate of nitrogen loss peaks in the hot summer months. However, total losses during the three dry and hot summer months can be similar to total losses during the wetter nine-month fall-spring season. Vegetated and soil lichen patches have higher rates of denitrification and respiration than bare interspaces or those covered with cyanobacterial crust (Virginia and others, 1982; Bolton and others, 1993; Lange, 2003). Winter-rainfall-dominated regions of the Mojave likely have less overlap between the timing of maximal nitrogen inputs (fall, winter, spring) and losses (summer) than in summer-rainfall-dominated regions, where maximum inputs and losses may coincide in time and space (summer). Disturbance is also important, as it decreases the input and increases the loss of both carbon and nitrogen (Belnap and Eldridge, 2003).

Example Feedbacks between Transfers, Reserves, and Pulses

Many feedbacks determine how precipitation events influence processes on scales ranging from interspace to hillslope (fig. A4). For instance, the longer soil crusts are wet, the more carbon and nitrogen they fix. More carbon and nitro-

gen results in more soil biota and plant biomass. Increased biomass increases soil aggregates, soil surface roughness, and soil stability, all of which increase retention of water and organic matter (Tongway and Ludwig, 1997). Greater retention of resources results in more microbial activity, and thus soil biota and plant biomass. There are also strong feedbacks between plant and interspace patches (Charley and West, 1975; Schlesinger and others, 1990, 1996). Because patches vary in their ability to intercept and retain water and provide nutrients, the strength of the feedback will vary among patches. Spatial configuration of patches will also influence water and nutrient retention on the hillslope, particularly as storm size and intensity increase (fig. A3). Plants influence the spatial and temporal distribution of soil resources through the capture of soil, water, organic matter, root exudates, litter deposition, shading of soils, concentration of soil biota, and nutrient uptake (for example, Noy-Meir, 1973; Tongway and Ludwig, 1994; Reid and others, 1999; Whitford, 2002; Ludwig and others, 2005; Puigdefabregas, 2005). Vegetation patterns, in turn, are driven by patterns of soil resource availability (Aguiar and Sala, 1999). Changes in the distribution of vegetation or soil resources at any scale can therefore determine the amount of resources that are retained or lost from an ecosystem at all scales.

Intra-patch Dynamics

There are also many dynamics that occur within a given patch that are important in ecosystem functioning. Competition and facilitation among biota can be important, because water and nutrients (or forage) are often limited in desert settings. Plants of similar functional types (for example, deeply rooted perennial shrubs) can compete for space and water (Brisson and Reynolds, 1994; Cody, 2000). Although data is generally lacking, it is assumed that dissimilar functional types (for example, shallow and deep rooting types) only compete for space, and that as long as water is partitioned into separate moisture pools, competition does not occur. Chesson and others (2004) suggest that climate variability, combined with differential plant phenology and competition, may drive species composition. When a preferred forage plant or habitat type is limited, animals can compete for resources within a patch as well (see sections on Ants and Termites and Small Mammals).

Facilitation may also be a common phenomenon within a plant patch. Exotic annual grasses preferentially grow under perennial shrubs. Many native plant seedlings use shrub canopies as “nurse” locations as well (Miriti and others, 1998; Brittingham and Walker, 2000; Schenk and Mahall, 2002), although these plants may eventually compete with each other. Facilitation can also occur among ecosystem components. For instance, biological soil crusts facilitate the development and maturity of subsurface soil biota (Belnap and Phillips, 2001; Austin and others, 2004; Schwinning and Sala, 2004). The conditions which determine whether relationships among ecosystem components are competitive or facilitating are not known. It is likely that competition and facilitation vary through time and space and are dependent on climate and resource variability (Chesson and others, 2004).

Appendix B: Mapping Surficial Geology

Most geologic maps for the Mojave Desert made before about 1990 focused on bedrock geology and have sparse information on surficial deposits. Over about the past 15 years, new approaches have been developed to identify surficial deposits, interpret those surfaces in terms of the processes that created them, and place them in age categories based on soil development (McFadden and others, 1987; Wells and others, 1987; McDonald and others, 1995). The most reliable studies employ field investigations supplemented by stereoscopic analysis of aerial photography, which permits viewing of the three-dimensional landforms as well as tonal differences (Slate and Berry, 1999). Aids to evaluating surficial geology include satellite images, such as Landsat TM data (Menges and others, 1999, 2001) and MASTER and ASTER data (see pages 76-78). Scales used in preparing surficial geologic maps range from 1:24,000 to 1:250,000, representing very detailed surficial data to generalized information, respectively. For regional studies requiring a uniform presentation, a scale of 1:100,000 is the most useful and most widely available. Examples of these maps are Schmidt and McMackin (2002), Bedford (2003), and Bedford and others (2006).

Field work associated with surficial geologic mapping generally includes study of surface characteristics, such as desert pavements, which increase in density with age; desert varnish, which increases in darkness with age; bar-and-swale microtopography, the expression of which decreases with surface age; and surface roughness of particles, which dissolve and fracture with increasing age. By studying stream cuts and digging shallow pits, these surface characteristics are tied to deposit characteristics, such as the presence and thickness of the vesicular A (Av) horizon and the degree of development of soil horizons, indicated by such features as color changes in parent material (cambic horizon development); accumulation of clay (a process termed illuviation); and accumulation of pedogenic carbonate or gypsum into calcic or gypsic horizons, respectively. Ages of surficial deposits typically are assigned by correlation with surfaces of known age in the region, preferably a soil chronosequence (for example, Reheis and others, 1989). In order to be finalized, maps must pass a field inspection by experienced Quaternary geologists.

Map Units Used to Describe Geomorphic Surfaces in the Mojave Desert

In recent years, the U.S. Geological Survey has attempted to standardize map units used to depict Quaternary geomorphic surfaces. Correlation tables have been developed to compare past and present map units in the Mojave Desert (Menges and others, 2001). Slate and Berry (1999) presented a generalized table of the characteristics used in aerial photography interpretation to distinguish surficial deposits that span a wide range in ages. Menges and others (2001) give detailed descriptions of 11 surficial geology units used for mapping in the vicinity of Death Valley National Park in the northeastern Mojave Desert; for example, map units Qac, Qfy, Qfi, Qay, Qfo, and Qta depict alluvial deposits that range in age from recent (historic to several hundred years old) to the Tertiary (greater than two million years old). Map units used by the U.S. Geological Survey in the Mojave Desert of California for alluvial deposits are summarized in table B1.

Surficial map units can be used to interpret both the characteristics of perennial vegetation and some of the abiotic factors that could affect productivity and long-term stability (Miller and others, in press; Bedford and others, in press). Young geomorphic surfaces (for example, Qac, Qfy, Qfi) have little pedogenic modification or soil structure; typically, these are deep soils with relatively rapid infiltration rates and

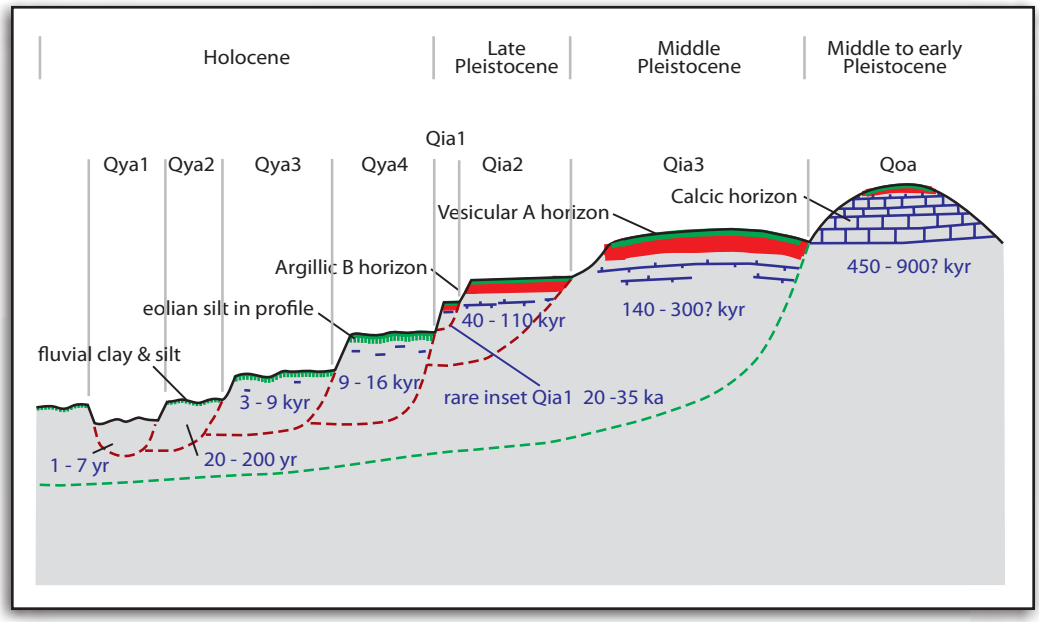

Figure B1. Schematic diagram showing units used in surficial geologic mapping in the Mojave Desert. All of the units are developed in alluvium or colluvium, as opposed to bedrock, and age generally increases from left to right.

Table B1. Summary of principal alluvial fan deposit characteristics and nomenclature used to describe Quaternary surficial deposits in the Mojave Desert.

[Features in brown type are most diagnostic. Deposits are poorly dated, but as a general guideline, young (Qya) deposits are roughly younger than 15 ka (ka = kilo-annum, one thousand years), intermediate deposits (Qia) are about 30–250 ka, and old deposits (Qoa) are generally 500–800 ka. Bt = clay (argillic) horizon]

Units on map		Surface topography or processes	Characteristics				
Scale of 1:100,000	Scale of 1:24,000		Desert pavement	Desert varnish	Av (vesicular A) horizon	B (argillic) horizon	K (calcic) horizon
Qaa	Qya1	Active wash or fan	None	None	None	None	None
	Qya2	Bars and swales prominent	None	None to very weak	Generally no development	None	None
Qya	Qya3	Remnant bar and swale topography, somewhat flattened surface	Incipient (lag gravel)	Weak	Weak, consisting of sandy silt	Weak development, reddish (cambic) development	Stage I (rind under pebbles) carbonate development
	Qya4	Weak remnant bar and swale topography, fairly flat surface	Weak development with some leveling of tops of pebbles	Weak to moderate on desert pavement	Weak, consisting of loose sandy silt	Bt horizon development	Stage I to II carbonate development
Qia	Qia1	Flat surface with faint bar and swale	Weak to moderate	Moderate	Structured silt, 2–6 cm thick	Strong red color (cambic) development, weak clay illuviation	Stage II (pebble rinds)
	Qia2	Flat surface, even pebble size, pebble tops level	Moderate to strong	Moderate to strong	Structured silt, 4–8 cm thick	Bt horizon present with moderate illuviated clay	Stage II to III carbonate development
	Qia3	Crowned surface, incipient whaleback	Strong to degraded; exposed Av	Strong with purplish casts	Structured silt, 4–15 cm thick	Bt present with high clay content	Stage III to IV (pores filled) carbonate development
Qoa	Qoa	Whaleback (highly crowned) surface	Calcic chips in pavement	Secondary or none	Secondary or none	Secondary or none	Stage IV — layered and massive carbonate development

relatively high cumulative biomass production. Vesicular A horizons restrict infiltration through the first soil horizon, and Av horizons increase in thickness and structure with age; desert pavements also develop, and surfaces smooth, reducing the potential for wind-transported seeds to lodge on the surface. Therefore, the potential for germination and establishment of certain perennial species may be diminished with increasing deposit age. Finally, eolian deposition over a pre-existing geomorphic surface may completely change its biotic characteristics, in effect making it more xerophytic than the original surface, despite no change in climate (D.M. Miller, oral commun.). As a result, the abiotic characteristics indicated on surficial geologic maps may provide important regional information needed to properly design monitoring protocols to examine the range of natural variability, as well as potential effects of management actions.

Maps depicting geomorphic surfaces and surficial deposits of the Mojave Desert are available from the U.S. Geological Survey (http://geopubs.wr.usgs.gov), as well as the California Geological Survey, the Arizona Geological Survey, and the Nevada Bureau of Mines and Geology.

An understanding of landform types present in arid regions is important to a full appreciation of these maps. Readers can consult several publications for descriptions of common landforms in the Southwest, such as Peterson (1981). A description of alluvial channels is given by Parker (2000), and an online data source is the Mojave Desert Ecosystem Program (http://www.mojavedata.gov). Commonly used terms in soil science are given in Soil Science Society of America's Glossary of Soil Science Terms (1997), and a general application of soil sciences to surficial geology is presented by Birkeland (1984). Finally, Wilshire and others (1996) discuss geomorphic processes that affect the stability of geomorphic surfaces in the southwestern United States.

Figure B2. An active wash (Qya1 deposit) that recently flowed, spurring abundant growth of annual plants in bands along the sides of the wash. Perennial plants generally do not establish in active washes owing to periodic scour.

Figure B3. *Ambrosia dumosa* (white bursage) and *Larrea tridentata* (creosote bush) on an early Holocene piedmont (Qya4 surface) near Kelso, California. *Opuntia echinocarpa* (staghorn cholla) appears in the left midground, and the blue flags at center mark plants in a permanent plot.

Figure B4. Desert pavement on a Qoa deposit with old soils devoid of perennial vegetation except in dissected gullies, where soil horizons are disrupted and *Larrea tridentata* (creosote bush) and *Ambrosia dumosa* (white bursage) are found.

Appendix C: Regression Relations For Perennial Plants

Regression relations for indirect biomass calculations for common Mojave Desert perennial plants.

Table C1. Regression equation producing a dry-weight biomass (kg).

[*V* is the shrub volume, which is vaguely defined as a width and a height (adapted from Wallace and Romney, 1972, p. 252)]

Species	Regression equation	*n*	R^2
Acamptopappus shockleyi	2.36*V* + 0.004	46	0.79
Achnatherum hymenoides	0.52*V*+0.022	6	0.59
Ambrosia dumosa	2.13*V*+0.001	67	0.79
Ephedra funereal	1.64*V* -0.030	16	0.86
Grayia spinosa	1.69*V*+0.0433	51	0.74
Krameria parvifolia	1.84*V*-0.001	34	0.74
Krascheninnikovia lanata	2.16*V*-0.002	51	0.76
Larrea tridentata	1.15*V*+0.076	33	0.83
Lycium andersonii	1.35*V*+0.190	52	0.77
Machaeranthera tortifolia	1.07*V*-0.004	13	0.98
Sphaeralcea ambigua	0.33*V*+0.001	16	0.77
Yucca schidigera	3.04*V*+0.458	13	0.59

Table C2. Regression equation with no intercept that produces *K*, the dry-weight biomass (kg).

[V = shrub volume (m^3), which is calculated as an elliptical tube using the equation $V = \frac{h \pi ab}{4}$, where h = height (m) and a and b = diameters (m; J.E. Kinnear, University of California Los Angeles, written commun., 1979)]

Species	Volume-biomass coefficient *K*	95% confidence limits
Acamptopappus shockleyi	3.1	0.3
Achnatherum hymenoides	1.1	0.6
Achnatherum speciosum	1.	0.6
Ambrosia dumosa	2.5	0.2
Artemisia spinescens	4.1	0.4
Artemisia tridentata	1.8	0.2
Atriplex canescens	2.57	0.5
Atriplex confertifolia	4.7	0.5
Atriplex polycarpa	2.1	0.4
Coleogyne ramosissima	5.2	0.5
Encelia virginensis	1.1	0.1
Ephedra funereal	2.3	0.4
Ephedra nevadensis	1.4	0.3
Grayia spinosa	2.3	0.2
Hymenoclea salsola	3.2	0.4
Kochia americana	3.1	0.3
Krameria parvifolia	2.0	0.2
Krascheninnikovia lanata	3.2	0.3
Larrea tridentata	1.3	0.1
Lepidium fremontii	3.2	0.4
Lycium andersonii	2.2	0.2
Lycium pallidum	1.2	0.1
Lycium shockleyi	3.8	0.3
Machaeranthera tortifolia	1.8	0.5
Menodora spinescens	8.3	1.0
Pleuraphis rigida	0.70	0.20
Psorothamnus fremontii	2.5	0.5
Salsola iberica	1.7	0.2
Salsola paulsenii	2.1	0.2
Sitanian jubatum	1.1	0.6
Sphaeralcea ambigua	0.43	0.10
Tetradymia axillaries	2.7	0.4
Tetradymia glabrata	2.7	0.4
Thamnosma montana	1.7	0.2

Table C3. Regression equation with no intercept that produces *K*, the dry-weight biomass (kg).

[V = shrub volume (m3), which is calculated as an elliptical tube using the equation $V = \frac{h\,\pi ab}{4}$, where h = height (m) and a and b = diameters (m). Root/stem ratio is live weight to live weight. n.d. = no data (Turner, 1973)]

Species	Volume-biomass coefficient *K*	*n*	R^2	Root/stem ratio
Acamptopappus shockleyi	2.793	43	0.81	0.527
Achnatherum hymenoides	1.044	7	0.64	n.d.
Ambrosia dumosa	2.238	62	0.85	1.155
Atriplex confertifolia	4.864	28	0.96	0.427
Coleogyne ramosissima	5.232	16	0.96	n.d.
Ephedra nevadensis	1.492	7	0.85	0.835
Grayia spinosa	2.002	53	0.67	0.715
Krameria parvifolia	1.937	34	0.61	0.789
Krascheninnikovia lanata	3.046	56	0.83	0.900
Larrea tridentata	1.539	41	0.81	1.240
Lycium andersonii	1.975	56	0.69	0.835
Lycium pallidum	0.786	29	0.56	1.646
Machaeranthera tortifolia	1.615	11	0.62	n.d.

Table C4. Regression equation with no intercept that produces *K*, the dry-weight biomass (kg).

[V = shrub volume (m^3), which is calculated as an elliptical tube using the equation $V = \frac{h\,\pi ab}{4}$, where h = height (m) and a and b = diameters (m). n.d. = no data, n.a. = not applicable. Sources: (1) California Desert Plan Staff, unpub. data, 1979. (2) Garcia-Moya and McKell, 1970. (3) Storey, 1969. (4) Green and others, unpub. data, 1978]

Species	Volume-biomass coefficient *K*	*n*	R^2	Source
Acacia greggii	0.8	20	n.d.	2
Acamptopappus sphaerocephalus	10.65	7	0.90	1
Achnatherum hymenoides	1.04	8	0.98	1
Achnatherum speciosum	2.92	10	0.97	1
Ambrosia dumosa	2.36	10	0.98	1
Artemisia spinescens	4.01	10	0.94	1
Atriplex confertifolia	6.39	10	0.99	1
Atriplex hymenelytra	2.83	12	0.98	1
Atriplex polycarpa	4.54	10	0.97	1
Chrysothamnus nauseosus	3.49	10	.84	1
Ceanothus greggii	4.73	31	0.97	4
Cercidium floridum	1.00	10	0.97	1
Coleogyne ramosissima	4.80	10	0.94	1
Distichlis spicata	1.82	9	0.89	1
Encelia farinosa	0.91	10	0.89	1
Ephedra nevadensis	4.29	10	0.94	1
Ephedra viridis	5.47	5	0.99	1
Ericameria cooperi	2.79	10	0.94	1
Ericameria linearifolia	2.44	10	0.99	1
Eriogonum fasciculatum	2.53	10	0.84	1
Erioneuron pulchellum	1.46	7	0.92	1
Ferocactus cylindraceus	107.29	6	0.98	1
Fouquieria splendens	6.13	10	0.97	1
Grayia spinosa	4.28	10	0.82	1
Gutierrezia microcephala	2.11	5	0.93	1
Haplopappus gooddingii	0.304	10	0.92	1
Hymenoclea salsola	1.54	10	0.96	1
Juniperus osteosperma	3.36	13	0.96	3
Krameria parvifolia	0.98	10	0.96	1
Krameria grayii	0.55	5	n.d.	2
Krascheninnikovia lanata	3.90	7	0.83	1
Larrea tridentata	2.14	10	0.86	1
Lycium brevipes	12.98	10	0.95	1
Menodora spinescens	8.36	5	0.89	1
Muhlenbergia porteri	1.92	10	0.88	1
Olneya tesota	0.91	10	0.91	1
Opuntia acanthocarpa	1.098	16	0.98	1
Opuntia bigelovii	10.2	2	n.a.	1

Table C4. Regression equation with no intercept that produces *K*, the dry-weight biomass (kg).—Continued

[V = shrub volume (m^3), which is calculated as an elliptical tube using the equation $V = \frac{h\,\pi ab}{4}$, where h = height (m) and a and b = diameters (m). n.d. = no data, n.a. = not applicable. Sources: (1) California Desert Plan Staff, unpub. data, 1979. (2) Garcia-Moya and McKell, 1970. (3) Storey, 1969. (4) Green and others, unpub. data, 1978]

Species	Volume-biomass coefficient *K*	*n*	R^2	Source
Opuntia phaeacantha	11.70	5	0.99	1
Pinus monophylla	2.47	26	0.98	3
Pleuraphis jamesii	5.21	10	0.88	1
Pleuraphis rigida	3.60	10	0.96	1
Prosopis glandulosa	0.81	10	0.86	1
Prunus fasciculata	3.45	5	0.98	1
Psorothamnus polydenius	4.00	n.d.	n.d.	1
Psorothamnus spinosus	0.63	10	0.91	1
Salazaria mexicana	0.9	50	n.d.	2
Senna armata	3.29	10	0.91	1
Sporobolus airoides	6.11	5	0.93	1
Suaeda torreyana	0.75	10	0.93	1
Thamnosma montana	2.99	5	0.97	1
Tetradymia spinosa	3.19	10	0.92	1
Yucca baccata	4.88	5	0.97	1
Yucca brevifolia	6.65	6	0.99	1
Yucca schidigera	16.94	10	0.98	1

Table C5. This table includes estimates of volume density (*K*) not included in tables C1-C4.

[*e* = estimated using an undocumented technique. See Table C4 for additional notes (Bureau of Land Management, 1980)]

Species	Volume density (kg/m3)
Agave deserti	5.0*e*
Agave utahensis	5.0*e*
Allenrolfea occidentalis	1.5*e*
Aristida sp.	2.9*e*
Artemisia nova	1.8*e*
Atriplex lentiformis	3.0*e*
Atriplex spinifera	6.4*e*
Atriplex torreyi	5.0*e*
Bebbia juncea	0.8*e*
Beleperone californica	3.0*e*
Bouteloua curtipendula	1.9*e*
Bouteloua eriopoda	1.9*e*
Bouteloua gracilis	1.9*e*
Brickellia arguta	1.3*e*
Cercocarpus intricatus	4.0*e*
Cercocarpus ledifolius	1.7*e*
Chilopsis linearis	0.5*e*
Chrysothamnus paniculatus	3.5*e*
Chrysothamnus teretifolius	3.3*e*
Chrysothamnus viscidiflorus	3.3*e*
Cowania mexicana	4.8*e*
Psorothamnus polydenius	3.0*e*
Echinocereus engelmanii	10.0*e*
Encelia fructescens	1.0*e*
Ephedra californica	5.5*e*
Eriogonum wrightii	3.0*e*
Fallugia paradoxa	4.0*e*
Garrya flavescens	4.7*e*
Gutierrezia californica	2.1*e*
Hyptis emoryi	1.3*e*
Isomeris arborea	3.5*e*
Juniperus californica	3.4*e*
Juniperus occidentalis	3.4*e*
Lepidospartum squamatum	3.0*e*
Lotus rigidus	2.0*e*
Lycium cooperi	2.0*e*
Mirabilis bigelovii	0.4*e*

Species	Volume density (kg/m3)
Muhlenbergia microsperma	2.5*e*
Nolina bigelovii	17.0*e*
Opuntia basilaris	11.7*e*
Oputia echinocarpa	1.1*e*
Opuntia ramosissima	1.1*e*
Petalonyx thurberi	3.3*e*
Peucephyllum schottii	3.0*e*
Poa scabrella	1.1*e*
Prosopis pubescens	0.8*e*
Purshia glandulosa	4.8*e*
Quercus chrysolepis	4.5*e*
Quercus dumosa	4.5*e*
Ribes velutinum	1.0*e*
Salcornia utahensis	1.5*e*
Salix exigua	1.0*e*
Salvia dorrii	3.0*e*
Salvia mohavensis	3.0*e*
Sarcobatus vermiculatus	4.0*e*
Sitanian hystrix	1.1e
Stephanomeria pauciflora	0.8*e*
Trixis californica	1.0*e*
Viguiera deltoidea v. *parishii*	1.0*e*

Appendix D: Additional Resources

Web Resources

Bainbridge, D., MacAller, R., Fidelibus, M., Franson, R., Williams, A.C., and Lippit., L., 1995, A beginner's guide to desert restoration: Denver, Colo., Department of the Interior, National Park Service, Denver Service Center [http://www.westernecology.com/pdfs/bainbridgebook.pdf].

Desert Managers Group: Russel Scofield, DOI Coordinator, Phone: 760-365-0955, Cell: 760-900-5643, Fax: 760-365-5526: http://www.dmg.gov/.

Bainbridge, D.A. Environmental restoration: http://www.ecocomposite.org/restoration/.

Thomas, K.A., Keeler-Wolf, T., Franklin, J., and Stine, P., 2004, Mojave Desert Ecosystem Program—Central Mojave vegetation database: U.S. Geological Survey, 251 p. [http://www.dfg.ca.gov/biogeodata/vegcamp/pdfs/VegMappingRpt_Central_Mojave_Vegetation_Database.pdf].

Mojave Desert Ecosystem Program: http://www.mojavedata.gov/.

Desert Research Institute: http://www.dri.edu/Aboutdri/.

Recoverability and Vulnerability of Desert Ecosystems: http://mojave.usgs.gov/rvde/index.html.

Rangeland health—New methods to classify, inventory, and monitor rangelands: Committee on Rangeland Classification, Board on Agriculture National Research Council [http://books.nap.edu/openbook.php?record_id=2212&page=18].

Belnap, J., 2005, Biological soil crusts: http://www.soilcrust.org/

Other Resources

Bauder, E.T., and Larigauderie, A., 1991, Rehabilitation success and potential of Mojave and Colorado Desert sites—Final Report to Department of Parks and Recreation, Off-Highway Motor Vehicle Recreation Division: Sacramento, Calif., 77 p.

Several guides and decision-making tools have been developed at Joshua Tree National Park, 74485 National Park Drive, Twentynine Palms, CA 92277-3597. Phone: (760) 367-5500.

Bureau of Land Management Ridgecrest Field Office, 300 S. Richmond Rd., Ridgecrest, CA, 93555, Phone: (760) 384-5400, Fax: (760) 384-5499: http://www.blm.gov/ca/st/en/fo/ridgecrest.html.

Soil Ecology and Restoration Group, San Diego State University: http://www.serg.sdsu.edu/SERG/index.html.

Racin (1988) published a report on revegetation of slopes along U.S. Highway 395 in Inyo and Mono Counties, California, with native plant seedlings: Racin, J.A., 1988, Revegetating desert cut slopes with containerized native shrubs: Sacramento, Calif., California Department of Transportation, FHWA/CA/TL-88.09 [http://www.dot.ca.gov/newtech/researchreports/1981-1988/88-09.pdf].

Knute, A., and Faber, C., 1991, Plants of the east Mojave: Cima, Calif., Wide Horizons.

Lovich, J.E,, and Bainbridge, D., 1999, Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration: Environmental Management, v. 24, p. 309–326.

Rosentreter, R., Bowker, M., and Belnap, J., 2008, A field guide to biological soil crusts of western U.S. drylands—Common lichens and bryophytes: Denver, Colo., U.S. Government Printing Office, 104 p.

Glossary

Attributes are any living or nonliving features or processes of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **indicator** is reserved for a subset of attributes that is particularly information-rich, in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon, 2003; *science.nature.nps.gov/im/monitor/Glossary.cfm*).

C_3 photosynthetic pathway: the most common biochemical pathway for plant photosynthesis, called C_3, because CO_2 is initially incorporated into a three-carbon compound. Because this pathway requires fewer enzymes and less specialized anatomy, and because stomata are open during the day, it is the most efficient in cooler, moister conditions.

C_4 photosynthetic pathway: a photosynthetic pathway that is an adaptation to high light and arid conditions, in which CO_2 is first incorporated into a four-carbon compound. Specialized anatomy and enzymes allow for rapid delivery of CO_2 to the photosynthetic pathway, allowing stomata to be closed more than in C_3 plants.

CAM photosynthetic pathway stands for Crassulacean Acid Metabolism; CAM is an adaptation to high light and aridity, because stomata are closed in the day and opened at night when evaporation rates are lower. The CO_2 is stored in an acid at night and released inside the plant during the day to be broken down for photosynthesis. CAM plants are typically succulents like cactus and agave.

Degradation refers to an anthropogenically induced reduction in the capacity of a particular ecosystem or ecosystem component to perform desired ecosystem functions (for example, degraded capacity for conserving soil and water resources). Human actions may degrade desired ecosystem functions directly, or they may do so indirectly by damaging the capacity of ecosystem functions to resist or recover from natural disturbances and/or anthropogenic stressors (derived from the concepts of Herrick and others, 1995; Ludwig and others, 1997; Whisenant, 1999; Archer and Stokes, 2000; Whitford, 2002).

Disturbance is "...any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (White and Pickett, 1985, p. 7). In relation to monitoring, disturbances are considered to be ecological factors that are within the evolutionary history of the ecosystem (for example, drought). These are differentiated from anthropogenic factors (stressors, below) that are outside the range of disturbances naturally experienced by the ecosystem (Whitford, 2002).

Driver refers to a natural agent responsible for causing temporal changes or variability in quantitative measures of structural and functional attributes of ecosystems.

Ecological indicator is explained below. Please see **indicator**.

Ecological integrity refers to a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relations are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes (*science.nature.nps.gov/im/monitor/Glossary.cfm*).

Ecological site indicates a kind of land with specific physical characteristics, which differs from other kinds of land in its ability to produce distinctive types and amounts of vegetation and in its response to management (Society for Range Management Task Group on Unity in Concepts and Terminology, 1995, p. 279, http://www.rangelands.org/ram/evaluating.shtml).

Ecological sustainability is the tendency of a system or process to be maintained or preserved over time without loss or decline (Dale and others, 2000, p. 642; see also **sustainable ecosystem**).

Ecosystem refers to a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries (Likens, 1992, cited by Christensen and others, 1996, p. 670).

Ecosystem functioning refers to the flow of energy and materials through the arrangement of biotic and abiotic components of an ecosystem. It includes many ecosystem processes, such as primary production, trophic transfer from plants to animals, nutrient cycling, water dynamics, and heat transfer. In a broad sense, ecosystem functioning includes two components: ecosystem resource dynamics and ecosystem stability (Díaz and Cabido, 2001).

Ecosystem health is a metaphor pertaining to the assessment and monitoring of ecosystem structure, function, and resilience in relation to the notion of ecosystem "sustainability" (following Rapport, 1998; Costanza and others, 1998). A healthy ecosystem is sustainable (see **sustainable ecosystem**). "Ecosystem sustainability" and "ecosystem quality" are preferable terms due to the confusion that "ecosystem health" conveys (Suter, 1993).

Ecosystem integrity is explained above. Please see **ecological integrity**.

Ecosystem management refers to the processes of land use decision making and land management practices that take into account the full suite of organisms and processes that characterize and comprise an ecosystem, and is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal of sustainability of ecosystem structure and function, recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity (Dale and others, 2000, p. 642).

Ecosystem sustainability is explained below under **Sustainable ecosystem**.

Functional groups indicate groups of species that have similar effects on ecosystem processes (Chapin and others, 1996). This term is frequently applied interchangeably with **functional types**.

Functional types are sets of organisms sharing similar responses to environmental factors, such as temperature, resource availability, and disturbance (= functional response types) or similar effects on ecosystem functions, such as productivity, nutrient cycling, flammability, and resistance/resilience (= functional effect types; Díaz and Cabido, 2001).

Hydrologic function (upland systems) refers to the capacity of a site to capture, store, and safely release water from rainfall, run-on, and snowmelt, to resist a reduction in this capacity, and to recover this capacity following degradation (Pellant and others, 2000).

Hydrologic function (lotic and lentic systems) refers to the capacity of an area to dissipate energies associated with (1) high stream flow (lotic); or (2) wind action, wave action, and overland flow (lentic), thereby reducing erosion and improving water quality; to filter sediment, capture bedload, and aid floodplain development; to improve flood-water retention and groundwater recharge; to develop root masses that stabilize channel banks against cutting action; to develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; and to support greater biodiversity (from Prichard and others, 1998).

Indicator (general use of term) is a term reserved for a subset of environmental attributes that is particularly information rich, in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon, 2003; http://science.nature.nps.gov/im/monitor/Glossary.cfm).

Indicators of ecosystem "health" (specific use of term) are measurable attributes of the environment (biotic or abiotic) that provide insights regarding (1) the functional status of one or more key ecosystem processes, (2) the status of ecosystem properties that are clearly related to these ecosystem processes, and/or (3) the capacity of ecosystem processes or properties to resist or recover from natural disturbances and/or anthropogenic stressors (modified from Whitford, 1998). In the context of ecosystem health, key ecosystem processes and properties are those that are most closely associated with the capacity of the ecosystem to maintain its characteristic structural and functional attributes over time (including natural variability). See Suter (1993) for criticism of using the term "health".

Landscape refers to a spatially structured mosaic of different types of ecosystems interconnected by flows of materials (for example, water, sediments), energy, and organisms.

Major functional groups refers to organisms with similar effects on ecosystem functions, such as primary production, nutrient cycling, and soil stabilization, and functional response types—organisms with similar responses to environmental factors, such as climate, resource availability, natural disturbances, and land-use activities.

Measures refer to the specific variables used to quantify the condition or state of an Attribute or Indicator (or **vital sign**). These are specified in definitive sampling protocols. For example, stream acidity may be the indicator, while pH units are the measure (http://science.nature.nps.gov/im/monitor/Glossary.cfm).

Rangeland indicates land on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs, or shrubs, and is managed as a natural ecosystem. Rangelands include natural grasslands, savannas, shrublands, many deserts, tundra, alpine communities, marshes, and wet meadows (Society for Range Management, 1999). For purposes of this document, we further include pinyon-juniper woodlands and oak woodlands in this definition.

Resistance is the capacity of a particular ecological attribute or process to remain essentially unchanged from its reference state, despite exposure to a disturbance and/or stressor (adapted from Grimm and Wissel, 1997). Resistance is a dynamic property that varies in relation to environmental conditions (Scheffer and others, 2001).

Stability refers to the capacity of a site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water (Pellant and others, 2000).

State, as applied to state-and-transition models, is defined as "a recognizable, resistant and resilient complex of two components, the soil [or geomorphic] base and the vegetation structure" (Stringham and others, 2003, p. 109). These two ecosystem components interactively determine the functional status of the primary ecosystem processes of energy flow, nutrient cycling, and hydrology. States are dynamic and "... are distinguished from other states by relatively large differences in plant functional groups and ecosystem processes [including disturbance and hydrologic regimes] and, consequently, in vegetation structure, biodiversity, and management requirements" (Bestelmeyer and others, 2003, p. 116; also see **threshold** and **transition**.)

Stressor refers to any physical, chemical, or biological entity or process that can induce an adverse response (modified from the Environmental Monitoring and Assessment Program Master Glossary, http://www.epa.gov/emap/html/pubs/docs/resdocs/mglossary.html). For purposes of monitoring, stressors are considered to be anthropogenic factors that are outside the range of disturbances naturally experienced by the ecosystem (Whitford, 2002). Compare **stressor** with **disturbance**, above.

Sustainable ecosystem indicates an ecosystem "...that, over the normal cycle of disturbance events, maintains its characteristic diversity of major functional groups, productivity, and rates of biogeochemical cycling" (Chapin and others, 1996, p. 1016).

Threshold, as applied to state-and-transition models, is a point "...in space and time at which one or more of the primary ecological processes responsible for maintaining the sustained [dynamic] equilibrium of the state degrades beyond the point of self-repair. These processes must be actively restored before the return to the previous state is possible. In the absence of active restoration, a new state ... is formed" (Stringham and others, 2003, p. 109). Thresholds are defined in terms of the functional status of key ecosystem processes and are crossed when capacities for resistance and resilience are exceeded. (Also see State and Transition.)

Transition, as applied to state-and-transition models, is a trajectory of change that is precipitated by natural events and/or management actions which degrade the integrity of one or more of the primary ecological processes responsible for maintaining the dynamic equilibrium of the state. Transitions are vectors of system change that will lead to a new state without abatement of the stressor(s) and/or disturbance(s) prior to exceeding the system's capacities for resistance and resilience (adapted from Stringham and others, 2003; also see **state** and **threshold**.)

Vital signs indicate a subset of physical, chemical, and biological elements and processes of ecosystems that are selected to represent the overall quality or condition of resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes; http://science.nature.nps.gov/im/monitor/Glossary.cfm).

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USGS

J. Belnap, R.H. Webb, M.E. Miller, D.M. Miller, L.A. DeFalco, P.A. Medica, M.L. Brooks, T.C. Esque, and D. Bedford—Monitoring Ecosystem Quality and Function in Arid Settings of the Mojave Desert—Scientific Investigations Report 2008-5064

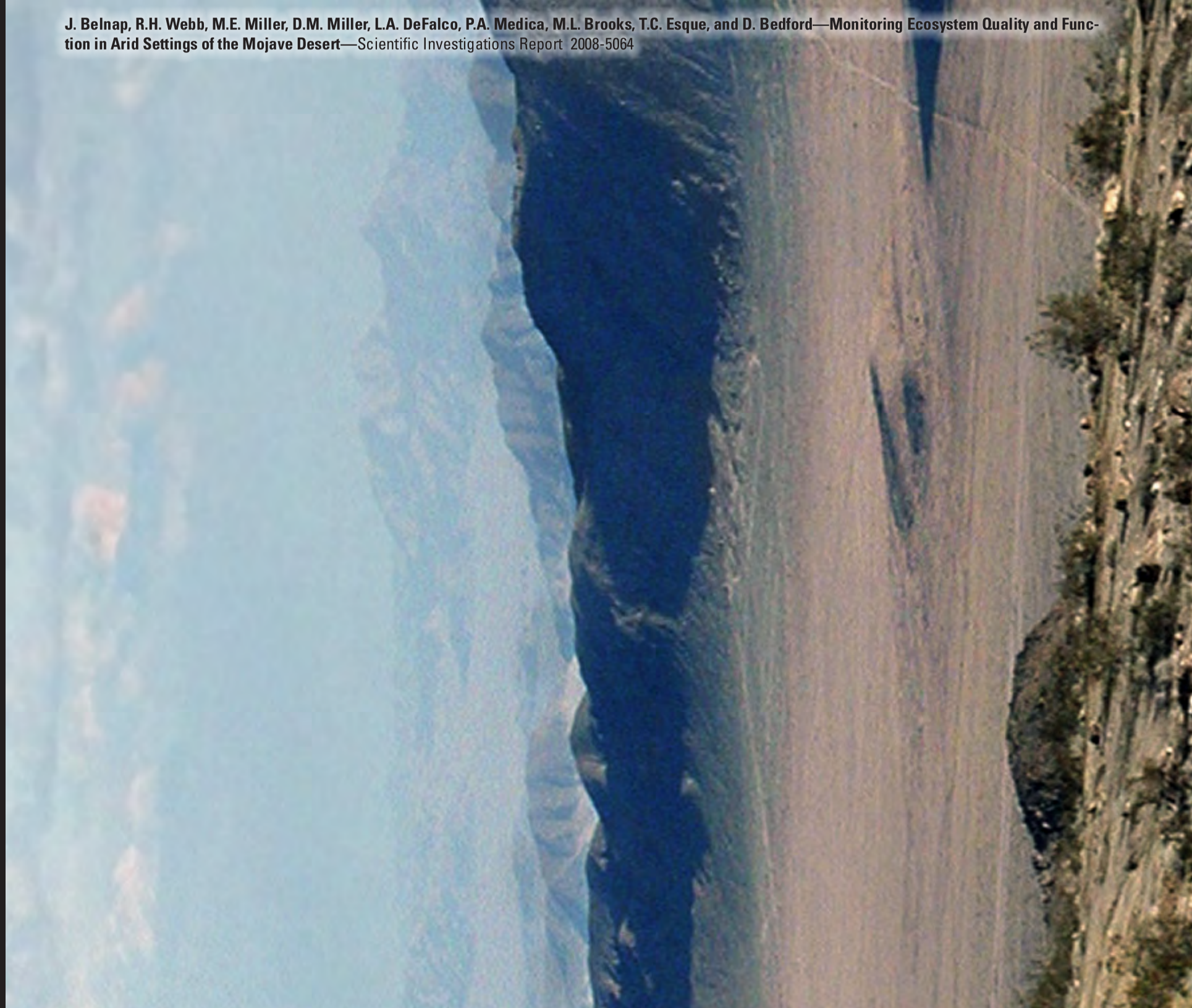
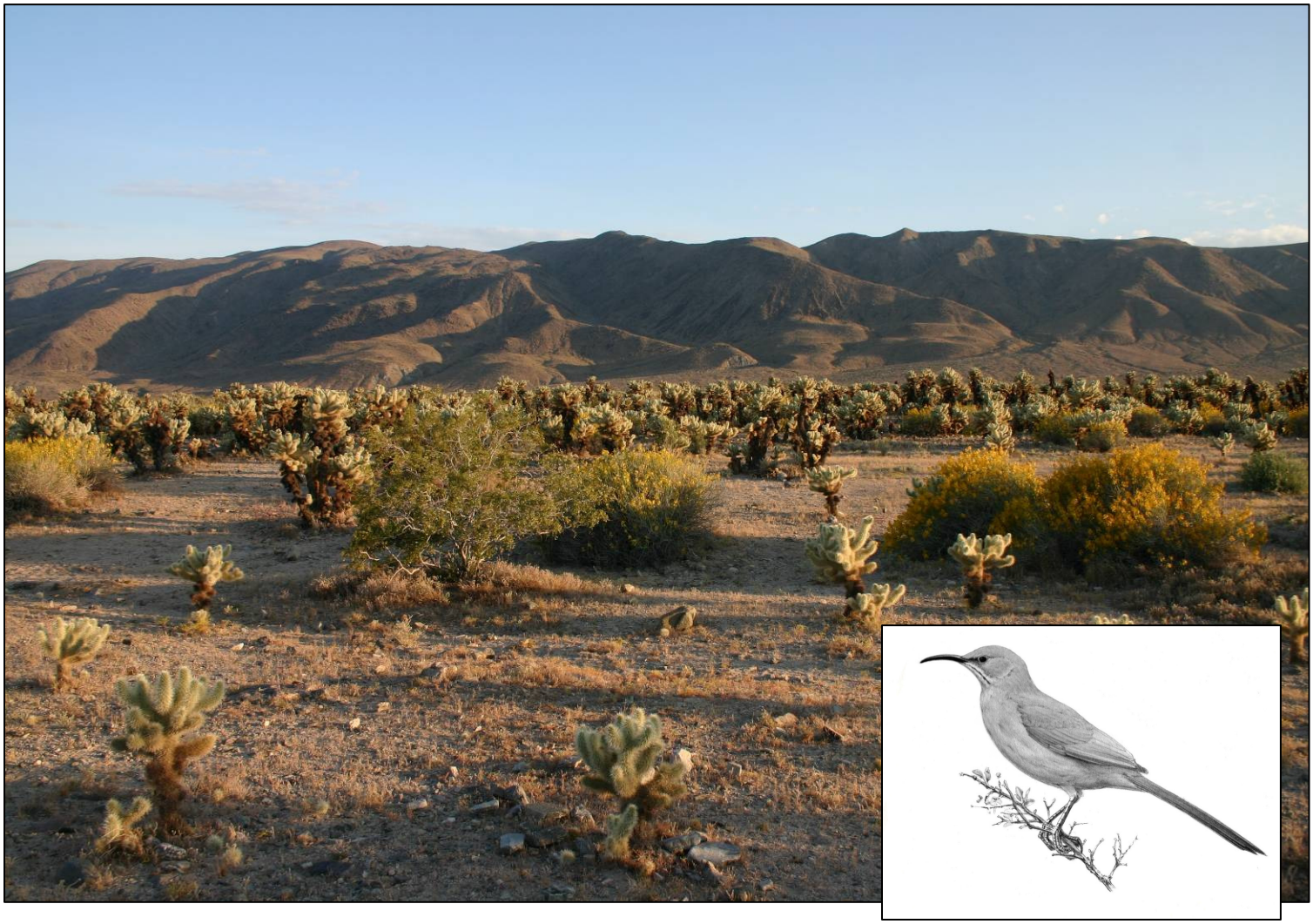


EXHIBIT 427

The Desert Bird Conservation Plan

A Strategy for Protecting and Managing Desert Habitats and Associated Birds in the Mojave and Colorado Deserts



A project of California Partners in Flight
and PRBO Conservation Science

The Desert Bird Conservation Plan

A Strategy for Protecting and Managing Desert Habitats and Associated Birds in the Mojave and Colorado Deserts

Version 1.0

2009

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Cover Illustration

Keith Hansen (www.keithhansen.com). Illustration is from the upcoming book entitled "A Guide to the Birds of the Sierra" by Ted Beedy and David Lukas.

Financial Contributors
PRBO Conservation Science
DMARLOU Foundation
National Fish and Wildlife Foundation
Sonoran Joint Venture

Acknowledgements:
PRBO Conservation Science and California Partners in Flight wishes to thank the DMARLOU Foundation, National Fish and Wildlife Foundation, and the Sonoran Joint Venture for funding this important project. Many thanks to everyone who helped write, edit, and publish this document. Many individuals and organizations volunteered time to this project and continue to support the mission of Partners in Flight. Special thanks to those who contributed to the development of this plan: University of Nevada-Reno, University of Arizona, University of California-Riverside, California Bureau of Land Management, Pronatura Sonora, Pronatura Baja California, IMADES, Arizona GFD, Yuma Proving Grounds, NPS Mojave I&M Network, Audubon California, Tucson Audubon, The Nature Conservancy, The Hummingbird Monitoring Network, Arizona Bureau of Land Management, U.S.D.A.- Natural Resources Conservation Service, Sonoran Joint Venture, ABCI, CDFG, CA SWRCB, Jones & Stokes, the United States Fish and Wildlife Service.

Recommended Citation

CalPIF (California Partners in Flight). 2009. Version 1.0. The Desert Bird Conservation Plan: a Strategy for Protecting and Managing Desert Habitats and Associated Birds in California. California Partners in Flight. http://www.prbo.org/calpif/plans.html

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Executive Summary

This Desert Bird Conservation Plan is a collaborative effort of the California Partners in Flight (CalPIF) and PRBO Conservation Science. It has been developed to guide conservation policy and action on behalf of desert habitats and wildlife. The geographic scope of this plan is the Mojave Desert in California, southern Nevada, and eastern Arizona, and the Colorado Section of the Sonoran Desert in California, eastern Arizona, northern Sonora, and Baja California Norte (Figure 1-1). The Conservation Plan focuses on data concerning focal species associated with desert habitats, but conservation recommendations, if implemented, should benefit many desert-associated species. The plan, which includes both this written document, an associated website, and a Geographic Information System (GIS) database of desert monitoring projects and focal species status is intended to provide a source of information on desert bird conservation for managers, agencies, landowners, academic institutions and non-governmental organizations.

This Conservation Plan, along with a (GIS) database of bird monitoring data obtained in desert habitats (maintained by PRBO Conservation Science and the California Avian Data Center) is the first iteration of a continuing process of updating habitat conservation recommendations based on the latest scientific data. This is not a regulatory document, nor does it represent the policies of any agency or organization.

An important extension of this Conservation Plan is the on-line GIS database of desert monitoring projects and focal species breeding status available through the California Avian Data Center at www.prbo.org/cadc/ (Ballard et al. 2003a). Contributing to and managing data in this database is accomplished through a web interface, to which access is available by request. This database is used for cataloguing new information and new analysis and for updating conservation recommendations and goals. Bird and study site data will be posted on this web site, periodically updated, and made available for use by the public. Therefore, this Conservation Plan is a "living" document.

Biological Need

The Mojave and Colorado (a sub-region of the Sonoran desert) deserts that are described in this plan contain the hottest, driest habitats in North America. As a result, Mojave and Sonoran ecosystems possess a host of endemic plants and animals, specialists that have evolved over millions of years to handle extreme environmental stresses. Due to remoteness and difficult research conditions, bird populations found in Mojave and Colorado desert habitats have poor or no trend data (Rich et al. 2004). Yet two of the top three fastest-growing metropolitan areas in the United States from 1990-2000 (Las Vegas, NV and Yuma, AZ) are found within the area covered by this plan. In the western Mojave Desert, human population has tripled over the last twenty years (Mojave Desert Ecosystem Program 2006 http://www.mojavedata.gov/westmojave/info.html). The Mojave and Colorado deserts face rapid and permanent loss of desert habitats, fierce competition for scarce water resources, and increased recreation pressures. These pressures have been found to negatively impact desert bird populations (Latta et al. 1999).

Desert riparian habitats are among the most imperiled habitats in North America. As a result, endangered species such as Southwestern Willow Flycatchers, western Yellow-billed Cuckoos, and Least Bell's Vireos that rely on desert riparian habitats have captured much of our research attention in recent years. The Mojave and Colorado deserts comprise roughly a quarter of the state of California—yet only a small fraction of this land can be classified as riparian. Mojave and Sonoran

Figure 1-1. Approximate area (dashed line) of desert regions addressed in the Desert Bird Conservation Plan, which includes the Mojave Desert (northern half of area) and the Colorado section of the Sonoran Desert (southern half of area).

desert scrubland, ephemeral riparian (also named "xeric riparian") woodland, and coniferous "sky islands" hold significant proportions of the global populations of several desert endemics.

Rapid human population increases in the Mojave and Colorado deserts have resulted in rapid increases in exotic, invasive species that have been shown to dramatically alter desert ecosystems. In many cases, ecosystem changes tied to exotic species have been shown to negatively impact native plant and animal diversity. African buffelgrass, red brome and Mediterranean grasses have altered fire regimes in the Plains of Sonora, and Arizona Uplands section of the Sonoran Desert, and are widespread in the Mojave and Colorado deserts (Esque and Schwalbe 2002). Saltcedar has replaced native cottonwood-willow riparian forests, as well as Fabaceous Sonoran Desert woodland vegetation in riparian transition zones and at desert springs and oases (Cleverly et al. 1997, Stromberg and Chew 2002). However, effects of exotic invasions on desert bird communities are generally unknown (Esque and Schwalbe 2002). Wild burro preferential grazing may also limit Sonoran Desert woodland regeneration in the lower Colorado River Valley (Woodward and Ohmart 1976, Hanley and Brady 1977).

Land ownership patterns in the Mojave and Colorado deserts provide a blend of opportunities and concerns that are relatively unique. The Mojave Desert has the highest proportion of public ownership of any ecoregion in North America (The Nature Conservancy 2001), with roughly 85% in federal or state ownership. In the United States, nearly 70% of the greater Sonoran Desert is in federal or state ownership (Marshall et al. 2000). South of the border, the opposite pattern holds: nearly 80% of Mexico's portion of the Sonoran Desert is in private or communal status under the *Ejido* system (Marshall et al. 2000).

Bird species of the southwestern United States tend to have smaller populations and smaller breeding ranges (Figure 1-2), rendering these species more vulnerable to ecological stresses (Rich et al. 2004). Thus land management decisions of American state and federal agencies (such as the Bureau of Land Management, Department of Defense, National Park Service, and Arizona Game and Fish Department) will have a large impact on global populations of Mojave and Colorado Desert breeding bird species. Conversely, recent changes in the Mexican Constitution allow for the sale and transfer of communal *ejido* lands, placing the conservation of Colorado Desert habitats into the hands of many. In light of increasing threats and under-studied desert bird populations in a matrix of land ownership challenges, it is important to assemble our current knowledge into a cohesive plan that will address the needs of the birds of the Mojave and Colorado deserts.

Growing interest and rapid implementation of large-scale alternative energy infrastructures in the desert further highlights the need for a Desert Bird Conservation Plan. The resources contained in this plan will also be extremely useful to help inform the planning and siting of wind and solar farms such that clean renewable energy may be developed while minimizing the impacts to desert bird populations and their sensitive habitats.

Mission and Objectives

The mission of Partners in Flight (PIF) is to stop the decline of, and maintain or increase, healthy populations of landbirds in North America. This mission translates into identification of habitat conservation and management priorities for bird species at risk in California. By developing the Desert Bird Conservation Plan, CalPIF seeks to promote conservation and restoration of these habitats to support long-term viability and recovery of both native bird populations and other native species. The goals of the Desert Bird Conservation Plan are to:

- Emphasize what is needed to conserve both populations of species, and species assemblages, which are defined here as groups of naturally co-occurring bird species.

- Synthesize and summarize current scientific knowledge of the requirements of birds in desert habitats.

- Provide recommendations for habitat protection, restoration, management, monitoring, and policy to ensure the long-term persistence of birds and other wildlife dependent on desert ecosystems.

- Support and inform efforts to increase the overall acreage and effectiveness of desert habitat conservation efforts in California by funding and promoting on-the-ground conservation projects.

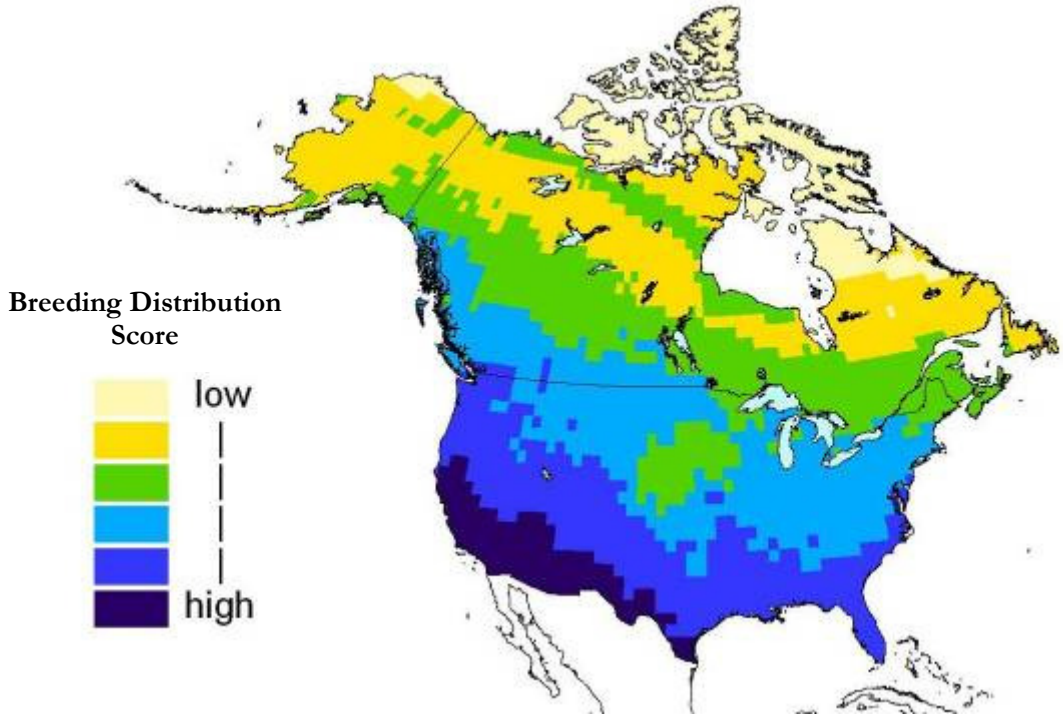

Figure 1-2. Average vulnerability among species occurring in each lat-long block during the breeding season, based on Breeding Distribution (BD) scores for 448 landbird species. Smallest range size = highest vulnerability (high BD score); largest range size = lowest vulnerability (low BD score) (Rich et al. 2004).

The subject of land management and land use, whether on private or public lands, can be contentious. CalPIF supports the need for land managers and landowners to have flexibility to develop systems that accommodate their needs while seeking to achieve the desired habitat characteristics that will maximize benefits to wildlife. CalPIF supports and will seek to maximize the benefits of new and ongoing efforts to ensure a critical level of desert habitat is protected, monitored, and properly managed for future generations of Californians and wildlife.

Findings and Recommendations

This Conservation Plan has been developed collaboratively by many of the leading bird researchers in California, Nevada, Arizona, and Mexico through a process designed to:

- Capture the conservation needs for the complete range of desert habitat types throughout the state.
- Develop biological conservation objectives using current data on desert-associated focal species.

At more than 25 monitoring sites throughout California, researchers have been collecting data on desert songbirds and are contributing to the CalPIF songbird monitoring database (http://cain.nbii.gov/prbo/calpifmap/index.html). Some of these data have contributed to the focal species accounts and recommendations presented in this plan. This document emphasizes a suite of 15 bird species chosen because of their conservation interest and as focal species representative of desert habitats.

Chapter 1. Introduction

Deserts comprise a large portion of the western United States. Each of the four major North American deserts (Great Basin, Mojave, Sonoran, and Chihuahuan) possesses a unique spectrum of climates and physiography that present hurdles and ultimately, opportunities for their representative flora and fauna. The Mojave Desert ecoregion alone contains 230 special status plant species, the majority of them endemics (The Nature Conservancy 2001). The Sonoran Desert was designated one of 200 world ecosystems to deserve special conservation attention due to its high diversity and number of endemics (Olson and Dinerstein 1998).

Desert aridity plays an integral part in plant and animal life – including human life - in this region. Stereotypes of the Mojave and Sonoran Deserts conjure images of sparse vistas emanating coils of heat into the atmosphere, cracked and desiccated soils, thorny plants and poisonous snakes. Yet the deserts of the southwestern United States and northwestern Mexico support an incredible diversity of flora and fauna found nowhere else in the world. The Mojave and Sonoran Deserts contain well-developed radiations of quail (family Odontophoriadae), doves (family Columbidae), owls (family Strigidae), hummingbirds (family Trochilidae), woodpeckers (family Picidae), gnatcatchers (family Sylviidae), and thrashers (family Mimidae), as well as the only North American occurrence of family Remizidae (Verdin) and the only occurrence of family Ptilogonatidae (Phainopepla) in the United States.

Our wide array of desert-adapted avian species is well known, but natural histories, demography and population trends for these species are often poorly understood (Sauer et al. 2005, Rich et al. 2004, Laudenslayer et al. 1992, Ehrlich et al. 1988). The Partners In Flight North American Landbird Conservation Plan (Rich et al. 2004) states that the population trends for the majority of PIF Watch List species for shrubland and woodland within the Southwest Avifaunal Biome remain unknown. One of the National PIF Landbird Conservation Plan's primary recommendations for the Southwest is straightforward and simple, and it highlights our paucity of knowledge regarding our desert birds: *"Conduct monitoring in the following southwestern habitats: thorn forest, coniferous forests, woodlands, Sonoran and Mojave Desert shrublands, and riparian."*

Photo by Ian Tait

Gila Woodpecker, a desert focal species

Birds are important targets of conservation planning not only because they are relatively conspicuous and charismatic, but also because they can serve as indicators of the health of the larger ecosystem in which they reside. Through focusing appropriate conservation efforts on a well-chosen suite of "focal" desert bird species, many other animals and plants may also benefit (Lambeck 1997). For example, demographic monitoring of bird species is especially valuable if those species serve as indicators of the presence of a threatened biological community (Chase et al. 2000), or are sensitive to a particular type of environmental change, such as habitat fragmentation (Noss 1990). Other species, especially those with large area requirements, may qualify as umbrella species, i.e., species whose protection will result in the protection of many other species (Noss 1990). Thus, this conservation plan focuses on a subset of Mojave and Colorado Desert bird species, with the aim of contributing to the conservation of desert ecosystems as a whole.

Conservation Plan Framework and Objectives

The California Partners In Flight Desert Bird Conservation Plan (Desert BCP) will address bird populations east of California's major mountain axis in the Mojave and Lower Colorado River Valley section of the Sonoran Desert, also referred to as the Colorado Desert (Figure 2) as defined in detail in Chapter 2. The Colorado Desert is one of six subsections of the Sonoran Desert first defined by Forrest and Wiggins, and is found in southeastern California, Arizona, Sonora, and Baja California Norte at elevations under 2000' (600 m) above Sea Level (Shreve and Wiggins 1964).

Desert habitats are also covered in the CalPIF Sagebrush Bird Conservation Plan (Great Basin Desert), the CalPIF Coniferous Forests Bird Conservation Plan, and in the CalPIF Riparian Bird Conservation Plan. The Desert BCP will generally relegate itself to Mojave Desert habitats found below the lower montane zone of the Mojave Desert, which begins at 3,500 (1500 m) above Sea Level, to avoid overlap with the Coniferous Forests BCP. The Desert BCP will also touch upon desert riparian habitats, but it is targeted at bird populations of "dry riparian" washes and at Mojave and Sonoran scrubland, to avoid overlap with the Riparian BCP.

Though the Desert BCP was originally conceived to address desert habitats in California, interest in a comprehensive, habitat-based desert plan extends beyond California's borders into Nevada, Arizona, and Mexico. State-based Partners In Flight conservation plans written for Nevada and Arizona do address desert habitats, yet due to myriad other habitats of these states, a conservation plan tailored specifically for desert habitats will provide managers and researchers with a more detailed look at bird assemblages generally unique to the desert. The CalPIF Desert BCP will address Mojave and Colorado Desert habitats in Arizona and Nevada with the goal of complementing and adding to existing bird conservation plans for these states. Desert conservation planning has not been addressed outside of riparian habitats in northwest Mexico, and the Desert BCP will represent an introduction to desert bird conservation south of the border.

The Salton Sea is also located within the Colorado Desert in California, and much has been written on its current demise, as well as its crucial importance for breeding and migrant birds. Version 1.0 of the Desert BCP will serve as a literature review of this non-traditional desert habitat, with a goal of additional chapters of Salton Sea information in subsequent versions of the Desert BCP. In the future, we hope to address desert riparian, coniferous, and habitats of the Salton Sea in greater detail.

Partners in Flight

This Conservation Plan is one of many to be created under the aegis of the international movement known as Partners in Flight (PIF), which seeks to protect North American landbirds throughout their ranges by reversing species declines, stabilizing populations, and "keeping common birds common." PIF is an international cooperative endeavor initiated in 1990 in response to alarming population declines noted among species of Neotropical migratory birds. The program encourages conservation through partnerships before species and their habitats become threatened or endangered and provides a constructive framework for guiding nongame landbird conservation activities throughout the United States, Canada, Mexico, and Central America.

Photo by Justin Hite

Female Long-eared Owl (Asio otus) incubating on the Milpitas Wash, Imperial County, CA. In wet years, Long-eared Owls can be found to nest in old-growth desert wash habitats in the southern Lower Colorado River Valley, outside their expected breeding range (McCreedy 2006[b]).

California Partners in Flight (CalPIF) was formed in 1992 with the full participation of the state's land and wildlife managers, scientists and researchers, and private organizations interested in the conservation of nongame landbirds. Noting that the major cause of population declines in California appeared to be habitat loss, CalPIF began identifying critical habitats important to birds and worked cooperatively to protect and enhance remaining habitat fragments. Recognizing their critical importance, CalPIF initially focused on riparian zones throughout the state. However, CalPIF has developed plans for most other ecosystems, including oak woodlands, coastal scrub and chaparral, grasslands, coniferous forests, shrubsteppe, and the Sierra Nevada. Visit http://www.prbo.org/calpif/plans.html for more information and current versions of these plans.

California Partners in Flight Partners

Arizona Game and Fish Department
Bureau of Land Management
Bureau of Reclamation
California Department of Fish and Game
Department of Defense
Klamath Bird Observatory
Institute for Bird Populations
National Audubon Society
National Fish and Wildlife Foundation
National Park Service
Natural Resources Conservation Service
Northern Arizona University
PRBO Conservation Science
Pronatura Noroeste
San Francisco Bay Bird Observatory
Sonoran Joint Venture

The Hummingbird Network
The Nature Conservancy
University of California - Riverside
University of Nevada - Reno
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S.D.A. Forest Service
Ventana Wilderness Society/Big Sur Ornithology Lab

Justification for the Conservation Plan

The justification for conservation can be articulated from various philosophical perspectives:

- An ecological perspective
- A perspective that emphasizes intrinsic value
- A primarily utilitarian or humanist perspective

Ecological Perspective

"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."

-Aldo Leopold, *The Sand County Almanac.*

The ecological arguments for conserving birds as a component of biodiversity emphasize the critical role that birds play in ecological systems. A conservation plan based on the needs of birds makes sense for a number of reasons. Birds are critical components of natural ecosystems, and they occupy an extremely diverse range of niches within desert systems. By managing for a diversity of birds, we will also protect many other elements of biodiversity and the natural processes that are an integral part of desert ecosystems. Also, because of their high metabolic rate, their relatively high position in the food chain and their distribution across a wide variety of habitats, birds are sensitive indicators of environmental conditions (Temple and Wiens 1989, Uliczka and Angelstam 2000, Bryce et al. 2002). Finally, birds are relatively easy and cost effective to monitor and they provide an excellent means by which to track larger changes in natural systems. Our rapidly expanding capacity to monitor demographic processes in birds (reproduction and survivorship) provides us with the ability to proactively address root causes of population declines and increases (Pienkowski 1991, DeSante and Rosenberg 1998).

Intrinsic Perspective

Modern philosophers and environmental leaders have increasingly recognized the intrinsic value of plants, animals, and even the inanimate physical environment (Callicott 1986, Sober 1986). Throughout human history, many cultural belief systems have greatly valued birds and other elements of the natural world for reasons other than materialistic needs. This tradition continues today and is meeting with broader acceptance in political and public life.

Utilitarian or Humanist Perspective

A strictly utilitarian or humanist argument for conservation of bird species focuses on the direct, tangible benefits that people and society derive from their ecosystem services. For example, many passerine species (including Neotropical migrants) play an indispensable role in control of forest and

agricultural insect pests, saving millions of dollars in the application of deleterious pesticides. Additionally, bird watching is a popular outdoor recreation and is currently enjoyed by an estimated 67.8 million Americans according to the 2000-2002 National Survey on Recreation and the Environment (NSRE 2000-2002). Non-consumptive bird use contributes 16,000 jobs and more than $622 million in retail sales annually to the California economy, which leads the nation in economic benefits derived from "birders." Ecotourism, with bird watching as a primary component, is increasingly seen as the best new source of income that can cushion resource-based economies as they transition to a sustainable level of resource use.

Black-throated Sparrow *Photo by Laura Hughes*

Chapter 2. Desert Habitats in California

The Desert Bird Conservation Plan is written for lower elevation habitats in the Mojave and Sonoran Desert bioregions east of California's major mountain axis. The Desert BCP will generally exclude traditional desert riparian habitats such as those found at the Amargosa, Mojave, Colorado, Virgin, Muddy, Bill Williams, and Gila Rivers, which are represented in the Riparian Bird Conservation Plan. The habitats covered by the Desert BCP align with Bird Conservation Region 33, which covers the Mojave and Sonoran Deserts.
(http://www.nabci-us.org/aboutnabci/bcrdescrip.pdf)

Deserts in general are defined as places that receive less than ten inches (250 mm) of annual precipitation (Dimmitt 2000[a]). However, climatologists also factor potential water loss (potential evapo-transpiration, or PET) into annual precipitation when defining aridity. Sunny, hot, and wind-exposed places have higher PET values, which equates to higher metabolic stresses to plants and animals. Thus Tucson, Arizona receives over ten inches of annual rainfall, but high PET values still render Tucson to be classified as Sonoran Desert. In general, PET:P (precipitation values) of over 3.0 signify a desert environment. Tucson's PET:P is 4.3, while Yuma, Arizona's ratio is 30 (Dimmitt 2000[a]).

The Mojave Desert and Colorado Desert are rain shadow deserts that receive the majority of their annual precipitation from sporadic winter storms that are strong enough to overcome the precipitation-draining coastal ranges to the west. The region also receives occasional bouts of tropical moisture during summer months, which can create intense thunderstorms referred to as "monsoons". Monsoonal moisture tends to enter the Sonoran and Mojave Deserts from the southeast, and the Sonoran Desert in particular harbors what is considered to be a bi-modal precipitation pattern. Summer rainfall becomes less common moving to the west and north, as successions of desert mountain ranges wring moisture from tropical summer systems.

In combination with a bi-modal precipitation pattern, the Sonoran Desert rarely freezes in the winter, enabling a diverse flora to exist, including columnar cacti and trees. However, due to the Colorado Desert's relative dryness in comparison to the eastern and southern Sonoran Desert (where columnar cacti such as Saguaro (*Carnegia gigantean*) and Organ Pipe Cactus (*Stenocereus thurberi*) are more common), these structurally diverse habitats tend to be relegated to valley floors as one moves west across the region. Columnar cacti and arboreal vegetation are largely absent in the Mojave Desert, which experiences frequent hard freezes during winter months. In the Mojave, structural diversity is primarily represented in the form of Joshua Trees (*Yucca brevifolia*), which often attain heights of over 4 m.

In general, the flora of the Mojave and Colorado Deserts is dominated by annuals. Shreve and Wiggins (1964) reported over 250 annual plant species, while in drier sites of the Colorado Desert, annuals represent close to ninety percent of the flora (Dimmitt 2000[b]).

Colorado Desert

The Sonoran Desert consists of six sections first defined by Forrest Shreve in 1951 (a seventh has since been re-classified as a non-desert biome). These include the Magdalena, Vizcaino, Central Gulf Coast, Plains of Sonora, Arizona Upland, and Lower Colorado River Valley sections (Figure 2-1). The Lower Colorado River Valley section (or Colorado Desert) is centered at the head of the Gulf of California and extends into Baja California Norte, Sonora, Arizona, and California. It is the hottest and driest of the six Sonoran sections, as well as the largest. It is this section of the Sonoran Desert that will be discussed in the California BCP.

In Arizona, habitats of the Colorado Desert typically extend to roughly 2000 feet (600 m) above Sea Level, where they begin to intergrade with habitats typical of the Arizona Upland section. The Colorado Desert extends south into Sonora, Mexico, where it dissolves into the Plains of Sonora and Central Gulf Coast sections. The Plains of Sonora section receives more summer moisture and freezes less often than the Colorado Desert, and it supports a greater diversity of tropical flora. Conversely, the Central Gulf Coast section is as dry as the Colorado Desert, but its aridity stems from its latitude (it is characterized as a horse latitude desert rather than a rain shadow desert) and it is characterized by many plant species not found in the Colorado Desert (Dimmitt 2000[a]).

To the west, the Colorado Desert's boundary follows the region's major mountain axis through eastern Baja California Norte and north to San Gorgonio Pass near Palm Springs. The Colorado Desert's northern boundary is somewhat indistinct, as it gradually fades into the Mojave Desert as the frequency of cold winter nights becomes too high to support Sonoran Desert vegetation.

Summer highs can exceed 120°F (49°C), and surface temperatures approach 180°F (82°C). Average rainfall can be below 3 inches (76 mm) at drier sites of the Colorado Desert, resulting in an early breeding season and a summer exodus of desert breeding species such as Phainopeplas, Costa's Hummingbirds, and Lucy's Warblers to wetter, cooler regions surrounding the Colorado Desert (Corman and Wise-Gervais 2005, Chu and Walsberg 1999).

Figure 2-1. The Lower Colorado River Valley Section of the Sonoran Desert, also referred to as the Colorado Desert (Dimmitt 2000a).

Mojave Desert

The Mojave Desert is the smallest of North America's four desert regions, but it is also perhaps the hottest and driest. Due to frequent hard freezes in the winter, Mojave cacti species are typically limited to representatives from the *Opuntia* and *Ferrocactus* genuses that are typically less than one meter in height. Traditional desert woodlands are limited to mesquites (*Prosopsis*) and Catclaw Acacia (*Acacia greggii*) that exist at springs, in washes, and in dune habitats where the roots of these phreatophytes can reach groundwater (The Nature Conservancy 2001).

The Mojave Desert extends from the northern boundary of the Colorado Desert in California west and then north along the eastern face of California's major mountain axis to the Owens Valley, where it meets the Great Basin Desert to the north. The Mojave Desert's northern boundary wends its way through a succession of basins and ranges to the east, where it meets a more abrupt delineation with the Colorado Plateau and Apache Highland ecoregions of Utah, Nevada, and Arizona (Figure 2-2)

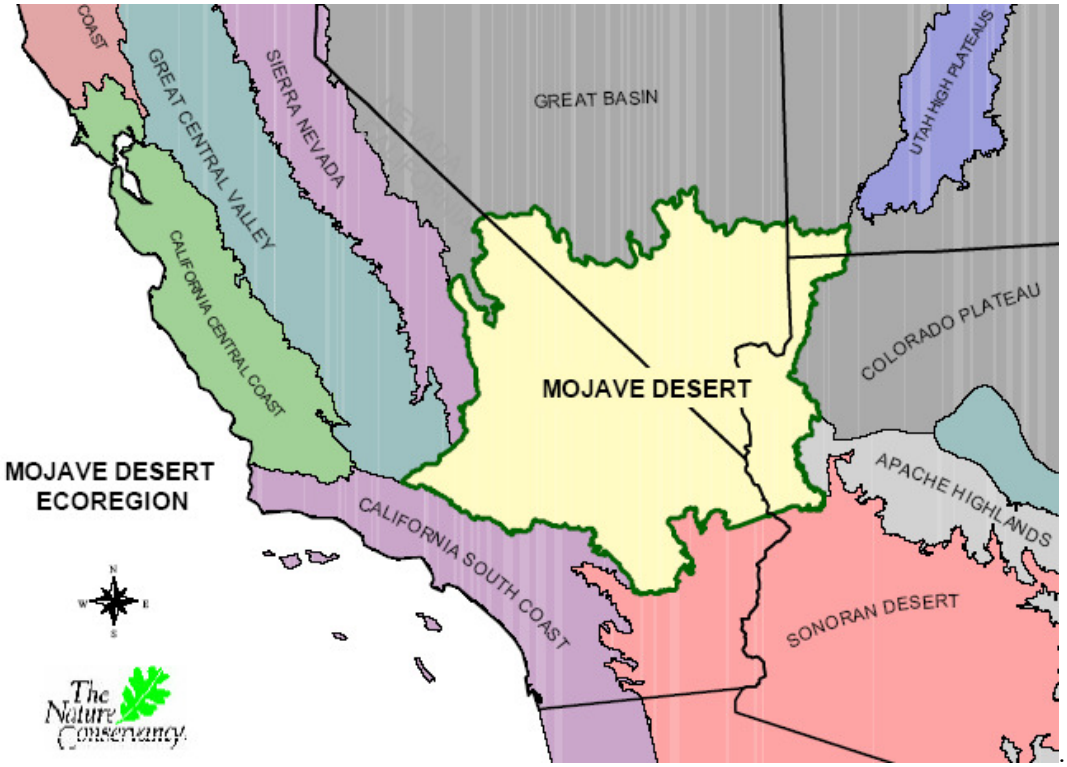

Figure 2-2. The Mojave Desert ecoregion, from the Nature Conservancy (2001).

As in the Colorado Desert, summer highs can exceed 120°F (49°C), and surface temperatures can approach 180°F (82°C). Annual rainfall ranges from 4 to 9 inches (101 – 229 mm), depending on location and elevation (The Nature Conservancy 2001).

The California Wildlife Habitat Relationships (CWHR) system of classification provides general descriptions of wildlife habitats in California. The following brief descriptions (developed by the California Department of Fish and Game) of the major desert habitats in California offer a window into the diversity of desert vegetation. For complete accounts, see Mayer and Laudenslayer (1988), updated periodically by the CA Department of Fish and Game (http://www.dfg.ca.gov/whdab/html/wildlife_habitats.html). For Latin names of species please refer to Appendix A.

Classification of Desert Habitat Types

The vegetation associations that define the habitats considered in this plan are dominated by shrubs. Shrubs are woody perennials that typically have multiple stems growing from the base. With few exceptions, California shrublands comprise associations of *xerophytes*, or species adapted to arid conditions. More specifically, these shrublands are composed of *drymophytes*, which experience regimes of alternating short, wet seasons and long, dry seasons (McMinn 1939). Pure forms of these shrub associations do not include trees of any kind, although old individuals of some species may resemble and/or function ecologically as trees. Despite superficial similarities in general growth form, there are notable structural and physiological differences among the major shrubland formations. These differences, in turn, translate variably into habitat features of importance to birds.

Desert wash habitats (also termed "dry riparian" or "xeric riparian") span a transition from upland to riparian habitat, as well as a transition from "shrubs" to "trees". Washes hold physiological traits similar to traditional riparian habitats, in that they collect precipitation and nutrients from the surrounding watershed, promoting greater floral diversity (Dimmitt 2000[a]). In the Mojave Desert, washes may hold the same species as upland habitats, and simply support taller and denser vegetation. As one moves south and east, washes are better able to support a variety *pheatophytes* which have their deep roots in a water table that is closer to the ground surface. Desert phreatophytes include mesquite, acacia, desert-willow, smoketree, palo verde, and ironwood. Cold winters in the Mojave Desert limit washes to holding only mesquite, acacia, desert-willow, and in the southern Mojave, smoketree.

The warmer Colorado Desert washes support these Mojave phreatophytes, as well as palo verdes and ironwood. Depending on the size of the watershed drained by the wash, Colorado Desert phreatophytes can attain "tree" status, with heights over 10 m and trunk diameters of over one meter. The Milpitas and Chemehuevi Washes in southeastern California are examples of desert washes that hold both traditional desert scrub vegetation and old growth Sonoran Desert wash woodland. In addition, desert wash phreatopytes typically form transition zones between true desert riparian habitats and desert scrub upland in both the Mojave and Colorado Deserts. Dimmitt (2000[a]) estimated that dry washes occupy less than five percent of the Colorado Desert but support 90% of the Colorado Desert's bird life.

Several major shrubland groupings are recognized by the California Wildlife Habitat Relationships System (CWHR). Those that occur primarily in the Mojave and Sonoran bioregions that are covered in this plan include: 1)alkali desert scrub; 2)Mojave desert scrub; 3)Sonoran desert scrub; 4)desert succulent scrub; 5)desert wash; and 6)Joshua tree stands.

Alkali Desert Scrub

Alkali desert scrub is found in broad valleys in the Mojave and Colorado Deserts, and consists of two phases, xerophytic and halophytic (Rowlands 2003). The xerophytic phase occurs on relatively dry soils and consists of widely-spaced, physiognomically similar shrubs typically less than two meters in height. The halophytic phase consists of denser stands of suffrutescent shrubs with varying degrees

of succulence. Halophytic stands can withstand occasional flooding and survive in soils high in salinity (Rowlands 2003).

Halophytic alkali desert scrub represents an important transition zone and vegetative buffer between desert riparian and upland scrub habitats in the Mojave Desert. Black-tailed Gnatcatchers, Crissal Thrashers, Bewick's Wrens, Greater Roadrunners, Verdin, and Phainopepla all utilize and nest in halophytic alkali desert scrub/riparian transition zones (McCreedy 2006[a]).

Desert alkali scrub is typically found on the margins of large prehistoric lakebeds or alkali playas, or in riparian floodplains such as those of the Mojave, Amargosa, Colorado, and Gila Rivers. Large sections of Gila River alkali scrub has been converted to agriculture (Latta et al. 1999). This habitat has been found to be important for Arizona LeConte's Thrasher populations (Corman and Wise-Gervais 2005). Where halophytic alkali scrub exists, groundwater is generally close to the surface and is highly mineralized. Xerophytic alkali scrub exists further from the groundwater table, but traditionally exists in soils less well-drained than those that contain surrounding creosote (Rowlands 2003).

Primary perennial species of xerophytic alkali desert scrub include saltbushes, such as Allscale, Desert-holly, Fourwing Saltbush, Nuttall Saltbush, Big Saltbush, Parry Saltbush, Shadscale, Torrey Saltbush, and Western Mojave Saltbush. Secondary shrubs include Bud Sagebrush, White Bursage, Creosote, Fremont Dalea, Nevada Ephedra, Black Greasewood, Spiny Hopsage, Spiny Menodora, Rabbit-thorn, Thurber Sandpaper-plant, Winterfat, and Anderson Wolfberry. Cacti diversity is low, but Cottontop, Hedgehog, Beavertail, Grizzlybear Pricklypear, Staghorn Cholla, and Red-spifned Sclerocactus can be locally common. Trees are generally absent from xerophytic alkali desert scrub (Rowlands 2003).

Primary perennial species of halophytic alkali desert scrub include Arrow-weed, Black Greasewood, Alkali Goldenbush, Kochia, Iodine Bush, Alkali Rubber Rabbitbrush, Seablite, Saltbush, and Tamarisk. Cacti are absent from halophytic alkali scrub, though sparse arborescent stands of Screwbean Mesquite, Honey Mesquite, and Tamarisk may be present (Rowlands 2003).

Sawyer and Keeler-Wolf (1995) habitat series common to alkali desert scrub include: Alkali Sacaton, Pickleweed, Saltgrass, Allscale, Fourwing Saltbush, Rubber Rabbitbrush, Greasewood, Hop-sage, Iodine Bush, Mixed Saltbush, Shadscale, Spinescale, and Mesquite. Plant zonation can occur in relation to soil salinity: Iodine Bush (tolerant to 6% salt), Saltgrass, Seablite, Tamarisk, Alkali Sacaton, Fourwing Saltbush, Arrow-weed, and Honey Mesquite (tolerant at 2% salt). At salinity below 2%, xerophytic alkali scrub predominates, and eventually grades into creosote scrub (Rowlands 2003).

Desert Succulent Scrub

Desert succulent scrub is dominated (at least visually) by succulent plants. Heights are generally less than 2 meters, unless Ocotillo or Saguaro are present, which can increase heights to over 5 m. Desert succulent scrub is generally an open scrub type, though it has a higher shrub density than Mojave or Sonoran desert scrub (Laudenslayer 2003[a]). Desert succulent scrub that holds stands of Joshua Trees is generally classified as Joshua Tree habitat.

Desert succulent scrub is more common in the warmer Colorado Desert. Succulent scrub habitats have greater floral and structural diversity than Mojave or Sonoran desert scrub habitats, and typically support a greater diversity of wildlife. Bird species found in succulent scrub include Northern Mockingbirds, Cactus Wrens, LeConte's Thrashers, Loggerhead Shrikes, and Black-throated Sparrows. Succulent scrub is generally found in rocky or well-drained soils with southern exposures

(Laudenslayer 2003[a]). This habitat type is slow to recover after fire disturbance; White Bursage and cacti species in particular take several years to recover from burns (Latta et al. 1999).

Dominant shrubs of desert succulent habitats include Ocotillo, Saguaro, Mojave Yucca, Desert Agave, Buckhorn, Teddy-bear, and Pencil Cholla, Grizzlybear Pricklypear, Hedgehog, Barrel, Hedgehog Barrel, and Fishhook Cacti. Understory shrubs include Creosote, White Bursage, and White Brittlebush (Laudenslayer 2003[a]).

Sawyer and Keeler-Wolf (1995) habitat series common to desert succulent scrub habitats include Mojave Yucca, Nolina, Ocotillo, and Teddy Bear Cholla.

Mojave and Sonoran Desert Scrub

Mojave and Sonoran Desert Scrub dominates the Mojave and Sonoran bioregions. It is described by open assemblages of broadleaf evergreen or deciduous microphyllous shrubs. Creosote signifies Mojave and Sonoran Desert scrub, though it may not necessarily dominate canopy cover. Shrub heights rarely exceed 3 m in height, and shrub height and density have been correlated to precipitation regimes and soil depth (Laudenslayer and Boggs 2003). Residents include Black-throated Sparrows, Loggerhead Shrikes, LeConte's Thrashers, and Greater Roadrunners.

This scrub type is generally found at low-mid elevations on coarse, well-drained soils. It dissolves into Joshua Tree and pinyon-juniper woodland at high elevations, and into Alkali Desert Scrub at lower elevations with higher salinity.

Mature creosote clones can persist for thousands of years, and are generally slow to recover after severe disturbance (Laudenslayer and Boggs 2003). Vasek (1979) reported that eight years after severe disturbance (in this case mining), only Brittlebush, White Bursage, Wire-lettuce, and Teddybear Cholla had re-established.

Mojave and Sonoran Desert scrub habitats tend to have lower shrub diversity relative to other scrub types. Perennial species include Creosote, Catclaw Acacia, Desert Agave, White Brittlebush, Burrobush, White Bursage, Barrel and Hedgehog Cactus, Pencil and Teddybear Cholla, Palmer's Coldenia, Wiggins Croton, Desert Globemallow, Jojoba, Littleaf Krameria, Ocotillo, Beavertail Cactus, Rabbitbrush, Sand Verbena, Desert Senna, Anderson's Wolfberry, and Mojave Yucca (Laudenslayer and Boggs 2003).

Keeler and Sawyer-Wolf (1995) habitat series associated with Mojave and Sonoran Desert Scrub include Alkali Sacaton, Big Galleta, Desert Needle-grass, Brittlebush, Brittlebush-White Bursage, White Bursage, California Buckwheat, Blackbrush, Creosotebush, Creosote-White Bursage, Desert-holly, Mojave Yucca, and Nolina.

Joshua Tree

Joshua Tree habitats provide far greater structural diversity than the above desert scrub habitats, and they generally have denser canopies of broadleaf evergreen and deciduous micropyllous shrubs that are also in found Mojave and Sonoran Desert Scrub. Joshua Trees themselves comprise only a small amount of the canopy cover and stem density of these habitats, but are visually dominant. Joshua Trees can exceed 6 m and may reach 12 to 15 m in height, providing arborescent cover that is missing from Mojave desert scrub communities (Laudensalyer 2003[b]). Though Joshua Tree stands in eastern Arizona contain several plant species that are more associated with the Sonoran Desert, Joshua Trees are perhaps the plant species most closely aligned with our image of the Mojave Desert bioregion. Joshua Trees provide song perches, canopy foraging, and cavity opportunities to desert

birds – structural opportunities rare in the Mojave Desert. Birds nesting in Joshua Tree habitats include Scott's Orioles, Ladder-backed Woodpeckers, Ash-throated Flycatchers, Loggerhead Shrikes, Bendire's and LeConte's Thrashers, Black-throated Sparrows, Cactus Wrens, and Greater Roadrunners.

Joshua Tree habitats are found at moderate elevations between Mojave Desert Scrub and Pinyon-Juniper Woodland. They occupy well-drained soils that can vary in structural characteristics but which typically contain higher organic material and lower salt concentrations than nearby desert scrub habitats (Laudenslayer 2003[b]).

Joshua trees frequently mix with other arborescent vegetation such as California Juniper, Utah Juniper, Singleleaf Pinyon, and Mojave Yucca at higher elevations. Perennial understory species include Big Sagebrush, Blackbrush, Nevada Ephedra, California Buckwheat, Cooper Goldenbush, Burrobush, Creosote, Anderson's Wolfberry, Cooper Wolfberry, Squawthorn, Spiny Menodora, Opuntia Cacti, Bladdersage, Longspine Horsebrush, and Spanish Bayonet (Laudenslayer 2003[b]). Associated Sawyer and Keeler-Wolf (1995) habitat series include Joshua Tree and Mojave Yucca.

Desert Wash

Dry washes contain less than five percent of the Sonoran Desert's area, but are estimated to support ninety percent of Sonoran Desert birdlife (Dimmitt 2000[a]). Desert wash habitats are found in alluvial soils on and adjacent to washes or arroyos. They are also referred to as "xeric riparian" or "dry riparian" habitats, and are typically found at a watershed's lowest elevations. Size and density of desert wash vegetation typically relates to the size of the wash's drainage (Shreve and Wiggins 1964). Desert washes in the northern Mojave typically hold taller individuals representative of the surrounding vegetation type, but structural complexity of wash habitat greatly increases as one moves south and east into the Colorado Desert (Laudenslayer 2003[a]). Surface water may only be present for a few hours in a year (Dimmitt 2000[a]). Desert washes also provide: surface flooding for seed scarification, alluvial nutrient buildups, loose soils for burrowing, compacted banks for additional burrowing opportunities, and corridors for dispersion (The Nature Conservancy 2001).

Great structural diversity can exist in desert wash habitat, particularly in the Colorado Desert. Blue Palo Verde and Ironwood trees can attain heights greater than 13 m, and provide numerous foraging and nesting opportunities for breeding and migrant songbirds (McCreedy 2006[b]). Phainopeplas, Ash-throated Flycatchers, Verdin, Crissal, LeConte's, and Bendire's Thrashers, Long-eared and Western Screech Owls, Black-tailed Gnatcatchers, Gila and Ladder-backed Woodpeckers, Lucy's Warblers, Northern Mockingbirds, and Loggerhead Shrikes all populate desert wash habitats.

Canopy wash species include Blue Palo Verde, Foothills Palo Verde, Ironwood, Smoketree, Catclaw Acacia, Honey Mesquite, Screwbean Mesquite, Desert-willow, and Tamarisk. Subcanopy species include Arrow-weed, Wolfberry, Crucillo, and Desert Broom. Understory perennials include Cheesebush, Rabbitbrush, Desert Lavender, Goldenbush, Creosote, White Bursage, Snakeweed, and Saltbush (Laudenslayer 2003[a]).

Many desert wash dominants are phreatophytes which require high water tables and occasional, albeit brief above-surface flows. Desert wash species found in Colorado Desert washes are often unable to withstand frequent freezes common to the Mojave Desert. Several wash species, particularly palo verde, are sensitive to fire disturbance and recover slowly after burns.

A Standardized California Vegetation Classification

Recognizing the importance of broad, habitat-based classification schemes (e.g., CWHR), a detailed floristic system of California vegetation classification has been developed by Sawyer and Keeler-Wolf (1995). Their Manual of California Vegetation (MCV) provides a system of classification at a more specific level; floristically based on lower units of plant associations (referred to as series). With a standardized classification system one can describe vegetation associated with many aspects of bird biology and conservation across space and time. A single, widely accepted terminology provides land managers, natural resources specialists, and conservationists with a common language that promotes clear communication and hence better-informed decisions. CalPIF has adopted the Sawyer and Keeler-Wolf/MCV system of vegetation classification as the standard used for all CalPIF objectives. The Sawyer and Keeler-Wolf system ties in with continental planning efforts of The Nature Conservancy and is compatible with most previous schemes used in California, such as that of the California Biodiversity Council (see Chapter 7, Bioregional Conservation Objectives). As of 2004, the second edition of the Manual of California Vegetation, a new hierarchical vegetation classification system consistent with the National Vegetation Classification Standard (NVCS), is being developed by Sawyer and Keeler-Wolf, in coordination with a statewide committee (Sawyer and Keeler-Wolf *in prep*). In the NVCS, there are several upper levels of classification (currently six, may be reduced to three) representing growth form, leaf characters, hydrology, and environment and two lower levels, representing floristics (Alliance, Association). Alliances are defined by the dominant one to three species, while Associations are distinguished by secondary associated species, usually in the understory.

Joshua Tree habitat in the Mojave Desert *photo by Ryan DiGaudio*

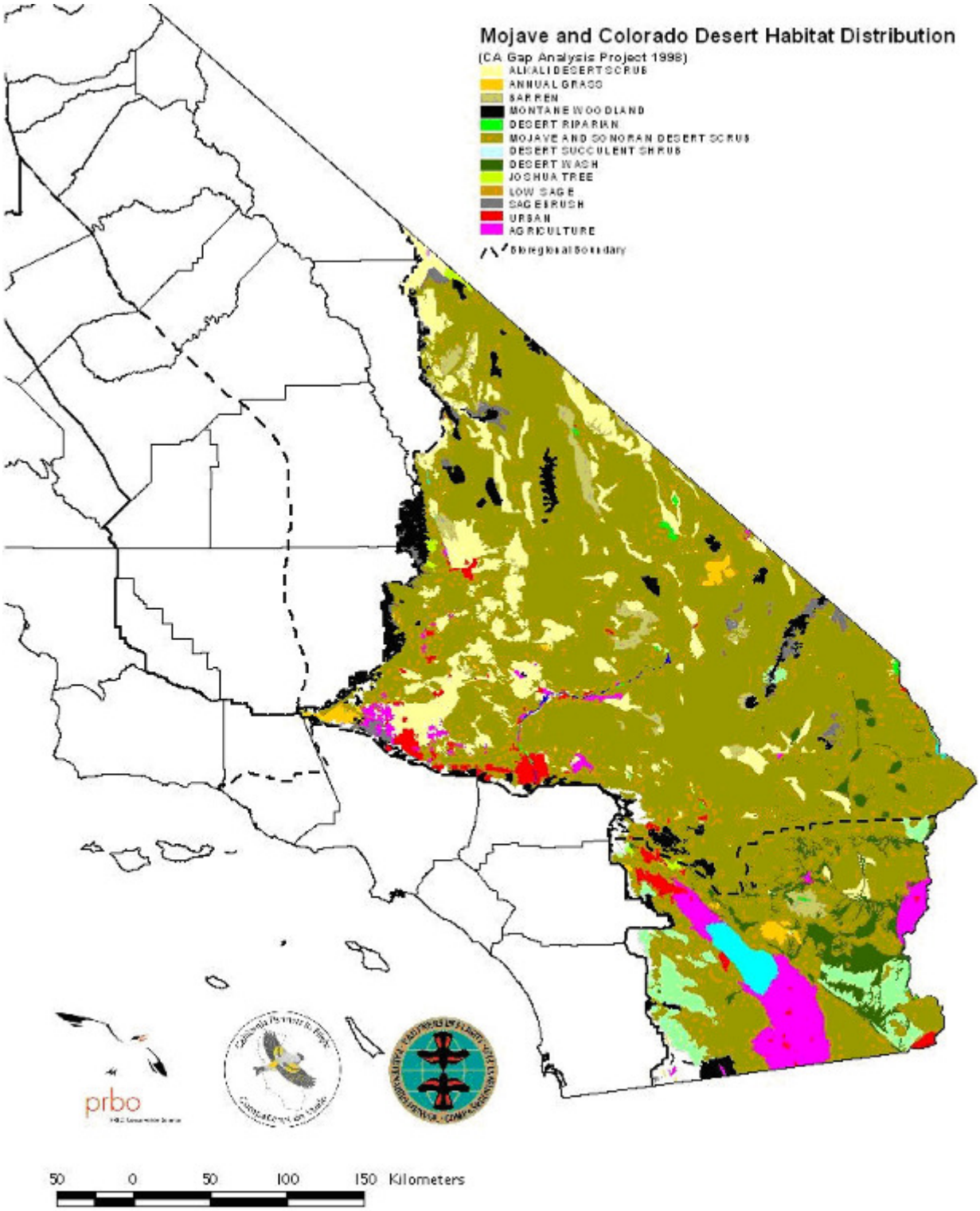

Figure 2-3. Approximate current coverage of desert habitats throughout California.

Chapter 3. Desert Habitat Conservation at the Landscape Scale

A number of issues covered in this Conservation Plan are united by the fact that they must be addressed on a relatively large spatial scale. When targets are set for restoring healthy population sizes of a given species (Chapter 6), researchers and land managers have to consider habitat at the scale of many hectares or square kilometers, and prioritizing land parcels for conservation and habitat restoration (Chapter 8) usually occurs at similar scales. Agricultural development in California's Central Valley, for example, has left remnant patches of riparian forest that measure from a few to a few hundred hectares (Hunter et al. 1999), and the conservation and restoration of this habitat involves consideration of the ecology of entire landscapes in which remnants are situated (Figure 3-1). Ecological conditions required for healthy wildlife populations in riparian habitats, such as complex vegetation structure that provides birds with nesting sites, are often measured at the scale of square meters (Kareiva and Andersen 1988); but additional conditions exist at much larger scales, and managers must also provide for these.

The need for research focused on large-scale issues has been stressed in bird conservation initiatives (Ruth et al. 2003) and other conservation efforts partly because this is the scale at which parcels of land are owned and managed, and partly because many important ecological processes occur, and can only be studied, at large scales. Since the emergence of landscape ecology, research has increasingly been directed toward understanding the consequences for wildlife of alterations to, and the potential restoration of, natural habitats at large scales.

What is Landscape Ecology?

Landscape ecology takes into consideration the large-scale heterogeneity of areas containing species or natural communities that might be targeted for conservation. Although the size of a landscape is not strictly defined and can vary widely, landscapes typically exist at the general scale of a vista that can be seen in all directions around an observer from a single point. Such a landscape is normally a complex mosaic of multiple component areas (landscape elements or *patches*) under varying management practices or natural succession regimes (Forman and Godron 1986). Different patches may have different values for wildlife; some may be largely unoccupied by a given species while other areas are densely occupied, and occupied areas may be sites of largely successful or largely unsuccessful breeding and reproduction (i.e., population sources and sinks—Pulliam 1988, With and King 2001).

Landscape ecology, then, is concerned with interactions among these patches, in terms of the flow of species, materials, and energy among them. It also focuses on the ways that the specific shapes and spatial arrangements of landscape elements affect their interactions. That is, landscape ecology is a spatially explicit science (Forman and Godron 1986, Wiens et al. 1993, Forman 1995). While patches can be defined at nearly any scale, landscape ecology often investigates interactions of biological populations or communities with relatively large-scale environmental features and processes, such as regional topography, the expansion of urban areas into wildlands, and forest fragmentation. The growth of landscape ecology as a discipline has been paralleled by growing recognition that conclusions drawn from ecological investigations can depend upon the scale at which a system is studied (Wiens 1989, Riitters et al. 1997, Saab 1999, Wiens 1999, Schneider 2001). Environmental factors may affect bird populations differently at different scales, may only have important effects at certain scales, and may affect different species at different scales. For example, Hochachka et al. (1999) found for sites across the western U.S. that, while rates of songbird nest parasitization by Brown-headed Cowbirds decreased with increasing forest cover within 10 km of nesting sites, the

relationship reversed when forest cover within 50 km was considered. Thus, the explicit consideration of scale has become an important aspect of ecological investigations, with consequences for conservation activities (Schneider 2001).

Landscape-scale factors that affect desert birds

Many environmental factors can affect desert bird populations at large scales. We mention here some of the more important ones that are of immediate conservation relevance.

Altered hydrology

Little research has investigated the impacts of California's large-scale alteration of natural hydrologic regimes to bird communities. Artificial flow regulation with local or upstream dams and diversions, as well as channel alteration and containment with levees and channelization, can alter plant communities at watershed scales (Ohmart 1994, Hunter et al. 1999). Transportation departments may channelize or re-direct sheet flow to manage rainfall events, altering hydrologic input to desert wash habitats (The Nature Conservancy 2001). Vegetation, and therefore vegetation-dependent wildlife, can be dramatically affected by distant upstream water management practices (Ohmart 1994), so that restoration efforts at specific sites may depend ultimately on the cooperation of partners managing water in the wider landscape.

Habitat fragmentation and landscape condition

More attention has been paid to the topic of habitat fragmentation because fragmentation has been perhaps the most apparent human-caused transformation of natural systems, aside from their outright reduction in size (Meffe and Carroll 1997). As Gila River Valley saltbush scrub has been converted to agricultural fields, for example, remnant undeveloped habitat has been left as a disconnected series of fragments of varying size and shape (Latta et al. 1999). Such habitat fragments have been likened to islands in a "sea" of inhospitable habitat. The theory of island biogeography (MacArthur and Wilson 1967) maintains that smaller, more isolated islands (or fragments) support fewer species, due to a higher likelihood of local population extirpation. This general property of small populations results from numerous ecological mechanisms working at relatively small scales within islands or fragments, as well as at larger scales around them. For example, small remnant patches of breeding bird habitat in urban areas may contain such low numbers of a particular species that small increases in predation rates can cause extirpation. In such cases, increased densities of cats and other predators subsidized by the surrounding urban landscape can be sufficient to cause the loss of several songbird species (Soulé et al. 1988, Bolger et al. 1991, Crooks and Soulé 1999, Crooks et al. 2001). Donovan et al. (1997) found that in Midwestern forest habitats, nest predation was higher on habitat edges within moderately and highly fragmented landscapes, compared to unfragmented landscapes. Chalfoun et al. (2002) found that edge effects on nest predators were stronger in agricultural landscapes than in more heavily forested landscapes. In western riparian and wash habitats, which are more naturally fragmented than eastern deciduous forests, densities of both nest predators and nest parasites (such as the Brown-headed Cowbird) in forest fragments may depend more on surrounding land use, such as the prevalence of agriculture in the landscape, than on fragment size or amount of edge (Tewksbury et al. 1999). Nest parasitism by Brown-headed Cowbirds can affect the reproductive success of songbirds (Chapter 4), so landscape features that influence cowbird abundance are an important consideration.

In some respects, the Mojave and Colorado Deserts provide us with great conservation opportunity. Ricketts et al. (1999) reported that approximately one-half of the Mojave Desert remains as intact habitat. A high degree of public ownership in the Mojave and in United States portions of the Colorado Desert provides some buffer to fragmentation.

However, localized and explosive urban growth within the Mojave and Colorado Desert may seriously impact desert flora and fauna unaccustomed to habitat fragmentation and its ecological effects. Studies near Tucson have shown that Black-throated Sparrows and Black-tailed Gnatcatchers in particular require undisturbed, native vegetation (Germaine et al. 1998). Cavity species, insectivores, ground-nesting species, and ground feeders are all sensitive to fragmentation from urbanization and conversion of desert scrub to agriculture (Latta et al. 1999). Phillips et al. (1964) noted that LeConte's Thrashers are sensitive to disturbance and have withdrawn from agricultural habitats in the Gila Valley. Northern Flickers, Pyrrhuloxia, Verdin, Gambel's Quail, Ash-throated Flycatchers, Greater Roadrunners, Rufous-winged Sparrows, and Ladder-backed Woodpeckers have all shown sensitivity to urbanization and resultant habitat fragmentation (Latta et al. 1999).

Barriers to Movement

In addition to affecting habitat patch quality, surrounding landscape conditions can also affect wildlife movement among habitat patches. In naturally patchy systems such as desert riparian woodland, and possibly in artificially fragmented systems, it may be appropriate to consider bird populations in patches as parts of a metapopulation, or group of interconnected populations (Hanski and Gilpin 1997). In this framework, the probability of a local population's extirpation is reduced by occasional immigration from other patches, so that the long-term stability of the entire metapopulation depends on some minimum level of patch interconnectivity. In other words, a particular habitat fragment may be too small to meet minimum requirements for a stable population of a given species, but effective movement of individuals (such as dispersing juveniles or adults seeking mates) among multiple fragments can render each fragment a functioning component of the whole population. Movement among fragments may be hindered by hostile conditions in developed areas around fragments, and such movement can become increasingly unlikely with increasing distance between fragments (e.g., Norris and Stutchbury 2001, Cooper and Walters 2002). For sedentary species such as Crissal and LeConte's Thrashers, increased fragmentation and barriers to movement can result in local population extirpation (Laudenslayer et al. 1992).

Conservation Approaches

Clearly, the quality of remnant habitat fragments can depend not only on their size and internal characteristics, but also on their configuration relative to one another and the characteristics of the surrounding landscape (Andren 1992, 1994; Sisk et al. 1997; Tewksbury et al. 1998; Saab 1999; Tewksbury et al. 2002). Prioritization of sites for bird conservation should therefore consider surrounding landscape conditions, such as the proximity and prevalence of other natural areas, urban areas, agricultural areas, or Brown-headed Cowbird foraging areas. Managing for healthy wildlife populations in remnant natural areas may entail developing cooperative relationships with the managers of adjacent lands.

Weaselhead.org photo.

Female Brown-headed Cowbird.

The Nature Conservancy has taken the lead in identifying habitat fragmentation and land classification status relating to conservation protection (Table 3-1; The Nature Conservancy, 2001).

Table 3-1. Land classification types developed by The Nature Conservancy (2001).

LAND CLASS	DESCRIPTION
Class I (L1)	Lands owned by private entities and managed for biodiversity conservation or administered by public agencies and specially designated for biodiversity conservation through legislative action where natural disturbance events proceed without interference. The agency acting alone cannot change these designations without legislative action and public involvement. Examples include many TNC preserves and other private preserves committed to biodiversity conservation and dedicated as state preserves or natural areas, some national parks, some national wildlife refuges, federal wilderness areas, and some state parks and nature preserves.
Class II (L2)	Lands generally managed for their natural values, but that may incur use that degrades the quality of natural Communities (e.g., habitat manipulation for game species). Also includes public lands with administrative designations for biodiversity conservation. Examples include many national wildlife refuges, state wildlife management areas, private preserves managed for game species, BLM areas of critical environmental concern, and federal research natural areas.
Class III (L3)	Lands maintained for multiple uses, including consumptive or recreational values, and not specifically or wholly dedicated to biodiversity conservation, and lands with restricted development rights. Examples include most nondesignated (i.e., multiple-use) public lands administered by the U.S. Department of Agriculture, Forest Service, and BLM, Department of Defense buffer lands, state forests, regional and large local parks and open space, and private lands protected from subdivision by conservation easements and other title restrictions.
Class IV (L4)	Lands with no known protection, including lands used for intensive human activity; agricultural, residential, and urban lands; public buildings and grounds; and transportation corridors.

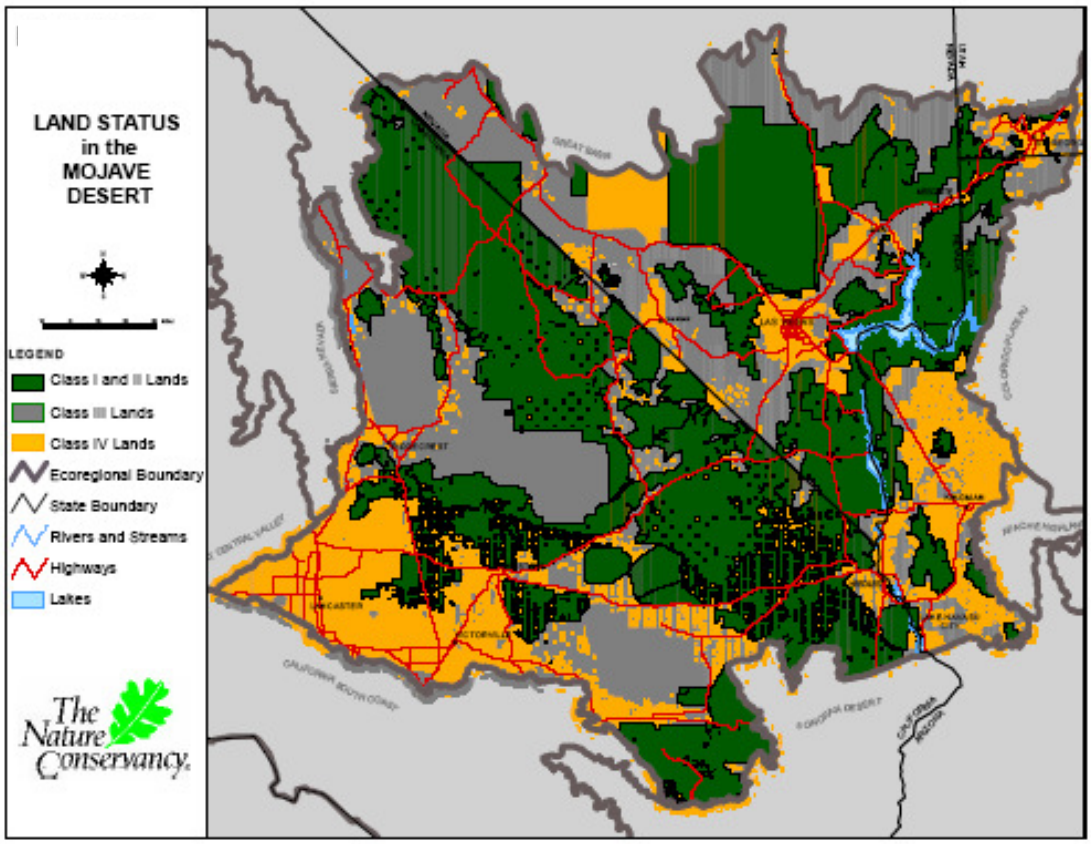

Figure 3-1. Land classification using land ownership and management analysis by The Nature Conservancy provides us a means to determine conservation priorities in across the Mojave Desert at the landscape scale.

Fragmentation vs. natural patchiness

The fragmentation of formerly contiguous habitat can reduce the usefulness of remaining habitat for wildlife conservation in some cases, so preservation and restoration efforts should in these cases prioritize large contiguous blocks of habitat and connectivity among those blocks. However, many natural systems are patchy or heterogeneous at large scales, and organisms can be adapted to naturally patchy environments. For example, desert riparian gallery forests often occur naturally as discreet patches along river stretches where conditions are favorable. This contrasts with the riparian forests of California's Central Valley, which were historically relatively wide, contiguous stands following river courses for long distances. Natural patchiness generates habitat heterogeneity that single organisms may use, as when bird species nest in one habitat and forage in another. In desert riparian systems, many riparian woodland-dependent species also forage in surrounding scrub habitat (Szaro and Jakle 1985). Thus, efforts to restore natural conditions must be tailored to the needs of specific systems, with consideration for the natural large-scale heterogeneity of many systems. In extreme cases of critical habitats that are very patchy, such as freshwater wetlands, conservation efforts may be best directed towards multiple small reserves where remnant habitat exists (Haig et al. 1998).

The landscape paradigm

It is increasingly recognized that viewing habitat remnants as islands embedded in a sea of unsuitable habitat is an oversimplification of reality for most species, and conservation planning should not necessarily follow this model. Each of the patches that compose a landscape is more accurately seen as falling somewhere along a continuous gradient of habitat quality, and quality varies depending on what particular wildlife species or community one considers as well as the scale at which patches are defined (Wiens 1995). As discussed above, habitat quality is also mediated by landscape composition and interactions among patches.

Advances in landscape ecology have therefore generated a framework for conservation planning within which the structure and function of all elements of a landscape can be considered together in a spatially explicit, scale-explicit manner. Resulting conservation approaches might identify priority areas for strict preservation of remnant and restored natural systems surrounded by areas with less strict forms of mixed-use conservation management, and management applications in permanently degraded areas that will minimize their adverse impacts on the broader landscape.

"Placing the conservation reserves firmly within the context of the surrounding landscape and attempting to develop complementary management strategies seems to be the only way to ensure the long term viability of remnant areas… This has important implications for land managers since it involves a radically new way of viewing management and requires that neighboring land uses, and hence neighboring landowners, interact in a positive way. This is difficult, but not impossible…"(Saunders et al. 1991).

Photo by James Gallagher, Sea and Sage Audubon.

Declines in Cactus Wren populations have been correlated to urbanization

Chapter 4. Problems Affecting Desert Birds

The PIF North American Landbird Conservation Plan characterizes species of the Southwestern Avifaunal Biome to have generally low population sizes, narrow distributions, high threats, and, when trend data exist, generally declining populations (Rich et al. 2004). PIF scored these characteristics to assess breeding vulnerabilities for landbirds that nest in the United States and Canada (Figure 4-1). In general, species of the Intermountain West, Southwest, and Pacific Avifaunal Biomes have the highest vulnerabilities on the continent.

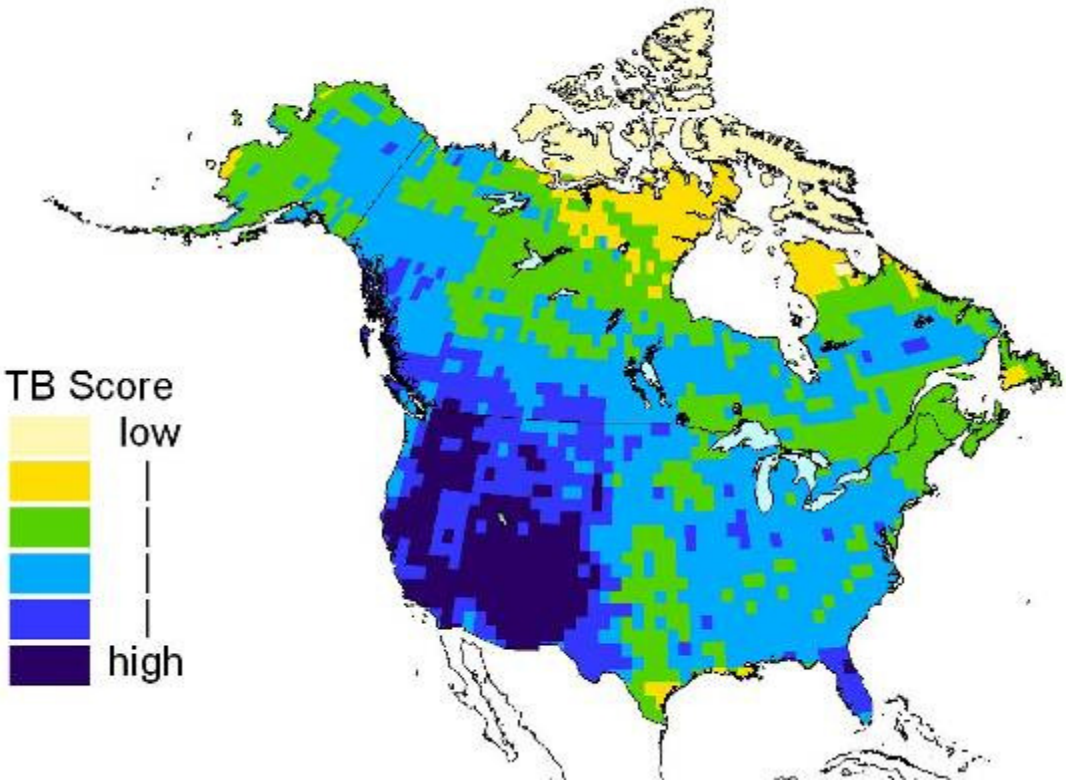

Figure 4-1. Average vulnerability among species occurring in each lat-long block during the breeding season, based on Threats to Breeding (TB) scores for 448 landbirds species. Severe threats = highest vulnerability (high TB score); no threats = lowest vulnerability (low TB score). Taken from Rich et al. 2004.

Threats to landbird populations can generally be traced to anthropogenic causes. Southwestern landbird breeding species' high vulnerability, the region's exploding human population growth, and desert ecosystems' generally slow recovery from disturbance are potent ingredients of potential declines in desert bird populations.

Base causes of landbird population declines include loss of habitat, habitat fragmentation, habitat degradation, and the introduction of predators and nest parasites into landbird communities. These engines for population decline are in turn powered by specific threats to landbird populations, many of which are present in the Mojave and Sonoran Deserts.

Urbanization

The Arizona Partners In Flight Bird Conservation Plan identified urbanization and resultant habitat fragmentation and habitat loss as the number one threat to desert bird populations (Latta et al. 1999). The Las Vegas and Yuma metropolitan areas were the first and third fastest-growing urban areas in the United States from 1990-2000 (U.S. Census Bureau 2000). The population of Arizona increased 64.3% from 1980-1996 (Latta et al. 1999). In the western Mojave Desert, the population has tripled in the last twenty years. These population trends are expected to continue through the twenty-first century.
Urbanization obliterates and simplifies desert scrubland communities, reducing the amount of native vegetation necessary for nesting and foraging opportunities for many desert bird species. Urban habitats are typically exploited only by traditionally urban species (often exotic) while only a handful of native desert species have succeeded in taking advantage of greater foraging, watering, and altered structural diversity found in urban environments (Beissinger and Osborne 1982, Emlen 1974). This results in a decrease in avian diversity in urban habitats, with the concomitant obliteration of several desert species. Black-tailed Gnatcatchers and Black-throated Sparrows have been found to be particularly sensitive to urbanization and the replacement of native desert scrub with exotic vegetation (Germaine et al. 1998 and Emlen 1974). Declines in Verdin, Pyrrhuloxia, Northern Flicker, Cactus Wren, LeConte's Thrasher, Crissal Thrasher, Bendire's Thrasher, Loggerhead Shrike, and Greater Roadrunner populations have all been correlated to urbanization, though Verdin and Cactus Wrens have also been found to be unaffected by urban development if nest-site alternatives are present in the urban matrix (Corman and Wise-Gervais 2005, Germaine et al. 1998, Emlen 1974).

Emlen (1974) identified two factors key to the decline of native desert avifauna in urban habitats: changes in the nature and quality of vital resources, and changes in the nature and magnitude of population suppressants.

Urbanization results in the rapid increase of foraging and watering opportunities, but these opportunities are generally skewed toward ground-foraging, seed-eating guilds (Beissinger and Osborne 1982, Emlen 1974). Thus while White-winged Doves, Mourning Doves, House Finches, and Common Ravens profit, the majority of native desert species are neutral to these increases in vital resources, and do not take advantage of foraging opportunities presented by exotic vegetation common to desert urban environments.

Urbanization also results in the alteration of vegetation structure important to desert avifauna (Germaine et al. 1998, Emlen 1974). Low desert scrub and thick understory vegetation are replaced with manicured lawns or sculpted canopy trees, which favors arborescent foraging and nesting species and penalizes ground and low-nesting species (Emlen 1974). Of 15 Desert BCP focal species, only Common Ravens, Gila Woodpeckers, and Ash-throated Flycatchers have gained from an increase in arboreal urban vegetation (Germaine et al. 1998, Emlen 1974). Phainopeplas and Lucy's Warblers will also nest in arborescent vegetation, but have not been found to increase in urban areas (Corman and Wise-Gervais 2005)

The majority of desert breeding species traditionally nest in low, scrub vegetation. Median nesting height for 579 Arizona Breeding Bird Atlas nests (1994-1996) was 1.8 m (Corman and Wise-Gervais 2005). Nesting habitats for these species are severely compromised in alteration to an urban and generally exotic environment. Exotic vegetation or desert urban communities is a poor substitute for desert scrub habitats traditionally occupied by the majority of desert nesting species, and only a small minority of nests located for Desert BCP focal species have been located in exotic vegetation (one notable exception is the Lucy's Warbler, which has successfully adapted to dense tamarisk vegetation (Johnson et al. 1997)).

In addition, low-nesting species are susceptible to population suppressants such as alteration of predation pressures and increased anthropogenic disturbance/traffic (Emlen 1974). Ground-nesting Gambel's Quail, Greater Roadrunners, and Black-throated Sparrows have been found to be especially sensitive to these urban predation and disturbance threats (Emlen 1974). Rosen and Schwalbe (2002) found that feral domestic cats have resulted in the loss of the native mammal community and the restructuring of the lizard assemblage at Tucson, AZ.

Exotic Vegetation

The introduction and insidious spread of exotic plant species into the Sonoran and Mojave Deserts is one of the leading threats to desert landbird populations. Roughly 11% of the flora of the Sonoran Desert and 7% of the flora of the Mojave Desert are now comprised of exotic species (Lovich 2002, Wilson et al. 2002). While these percentages are relatively low compared to invasions in other bioregions, nearly all of the exotic introductions to the Mojave and Sonoran Deserts have occurred in the last one hundred years. Importantly (as in the case of buffelgrass or tamarisk), it takes only a handful of highly successful naturalized plant species to severely alter desert ecosystems.

It is crucial to recognize that presence and success of exotic species can often be correlated to anthropogenic disturbance. Disturbed soils and soils lacking intact microbiotic crusts are more susceptible to exotic plant colonization (Wilson et al. 2002). Altered hydrologic regimes brought about by municipal diversions and water impoundments have fostered conditions ideal for the spread of saltcedar in riparian systems (Stromberg and Chew 2002). Agriculture, ranching, and recreation have provided introduction of exotic flora into previously undisturbed habitats (USFS 2003, Esque and Schwalbe 2002, Stromberg and Chew 2002).

The introduction and spread of exotic flora into the Mojave and Sonoran Deserts can come back to haunt desert bird populations through several, often complex mechanisms. These include fundamental ecosystem alteration, reduction in native plant diversity and abundance, and outright extirpation of native plant communities (Mack 2002).

One of the most important exotic plant threats may be the spread of exotic annual grasses initially brought to the desert as livestock feed. Red Brome and Mediterranean grasses have been shown to alter fire regimes in the Arizona Upland section of the Sonoran Desert (Esque and Schwalbe 2002), and these non-native grasses have become widespread in the Colorado Desert as well. Red brome and Mediterranean grasses build up fuel loads during wet seasons, quickly drying as winter rains end in March. They are aggressive colonizers and are notable in their ability to fill open spaces between desert scrub vegetation, providing vectors for the spread of wildfires presumed to be absent prior to exotic grass introduction. They respond quickly after burns, promoting future wildfires once habitats are initially stricken by fire.

The introduction of African Buffelgrass may be potentially even more devastating to Sonoran Desert scrub habitats. African Buffelgrass was originally brought to the Americas in the 1940s by the Soil Conservation Service of the USDA for erosion control. It was heavily introduced in Sonora and Tamaulipas, Mexico to increase cattle forage in the 1960s (Burquez-Montijo et al. 2002). It has spread rapidly from the Plains of Sonora section of the Sonoran Desert both northward and to the south, and is now found in Arizona as well (Burquez-Montijo et al. 2002). It is now estimated that Buffelgrass is the dominant herbaceous plant across an area of 8 – 10 million hectares. It can spread to undisturbed habitats via windborne seeds, but livestock and anthropogenic disturbance have hastened its spread (Burquez-Montijo et al. 2002).

Buffelgrass habitats contain three-to-four times the above-ground biomass held by desert scrub habitats, yet floral diversity decreases tenfold from native scrub to Buffelgrass habitats. While this increase in forage is much more ideal for cattle production, few native flora and wildlife benefit from introduced Buffelgrass habitat (Burquez-Montijo et al. 2002). In total, 800,000 hectares of Sonoran desert scrub habitat have been officially approved for conversion to buffelgrass by the Mexican government. Significantly more conversion occurs without approval, as privatization of communal ejido lands to large landowners has coalesced resources for the conversion of scrub to grassland.

The National Park Service halted buffelgrass invasion of Organ Pipe National Monument with active management through manual removal and subsequent re-visits (Rutman and Dickson 2002). This example highlights that, as is the case of many exotic invasions, early and rigorous management can control outbreaks before they reach critical levels. Yet across areas of Sonora, the spread of Buffelgrass and the elimination of native arborescent and succulent desert vegetation through subsequent fires may have reached an irreversible ecological threshold, with permanent and increasing loss of native Sonoran Desert Scrub habitats (Burquez-Montijo et al. 2002).

While a minority of the perennial flora native to the Mojave and Sonoran Deserts respond positively to fire disturbance, the great majority do not (Esque and Schwalbe 2002). In particular, succulent species (primarily columnar cacti), palo verde, and White Bursage respond poorly to fire damage (Esque and Schwalbe 2002, Latta et al. 1999).

Buffelgrass, Red Brome and Mediterranean grasses have become ubiquitous in the Colorado Desert and are outside control (Wilson et al. 2002). It is not a question of *if* exotic grasses will alter fire regimes and native vegetation cover in the Mojave and Colorado Desert, but a question of when and to what degree (Esque and Schwalbe 2002).

Of all wildlife, Esque and Schwalbe (2002) put forward that birds are most susceptible to loss of native Sonoran Desert perennial vegetation. Thirty-five percent of 579 Arizona Breeding Bird Atlas nests located between 1994 and 1996 were constructed in palo verdes (Latta et al. 1999). In Colorado Desert washes, McCreedy et al. (2006) reported that up to 69% of nests were built in either palo verdes or ironwoods. On the Chemehuevi Wash, San Bernardino County, CA (where ironwood is absent), 64% of nests were built in blue palo verde (McCreedy et al.2006). Yet Esque and Schwalbe (2002) found that repeatedly-burned areas near Phoenix and Tucson have become nearly devoid of perennial scrub, which has been replaced by exotic grasses. The potential loss of fire-sensitive Fabaceous desert woodland and columnar cacti scrub will continue to menace desert bird populations as exotic grasses continue to spread throughout the Mojave and Sonoran Deserts.

Recreation

Off-highway vehicle (OHV) use increased 32% in the United States from 1994-2000, and OHV sales more than tripled between 1995 and 2003 (The Wilderness Society, 2006). In California, there has been a 108% increase in off-road license registrations since 1980, and a 74% increase in street-licensed four-wheel vehicles since 1994 (Calfornia State Parks Off-Highway Motor Vehicle Recreation Division 2006). Impacts from OHV use include erosion, soil compaction, damage to cultural resources and sites, creation of new roads (leading to habitat fragmentation), disrupted wildlife and their habitats, and spread of exotic vegetation (USFS 2003).

While it is widely known that off-highway vehicles are both highly popular and carry the potential to negatively impact bird populations in a number of ways, actual research into this problem is only beginning (McCreedy et al.2006, Barton and Holmes 2004). It may be difficult to demonstrate direct OHV-impacts on desert bird populations, but indirect impacts such as destruction of microbiotic soil crusts, introduction of exotic flora to undisturbed areas, potential for fire ignition, and damage to

native vegetation highlight the importance for land agencies and non-governmental organizations to identify and protect portfolio desert habitats (such as desert washes) that hold the highest densities of plant and wildlife diversity.

Domestic and feral livestock grazing

Livestock grazing has contributed to the degradation of coastal sage scrub habitat by preventing the growth of young shrubs, opening up the scrub canopy to invasion by exotic annuals, and reducing the ability of native forbs and grasses to compete with exotics (McBride and Heady 1968, McBride 1974, O'Leary 1990). Domestic livestock grazing is most prevalent in the western Mojave (The Nature Conservancy 2001).

Feral burro populations are heaviest in the Lower Colorado River Valley, where preferential grazing in desert wash habitats has resulted in significant losses to canopy cover and palo verde regeneration (Hanley and Brady 1977, Woodward and Ohmart 1976). Palo verdes and White Bursage were found to be particularly palatable for feral burros at sites on the Standard Wash and Chemehuevi Mountains. Given the high preference for Blue Palo Verde as a nesting substrate at nearby Chemehuevi Wash (McCreedy et al.2006), heavy grazing pressure from feral burros on young palo verde plants could significantly reduce vital nesting habitat in primary and secondary washes near the Colorado River.

In addition, McCreedy et al.(2006) reported average nest heights on the Chemehuevi Wash of 2.49 m (n=156), and Latta et al. (1999) reported Arizona Breeding Bird Atlas nest height averages of 2 m (n=579). These heights are within reach of feral burro grazing disturbance, and significant amounts of habitat cover for low-nesting desert birds could be lost to feral burro overgrazing in desert wash habitats.

Nest Parasitism

Brown-headed Cowbirds (*Molothrus ater*) and Bronzed Cowbirds (*Molothrus aeneus*) have been found to parasitize nests in Mojave and Sonoran Desert habitats (McCreedy et al.2006, Corman and Wise-Gervais 2005). Urbanization and irrigated agriculture have significantly aided these species' expansion in arid desert habitats, enabling them to parasitize nests in scrub habitats otherwise hostile to cowbird foraging and watering requirements. McCreedy et al.(2006) reported Brown-headed Cowbird parasitism over 18 km from the closest urban area capable of providing foraging habitat for commuting females.

While Bronzed Cowbirds have spread throughout Arizona in the twentieth century, they are still considered rare. Icterids (particularly Hooded Orioles) represented the majority of hosts parasitized by Bronzed Cowbirds in nests found by the Arizona Breeding Bird Atlas program (Corman and Wise-Gervais 2005).

Like Bronzed Cowbirds, Brown-headed Cowbirds have only become widespread in Mojave and Sonoran Desert habitats during the twentieth century. However, Brown-headed Cowbirds are much more common, and will parasitize a much greater diversity of host species' nests. Black-tailed Gnatcatchers represented over ten percent of 225 incidents of Brown-headed Cowbird parasitism recorded by the Arizona Breeding Bird Atlas. Yellow Warblers, Bell's Vireos, Black-throated Gray Warblers, and Black-throated Sparrows were the other most common host species found by the atlas (Corman and Wise-Gervais 2005).

Though Brown-headed Cowbirds are present in the Mojave and Sonoran Desert throughout the winter, they are generally only found in large flocks (generally in urban or agricultural settings), and

do not begin to parasitize nests until March. In addition, the Brown-headed Cowbird breeding season's timing is variable, and is likely related to climatic conditions. This is crucial for desert bird species, which often initiate first clutches well before the Brown-headed Cowbird breeding season begins. In the Lower Colorado River Valley, McCreedy et al.(2006) found that while zero Black-tailed Gnatcatcher first brood attempts were parasitized, three out of four double brood attempts were parasitized (the fourth nest, which was suspiciously abandoned during incubation, was too high to view nest contents). As Brown-headed Cowbirds have only recently re-occupied Mojave and Sonoran Desert habitats, it will be interesting to see if their breeding phenology evolves to more closely match the breeding seasons of their desert hosts.

Though the following sections on habitat loss and fragmentation pertain to problems facing bird communities in the Mojave and Sonoran Deserts, they were originally written for the California Partners in Flight Coastal Scrub Bird Conservation Plan. The three ecoregions share patterns of habitat loss, fragmentation, and degradation due to rapid development, escalating fire frequency, and increasing recreation pressure. Bird conservation in the Mojave and Sonoran Deserts - which share several species discussed in the Coastal Scrub Plan - will be handicapped without a concerted effort by land managers and local and state elected officials to address these problems.

Habitat Loss

The most profound factor that threatens shrubland birds is the direct and permanent loss of habitat. Permanent habitat loss is most often the result of human land uses, such as residential development, agriculture, or associated factors such as high fire frequencies. In addition to directly reducing the amount of habitat available for birds, habitat loss also changes the size, shape, and connectedness of the remaining habitat. The spatial pattern of habitat loss is very important in determining how habitat loss will affect birds, as discussed below. Thus, the loss of habitat area may cause not only a proportional reduction in the size of bird populations, but also may have more insidious effects on remaining populations, such as reduced reproductive success.

Habitat Fragmentation

Theoretically, a given amount of habitat loss within a landscape can occur in any number of configurations. However, in most topographically varied areas the patterns of human land use are fairly predictable and often result in the creation of many isolated fragments of natural vegetation (Swenson and Franklin 2000). Another consequence of human settlement patterns is that some vegetation types are lost at higher rates than others. In this sense, some shrublands are relatively protected from loss by virtue of their occurrence on steep slopes. Nevertheless, remaining fragments of shrub vegetation may be quite small and isolated from other native landscape elements, such as watercourses. Even where remaining shrublands are still relatively large and connected, the presence of urbanization in the landscape appears to affect the abundance of shrubland birds in remaining habitat (Stralberg 2000).

Fragmented shrubland areas may not provide enough continuous acreage to support those birds that require large areas of habitat for an individual to survive (Soulé et al. 1992, Lovio 1996). However, even birds that can survive in smaller patches of habitat may disappear from fragmented areas. This may be caused in part by individual birds that have difficulty moving from one habitat fragment to another when the fragments are separated by inhospitable developed areas. Sedentary species, such as Crissal and LeConte's Thrashers are particularly vulnerable to this outcome of habitat fragmentation (Laudenslayer et al. 1992). Movement through fragmented habitats becomes more risky for the individual birds that move (usually juveniles) and thus the number dispersing successfully from one population to another is reduced. This movement of individuals (dispersal) is necessary to prevent

the extirpation of bird species because the survival of a bird population in one habitat patch may depend on the influx of new individuals from other habitat patches. Also, if local extirpation occurs (i.e., a distinct population dies out), the colonization of that habitat by other individuals of that species may be delayed or prevented. Such systems of isolated habitat remnants connected by occasional dispersal events are referred to as "metapopulations." A reduction in dispersal also can cause a reduction in genetic exchange between populations.

A landscape containing many isolated habitat fragments can be compared to an ocean with many islands. As suggested earlier, the equilibrium theory of island biogeography (MacArthur and Wilson 1967) states that colonization and extinction rates on habitat islands are influenced by the size of islands and degree of isolation from other islands or "mainlands." This means that more species are typically present on larger and less isolated islands, and the same pattern often holds true for habitat fragments. As the size of fragments decreases and isolation increases, "faunal relaxation" (loss of species) in the region initially results, although the rate of decline depends on many factors. These long term patterns of extinction and recolonization of habitat fragments are also called "metapopulation dynamics." The existence of metapopulation dynamics in particular areas such as coastal southern California is somewhat controversial. Soulé et al. (1992) provide evidence that habitat remnants are rarely if ever "rescued" by dispersal, whereas other studies (ERC 1991, Lovio unpublished data) have documented fairly frequent movement of birds among remnants. However, even fragmentation of shrubland habitats into relatively large remnants will result in the decline or loss of shrubland specialists (Lovio 1996). More recently, Crooks et al. (2001) found that extirpation were more common than colonizations in shrubland fragments.

Fragmentation frequently creates patches of shrubland that have long boundaries with developed areas, and this can create conditions that further compromise the ecological integrity of the habitat. Although natural ecotones (edges) between native habitat types usually provide conditions that enhance diversity (Brown and Gibson 1983), anthropogenic edges often are accompanied by reductions or losses of specialist species (e.g., Bolger et al. 1997). In California wildland-urban interfaces, improving vegetation structure and increasing the availability of water and food may improve habitat value near edges for some species. Complex interfaces often mimic natural ecotones in that they support enhanced diversities of birds (Guthrie 1974, Lovio unpublished observations). However, negative edge effects include the creation of barriers to dispersal, increases in native and non-native predators (Crooks and Soulé 1999), and potential increases in nest parasitism by the Brown-headed Cowbird. A complex causal relationship between the decline of large predators (e.g., coyotes and bobcats) associated with human development, the resultant increase in mid-sized native and non-native predators, and the predator-mediated declines of nesting birds has been postulated (Soulé et al. 1988, Crooks and Soulé 1999), but needs more study.

Chapter 5. The Conservation Planning Process

The Desert Bird Conservation Plan has been developed cooperatively by leading bird researchers in California through a process designed to:

- Capture the conservation needs of the complete range of desert habitat types throughout the state.
- Develop, by consensus, biological conservation objectives for selected desert bird species.

Criteria for Selecting Desert Focal Species

The majority of the PIF planning efforts use the national PIF database (Carter et al. 2000) to prioritize species in need of conservation attention and then select focal species by region for conservation plans. CalPIF elected against this method for the Desert Bird Conservation Plan for a number of reasons. The national PIF prioritization scheme relies heavily on BBS trend estimates that likely do not adequately monitor desert birds in California. Additionally, the PIF database does not yet recognize many subspecies including the Western Yellow-billed Cuckoo, a California endangered species. These factors render such a "priority" species list less representative than CalPIF preferred. Instead, CalPIF chose to emphasize the ecological associations of individual species *as well as* those of conservation concern (Chase and Geupel 2005). In doing so, CalPIF included a suite of focal species whose requirements define different spatial attributes, habitat characteristics, and management regimes representative of a "healthy" system (Table 5-1). Additionally, CalPIF decided that some of the most useful indicators were those with populations and distributions large enough to be easily monitored and to provide sufficient sample sizes for statistical analysis across sites and/or regions.

CalPIF included species in the conservation planning process based on five factors:

- Use desert vegetation as their primary breeding habitat in most bioregions of California.
- Warrant special management status—endangered, threatened, or species of special concern on either the federal or state level.
- Have experienced a reduction from their historical breeding range.
- Commonly breed throughout California's desert areas—allowing adequate sample sizes for statistical comparisons and therefore the ability to rapidly assess responses to changes in management (such as restoration).
- Have breeding requirements that represent the full range of successional stages of desert ecosystems—to assess the success of restoration efforts.

Because birds occupy a wide diversity of ecological niches in desert habitat, they serve as useful tools in the design of conservation efforts. Birds are relatively easy to monitor in comparison with other taxa and can serve as "focal species," whose requirements define different spatial attributes, habitat characteristics and management regimes representative of a healthy desert system (Chase and Geupel 2005). For example, the bird that requires the largest area to survive in a certain habitat will

determine the minimum suitable area for that habitat type. Likewise, the requirements of non-migratory birds that disperse short distances to establish new territories will define the attributes of connecting vegetation. The species with the most demanding or exacting requirements for an ecological characteristic, such as stream width or canopy cover, determines its minimum acceptable value. Therefore, the assumption is that a landscape designed and managed to meet the focal species' needs encompasses the requirements of other species (Lambeck 1997).

Focal Species

The following were selected as focal species for preparing the Conservation Plan. They are listed below followed by the species account author and any special-status designations. Latin names are given in Appendix B.

Burrowing Owl: California species of special concern. Christine Bates, Arizona BLM

Costa's Hummingbird: Susan Wethington and Barbara Carlson, The Hummingbird Network

Gila Woodpecker: California listed as endangered**.** Chris McCreedy, PRBO Conservation Science

Ladder-backed Woodpecker: Dennis Jongsomjit and Lishka Arata, PRBO Conservation Science

Ash-throated Flycatcher: Debra Hughson, National Park Service

Common Raven: William Boarman, United States Geologic Survey

Verdin: Roy Churchwell, San Francisco Bay Bird Observatory

Black-tailed Gnatcatcher: Jason Tinant, California BLM

Crissal Thrasher: California species of special concern. Justin Hite, PRBO Conservation Science

LeConte's Thrasher: California species of special concern. James Weigand, California BLM, and Sam Fitton, Audubon Ohio.

Phainopepla: Lisa Crampton, University of Nevada-Reno

Lucy's Warbler: California species of special concern. Chris Otahal, U.S. Fish and Wildlife Service

Black-throated Sparrow: Matt Johnson, United States Geologic Survey

Scott's Oriole: Ronald Gartland, California BLM

Range maps of each focal species, including site-specific breeding status are shown in Figures 5-1 – 5-15. Additional key findings from the species accounts are available at http://www.prbo.org/calpif/htmldocs/desert.htm. These findings and the detailed information found in each species account provide the basis for the conclusions and conservation recommendations presented in this Conservation Plan. Account authors and other conservation and land management experts gathered to discuss and synthesize their results into a summary of concerns, habitat requirements, conservation objectives, and action plans (or recommendations). The species accounts and the results from this meeting form the backbone of this Conservation Plan.

A focal species of the California Partners In Flight Shrubsteppe Plan, Loggerhead Shrikes are also found throughout the Mojave and Sonoran Deserts, which are considered their population's stronghold. *Photo by Justin Hite.*

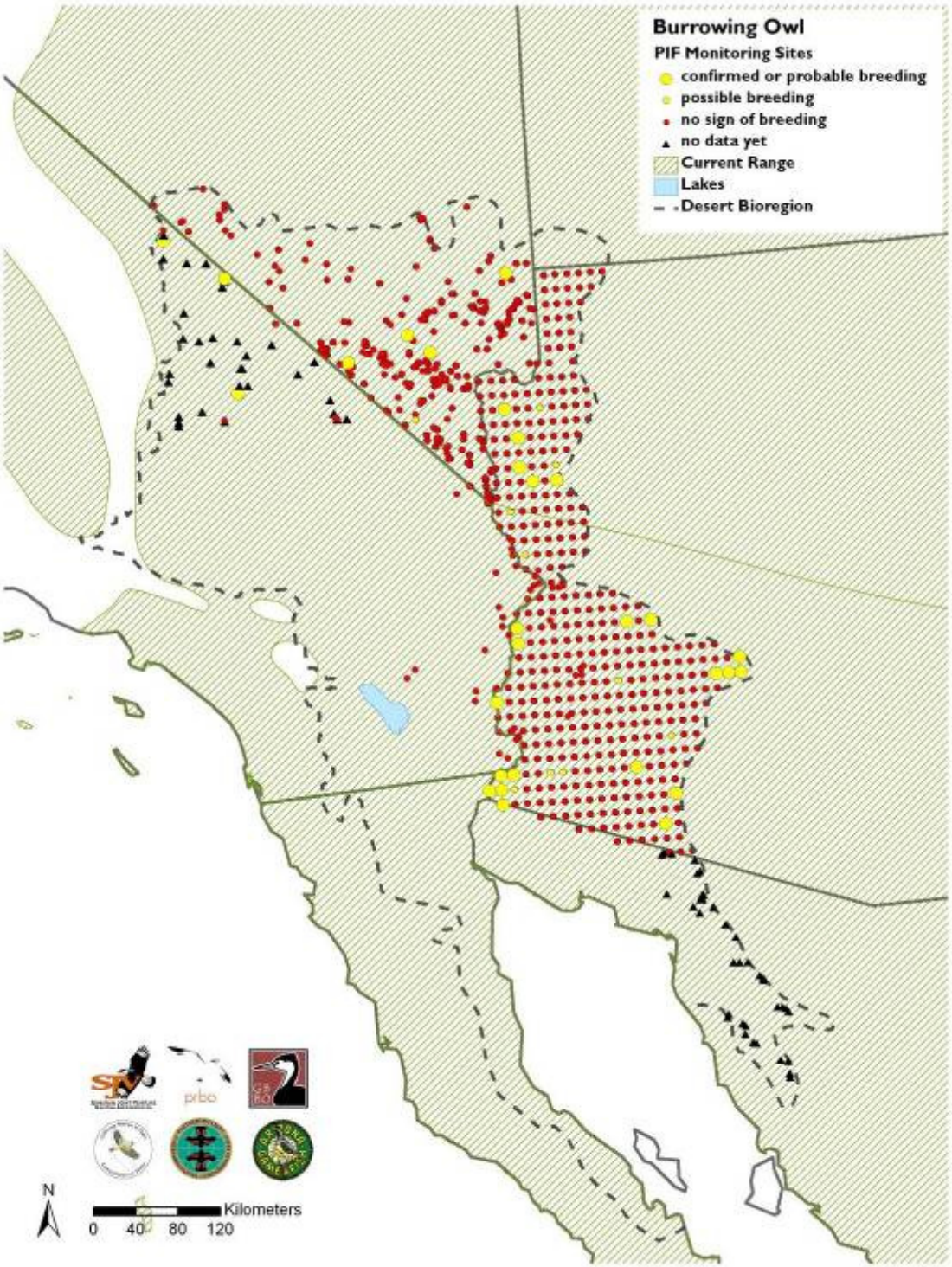

Figure 5-1. CalPIF monitoring sites, breeding status, and current range for the Burrowing Owl in California.

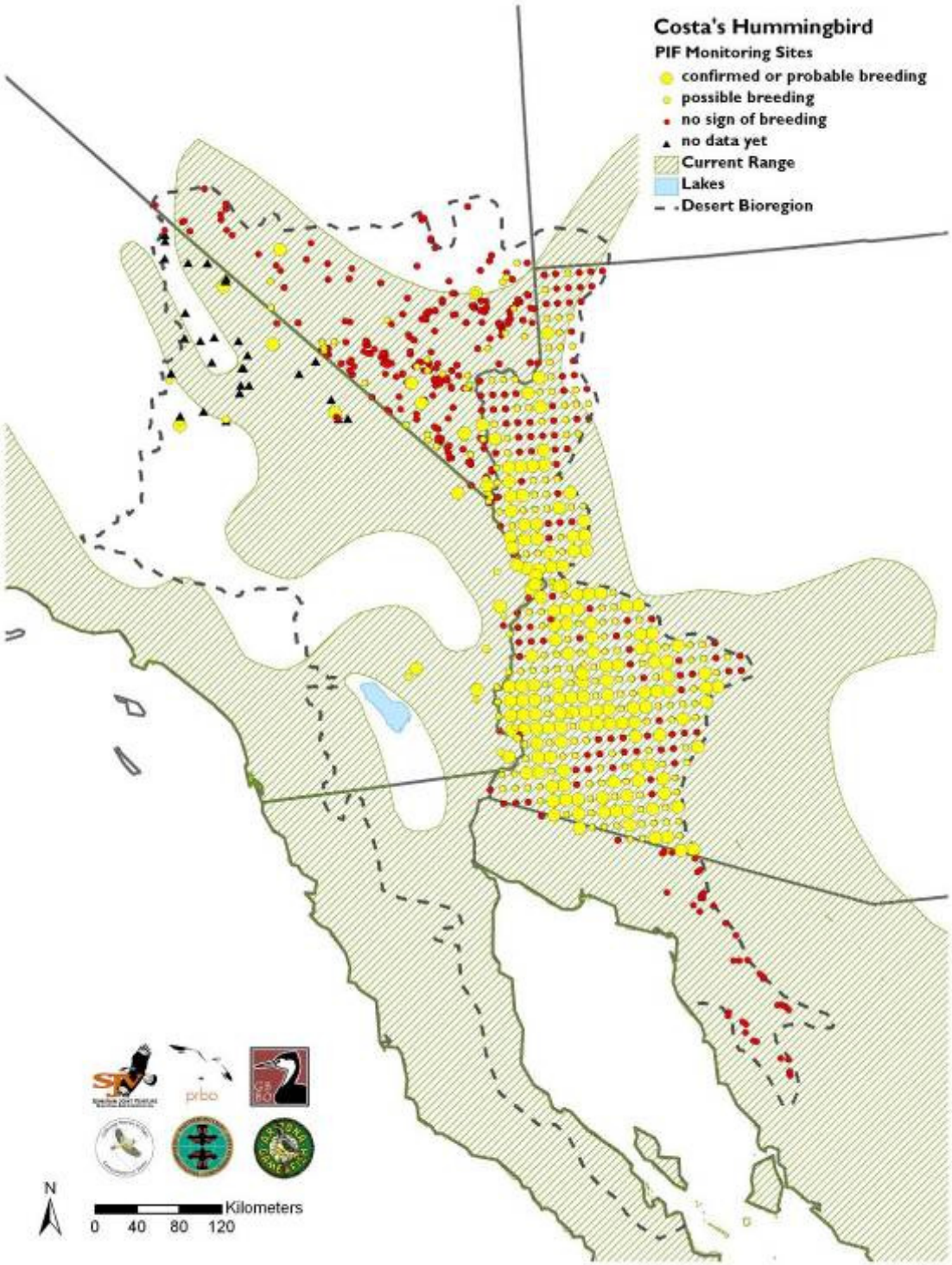

Figure 5-2. CalPIF monitoring sites, breeding status, and current range for the Costa's Hummingbird in California.

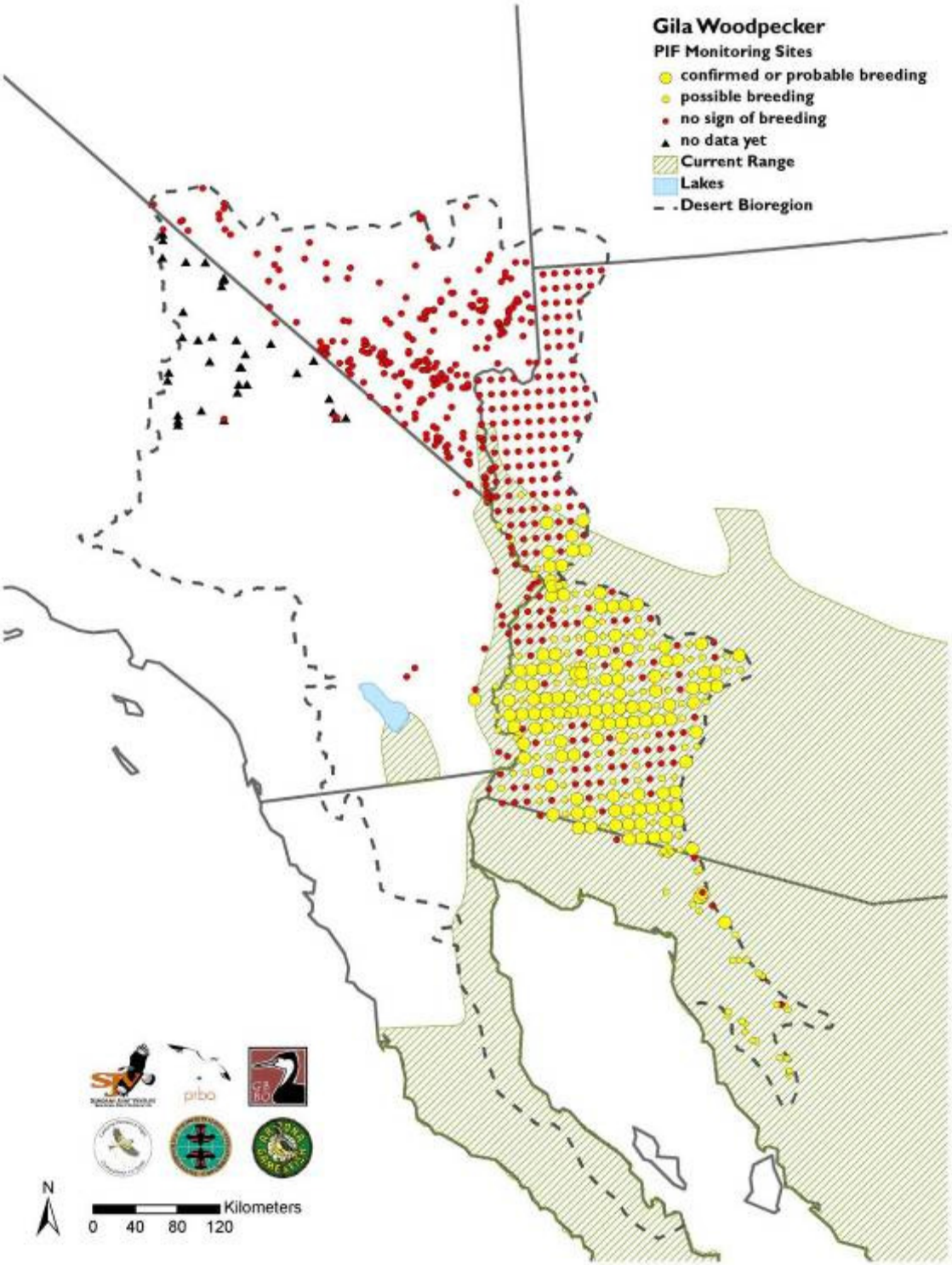

Figure 5-3. CalPIF monitoring sites, breeding status, and current range for the Gila Woodpecker in California.

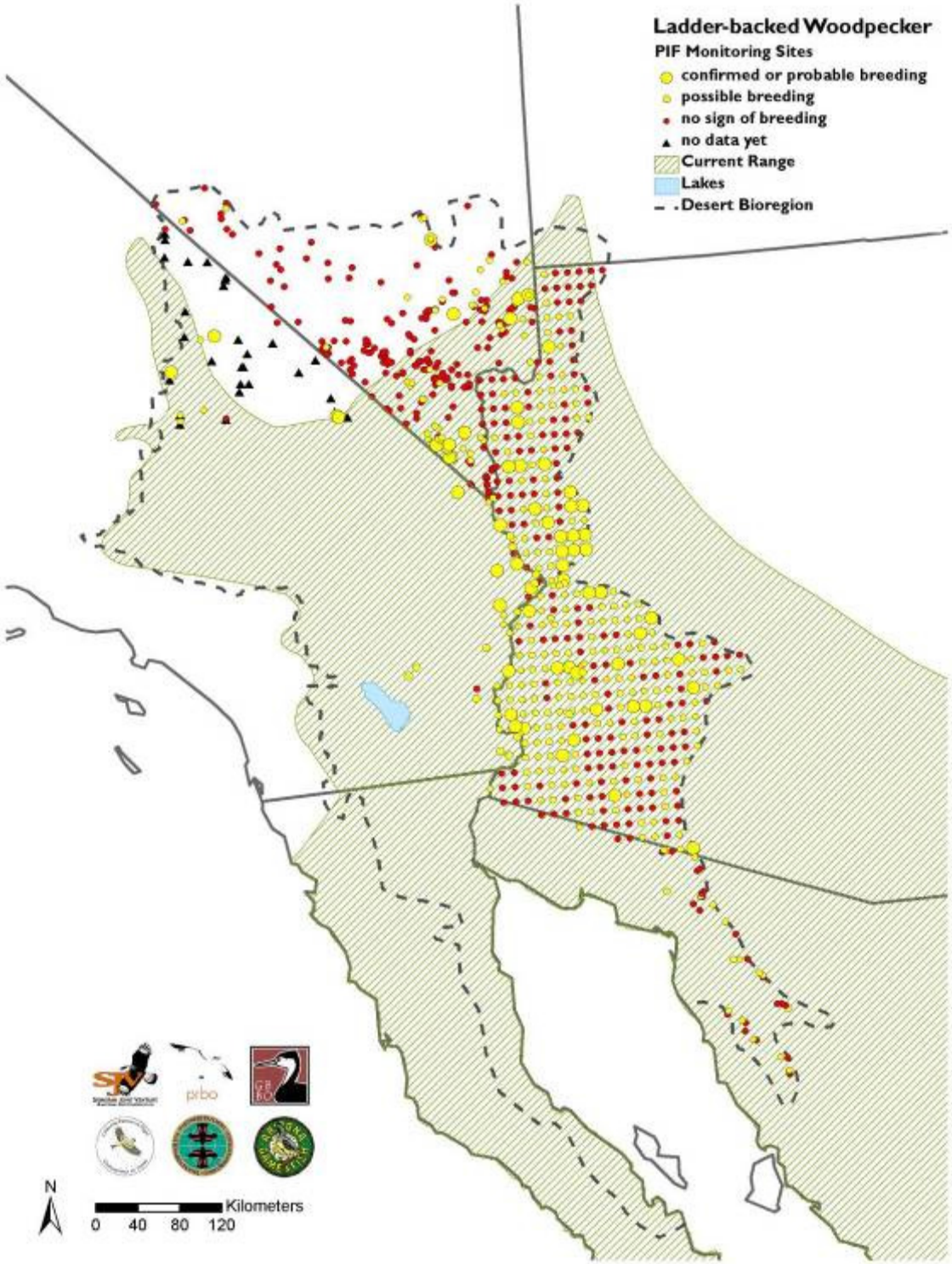

Figure 5-4. CalPIF monitoring sites, breeding status, and current range for the Ladder-backed Woodpecker in California.

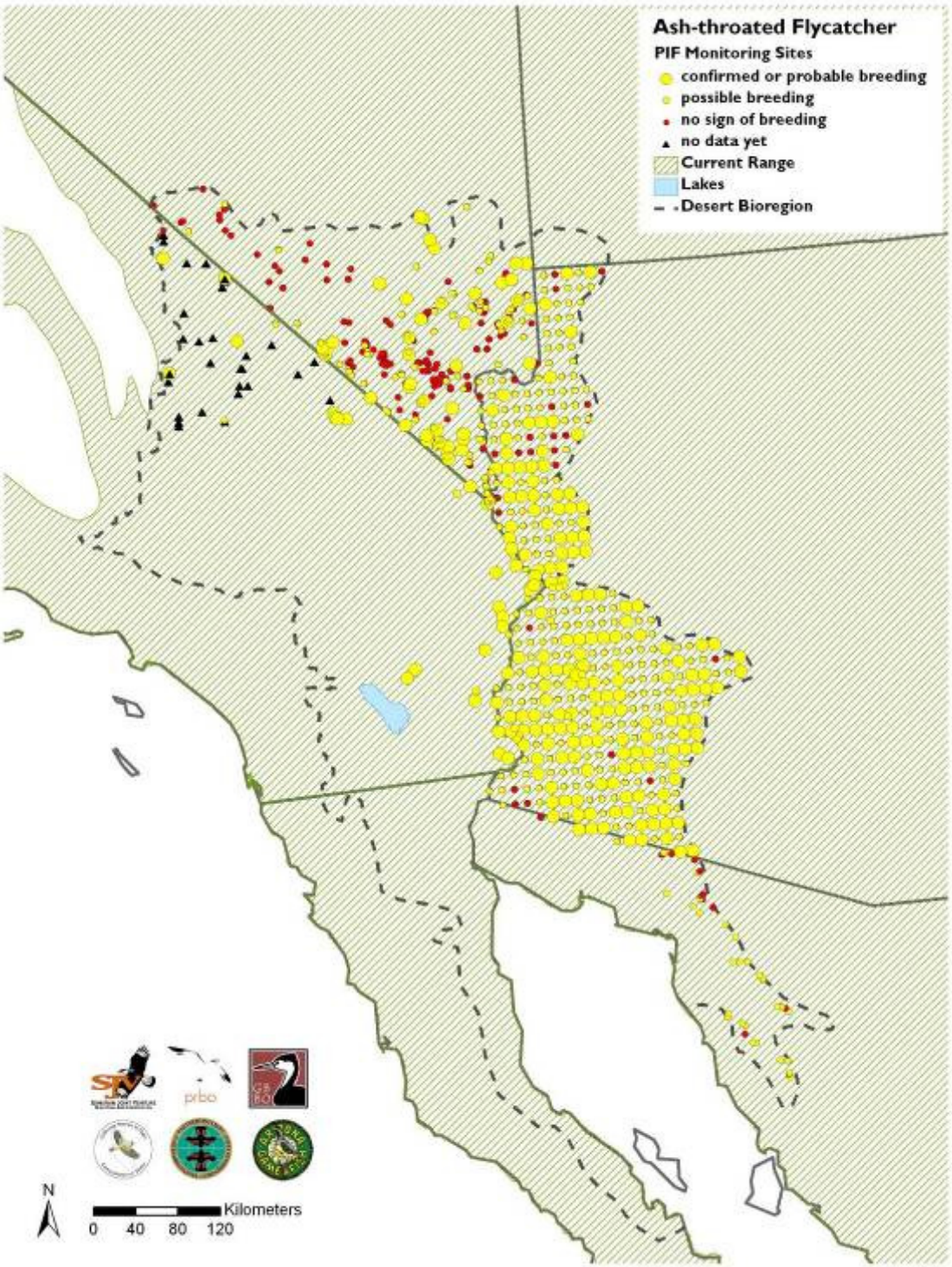

Figure 5-6. CalPIF monitoring sites, breeding status, and current range for Ash-throated Flycather in California.

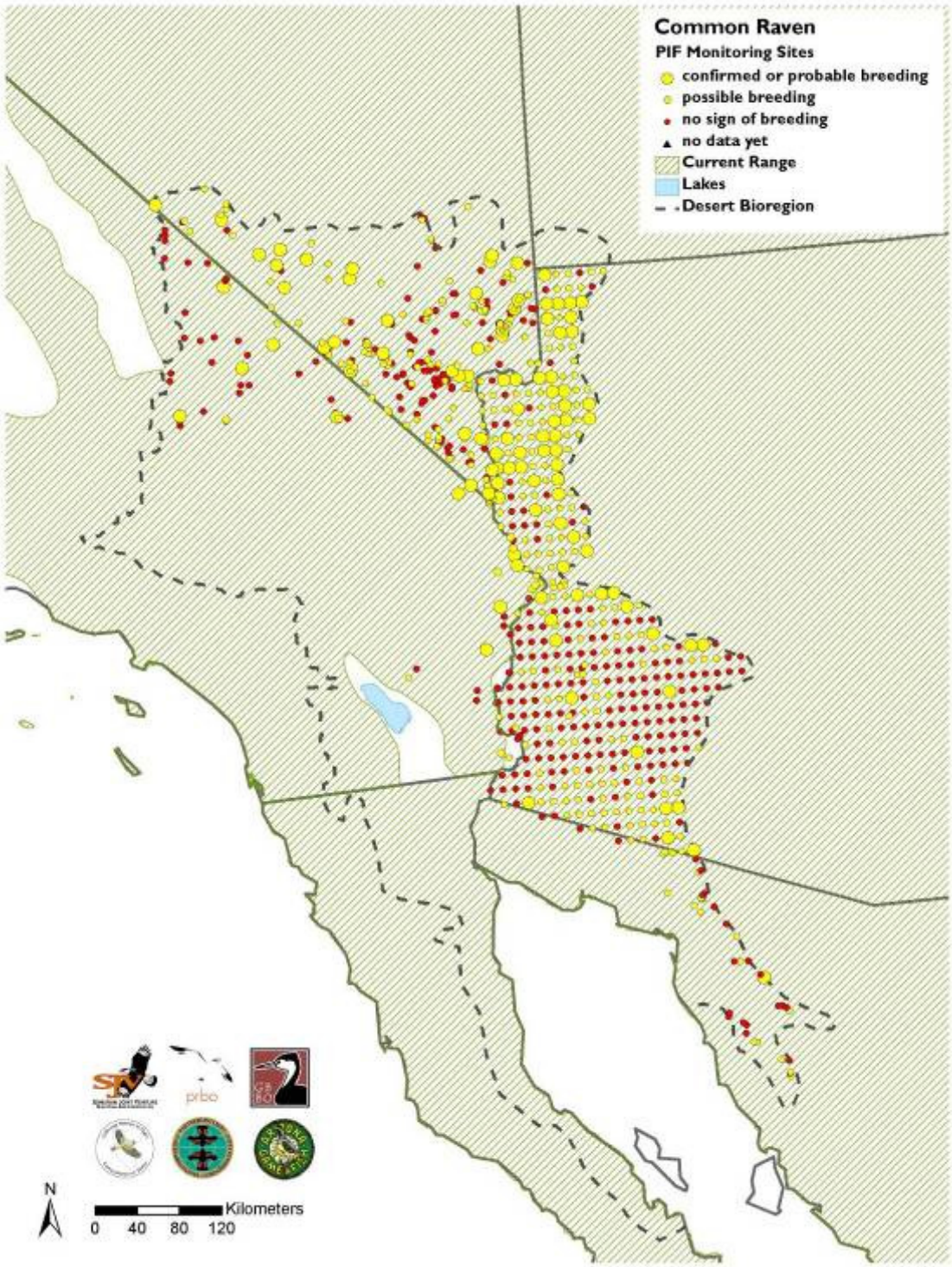

Figure 5-6. CalPIF monitoring sites, breeding status, and current range for the Common Raven in California.

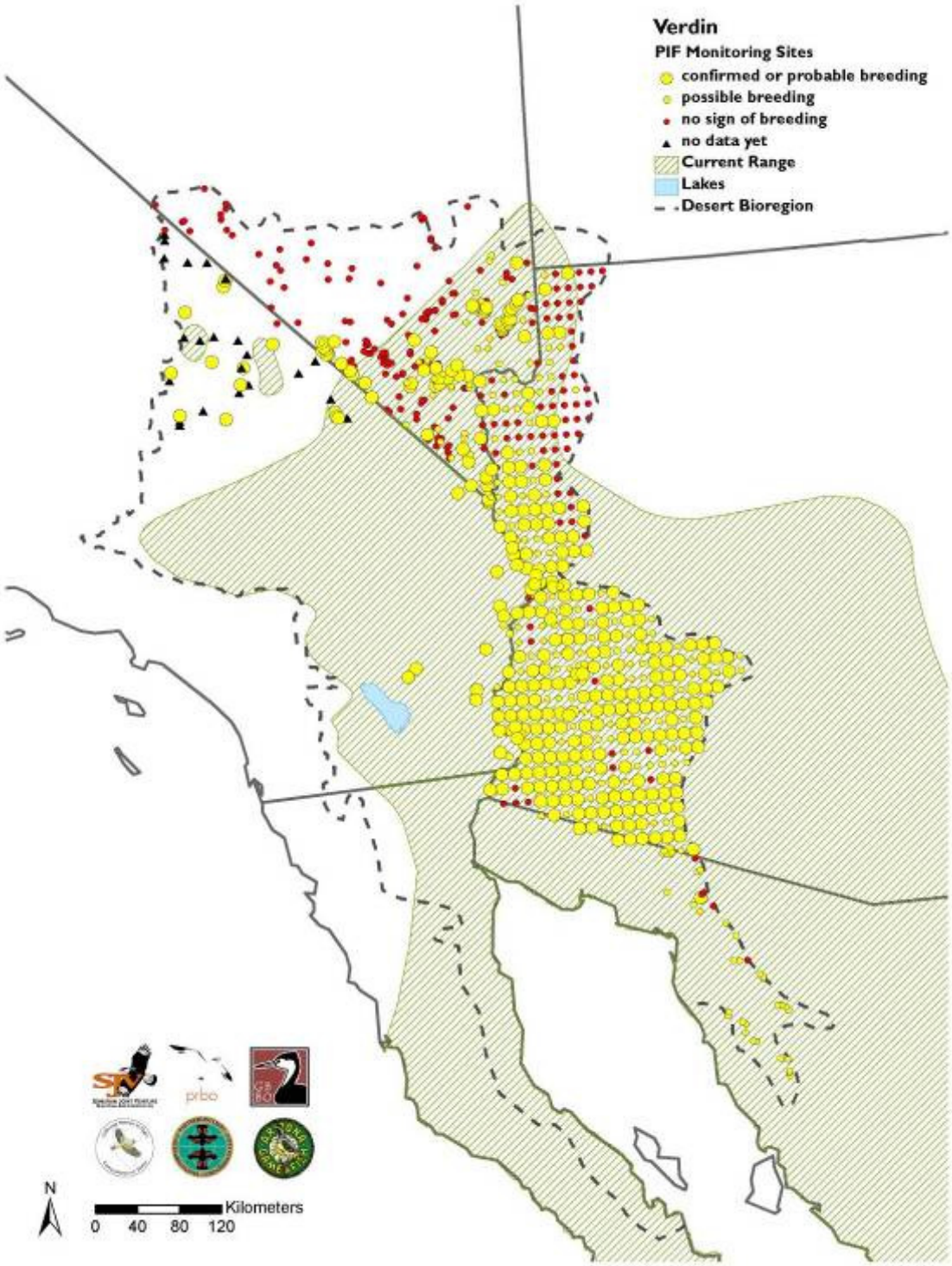

Figure 5-7. CalPIF monitoring sites, breeding status, and current range for the Verdin in California.

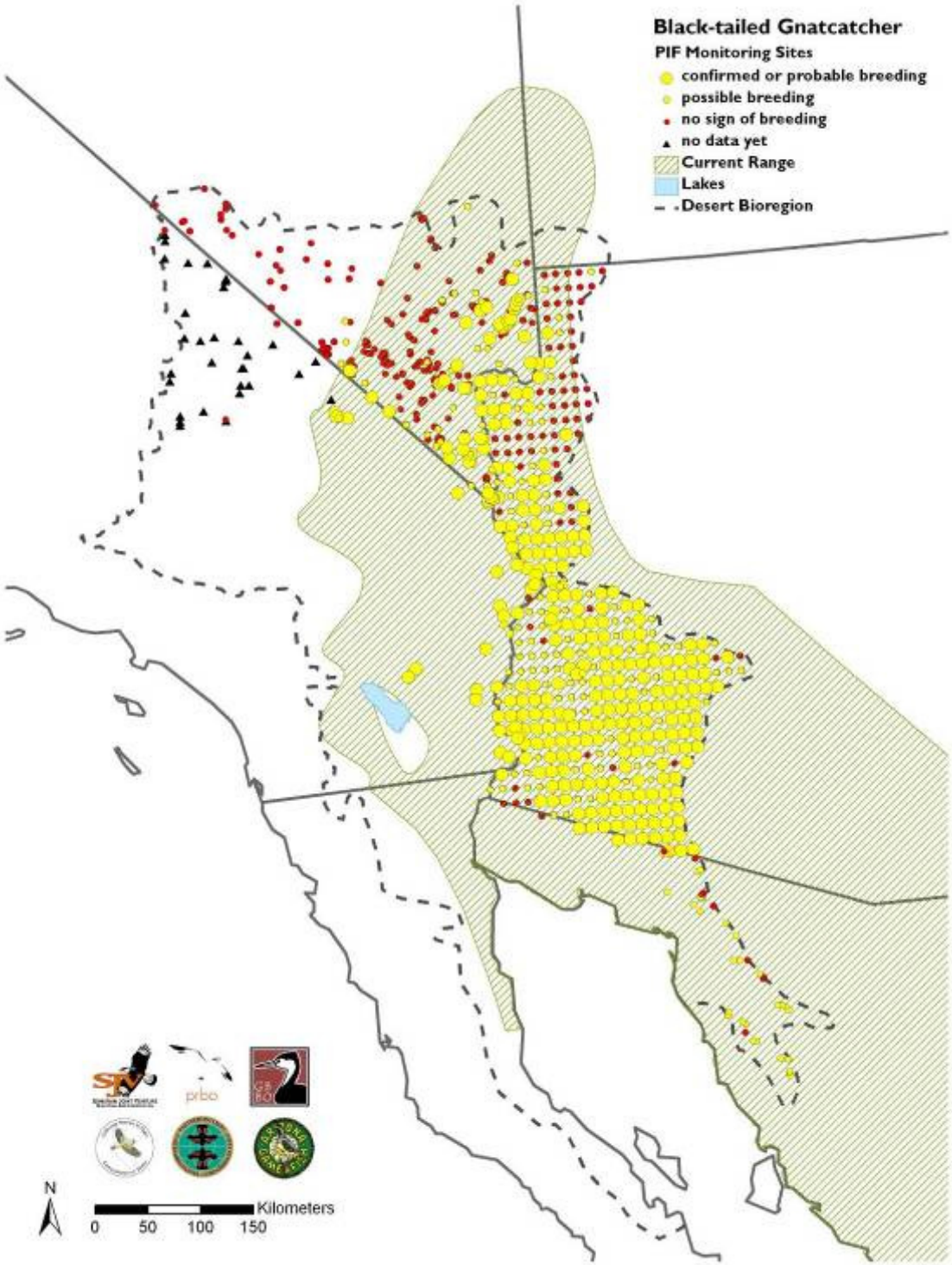

Figure 5-8. CalPIF monitoring sites, breeding status, and current range for the Black-tailed Gnatcatcher in California.

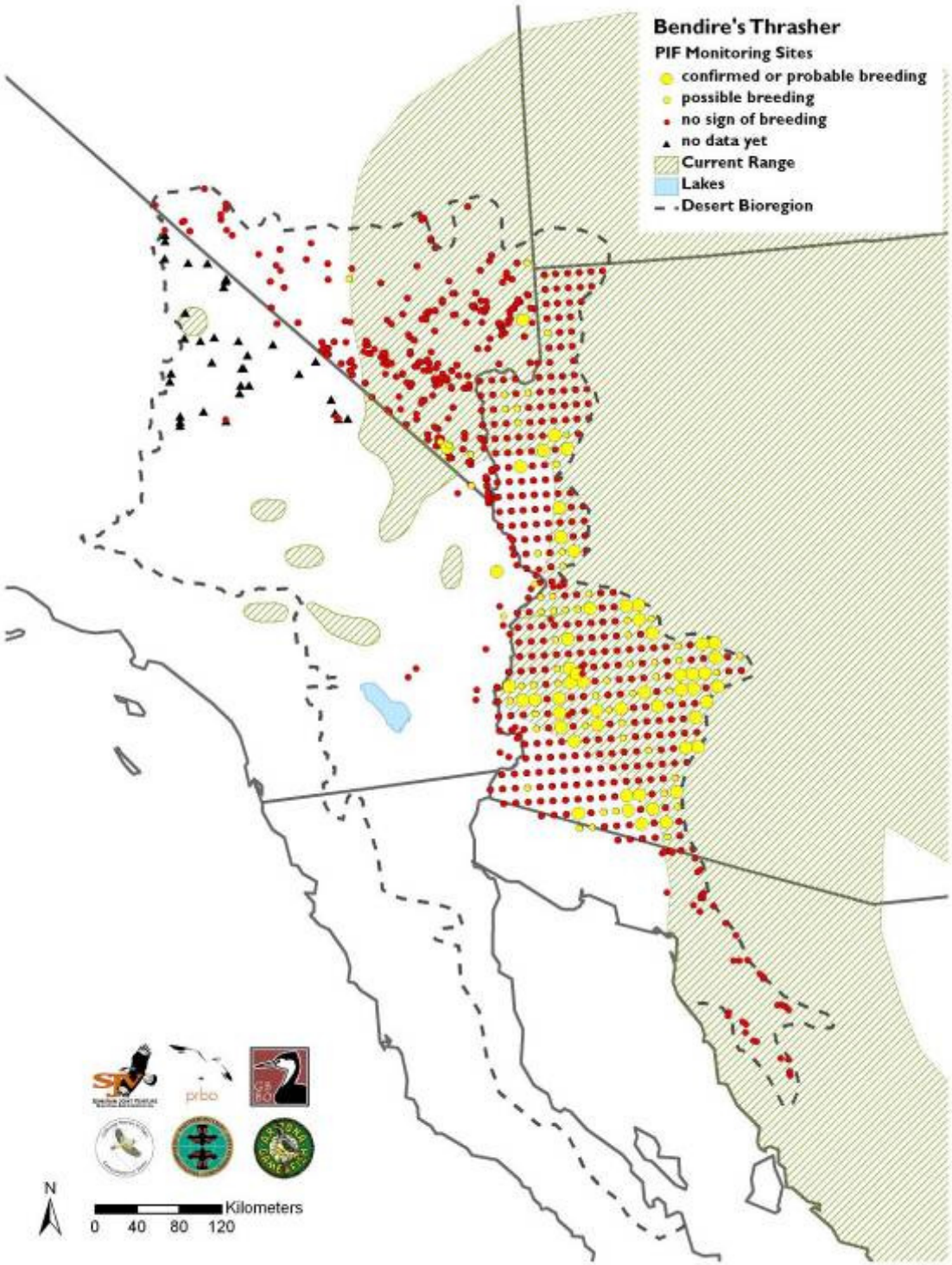

Figure 5-9. CalPIF monitoring sites, breeding status, and current range for the Bendire's Thrasher in California.

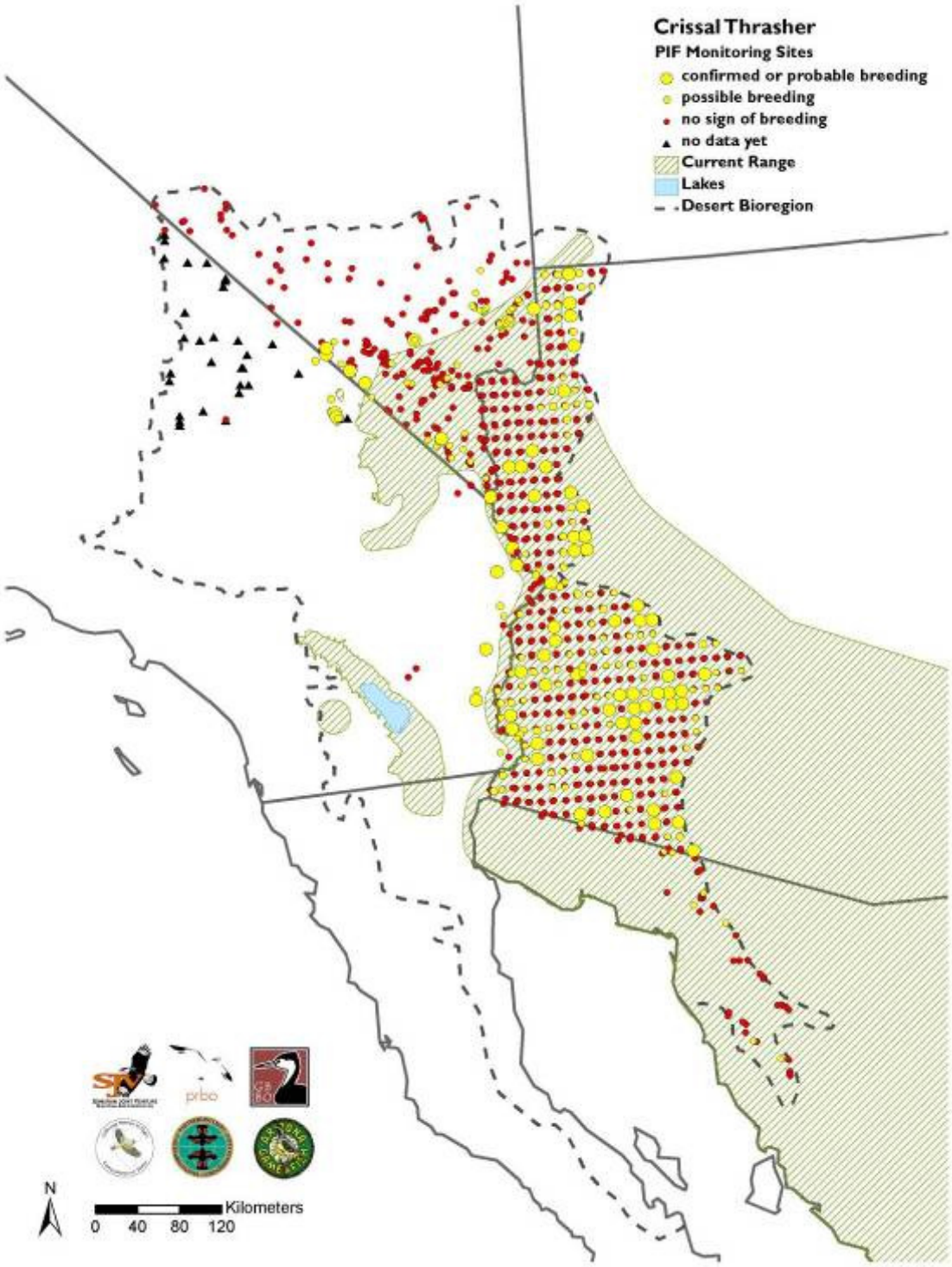

Figure 5-10. CalPIF monitoring sites, breeding status, and current range for the Crissal Thrasher in California.

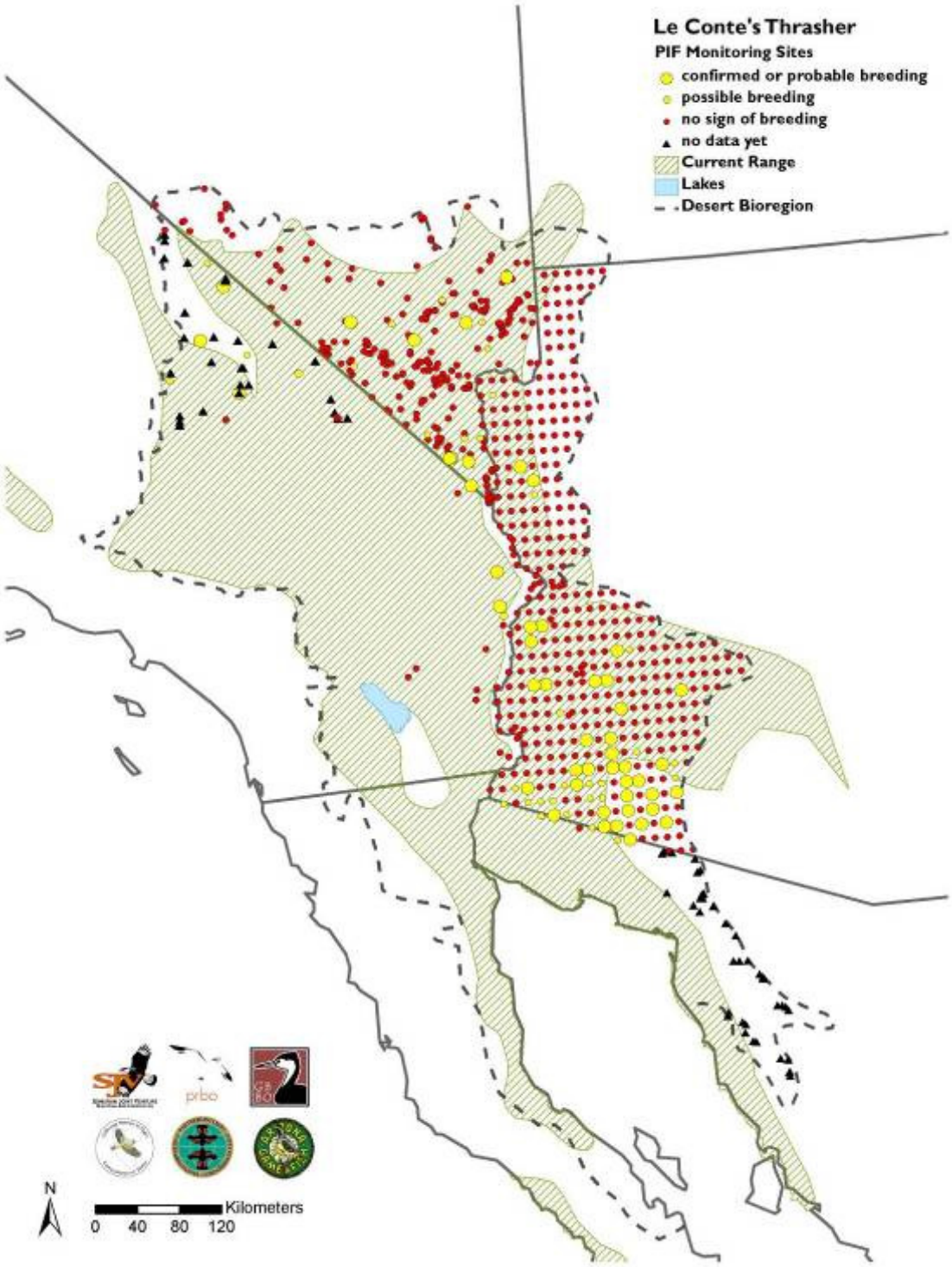

Figure 5-11. CalPIF monitoring sites, breeding status, and current range for the LeConte's Thrasher in California.

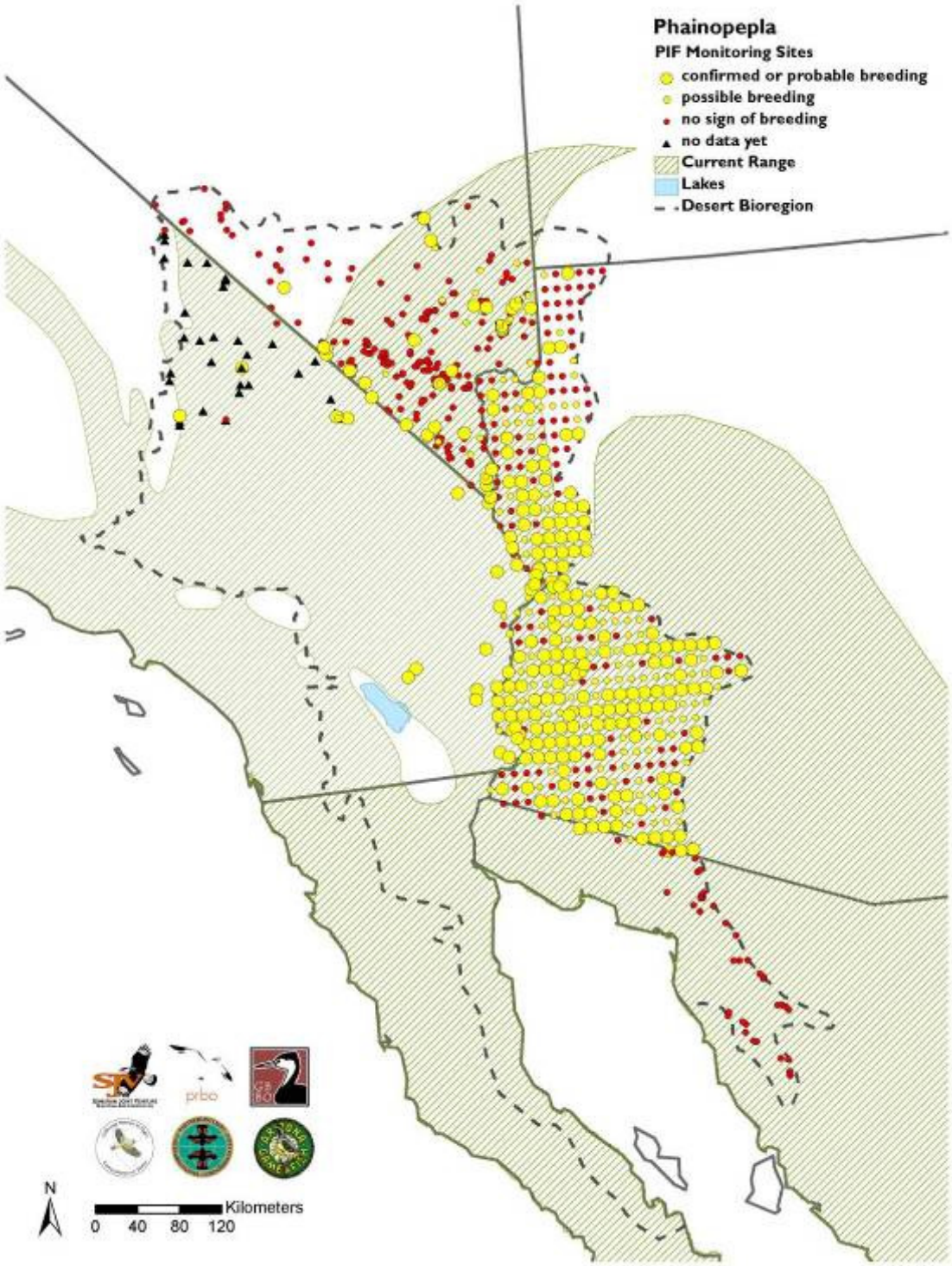

Figure 5-12. CalPIF monitoring sites, breeding status, and current range for the Phainopepla in California.

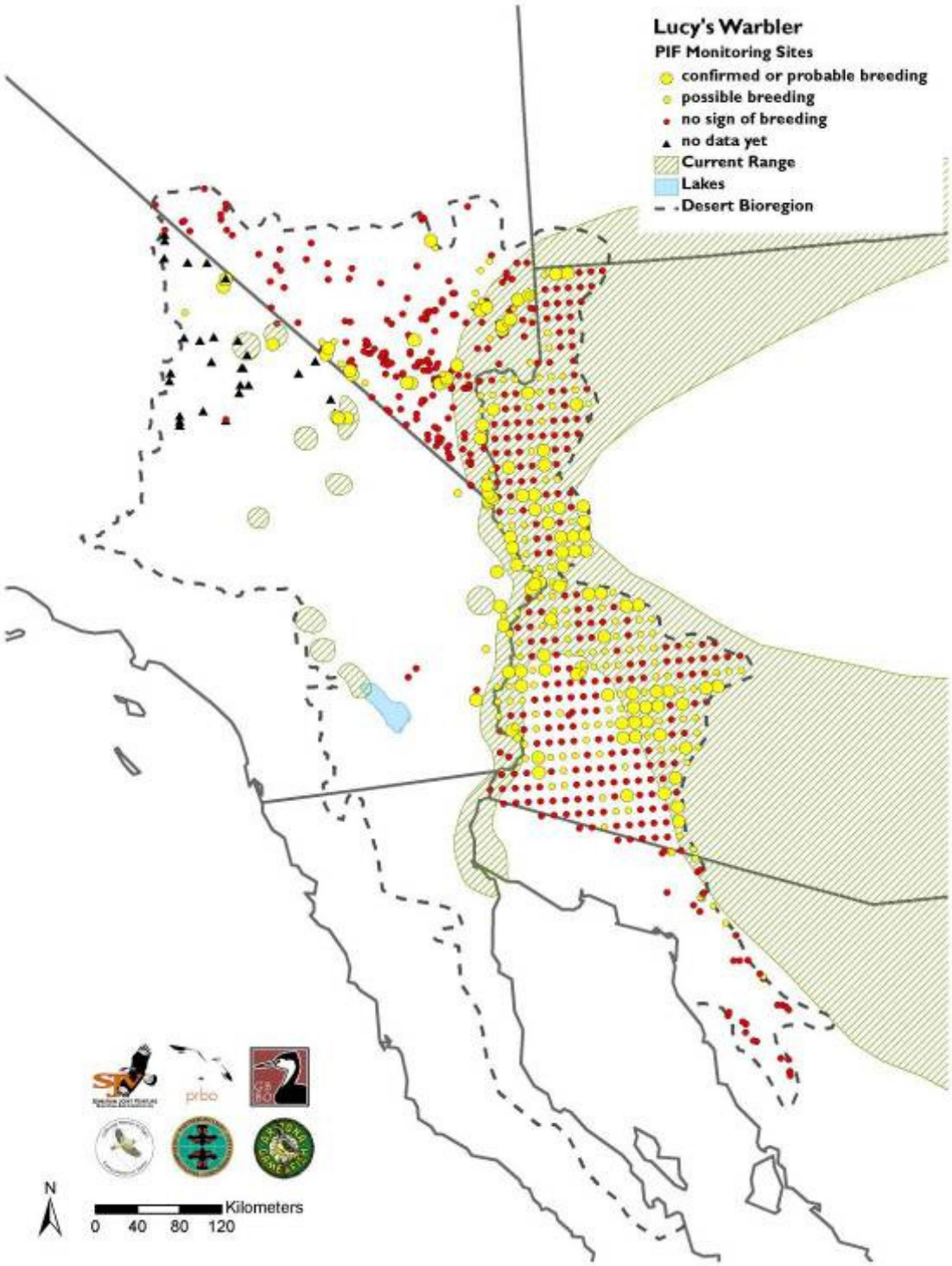

Figure 5-13. CalPIF monitoring sites, breeding status, and current range for the Lucy's Warbler in California.

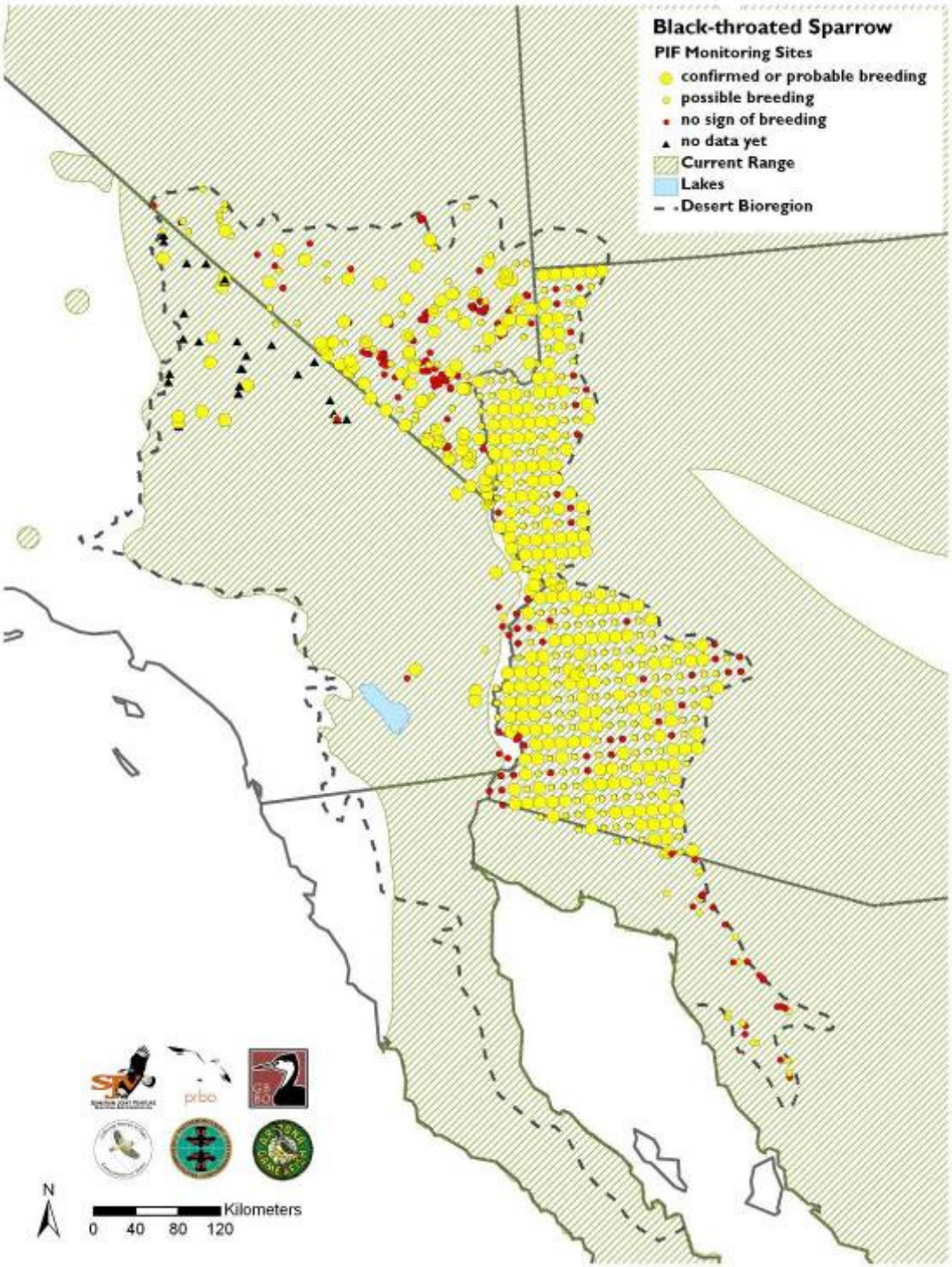

Figure 5-14. CalPIF monitoring sites, breeding status, and current range for the Black-throated Sparrow in California.

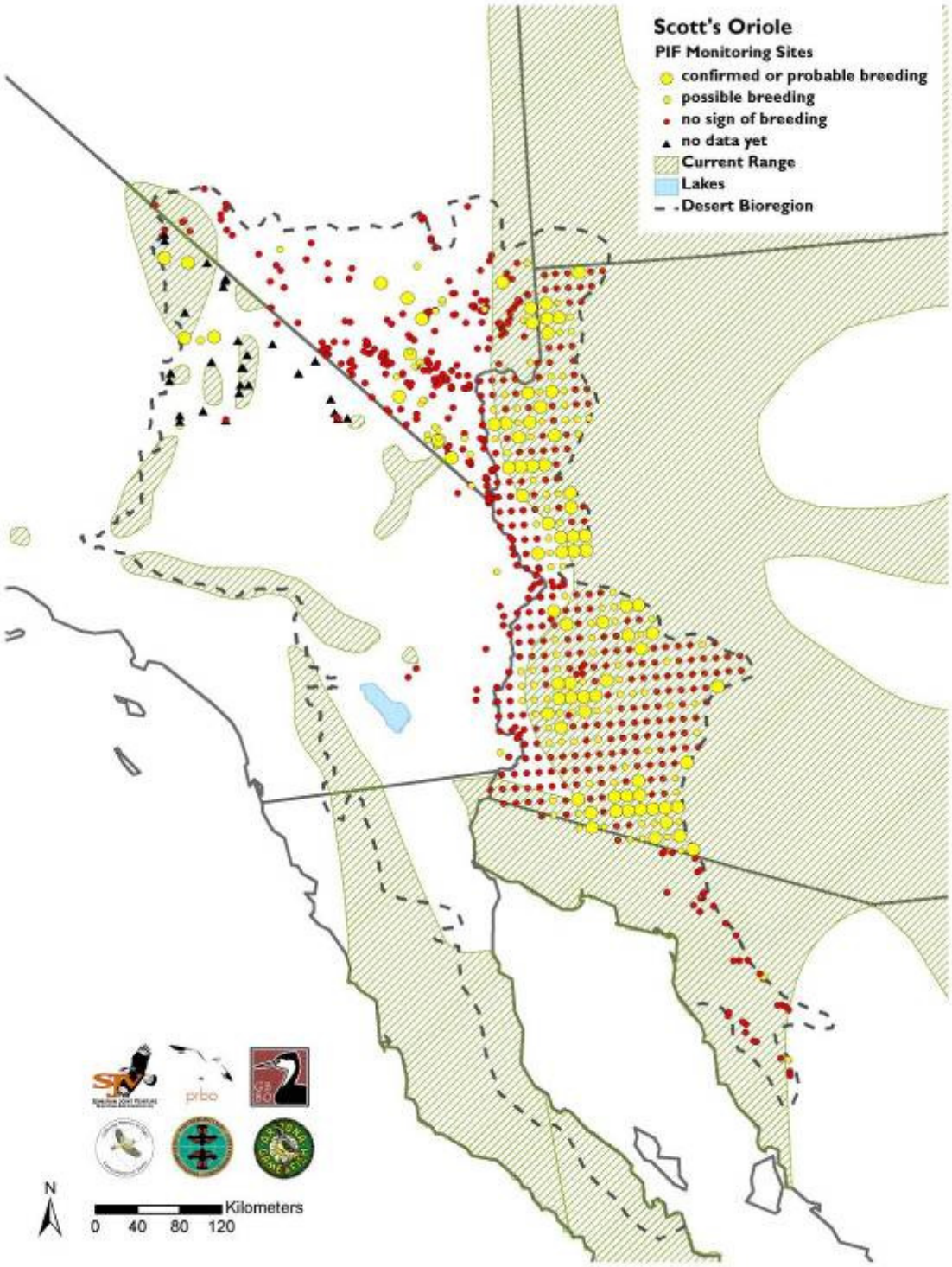

Figure 5-15. CalPIF monitoring sites, breeding status, and current range for the Scott's Oriole in California.

Data-Gathering Effort

Identifying the causes of population fluctuations requires an understanding of how demographic and physiological processes—annual survival, reproductive success, dispersal, and recruitment—vary across habitats, landscapes, and management practices. This information must be gathered using scientifically sound research and monitoring techniques (Appendix C, Ralph et al. 1993, Bonney et al. 2000 for review). The Breeding Bird Survey (BBS), coordinated by the USFWS and the Canadian Wildlife Service, produces most of the available information regarding changes in the sizes and ranges of landbird populations in North America (Sauer et al. 2005). These roadside counts provide an excellent baseline by which to assess long-term population trends, but they do not identify factors contributing to these changes (e.g., habitat and landscape variables) and may fail to adequately monitor bird populations away from roads and human disturbance (Peterjohn et al. 1995). Furthermore, the inability of BBS data to detect trends within certain habitats, particularly patchily distributed habitats, contributes to the need for more intensive, site-specific monitoring techniques.

Biologists throughout California have contributed data to this document. They have sent information garnered from constant-effort mist netting, nest searching, point counts and other standardized techniques. The locations of study areas, contact information, types of data collected, and breeding status information for all focal species are stored and updated in real time through the California Avian Data Center at www.prbo.org/cadc via an interactive map interface to a relational database system (Ballard et al. 2003a). In some cases, more extensive data will be linked to this interface, allowing for calculations of population estimates and demographic parameters. Figure 5-16 provides a map of desert bird data showing biodiversity "hotspots" in California desert habitats as defined by the richness of 10 focal species.

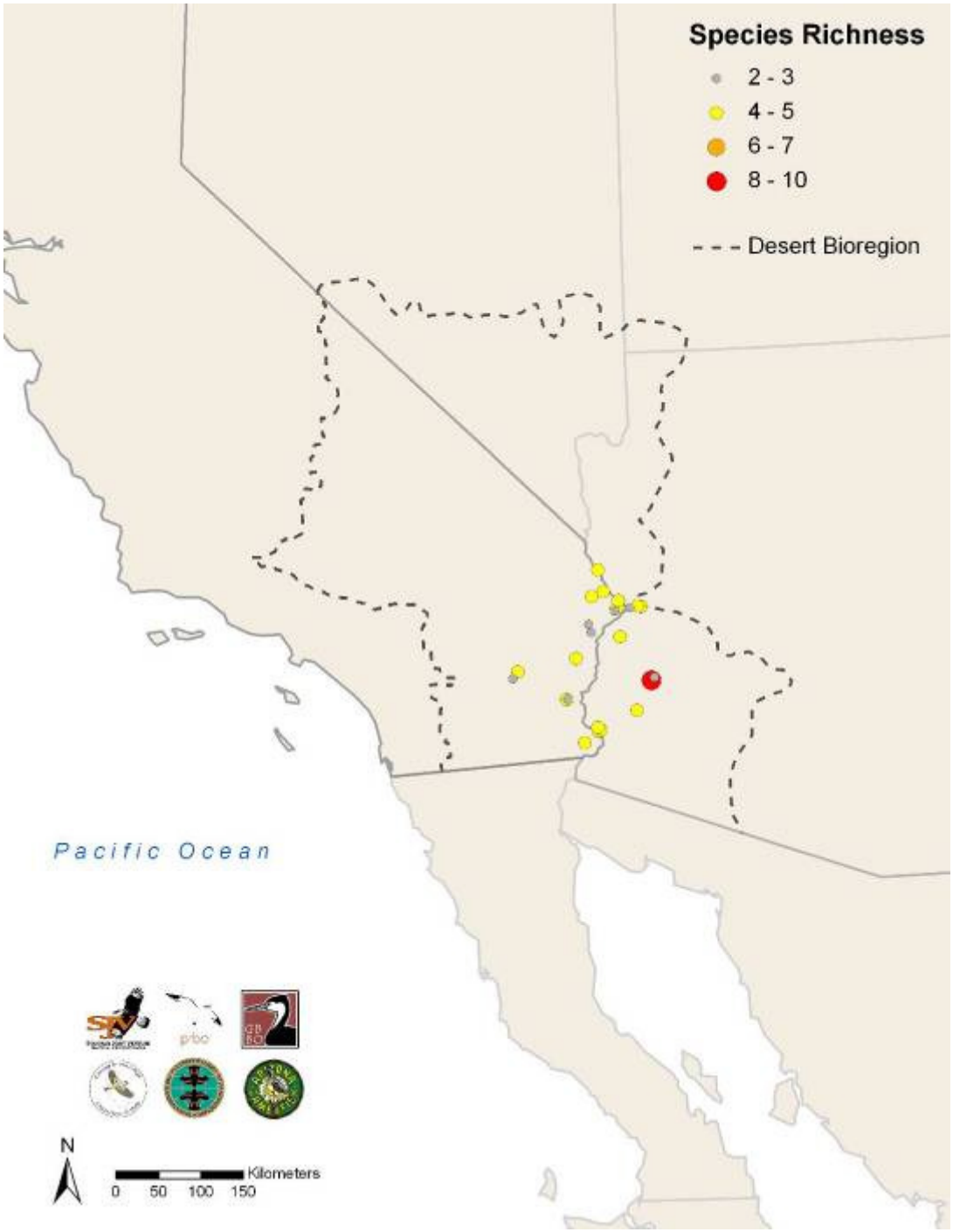

Figure 5-16. Species richness for 10 focal desert species at census sites throughout California. Data were collected and submitted by CalPIF contributors.

Table 5-1. Status, special factors, and nesting requirements of desert focal species.

Species	Statewide Status	Historical Breeding Range[1]	Reliable BBS trend?	Special Factors	Nest Site	Breeding Grounds Description	Territory Size and Breeding Density
Burrowing Owl	California Species of Special Concern	Statewide, but extirpated from parts of BA/DE	COLD = No MOJA = No	Loss of nesting and foraging habitat due to intensive agriculture and urbanization Negatively affected by control programs for burrowing mammals	Burrows created by other animals, surrounded by bare ground or short grass	Uses a variety of arid and semi-arid environments characterized by sparse vegetation and bare ground	Territory size in NM ranged from 4.8-6.4 ha. Density estimated at 0.9 pairs/km^2 in SAJO and 8.3 pairs/km^2 in COLD
Costa's Hummingbird	None	CECO, SINE, COLD, MOJA, SOCO	COLD = No MOJA = No	Loss of habitat due to agriculture, urbanization, and conversion of desert scrub to cattle forage Intense drought may result in skipped breeding season	Nests located in cacti, paloverde, jojoba, smoke tree, and other xeric shrubs, usually within 3 meters of ground	Prefers desert scrub and desert wash habitats	Territory size varies depending on resource availability.
Gila Woodpecker	California Endangered Species	COLD, extirpated from MOJA	COLD = Yes	Absent from riparian areas where tamarisk has usurped cottonwood and willow Competition for nest sites with European Starling could be detrimental	Uses cavities primarily in large saguaro cacti; occasionally nests in honey mesquite or screwbean mesquite	Prefers sparsely covered desert habitats containing large saguaro cacti	Estimated territory size was 4.57 ha in AZ desert wash. Breeding densities were 14.8-24.9 birds/ km^2 in desert wash and 9.8 birds/ km^2 in open desert
Ladder-backed Woodpecker	None	COLD, MOJA, SOCO	COLD = No MOJA = No	Grazing may have adverse effects on the quantity and quality of habitat available for this species	Uses cavities primarily in Joshua tree, willow, and cottonwood.	Prefers shrub desert dominated by Joshua trees.	Density estimated at 1.15 birds/40 ha for lower plateau of Deep Canyon, CA
Ash-throated Flycatcher	None	Statewide	COLD = Yes MOJA = Yes	Loss of habitat from clearing for agriculture, urbanization, and suburbanization, and from flood-control projects	Nests primarily in natural cavities, woodpecker holes, and nest boxes	Prefers arid and semiarid scrub and open woodland, as well as riparian woodland	In n. Pinal Co., AZ, densities 4.6–6.7 individuals/40 ha in desert-wash habitat, and 6.4–6.8/40 ha in desert-upland habitat.

Table 5-1. Status, special factors, and nesting requirements of desert focal species.

Species	Statewide Status	Historical Breeding Range[1]	Reliable BBS trend?	Special Factors	Nest Site	Breeding Grounds Description	Territory Size and Breeding Density
Common Raven	None	Statewide	COLD = Yes MOJA = Yes	Implicated as a causative factor in the decline of the desert tortoise Desert populations increasing rapidly due to food subsidization from humans	Highly variable. Uses manmade structures such as power line towers, telephone poles, abandoned buildings	In desert habitats, occurs near humans; in significantly greater numbers at landfills, ag fields and along highways	Territory size varies greatly. Nests as little as 300m apart in human-dominated landscape in Mojave.
Verdin	None	COLD, MOJA, SOCO	COLD = Yes MOJA = No	Land-clearing for agriculture and rapid development of resort areas and golf courses has reduced available habitat	Nests often are located along desert washes or at edge of vegetative boundaries	Desert scrub, chiefly in areas along washes where thorny vegetation occurs or in desert riparian zones	Territory size of 8 ha recorded in NM. Breeding densities ranged from 16-28 indiv/40 ha
Black-tailed Gnatcatcher	None	COLD, MOJA	COLD = No MOJA = No	Requires native vegetation; cannot adapt to exotic vegetation or high density of buildings Highly sensitive to cowbird presence, nearly non-existant in urban areas	Nests in dense, thorny or leafy shrub or tree.	Desert thorn scrub and thickets. Densely lined arroyos and washes dominated by creosote bush and saltbush	Territory size ranged from 1.1-2.7 ha in NM. BBS densities of 4-10 birds/route/2.5 hrs of observation in MOJA
Bendire's Thrasher	California Species of Special Concern	COLD, MOJA	COLD = No MOJA = No	Degradation of habitat due to off-road vehicle activity	Nests in shrubs, cacti, or trees. Substrates include cholla, mesquite, and juniper.	Prefers relatively open, grassland, shrubland, or woodland with scattered shrubs or trees	Territory size unknown. Density estimates difficult due to secretive nature.
Crissal Thrasher	California Species of Special Concern	COLD, MOJA, SOCO	COLD = No MOJA = No	Loss of habitat to clearing for agriculture or urban and suburban development Tolerant of tamarisk, but significant habitat losses due to groundwater mining	Nest site generally well hidden in interior of densest shrubs in habitat.	Prefers foothill scrub, desert washes, mesquite thickets	Breeding densities range from 0.2-18.5 pairs/40ha, depending on habitat type

Table 5-1. Status, special factors, and nesting requirements of desert focal species.

Species	Statewide Status	Historical Breeding Range[1]	Reliable BBS trend?	Special Factors	Nest Site	Breeding Grounds Description	Territory Size and Breeding Density
LeConte's Thrasher	California Species of Special Concern	COLD, MOJA, SAJO	COLD = No MOJA = Yes	Degradation of habitat due to destruction of substrate, litter, or shrubs or repeated All Terrain Vehicle (ATV) usage	Nests in thick, dense, and thorny desert shrubs or cholla cactus	Typical habitat throughout range consists of sparsely vegetated desert flats, dunes, alluvial fans, or gently rolling hills of saltbush	Breeding densities range from 0.2-7.3 pairs/km^2
Phainopepla	None	BA/DE, CECO, SOCO, COLD, MOJA, SINE	COLD = No MOJA = No	Closely associated with desert mistletoe. Loss of riparian woodlands and mesquite thickets to agriculture.	Often nests in trees and shrubs that are parasitized by desert mistletoe.	Breeds along desert washes and desert riparian habitats.	In desert habitats, territories of 0.40 ha have been recorded. Density estimates of 3-10 pairs/ha in summer range.
Lucy's Warbler	None	MOJA	COLD = No MOJA = No	Closely associated with mesquite bosques. Loss and degradation of mesquite habitat has led to local extirpations.	Nests behind loose bark of tree, in natural cavities, or amongst roots along riverbanks.	Breeds most often in dense lowland riparian mesquite woodlands.	Densities up to 12.5 pairs/ha.
Black-throated Sparrow	None	MODO, SINE, COLD, MOJA	COLD = Yes MOJA = Yes	Long-term fire suppression may make habitat unsuitable Negatively affected by urbanization.	Nests in creosote bush, chaparral, mesquite, acacia and intermixed areas of Joshua trees.	Desert scrub, washes, and canyons.	Mean territory size in AZ was 0.84 ha. Densities range from 5.2 individuals/km^2 to 87.4/ km^2 depending on habitat.
Scott's Oriole	None	SINE, MOJA	COLD = No MOJA = Yes	Loss and degradation of yucca and pinon-pine woodlands Increasing fire frequency threatens Joshua tree and yucca habitats	Nests partially suspended from overhanging leaves at the top of a yucca tree.	Yucca and pinon-pine woodlands	Territory size not well studied; probably depends on availability of Yucca spp. or other suitable nesting trees

1. Bioregions included in historical breeding range as estimated from Grinnell and Miller 1944: BA/DE=Bay/Delta; SINE=Sierra Nevada; CECO=Central Coast; MOJA=Mojave; SOCO=South Coastal; COLD=Colorado Desert; SAJO=San Joaquin. See the range maps and species accounts at http://www.prbo.org/calpif/data.html for more information.

Chapter 6. Population Targets and Species Specific Recommendations

California Partners in Flight seeks to develop avian population targets that will guide conservation efforts and provide land managers with a gauge of success for their restoration and management activities. Although ambiguous and based on assumptions difficult to test, numerical population targets provide a compelling means of communicating with the public and policy makers. Furthermore they provide: 1) monitoring objectives and an evaluation procedure of project's success ("accountability"); 2) ranking criteria for project proposals that allow reviewers to determine which sites or projects will be more advantageous for a particular species or suite of species; 3) current data for scientifically sound biological objectives; and 4) integration and comparison with population objectives of larger regional, national, and international schemes (e.g., Rosenberg and Blancher, 2005). In some cases, targets may simply require maintenance of populations at existing levels. However, targets for rare or declining species will encourage actions that increase existing populations to sustainable levels.

Bioregionally-based population targets for many of the desert bird focal species have been developed using currently available data (Tables 6-1). These targets are simply the highest densities (either indirectly through point counts, or directly through spot mapping) found for that species within a given bioregion. The targets presented indicate suggested breeding bird densities in terms of the number of birds per a 10 hectare area. These data are currently lacking for many species in many bioregions. More data likely exist for some of these species, and contributions of data to California Partners in Flight is encouraged for incorporation into future versions of this living document.

Two types of target population densities are presented based on two field methods used to measure bird density. The first method is the point count census method, in which all adult birds detected within a 100 meter radius around a fixed point are recorded. The second is spot map data, in which each breeding territory is mapped within a defined study area (see Ralph et al. 1993 for explanation of these two nationally standardized monitoring methods). These two types of data are not necessarily comparable to one another, nor convertible. Such reference density estimates are useful as population density targets that can translate into habitat acreage protection for some species, or be considered in restoration goals.

Burrowing Owl, a desert focal species *Photo by Colin Woolley*

Table 6-1. Suggested Population Targets (birds per 10 hectares) by Species and Bioregion[1].

Species	Sonora Desert			Mojave Desert
	Lower Colorado		Arizona Upland	
	Point Count	Spot Map	*No data*	*No data*
Burrowing Owl	-	-	-	-
Costa's Hummingbird	2.7	4.1	-	-
Gila Woodpecker	0.4	-	-	0
Ladder-backed Woodpecker	0.5	1.5	-	-
Ash-throated Flycatcher	2.1	4.6	-	-
Common Raven	0.1	0.5	-	-
Verdin	2.8	7.7	-	-
Black-tailed Gnatcatcher	1.9	6.6	-	-
Bendire's Thrasher	0.1	-	-	-
Crissal Thrasher	0.4	2.0	-	-
Le Conte's Thrasher	0.1	0.6	-	-
Lucy's Warbler	3.0	8.7	-	-
Black-throated Sparrow	2.9	1.1	-	-
Scott's Oriole	-	-	-	-

[1]Suggested population targets were developed from PRBO Conservation Science unpublished data. Target densities derived from point count data represent the highest density measured among 20 individual study sites, whereas target densities derived from spot map data represent the density measured at one site, the Chemahuevi Wash. Reference populations such as these may not be representative of healthy populations. More research is needed, particularly for the Mojave and Arizona Upland deserts. Point count data provide an *index* of abundance, generally thought to be conservative. Spot mapping numbers are probably closer to true abundance. Dashes represent "no data." Zeroes indicate the species probably never bred in that bioregion.

Species-Specific Objectives

The birds of California's desert habitats are threatened in a variety of ways, though habitat loss due to human encroachment is a common theme for all species. The rapid growth of human population in the Sonoran and Mojave deserts and the associated large-scale changes in land use, invasion of exotic species, and changes in disturbance regimes threaten all native bird species. Large-scale conversion due to urbanization, ranching, agriculture, and pumping of ground water continues to rapidly reduce available habitat. Cowbirds, ranching, and the encroachment of exotic plants are particular threats for certain species.

Although California Partners in Flight strongly endorses the concept of multiple-species management, it recognizes that the needs of select focal and secondary species, representative of the different aspects of California's Mojave and Sonora Desert habitats, may need to be specifically addressed. It also recognizes that managing for the specific requirements of some species is likely to affect, in either positive or negative ways, other species in the community. The challenge is that conservation actions must attempt to benefit multiple species while simultaneously tailoring their management activities for birds with very specific requirements. Furthermore, conservation planners must bear in mind that population dynamics are influenced by many factors other than breeding habitats (e.g., overwintering survival, juvenile recruitment into the breeding population) and may result in population declines even as efforts increase available quality habitat.

In preparation for this conservation plan, California Partners in Flight developed a series of species accounts on a suite of desert-associated bird species in California. Species were chosen because they represented niches and particular habitat needs, with the rationale that they represented other species with similar requirements. These detailed accounts described historical and current ranges, life history traits, habitat needs, and management concerns for each species. Information in the species-specific recommendations is derived from these accounts unless otherwise cited. The accounts will be available as electronic appendices to this plan at http://www.prbo.org/calpif/htmldocs/desert.htm. Below are recommendations for five of the focal species.

These recommendations need to be implemented, monitored, and altered as necessary. As this plan is a "living document," so should be these recommendations. With future research, management decisions can be made that best benefit both the birds and humans using desert habitats.

Black-tailed Gnatcatcher (*Polioptila melanura*)

Population:
The Black-tailed Gnatcatcher is a resident species restricted to arid and semiarid zones of the Lower Sonoran Life Zone in the southwestern United States and central Mexico (Figure 5-8). P.m. lucida occurs throughout the Sonoran, Colorado, and Mojave deserts (Farquhar 2002). The northernmost breeding area is in the Panamint Mountains (Wauer 1964). In California, the main range extends south from extreme southern Inyo County (along the Amargosa R.) through eastern San Bernardino, Riverside, and Imperial counties to the Mexican border, and west through the Colorado and Mojave

Photo by Ian Tait

Deserts to as far west as Barstow and Morongo Valley San Bernardino County, San Gorgonio Pass Riverside County, and Anza Borrego State Park (Small 1994). Southwestern Riverside County constitutes an area of sympatry with the California Gnatcatchers (Weaver 1998). Range extends through western and central Arizona, southwestern New Mexico (Farquhar 2002).

Breeding bird survey data show Black-tailed Gnatcatcher populations to be stable or declining slightly throughout much of its range. In areas where gnatcatcher habitat has been lost to agricultural or urban use, populations have experienced significant declines or even extirpation.

Habitat needs:
The Black-tailed Gnatcatcher prefers nesting and foraging in densely lined arroyos and washes dominated by creosote bush and salt bush. Black-tailed Gnatcatchers are very sensitive to human disturbances, such as urbanization, irrigated agriculture, or intensive off-highway vehicle use.

Concerns:
Destruction of the mesquite brushland in the Coachella, Imperial and Colorado River valleys is the main factor causing the decline of the Black-tailed Gnatcatcher in California. Off-road vehicle use in desert washes may also contribute to population declines.

Black-tailed Gnatcatchers are highly sensitive to habitat fragmentation, and housing developments dominated by exotic vegetation will not support this species. The invasion of salt cedar along ephemeral drainages reduces habitat quality for gnatcatchers.

Research and Monitoring:
Continued monitoring of Black-tailed Gnatcatcher populations is clearly necessary. The primary objective should be to locate, monitor and protect the remaining key breeding locations for Black-tailed Gnatcatcher in the Mojave Desert, the Coachella, Imperial and Colorado River valleys.

Action:
Continue and expand the study of bird populations in xeric riparian woodlands along the lower Colorado River.

Coordinate and maintain data sharing among appropriate agencies and organizations including the Bureau of Land Management, National Park Service, PRBO Conservation Science, and Department of Defense.

Mesquite bosque, riparian areas and washes must be left vegetatively intact and undisturbed by excluding off-road vehicle use and limiting feral burro populations.

Protect dense catclaw acacia-smoke tree washes in the Colorado and Mojave deserts.

Protect mesquite brushlands in the Coachilla, Imperial, and Colorado River valleys.

In areas where urban or agricultural development is imminent, working with developers to retain native Sonoran vegetation patches of greater than 1-ha, especially along washes and arroyos, is critical. These patches must be interspersed throughout the urban or agricultural matrix at a distance of less than 0.5 kilometers.

Black-throated Sparrow (*Amphispiza bilineata*)

Population:

Photo by Laura Hughes

This small migratory sparrow is found in desert areas in California east of Cascades and Sierra Nevada Mountains and through San Joaquin Valley east to Owens Valley and Mojave Desert, north through Santa Barbara County, south through San Diego County; throughout Baja California and adjacent Islands in the Gulf of California (Banks 1963, Grinnell and Miller 1944, Small 1994, Garrett and Dunn 1981, Unitt 1984, George 1987, Howell and Webb 1995; Figure 5-14). Black-throated Sparrows are also found throughout year in southeast and central California and Baja California, Sonora (Mexico) west to Gulf of California where winter range overlaps with breeding range, casual along coast (Garrett and Dunn 1981, Weathers 1983, Small 1994).

Breeding Bird Survey (BBS) data suggest highest average numbers in Nevada, Arizona, California and Utah where major deserts overlap (Chihuahuan, Great Basin, Sonoran, and Mojave). Highest average densities are in Chihuahuan Desert (x = 43.2 per route, *n* = 34, 1966 – 1998),); followed by Great Basin Desert (x = 40.6 per route, *n* = 27, 1966 – 1998), ; Mojave Desert (x = 39.2 per route, *n* = 27, 1966 – 1998), ; and average lowest densities are in Sonoran Desert (x = 16.4, *n* = 19, 1966 – 1998; BBS) .

Habitat Needs:

Throughout its range generally prefers semi-open habitat with evenly spaced shrubs and trees 1-3 m high. Common in desert alluvial fans, canyons, washes, flats, badlands and desert scrub type ranging from creosote bush (*Larrea tridentata*), ocotillo (*Fouquieria splendens*), cholla (*Opuntia spp.*), mesquite (*Prosopis spp.*), catclaw (*Acacia greggii*), blackbrush (*Coleogyne ramosissima*), sagebrush (*Artemisia spp.*), antelope brush (*Purshia tridentata*) and rabbitbrush (*Chrysothamnus spp.*), interspersed with taller plants such as Joshua trees (*Yucca brevifolia*), pinyon-juniper, and canotia (*Canotia holacantha*). Habitat and vegetation density may influence habitat selection more than specific shrub species, however, Black-throated Sparrows are closely associated with creosote bush throughout southern part of its range**.** Black-throated Sparrows prefer semi-open areas of evenly spaced 1-3m high shrubs or trees (Hastings 1965). At higher elevations (1219-2133 m) can be found in pinyon/juniper forests. (Bent 1968). Their winter habitat is structurally similar to their breeding habitat; these include desert washes in creosote bush, mesquite, cactus shrub, sagebrush, arid grasslands and pinyon/juniper woodlands (Weathers 1983, Unitt 1984).

Landscape fragmentation and connectivity:

Black-throated Sparrows appear to be particularly susceptible to urban development and habitat fragmentation. Preservation of unfragmented suitable habitat and maintaining connectivity between habitat patches is therefore essential for maintaining local populations. Numbers of breeding Black-throated Sparrows and Brown Towhees were found to be greatly reduced in urbanized environments, regardless of the use of native vegetation (Mills et al.1989). Also, where Brown-headed Cowbird feeding habitat has been created in agricultural and urban areas, and in other situations where cowbird numbers are high they greatly affect reproductive success of Black-throated Sparrows (Johnson and van Riper in press).

Fire management:
Long term fire suppression throughout the southwest alters plant succession, allowing shrub communities to become thicker and taller, reducing habitat for Black-throated Sparrows which prefer semi-open areas of evenly spaced 1-3m high shrubs or trees (Hastings 1965). Due to fuel build up, fire suppression enables high intensity wildfires to destroy large tracts of desert shrub habitat. Increased intensity of fires in the Great Basin adversely affects native grass and shrubs, which are often replaced by exotic, fire tolerant cheatgrass (Cooperrider and Wilcox 1995). Cheatgrass (*Bromus tectorum*) retards or prevents recovery of native plants by capturing water and fueling recurring fires. It has spread virtually throughout the entire Great Basin and is prevalent in other areas of the southwest (Hasting 1965, Cooperrider and Wilcox 1995).

Monitoring and research needs:
Most studies involving Black-throated Sparrows are community wide, multi-species studies, with little detail focused on *A. bilineata*. Population and breeding studies that focus specifically on *A. bilineata* would provide needed additional information on survivorship, longevity and causes of death.

Presently, one of the fastest growing human populations in North America exists in the desert southwest. Specific habitat requirements of Black-throated Sparrows are needed on both breeding and wintering grounds in order to aid wildlife managers to preserve and protect this unique desert species and the fragile habitat it inhabits.

Gila Woodpecker (Melanerpes uropygialis)

Population:
Though Gila Woodpeckers are not difficult to find in sprawling cities like Phoenix and Tucson, this species faces significant declines across its range and an increased and persistent threat of habitat loss to fire and urbanization into the foreseeable future. The Gila Woodpecker was added to the California State Endangered List in 1988. Using Breeding Bird Survey data, the Patuxent Wildlife Research Center reports a significant negative population trend of -2.2% (P= 0.04) for Gila Woodpeckers in Arizona from 1980-2007, which is the time period for which most surveys have occurred (Sauer at al. 2008). In addition, Rosenberg et al. (1991) and Hunter (1984) have recorded near extirpation of this species from southeastern California, and Laymon and Halterman (1986) estimated that less than 30 pairs survive in California altogether. Population trends for this species in Mexico is totally unknown, though conversion of Sonoran Desert scrub to exotic buffelgrass has been much more dramatic than in the United States (Búrquez-Montijo et al. 2002). It is reasonable to suggest that Gila Woodpecker population declines in Mexico may be even more significant than in the United States.

Generally permanent resident where found. In the United States, from extreme southwestern New Mexico (Hidalgo and Grant Counties), through southern Arizona north to the Mogollon Rim west to extreme southeast California (Figure 5-3). Edwards and Schnell (2000) report Gila Woodpeckers in Clark County, Nevada, but Floyd et al. (2007) did not find evidence of Gila Woodpeckers breeding in the state. Nevada and California populations generally constrained to the last riparian remnants of the Colorado River, though small numbers - perhaps up to 100 pairs (G. McCaskie, pers. comm..) - may be still found in the Imperial Valley (Alcorn 1988, Hunter 1986). Researchers recently discovered a small population in *Cercidium – Olneya* woodland near the Palo Verde Mountains, raising the possibility that more Gila Woodpeckers may be found in large, old-growth xeric riparian woodlands in Imperial County (McCreedy *in prep.*).

Habitat needs:
Require environments with large boles for nesting substrate, either columnar cacti or large trees, including riparian woodlands, old-growth xeric-riparian wash woodlands, uplands with concentrations of large columnar cacti, dry subtropical forests, and urban residential areas (Edwards and Schnell 2000). It is questionable why Gila Woodpeckers have not succeeded in colonizing urban residential areas of southern California west of the species' traditional breeding range. It is also questionable why Gila Woodpeckers have not managed to occupy other large wash woodlands in California outside of Imperial County.

Exotic Species Invasion / Encroachment:
Large-scale conversion of cottonwood-willow riparian forest to monotypic salt-cedar (*Tamrix* sp.) stands due to altered hydrology and fire regimes has robbed Gila Woodpeckers of much of the remaining desert riparian habitat left in the Sonoran Desert. Though Gila Woodpeckers will occasionally nest in large Athel Tamarisk, the more common salt-cedar stands that dominate the Lower Colorado River and Gila River are not viable Gila Woodpecker nesting habitat (Rosenberg et al. 1991). Large-scale cottonwood-plantation and *Tamarix*-removal projects are underway in the Lower Colorado River Valley and may add Gila Woodpecker habitat in the future.

Widespread invasion of Sonoran Desertscrub by exotic grasses has resulted in increased fire frequency and large-scale eradication of saguaro cactus stands across southern Arizona and Sonora.

Research and Monitoring:
Demographic data virtually nonexistent for this species, including productivity, productivity in rural versus urban environments (which would consider Starling presence/absence), survivorship, reliance of urban populations on immigration from rural populations, individual response to catastrophic fire events (nest success, emigration, carrying capacity of habitats adjacent burns, etc.).

An unknown number of Gila Woodpeckers may breed in xeric riparian habitats in Imperial County, CA: only Milpitas Wash has been surveyed. The remainder of the largest wash systems in Imperial County should be censused, and it would be instructive to learn what happens to young produced at these sites/why more xeric riparian habitats in southeastern California are not colonized.

Virtually no demographic information exists for Mexico. Distribution in should be addressed throughout Sonora in the face of increasing development, competition for water resources, and conversion of Desertscrub habitats to exotic grass-dominated habitats.

Le Cont's Thrasher (*Toxostoma lecontei*)

Population:
Le Conte's Thrasher [*sensu stricto* Zink (1997)] is non-migratory and occurs in two disjunct geographic areas: (1) the Sonoran and Mojave deserts (Figure 5-11) and (2) the west side of the San Joaquin Valley. All populations in the San Joaquin Valley and in regions around urban centers in the Mojave and Sonoran deserts have declined because of habitat loss. Sheppard (1996) reports that 26 percent of historical localities no longer had suitable Le Conte's Thrasher habitat within three kilometers.

Habitat needs:
Le Conte's Thrashers nest preferably in thorny shrubs or small desert trees. This species favor settings with higher fertility and above-ground biomass so that vegetation is thick and able to support and hide a substantial nest. Shrubs in the Chenopodiaceae plant family, especially in alkaline or saline soils, are common settings for nests. Although Le Conte's Thrashers do not build nests in creosote (*Larrea tridentata*), they occur frequently in the widespread creosote – burrobush (*Ambrosia dumosa*)

plant association, where desert-thorns (*Lycium* spp.) have stout stems to support thrasher nests (Hill 1980). Joshua tree (*Yucca brevifolia*) woodlands with abundant shrubs are also widely used in the Mojave Desert. Dense mesquite thickets close to extensive shrub lands are also good sites, but more massive Sonoran Desert woodlands do not support Le Conte's Thrasher except at woodland-shrubland edges.

Research and monitoring:
Because Le Conte's Thrashers have large territories, they have low density and thus low likelihood to be recorded with conventional point counts. Detecting them is also made difficult because their ventriloqual vocalizations carry over long distances, vocalizations are crepuscular, and birds are secretive.

Long-term tracking of resident birds would provide the best demographic and range data for local populations. The cost and labor for remote sensing to track individual birds and the remoteness of sites for monitoring are deterrents to study.

Lucy's Warbler (*Vermivora luciae*)

Population:

A denizen of desert riparian mesquite thickets, the migratory Lucy's Warbler breeds from southeastern California, southern Nevada and Utah south to southern Arizona, northern Mexico, and extreme western Texas (DeGraaf and Rappole 1995; Figure 5-7). This species breeds in southeastern California mainly along the lower Colorado River, but locally north to Death Valley National Monument and west to Morongo and Borrego Valleys (Dunn and Garrett 1997). Lucy's Warbler may also breed in Chihuahua, Mexico, adjacent to the Rio Grande Valley of western Texas (Scott 1987). Lucy's Warbler population numbers may be diminishing throughout its breeding range because of riparian habitat loss and mesquite cutting throughout the southwestern United States. However, the population seems to be increasing and expanding to new locations in some areas. Some population fluctuations are unexplained and need further investigation (Johnson et al. 1997).

Habitat needs:
The cavity nesting Lucy's Warbler breeds mainly in thickets of mesquite (*Prosopis* spp.) bosques, mainly honey mesquite (*Prosopis glandulosa*) but also screwbean mesquite (*Prosopis pubescens*), and frequently along watercourses or near ponds that have willows (*Salix* spp.) and cottonwoods (*Populus* spp.). However, Lucy's Warblers tend to shun mature cottonwood-willow riparian associations (Dunn and Garrett 1997) but will occasionally nest in lowland cottonwood-willow riparian gallery forests (Johnson et al. 1997) and less often in mid-elevation sycamore-ash-live oak (*Platanus-Faxinus-Quercus*) associations (Johnson et al. 1997). This species ranges into sparser thorn-scrub of palo verde (*Cercidium* spp.), ironwood (*Olneya tesota*), and catsclaw acacia (*Acacia greggii*) where such habitat borders stands of mesquite (Dunn and Garrett 1997). Lucy's Warbler has also recently begun breeding in tamarisk (*Tamarix ramossisima*) forests in the Grand Canyon region of Arizona (Johnson et al. 1997).

Grinnell (1914) in (Bent 1953) referring to the Colorado Valley states: "On the California side, both at Riverside Mountain and above Blythe, Lucy's Warblers were numerous, and very closely confined

to the narrow belt of mesquite. The birds foraged out to a limited extent from the mesquite towards the river into arroweed (*Tessaria sericea*) and willows, and away from the river at the mouths of washes into the ironwoods and palo verdes. But the metropolis was always most emphatically the mesquites."

Management Issues:
Riparian ecosystems have been greatly reduced locally throughout much of the southwestern United States, extirpating many breeding populations of Lucy's Warbler. Degradation and loss of riparian mesquite habitat is generally detrimental to this species and has extirpated some local populations, although current habitat losses do not appear to present a threat to the species as a whole (Johnson et al. 1997). Based on a few sightings elsewhere in San Diego County, Lucy's Warbler could colonize additional stands of mesquite. However, the future of bosques in Borrego Valley where they now occur is endangered by the continued pumping of groundwater (Unitt 2004).

Unlike many cavity-nesting species, Lucy's Warblers will not use nest boxes (Johnson et al. 1997). Since Lucy's Warbler also breeds in cottonwood and willow, degradation and destruction of southwestern riparian habitats has had a heavy impact on this species. No direct management actions specifically targeting this warbler have been taken, but generalized riparian restoration efforts should eventually benefit this species. However, in a few instances, population increases have been noted in tamarisk thickets along the Colorado River in the Grand Canyon, Arizona (Johnson et al. 1997).

Research and Monitoring:
Aside from the review of Bent, a complete life history study has never been conducted for this species. Complete information is lacking on this species' breeding ecology (e.g., mate selection and copulation, nest building, incubation, and parental care) as well as information on demographics, causes of population fluctuations, and general life history and ecology. The following research needs are taken from Johnson et al. 1997.

1. Investigate general natural history and ecological traits such as song types and vocalization patterns, and breeding/nesting phenology.

2. Verify current life history assumptions including monogamy, only males sing, only females build nests, only females incubate.

3. Examine the possible breeding area in Chihuahua, Mexico

4. Determine basic migration information including whether they are nocturnal or diurnal migrants, whether they migrate singly or in flocks, the speed of migration.

5. Investigate wintering grounds needs, especially regarding the recently discovered (1990's) wintering in the Big Bend region of Texas.

6. Expand Christmas Bird Counts into western Mexico.

7. Establish standardized population monitoring.

8. Expand existing banding programs.

Chapter 7. Bioregional Conservation Objectives

California has a higher biodiversity of wildlife and plants than any comparable area in the northern temperate zone (Biosystems Analysis 1994). The state also has more endemic species, particularly plants and birds, than any other state except Hawaii. This great diversity provides significant challenges in conservation planning, particularly over a state as large and geographically diverse as California.

As with the other habitat plans, we have adopted the California Biodiversity Council's 10 bioregions as a guideline for dividing the geography of California into natural communities organized by biota, climate, topography and soils (RAC 1998). See Figure 6-1 for bioregion boundaries. These contrast slightly with the 11 discrete regions recognized by Sawyer and Keeler-Wolf (1995) and Biosystems Analysis (1994).

Unlike several of California Partners In Flight's Bird Conservation Plans, the Desert Plan extends well-beyond California's boundaries. However, the Desert Plan is defined by two of the California Biodiversity Council's 10 bioregions: the Mojave Desert and the Colorado Desert, which is also referred to as the Lower Colorado River section of the Sonoran Desert. The Desert Plan's coverage into other states and Mexico simply represents the extension of these bioregions outside California.

Setting conservation goals by bioregion helps facilitate planning site-specific projects in a broader context, and provides a similar framework to other conservation planning efforts. Setting and achieving conservation goals by bioregion will:

- Ensure that a suite of ecological communities representative of California's diversity will be conserved.
- Ensure that the broadest range of biodiversity and locally adapted races of species will be conserved.
- Facilitate action at the local level.

Portfolio Sites

For each bioregion, we list potential "Portfolio Sites," i.e., areas that are distinguished by their protected status and potential for managing desert habitat for birds. Many of these Portfolio Sites contain desert habitat located near other habitats of concern. Thus, there is considerable potential for management of such areas to achieve goals for many CalPIF habitat plans, particularly the Riparian Plan and the Coastal Scrub and Chaparral Plan. This list is not comprehensive and will be updated as the Plan is revised. We ask that individuals and groups working in these bioregions bring important sites and activities to our attention.

It is important to make a distinction between our use of the term "Portfolio Site" and its use by other organizations. Most notably, The Nature Conservancy of California has identified a list of sites that are prime candidates for conservation and are prioritized based on their biological richness and the immediacy of threats to them. Some of these sites are also considered as Portfolio Sites in this and other CalPIF Bird Conservation Plans, and more may be included in the future as they become protected and efforts to manage for desert birds are expanded.

Mojave Desert Bioregion

Much of the Mojave Desert bioregion falls within the jurisdiction of the following multiple-species habitat conservation plans, not all of which were released to the public:

West Mojave Plan
Clark County Multiple Species Habitat Conservation Plan
Ecoregion-based Conservation in the Mojave Desert (TNC)
Northern and Eastern Mojave Desert Management Plan (NEMO)
Sonoran Joint Venture Conservation Plan

These plans have been developed to resolve conflicts between development and conservation and have been driven occasionally by economic and aesthetic values, rather than by science (Scott and Sullivan 2000). The best way currently to incorporate conservation science into the plans may be through the development and improvement of plans for long-term management of multi-species reserves. Such management must help mitigate problems associated with less-than-optimal reserve design, for example problems caused by habitat fragmentation and edge effects.

Portfolio Sites of the Mojave Desert

The following list of sites briefly describes ecologically important desert habitat areas within the Mojave Desert Bioregion of southern California, Nevada, Utah, and Arizona. This list is by no means complete, but highlights some of the larger and more contiguous habitat areas that offer the greatest potential for management and conservation of desert habitat for birds. Sites with an active monitoring and/or management program for desert birds are noted, but many of these areas are not currently protected and managed for habitat and species preservation.

Inyo County

Death Valley National Park

While Death Valley is well known as the hottest and perhaps driest place in North America, Death Valley National Park also hosts over 1000 species of plants and 440 species of animals, many of which are endemic. Death Valley NP is the largest national park outside of Alaska (over 3.3.million acres) and extends from 282 feet below sea level to over 11,000 feet above sea level. Death Valley NP contains a wide variety of Mojave Desert habitat types and, in total, 307 bird species have been recorded within the park. Over 95% of Death Valley NP is protected as wilderness.

Amargosa Canyon Area of Critical Environmental Concern

One of the most important riparian areas of the Mojave Desert, the Amargosa Canyon ACEC also hosts several Desert Plan focal species that breed in screwbean and honey mesquite stands in drier sections of the riparian corridor. Ladder-backed Woodpecker, Costa's Hummingbird, Ash-throated Flycatcher, Common Raven, Verdin, Black-tailed Gnatcatcher, Crissal Thrasher, Phainopepla, and Lucy's Warbler all breed here.

San Bernardino County

Mojave National Preserve

Elevations range from 880 feet to nearly 8,000 feet above sea level, encapsulating Sonoran, Mojave, and Great Basin Desert habitats. This is the third largest National Park Service area outside Alaska. Its bird populations are not well documented, but the Mojave National Preserve may contain the largest Bendire's Thrasher population in California.

Riverside County

Joshua Tree National Park

Over 250 bird species have been recorded in Joshua Tree National Park, which is just over one million acres in area. Seventy-eight species breed within park boundaries, which straddles the Mojave and Sonoran Desert boundary and which contains habitats unique to each. Desert Plan focal species breeders include Ladder-backed Woodpecker, Costa's Hummingbird, Ash-throated Flycatcher, Common Raven, Verdin, Black-tailed Gnatcatcher, Verdin, LeConte's Thrasher, Bendire's Thrasher, Black-throated Sparrow, and Scott's Oriole.

Nye County

Ash Meadows National Wildlife Refuge

Over 23,000 acres of spring-fed wetlands and alkaline desert uplands in the Amargosa River Valley. Due to a network of springs releasing waters that precipitated over 10,000 years ago and rise in one of the hottest and driest locations in North America, Ash Meadows has high concentrations of endemic plants and animals. Two hundred and twenty bird species have been found in Ash Meadows NWR, with 57 breeding species. Breeding Desert Plan focal species include: Burrowing Owl, Costa's Hummingbird, Ash-throated Flycatcher, Common Raven, Verdin, Crissal Thrasher, Le Conte's Thrasher, Phainopepla, Lucy's Warbler, and Black-throated Sparrow.

Clark County

Desert National Wildlife Refuge

One-and-a-half million acres, the largest NWR in the lower 48 states. The Desert NWR contains six mountain ranges and spans in elevation from 2,500 feet above sea level to nearly 10,000 feet above sea level. Three hundred seventeen species have been documented at the Desert NWR, and 114 species have been found to nest here. Breeding Desert Plan focal species include: Ladder-backed Woodpecker, Ash-throated Flycatcher,Common Raven, Verdin, Black-tailed Gnatcatcher, Bendire's Thrasher, Crissal Thrasher, LeConte's Thrasher, Phainopepla, Lucy's Warbler, Black-throated Sparrow, and Scott's Oriole. Of the Desert NWR's 1.5 million acres, 1.4 million acres have been proposed as wilderness and have been managed as such since 1974.

Red Rock Canyon National Conservation Area

Nearly 200,000 acres, Red Rock NCA is administered by the Bureau of Land Management and was created in 1990. Adjacent to one of the fastest-growing metropolitan areas in the United States (Las Vegas), it attracts one million visitors annually.

Clark and Mohave Counties

Lake Mead National Recreation Area

Over 1.5 million acres, Lake Mead National Recreation Area has been administered by the National Park Service for over 70 years. Nine of the 18 Clark County wildernesses created by the 2002 Clark County Conservation of Public Land and Natural Resources Act are within LMNRA (there are no wilderness areas in the Arizona portion of LMNRA). Over 240 different bird species have been recorded at LMNRA.

Washington County

Zion National Park

Zion National Park contains the extreme northeastern edge of the Mojave Desert. It's wide variety of elevations and habitats are home to 291 bird species. Desert Plan Focal Species include Costa's Hummingbird, Ladder-backed Woodpecker, Ash-throated Flycatcher, Common Raven, Verdin, Crissal Thrasher, Phainopepla, Lucy's Warbler, Black-throated Sparrow, and Scott's Oriole.

Sonoran Desert (Lower Colorado section) Bioregion

Much of the Sonoran Desert (Lower Colorado section) bioregion falls within the jurisdiction of the following multiple-species habitat conservation plans, not all of which were released to the public:

- Northern and Eastern Colorado Desert Coordinated Management Plan (U.S. Bureau of Land Management 1998)
- An Ecological Analysis of Conservation Priorities in the Sonoran Desert Ecoregion (TNC, IMADES, Sonoran Institute)
- Arizona Partners in Flight Bird Conservation Plan (AZGFD)
- Sonoran Joint Venture Conservation Plan

These plans have been developed to resolve conflicts between development and conservation and have been driven occasionally by economic and aesthetic values, rather than by science (Scott and Sullivan 2000). The best way currently to incorporate conservation science into the plans may be through the development and improvement of plans for long-term management of multi-species reserves. Such management must be used to help mitigate problems associated with less-than-optimal reserve design, for example problems caused by habitat fragmentation and edge effects.

Portfolio Sites of the Sonoran Desert (Lower Colorado section)

The following list of sites briefly describes ecologically important desert habitat areas within the Sonoran Desert (Lower Colorado section) of southern California, Arizona, Sonora, and Baja California. This list is by no means complete, but highlights some of the larger and more contiguous habitat areas that offer the greatest potential for management and conservation of desert habitat for birds. Sites with an active monitoring and/or management program for desert birds are noted, but many of these areas are not currently protected and managed for habitat and species preservation.

Riverside County

Joshua Tree National Park

Over 250 bird species have been recorded in Joshua Tree National Park, which is just over one million acres in area. Seventy-eight species breed within park boundaries, which straddles the Mojave and Sonoran Desert boundary and which contains habitats unique to each. Desert Plan focal species breeders include Ladder-backed Woodpecker, Costa's Hummingbird, Ash-throated Flycatcher, Common Raven, Verdin, Black-tailed Gnatcatcher, Verdin, LeConte's Thrasher, Bendire's Thrasher, Black-throated Sparrow, and Scott's Oriole.

San Diego County

Anza-Borrego Desert State Park

California's largest state park, Anza-Borrego contains 12 wilderness areas. It preserves over 600,000 acres of land on the extreme western edge of the Sonoran Desert. As such, it represents the western edge of a number of ranges for Sonoran Desert bird species. Over 200 bird species and approximately 70 breeding species have been documented within Anza-Borrego. Desert Plan focal species include Costa's Hummingbird, Ladder-backed Woodpecker, Ash-throated Flycatcher, Common Raven, Verdin, Le Conte's Thrasher, Phainopepla, Black-throated Sparrow, and Scott's Oriole. Crissal Thrasher and Lucy's Warbler breed at an exceptionally isolated mesquite bosque at Borrego Springs, private land that is surrounded by the Park.

San Bernardino and Mohave Counties

Havasu National Wildlife Refuge

The Havasu National Wildlife Refuge was created in 1941. The refuge covers 44,371 acres on each side of the Colorado River, of which over 14,000 acres are managed as wilderness. The Havasu NWR is dominated by riparian and open water habitat, but it contains several small xeric riparian washes that support some of the densest breeding and migrant songbird populations of the region (McCreedy *in prep*). Two hundred ninety-nine bird species have been detected within the Havasu NWR, 83 of them breeders. Desert plan focal species include Burrowing Owl, Costa's Hummingbird, Gila Woodpecker, Ladder-backed Woodpecker, Ash-throated Flycatcher, Common Raven, Verdin, Black-tailed Gnatcatcher, Crissal Thrasher, Phainopepla, Lucy's Warbler, and Black-throated Sparrow.

Mohave and La Paz Counties

Bill Williams National Wildlife Refuge

The Bill Williams National Wildlife Refuge was established in 1941, and covers just over 6,000 acres of the Bill Williams River's final descent to the Colorado River. It contains one of the (perhaps the only) remaining cottonwood-willow gallery forests left in the Lower Colorado River Valley. While The Bill Williams NWR consists primarily of riparian habitat, it is likely an important source for several Desert Plan focal species, including Costa's Hummingbird, Gila Woodpecker, Ladder-backed Woodpecker, Ash-throated Flycatcher, Verdin, Crissal Thrasher, Phainopepla, and Lucy's Warbler. At least 290 species have been recorded here, including 80 breeders. Additional breeding Desert Plan species include Burrowing Owl, Common Raven, Black-tailed Gnatcatcher, and Black-throated Sparrow.

Riverside and La Paz Counties

Cibola National Wildlife Refuge

The Cibola National Wildlife Refuge was created in 1964 (16,600 acres), and largely consists of riparian habitat on the Colorado River, as well as large tracts of agricultural fields (2,000 acres) planted for forage. Two hundred eighty-eight bird species have been detected at the Cibola NWR, with 52 breeders. Desert Plan breeding species include Burrowing Owl, Costa's Hummingbird, Gila Woodpecker, Ladder-backed Woodpecker, Ash-throated Flycatcher, Verdin, Black-tailed Gnatcatcher, Crissal Thrasher, Phainopepla, and Lucy's Warbler.

Imperial and Yuma Counties

Imperial National Wildlife Refuge

The Imperial National Wildlife Refuge was also created in 1941, and stands at 25,768 acres on each side of the Colorado River. While the Imperial NWR is primarily a riparian corridor, it contains several small xeric riparian washes that host some of the highest breeding and migrant densities for that habitat type in the region (McCreedy 2007). Over 15,000 acres of the Imperial NWR are managed as wilderness. Two hundred seventy-five species have been detected here, with 76 breeding species. Desert Plan focal species that breed here include Costa's Hummingbird, Gila Woodpecker, Ladder-backed Woodpecker, Ash-throated Flycatcher, Verdin, Black-tailed Gnatcatcher, Crissal Thrasher, Phainopepla, and Lucy's Warbler.

La Paz and Yuma Counties

Kofa National Wildlife Refuge

Like the Desert NWR (above), and the Cabeza Prieta NWR (below), the Kofa NWR is a refuge whose emphasis is on the desert's (i.e. not water-based) resources. In the Kofa NWR's case, its establishment in 1939 was to help protect bighorn sheep. However, the Kofa NWR covers 665,400 acres of primarily pristine Sonoran Desert, and 82% of it is managed as wilderness. Draining the New Water Mountains in the northeast corner of the refuge, the Alamo Wash held the highest densities for a number of Desert Plan focal species in a study of 10 xeric riparian sites in western Arizona (McCreedy 2007). Species with highest densities recorded at Alamo Wash include Costa's Hummingbird, Gila Woodpecker, Ladder-backed Woodpecker, Verdin, Black-tailed Gnatcatcher, Crissal Thrasher, and Black-throated Sparrow. Prior to a 26,000 acre catastrophic burn caused by weapons testing on the adjacent Yuma Proving Grounds in 2005, the King Valley wash complex likely held high densities of desert breeders as well. In total, 185 bird species have been reported at the Kofa NWR, and 25 species have been recorded as nesting here. Additional Desert Plan breeders include Ash-throated Flycatcher, Bendire's Thrasher, Lucy's Warbler, and Scott's Oriole.

Yuma and Pima Counties

Cabeza Prieta National Wildlife Refuge

Also created in 1939, the Cabeza Prieta NWR contains 860,000 acres, over 90% of which are managed as wilderness. It shares a 56-mile border with Mexico to the south, and is bordered by the Barry Goldwater Air Force Range to the north and Organ Pipe National Monument to the east, rendering it one of the most remote locations in the lower 48 continuous states. Two hundred

twelve bird species have been detected at Cabeza Prieta NWR, 42 of them breeding species. All Desert Plan focal species save Burrowing Owl have been found to breed here.

Pima County

Organ Pipe National Monument

Organ Pipe National Monument (established in 1937) contains the most intact Sonoran Desert ecosystems in the United States, and perhaps in Mexico as well. It is a United Nations Educational, Scientific, and Cultural Organization (UNESCO) biosphere reserve, and 95% of its 330,000 acres are managed as wilderness, comprising the third largest wilderness area in Arizona. The boundary between lower-elevation Lower Colorado section habitat and higher-elevation Arizona Upland section habitat runs north-south through the monument, and much more rainfall and columnar cacti occur in the eastern half of Organ Pipe. Two hundred seventy-eight bird species have been detected at Organ Pipe NM, 63 of them breeding species. All Desert Plan focal species have been found to breed here, save Burrowing Owl.

Sonora

El Pinacate y Gran Desierto de Altar Reserva de la Biosfera

Managed by the Mexican Ministry of the Environment and Natural Resources (SEMARNAT) and the State of Sonora (IMADES). El Pinacate hosts over 200 bird species, as well as several endemic animals and plants. The Nature Conservancy has identified cattle grazing, cinder mining, and unchecked off-highway vehicle use as important dangers to ecosystem integrity at the reserve. TNC's Parks in Peril program has worked with IMADES to install a park staff, control mining activity, and work with local ejidos to preserve the reserve's resources.

Harris's Hawk *Photo by Colin Woolley*

Chapter 8. Conservation Action Recommendations

This chapter provides specific recommendations for desert habitat activities throughout the state. They consider habitat protection and restoration, land management, research and monitoring, and policy action. Conservation organizations, agencies, scientific researchers and the public provided the information used in developing this chapter and most recommendations were derived from the most recent scientific data and analyses available. Unless otherwise referenced, most information from this section is derived from the focal species accounts (see http://www.prbo.org/calpif/). Some, however, rely upon well-informed assumptions that require more scientific investigation. Standardized monitoring and adaptive management will test and develop these assumptions, continually improving our knowledge of conservation and restoration science.

These recommendations seek to reverse the current declines of many desert-associated bird populations. By restoring healthy, stable populations, we will avoid the expensive and intrusive last resort of listing more species as threatened and endangered. We hope that these recommendations will galvanize and guide conservation organizations, project funding, and the actions of land managers and owners across the state. All of the following objectives and recommendations seek to fulfill CalPIF's central mission, which is to promote conservation and restoration of desert habitat sufficient to support the long-term viability and recovery of native bird populations.

Habitat Protection Recommendations

OBJECTIVE 1

Prioritize desert sites for protection and restoration.

Recommendations

1.1. Prioritize potential desert protection sites according to current indicators of avian population health.

Conservation efforts should use the most recent information regarding the quality of existing habitat and wildlife populations to prioritize the acquisition and protection of sites. Reproductive success, in particular, is an important demographic parameter that provides a foundation around which to build desert conservation programs. Standardized data collection during a single breeding season (generally February 1 through July 1, though summer monsoons can extend breeding in eastern portions of the Sonoran Desert) provides only cursory assessment of habitat quality. Multiple years of data collection provides more insight into proximal determinants of habitat quality, and due to high annual climatic variation in desert environments, are necessary to properly gauge avian responses to habitat quality.

1.2. Prioritize restoration sites according to their proximity to existing high-quality sites.

Restoration sites near existing high-quality sites and population sources have a higher probability of being re-colonized by extirpated species. In addition, restoration of sites near high-quality sites provides buffers and offsets fragmentation of source population habitat.

1.3. Prioritize sites according to surrounding land use.

Landscape scale land use patterns may significantly affect the sustainability of desert bird populations over the long term (The Nature Conservancy 2001, Germaine et al. 1998). Surrounding land uses

influence the population sizes of Brown-headed Cowbirds and predators such as domestic cats, jays, skunks, raccoons, ravens, and crows. More research is needed regarding habitat buffers and their influence on predation and parasitism rates. It is known that Brown-headed Cowbirds may commute more than 18 kilometers between foraging grounds and the nest sites of their hosts (McCreedy et al. 2006). For more information, refer to Recommendation 6-3.

OBJECTIVE 2

Promote desert ecosystem health (i.e., a self-sustaining, functioning system).

Recommendations

2.1. Ensure that the patch size, configuration, and connectivity of restored desert habitats adequately supports the desired populations of desert dependent species.

The size and connectivity of desert habitat patches may be limiting to bird species' occupancy and population size. A habitat patch is a contiguous area of similar vegetation, usually defined by the dominant vegetation (e.g., Joshua Tree). Patch sizes must not fall below the minimum necessary to support populations based on:

- Territory size requirements.
- Community dynamics.
- Sensitivity of some species to fragmentation and edge effects (increased predation/parasitism rates).

When determining the minimum acceptable patch size for a site, managers should consider the mean territory size of their target species as a guideline. When considering a suite of species, managers should use the species with largest territory needs (e.g., Gila Woodpeckers, or *Toxostoma* thrashers) to set the minimum patch size requirement, and they should design corridors to connect habitat fragments according to the needs of the species with the highest sensitivity to fragmentation (Bolger et al. 2001).

Restoration Recommendations

OBJECTIVE 3

Increase the value of ongoing restoration projects for bird species.

Recommendations

3.1. Restore and manage desert habitats to promote structural diversity and volume of the understory. Desert breeding birds often do not have arborescent vegetation available for nest site selection, and they traditionally place nests less than 2.5m above the ground (Corman and Wise-Gervais 2005, McCreedy et al. 2006). Even when arborescent vegetation, such as palo verdes or ironwood are available, many nests are placed in low, brushy sections of palo verdes or in secondary shrubs such as wolfberry (*Lycium* spp.), cacti, or desert lavender (*Hyptis emoryi*). Desert understories provide cover, shade, and foraging opportunities that complement overstory vegetation.

3.2 Actively protect site integrity through fencing, vertical mulching, gating, lining trails with rocks, etc. A great deal of desert restoration will be focused on eliminating illegal off-highway

vehicle trails, construction sites, and grazing activity. In general, the majority of off-highway vehicle users will not create new trails, but they will follow illegal trails and tracks. Once illegal trails are removed, restored habitat can be effectively protected by simply providing vegetative or rock obstruction to restored ground, which deters drivers from accessing the restored site.

3.3 Guide restoration activity through monitoring components that include habitat assessment. Due to a relative paucity of avian data from non-riparian desert habitat, restoration projects should be equipped with avian monitoring to assess the success of restoration. Any monitoring should thus include a habitat assessment component that evaluates what habitat attributes are responsible for highest avian abundance and productivity. Desert vegetation is slow-growing, and managers may lose several years of effort if restoration projects need to be re-done.

3.4 Develop silvicultural knowledge for desert tree species. Sonoran Desert breeders and migrants largely depend on arboreal species such as ironwood, palo verde, mesquite, and acacia (McCreedy *in prep*). However, compared to other North American tree species, a great deal less is known about the propagation of these species for restoration efforts. Agencies should develop nursery sources and silvicultural techniques to ensure successful propagation of these species to minimize costs and maximize benefit to restoration effort. Agencies can partner with urban xeriscaping technicians and landscape architects to take advantage of their significant silvicultural experience with similar arboreal species.

3.5 Actively remove exotic invasives from restoration sites, particularly exotic grasses that can increase fire frequency and ultimately result in catastrophic loss of ongoing restoration. Due to disturbed soils, restoration sites are susceptible to invasion by weedy invasive species such as brome, buffelgrass, and other exotic annuals. These annuals provide fuel for potentially catastrophic fires which would erase restoration progress and potentially burn nearby, high-quality habitat.

Cultivated Restoration Recommendations

Restoration and improved management are the best means by which to increase the amount and quality of desert habitat in the state, thereby increasing the reproductive success and population sizes of desert-associated birds.

OBJECTIVE 4

Design and implement cultivated restoration projects that mimic the diversity and structure of a natural desert plant community.

Recommendations

4.1. Increase our understanding of desert plant succession to increase restoration success.

4.2. Plant a minimum of two or more species of native shrubs or trees (i.e., avoid monotypic plantings).

Several vegetation features have broad positive effects on bird species diversity, abundance and nesting success (Table 8-1, 8-2). Many non-avian species also respond positively to these vegetation components in riparian habitats. Microhabitat characteristics can also influence nest-site selection by breeding birds. The availability of appropriate nest sites may have a direct effect on the ability of birds to reproduce and maintain a viable population (Martin 1993, Nur et al. 1996, Small et al. 1998).

Table 8-1. The following plant species and cover types have been found to positively influence breeding bird diversity or breeding species richness in desert habitats, by California bioregion.

	Mojave Desert	**Colorado Desert**
Canopy Layer	Joshua Tree, Honey Mesquite, Screwbean Mesquite	Blue Palo Verde, Ironwood, Saguaro, Organ Pipe Cactus
Shrub Layer	Quailbush, Mojave Yucca	Cholla Cactus Species, Jojoba, Snakebush, Quailbush, Saltbush

Table 8-2. The following plant species and cover types have been found to positively influence presence and abundance of the following Desert Plan focal species.

	Mojave Desert	**Colorado Desert**
Burrowing Owl		Irrigation canals
Costa's Hummingbird	Goodding's Willow	Chuparosa, Goodding's Willow, Palo Verde, Ironwood
Gila Woodpecker		Blue Palo Verde
Ladder-backed Woodpecker	Goodding's Willow, Yucca, Joshua Tree	Blue Palo Verde, Ironwood, Goodding's Willow
Ash-throated Flycatcher	Goodding's Willow, Fremont Cottonwood	Blue Palo Verde, Ironwood, Goodding's Willow, Fremont Cottonwood
Common Raven	Urban Development, Roadside Habitats	Urban Development, Roadside Habitats
Verdin	Honey Mesquite, Screwbean Mesquite, Desert Mistletoe	Honey Mesquite, Blue Palo Verde, Ironwood, Desert Mistletoe
Black-tailed Gnatcatcher	Big Saltbush, Smoketree	Wolfberry, Blue Palo Verde, Catclaw Acacia, Desert Mistletoe, Smoketree
Bendire's Thrasher	Joshua Tree	Blue Palo Verde
Crissal Thrasher	Big Saltbush, Screwbean Mesquite, Honey Mesquite, Goodding's Willow	Blue Palo Verde, Honey Mesquite, Screwbean Mesquite, Ironwood
LeConte's Thrasher	Saltbush	Saltbush
Phainopepla	Desert Mistletoe, Honey Mesquite, Catclaw Acacia	Desert Mistletoe, Honey Mesquite, Catclaw Acacia, Blue Palo Verde, Wolfberry
Lucy's Warbler	Tamarisk, Fremont Cottonwood, Goodding's Willow	Ironwood, Blue Palo Verde, Fremont Cottonwood, Goodding's Willow
Black-throated Sparrow	Saltbush	Jojoba, Cholla Cactus
Scott's Oriole	Joshua Tree, Mojave Yucca	

4.3. Plant native trees and shrubs that are highly correlated to avian abundance and diversity.

McCreedy et al. (2006) reported that Ironwood, and in particular, Blue Palo Verde are widely used by nesting desert birds for foraging opportunities, song perches, and nesting substrates. At desert wash sites in the Lower Colorado River Valley, Blue Palo Verde habitats typically held greater species richness and breeding abundances than Foothills Palo Verde habitats, due to greater use of Blue Palo Verde by cavity nesting species, and due to greater mistletoe parasitism of Blue Palo Verde trees over Foothills Palo Verde. On the Milpitas Wash (Imperial County, CA), 100% of detected Gila Woodpecker nests have been found in Blue Palo Verdes, despite the presence of Ironwood trees in equitable number and girth (McCreedy et al. 2006).

4.4. Increase shrub richness, shrub density, and the rate of natural reestablishment by including plantings of understory species in restoration design.

Understory vegetation is critical as nesting substrate for many desert bird species, especially in newly restored habitats (Germain et al. 1998, Emlen 1974). Avian density may increase in a habitat with increased foliage density because of a higher number of potential nest sites (Martin 1988). The greater the number of potential nest sites within a given habitat patch, the greater the effort required for predators to locate prey (nest sites). Thus, nests may possess a higher probability of fledging young.

4.5. Plant native forb and sedge species.

Increasing presence of exotic annuals such as Red Brome, Medditerranean grasses, and Sahara Mustard place pressure on native annuals competing for limited water resources. In addition, exotic annuals quickly exploit disturbed soils, gaining additional advantage over native annuals.

4.6. Plant vegetation in a mosaic design modeled after the spatial design of an existing healthy site with similar abiotic characteristics.

Plantings that are concentrated into clumps will create more productive patches of habitat for nesting birds than plantings uniformly spaced over a large area.

4.7. Connect patches of existing desert habitat.
The connection of habitat patches is an important restoration consideration. Relatively sedentary species, such as (LeConte's and Crissal Thrashers), may be affected most by patch isolation. These birds may disperse more widely and effectively if existing source populations were well connected with unoccupied habitats.

Management Recommendations

Effective management of desert areas is as crucial as habitat restoration to the survival and recovery of desert birds. Proper management increases habitat value to wildlife, arrests species declines, and contributes to the recovery of declining bird populations. Landscape-scale patterns of land use are of critical importance, influencing whether desert bird populations remain stable over the long term.

OBJECTIVE 5

Implement and time land management activities to increase avian reproductive success and enhance populations.

Recommendations

5.1. Prevent and eradicate populations of African Buffelgrass, Red Brome, and Mediterranean grasses spreading throughout the Colorado and Mojave Desert.

Exotic grasses have been shown to alter desert fire regimes, resulting in conversion from native desert thornscrub habitats to annual grasslands. It will be crucial for our management agencies to prevent the spread of these grasses into undisturbed areas of the Colorado and Mojave Desert, to avoid the elimination of fire-sensitive habitats that our desert birds rely upon for survival. In addition, land management agencies must adopt mixes of control strategies (e.g. mechanical, and biochemical) to handle populations of exotic grasses already present in desert habitats.

5.2. Avoid the construction or use of facilities and pastures that attract and provide foraging habitat for Brown-headed Cowbirds.

Management should avoid aggregations of livestock and associated livestock facilities (e.g., corrals, pack stations, salting areas and feedlots) during the breeding season whenever possible. Livestock, livestock facilities and human habitation provide foraging areas for cowbirds (Mathews and Goguen 1997, Tewksbury et al. 1998), who feed in short stature vegetation within "commuting distance" of their laying areas. Desert bird species are poorly adapted to parasitism pressure and introduction of livestock into desert systems greatly increases the amount of desert habitats accessible to cowbirds.

5.3. Manage or influence management at the landscape level.

Landscape scale land use patterns significantly affect the population levels of Brown-headed Cowbirds and avian predators in an area. With increases in cowbird and predator populations, species often suffer poor reproductive success and, possibly, population declines. Eventually, local extirpation of the species may occur. Managers should discourage certain adjacent land uses that subsidize cowbirds and avian predators, including intensive grazing, golf courses, human habitation and recreation areas, and pack stations.

5.4. Limit restoration activities and disturbance events such as grazing, disking, raking, herbicide application, and high-water events to the non-breeding season. When such actions are absolutely necessary during the breeding season, time disturbance to minimize its impacts on nesting birds.

The nesting season is a critical period for the maintenance of bird populations (Martin 1993). Some management activities, such as ground preparation for planting or water impoundment, can have serious consequences for breeding songbirds by destroying nests and nesting habitat or causing nest abandonment. Managers often have a degree of flexibility, allowing them to schedule these activities outside the breeding season while still achieving their management objectives. In general, the breeding season in the Mojave and Sonoran Deserts may begin as early as January and continue through August, depending on region, habitat type and elevation (Table 8-3).

5.5. Coordinate with management and restoration projects targeted at non-avian taxa to maximize the benefits of conservation of desert habitats.

Restoration and management activities such as removal of tamarisk and exotic grasses, feral horse or burro removal, or replanting should be conducted with bird monitoring components to assess outcomes and impacts of the restoration or management on bird populations. Exotic species removal can displace some breeding bird populations (e.g. Lucy's Warblers and Crissal Thrashers) while promoting others. Incorporating bird monitoring programs in these efforts allows managers to gauge and advertise restoration and management successes.

Table 8-3. Dates of earliest egg, latest first egg, peak of egg initiation and timing of breeding season for desert-breeding bird species by study site and bioregion. Derived from nests monitored every four days, all nests for all species combined.

Bioregion and study site	Earliest first egg	Latest first egg	Peak of egg initiation	Breeding Season
Mojave Desert				
Amargosa Canyon	March 5	July 5	n/a	February 15 – July 30
Colorado Desert				
Chemehuevi Wash	February 3	May 23	April 8	January 15 – July 15

OBJECTIVE 6

Protect, enhance or recreate natural desert processes.

Recommendations

6.1. Control and eradicate non-native animal species.

Non-native animals can have a severely negative impact on birds (Table 8-4). Invasive bird species such as European Starlings and House Sparrows often out-compete native birds for nest sites and have been known to destroy active nests and even kill nesting adults. Introduced animals, such as domestic cats, kill millions of birds every year, while feral horses and burros can overgraze habitats crucial for breeding desert birds. To reduce the effects of non-native animals on native birds:

- Avoid establishing human habitat near riparian and dry wash zones.
- Do not feed or otherwise encourage populations of feral animals.
- Keep cats indoors.
- Do not put bird feeders in a yard where a cat might ambush feeding birds.
- Humanely control non-native species when necessary.

6.2 Limit fragmentation of pristine desert environments by controlling off-highway vehicle use through fencing, signing, and lining trails in problem areas with logs, boulders, or debris. One of the greatest threats to desert ecosystem function is the increasing pressure of off-highway vehicle (OHV) use, both legal and illegal, that is widely distributed across the Mojave and Sonoran Deserts. The number of miles of trails created by off-highway vehicles in the Mojave and Sonoran Deserts has increased exponentially in recent decades, causing erosion, spread of exotic plants, increased fire threat, destruction of vegetative cover, and disruption of cryptobiotic crusts which fix nitrogen and enrich soil. Off-highway vehicle users often use illegal trails due to a lack of signs or other obstructions to the use of legal trails. Agencies and non-profits can do much to prevent this fragmentation by actively signing, vertically mulching, and placing materials or debris along legal trails to steer users in the right direction. Furthermore, adequate support for existing California State Park and U.S. Forest Service OHV riding areas may help concentrate OHV's in areas designated for such uses.

Table 8-4. Non-native animal species and their effects in desert habitat.

Introduced Species	Scientific Name	Effects/Bird Species Affected [1]
European Starling	*Sturnus vulgaris*	Evicts cavity-nesting species such as Gila Woodpecker and Gilded Flicker from nest sites (Kerpez and Smith 1990).
Brown-headed Cowbird	*Molothrus ater*	A species native to North America but which would be unable to survive in desert habitats without human subsidization. Can cause nearly complete breeding failure in ill-adapted desert species such as Black-tailed Gnatcatcher and Black-throated Sparrow.
Feral Burro	*Equus asinus*	Severely overgraze slow-growing, xeric riparian canopy species such as palo verde and ironwood, resulting in zero regeneration and unhealthy population structure of xeric riparian woodland. As the majority of desert breeders are strongly associated with these woodland species, burros can negatively impact the entire desert bird community.
Feral Cat	*Felis catus*	Populations flourish in and around urban areas of warm desert climes. Severe negative impacts on several low-nesting desert bird species, and extermination of several lizard species as well.

1 Unless otherwise noted, sources for the information provided in this table came from the species accounts developed as the first step in producing this conservation guide. Visit http://www.prbo.org/calpif/ .

6.3 Improve zoning and draft local ordinances to preserve a clean urban/wild interface in desert habitats. Urban areas in the desert Southwest have some of the most lax zoning regulations in the country – when urban planning strategies exist at all. Edges of urban areas typically expand far beyond actual housing areas due to absence of fencing and/or regulations limiting off-highway vehicle use on public lands adjacent private lands.

6.4 Minimize or eliminate desert livestock grazing whenever possible. Livestock grazing in the Mojave and Sonoran Desert is detrimental for many reasons-- it causes erosion, soil compaction, destruction of cryptobiotic crusts, spread of exotic annuals, and elimination of vegetation. Mojave and Sonoran Desert environments cannot support high numbers of livestock and are easily overgrazed. Agencies have ended grazing leases across much of the Mojave and Sonoran Desert, but high grazing pressures still exist, particularly in areas of Arizona and Sonora.

Monitoring and Research Recommendations

OBJECTIVE 7

Provide data on pressing conservation issues affecting birds.

In order to successfully protect and expand native bird populations, managers must have the most recent data available on populations and their habitat needs. Standardized scientific monitoring of populations will provide decision-makers with these essential tools. Desert land managers in particular lack basic density and trend data for many desert species, including several Desert Plan focal species. Thus Partners in Flight has listed desert monitoring as one of the primary objectives for the Southwest Avifaunal Biome (Rich et al. 2004).

Recommendations

7.1. Consider reproductive success and survival rates when monitoring populations, assessing habitat value, and developing conservation plans.

The number of young produced in a bird population (reproductive success) critically influences a population's presence, health and sustainability in an area. Reproductive success is a primary demographic parameter that provides critical information for understanding patterns of population change. Hence, these data can be used to understand trends, focus conservation action and funds, and identify hypotheses for further evaluation. When fewer than 20% of nestlings survive to fledge young, nest success is considered poor and probably indicates a nonviable population. Nur et al. (2004) and Shaffer (2004) describe feasible analytical techniques for monitoring nest survival as a function of covariates such as environmental and/or temporal variables. These variables may be quantitative (e.g., vegetation measurements, nest height, date, nest age) or qualitative (e.g., habitat type, management practice). However, to adequately measure annual productivity, investigators should not stop at calculating nest success alone (Thompson et al. 2001, Anders and Marshall 2005); instead we should also strive to accurately 1) count re-nesting attempts after nest failure, 2) count number of young fledged per successful nest, 3) measure double brooding frequency by following color-marked birds throughout the breeding season.

Monitoring annual adult survival is important in the same way as discussed for reproductive success; population trends can thus be better understood from monitoring the interaction of these demographic parameters. Survival can only be confidently calculated for adults after at least four years of mark/recapture data (such as mist-netting) have been obtained (Nur et al. 1999). Research seeking to determine productivity for a breeding population should include at least four years of nest-searching and/or mist-netting.

7.2. Conduct intensive, long-term monitoring at selected sites. In order to analyze trends, long-term monitoring should continue for more than five years.

Long-term data are vital to deciphering the difference between a true population decline and a natural fluctuation in population size. The Breeding Bird Survey lacks trend data for ten of fifteen Desert Plan focal species in both Mojave and Sonoran Desert habitats (Sauer et al. 2007). Because conservation dollars are limited, the best possible data on population trends are needed so as not to squander scarce resources on a species that is not truly in decline. Long-term monitoring should be conducted at reference sites that embody the characteristics restoration efforts strive to recreate. Additionally, long-term monitoring at key experimental sites can test the assumptions that currently drive restoration and management practices. Intensive monitoring includes collecting data on primary demographic processes and associated habitat characteristics and seeks to identify causal connections between habitat variables and species viability. Biologists collect data on reproductive success, breeding densities, parasitism, survival, vegetation data, suitable habitat requirements, and general life-history information. Managers can employ these data to make well-informed, adaptable management plans.

In addition, due to great fluctuation in annual precipitation (on both regional and local levels) and differential response to precipitation between breeding species and migrant species (McCreedy *in prep*), it is critical to obtain several consecutive years of demographic data in the Mojave and Sonoran Deserts. Without multiple years of data, collected in the context of annual precipitation (winter and spring precipitation, in particular), by-site and by-treatment comparisons can be confounded by dramatic swings in population abundance, diversity, and productivity.

7.3. Develop a series of monitoring and research projects that:

1) Determine the habitat attributes that affect migratory stopover use.
2) Assess how migratory stopover habitat may affect species survival.
3) Define conservation priorities and recommendations for stopover habitat.

While vital as breeding grounds, desert wash corridors also provide essential stopover habitat for migrating birds. However, little information exists regarding which habitat factors attract and affect migrants. Events at migratory stopover areas may significantly affect certain populations and contribute to declines (Moore et al. 1995, Yong et al. 1998). Monitoring programs should attempt to cover a broad geographic scope and seek to collect data on a wide variety of variables, including avian diversity, abundance, stopover duration, fat deposition/physical condition, and vegetation characteristics.

7.4. Develop monitoring programs with replicates spread over a wide area:

Due to the ephemeral nature of desert breeding bird populations, patchy breeding distributions, and widely variable precipitation patterns, it is crucial to design desert monitoring programs that cover study areas large enough to assess annual geographic shifts in breeding populations that relate to patchy seasonal rainfall. Black-throated Sparrows, Bendire's Thrashers, Northern Mockingbirds, and Phainopeplas are all highly vagile species that will temporally inhabit or abandon study sites in response to favorable or harsh breeding conditions. Monitoring programs that are too small in geographic scope or duration may incorrectly assess desert population trends as site-based and not climate-based. Thus desert monitoring programs should not only be wide in geographic scope, but should be linked to other ongoing monitoring efforts to correctly read population shifts in vagile desert species.

7.5. Conduct selective monitoring at critical sites to determine the effects of cowbird parasitism on Black-tailed Gnatcatchers, Black-throated Sparrows, and Lucy's Warblers.

Brown-headed Cowbird parasitism has potentially devastating effects on the populations of these and many other species. Over a forty-year period (1966-2007) the BBS has found Black-throated Sparrow populations to be in significant decline (-3.0% annual decline, p=0.00), along with Black-tailed Gnatcatchers (-2.7% annual decline, p=0.11) and Lucy's Warblers (-0.5% annual decline, p=0.37). Habitat size, vegetation structure, and adjacent land use all influence the rates of cowbird parasitism. By studying the variables involved, conservationists can better formulate landscape-level management plans to enhance bird populations.

7.6. Conduct selective monitoring at key sites to determine the factors influencing nest success of the Bendire's Thrasher, Crissal Thrasher, LeConte's Thrasher, Gila Woodpecker, Burrowing Owl, Elf Owl, and Cactus Ferruginous Pygmy-Owl.

Relatively recent, local extirpation and declines of these and other western species from their historical breeding ranges appear to be caused by low productivity (Latta et al. 1999, Laudenslayer et al. 1992, Rosenberg et al. 1991). Local extirpation may signal the early stages of a process of severe population decline. By determining the factors associated with low reproductive success, research may identify which management and restoration actions will help reverse these population declines. Land managers, owners and regulatory agencies gain greater freedom in their decision-making if they conserve bird species before special-status listing becomes necessary. Monitoring the reproductive success of key species provides gauges that allow management changes before it is too late.

7.7. Encourage citizen-science monitoring efforts that increase coverage of desert habitats to better handle vagile desert bird species.

7.8. Employ radar to monitor migration.

Utilizing radar at select migration sites (e.g. Salton Sea, Lower Colorado River Valley) will provide information on migration timing, flyway locations, and critical stopover areas.

7.9. Institute fall migration monitoring at high elevations.

Little is known on fall migration patterns through Mojave and Sonoran Desert habitats, though it is known that significant numbers of Neotropical migrants depend on high-elevation meadow habitats in the Sierra Nevada. Autumn mist-netting and surveys at high elevation "sky island" habitats will shed light on the importance of desert montane habitats during fall migration, which may be particularly important in the survival of first-year migrant birds.

OBJECTIVE 8

Maximize the effectiveness of ongoing monitoring and management efforts.

Recommendations

8.1. Increase communication and coordination between land managers and specialists hired to implement specific projects or conduct monitoring.

Experts, such as those conducting endangered species or biodiversity inventories, should be consulted and included as part of project implementation teams. By doing so, managers can quickly and easily access a wealth of detailed information on local birds and their response to management activities.

8.2. Use standardized monitoring protocols.

By standardizing monitoring techniques, researchers ensure that results can be compared across space and time. It is especially imperative to standardize monitoring protocols in desert habitats to ensure proper coverage of vagile desert species. The USDA Forest Service has published guidelines for standardized monitoring techniques for monitoring birds (Ralph et al. 1993).

8.3. Maximize the cost effectiveness and value of existing specialized monitoring programs for listed species (e.g., those oriented toward Southwestern Willow Flycatchers, Least Bell's Vireos, Western Yellow-billed Cuckoos, Elf Owls, and Cactus Ferruginous Pygmy-Owls) by collecting standardized data on multiple species (such as point counts) in addition to any specialized protocols aimed at one species.

Many state and federally-sponsored surveys only monitor special-status species. By adding a standard protocol that provides information on multiple species while conducting special-status species surveys, researchers will rapidly expand their knowledge of California's birds. Such data could be shared and analyzed and results would be added to conservation plans and incorporated into management regimes. Even if resources are not immediately available for analysis, the information will provide a baseline or historical perspective on bird distribution and abundance.

8.4. Coordinate with monitoring and research projects targeted at non-avian taxa to maximize the benefits of the protection, management and restoration of desert habitats.

Significant effort is placed on monitoring populations of Desert Tortoises, and numerous opportunities exist in coordinating study sites and surveys with tortoise surveys and other desert taxa such as plants, bats, and

lizards. Due to logistical difficulties in assessing hard-to-reach and often remote desert surveys, integrating bird monitoring with monitoring of other taxa will save agencies and researchers significant funds due to costs of scale.

OBJECTIVE 9

Expand research and monitoring of selected special-status species to address pressing conservation issues.

Recommendations

9.1. Identify and implement research relevant to management of Gila Woodpeckers, Elf Owls, LeConte's, Crissal, and Bendire's Thrashers, and Lucy's Warblers, whose population trends are declining or are of unknown status in California.

9.2. Identify winter range, habitat, and possible over-wintering conservation issues for as many Neotropical migrants as possible, including Lucy's Warblers, Phainopeplas, Sage Sparrows, Brewer's Sparrows, Green-tailed Towhees, Sage Thrashers, and Bendire's Thrashers.

Wintering grounds play a significant role in the life cycles of Neotropical migratory birds. If a population is declining primarily due to low over-winter survival, no amount of effort to restore or protect breeding grounds will suffice to conserve the species. Additionally, recent research implies that declines in habitat quality on wintering or migratory stopover grounds may lead to lower productivity on breeding grounds (Marra 1998).

For many species, including Mojave and Sonoran Desert breeding species (e.g. Phainopepla and Lucy's Warblers), and several Great Basin Desert breeding species that utilize Sonoran Deserts in the winter, little information is available on over-wintering habitat requirements.

Policy Recommendations

Conservation efforts will make little headway without effective policy development. The future of habitat conservation in the West lies not only in the activity of scientists and restoration experts in the field, but also within the walls of statehouses and the pages of law. Policy makers need to examine and appropriately amend statutory and regulatory programs that endanger native habitats or that unnecessarily impede restoration actions. Whenever possible, policy should encourage governmental support of innovative local conservation and sustainable-growth projects.

To achieve conservation and management goals, diverse interests must effectively combine their skills and financial resources. Partners in Flight embodies this kind of cooperative effort. In these groups, scientists, governmental agencies, nonprofit organizations and private citizens share information and concerns and collaborate on solutions. The biological recommendations in this Conservation Plan are readily available to policy-makers, public land managers and private landowners. Furthermore, the findings described here will be relevant to the Partners in Flight North American Landbird Conservation Plan, enhancing conservation efforts throughout the country.

Funding from the National Fish and Wildlife Foundation, derived from the Neotropical Migratory Bird Conservation Initiative, and the USDA Forest Service Partners in Flight awards continue to catalyze conservation activity across the country. Government agencies participating in CalPIF intend to use this Conservation Plan to guide their desert conservation projects. These agencies include the California Wildlife

Conservation Board, the California Department of Fish and Game, the U.S. Fish & Wildlife Service, and the Bureau of Land Management.

The following recommendations seek to assist policy advocates and decision-makers as they shape the regulations and procedures that affect avian conservation in the West.

OBJECTIVE 10

Encourage regulatory and land management agencies to recognize that avian productivity is a prime criterion for determining protected status of specific habitats, mitigation requirements for environmental impacts, and preferred land management practices.

Recommendations

10.1. Land managers should consider avian population parameters, such as reproductive success, as important criteria when designating priority or special-status sites, such as Areas of Critical Environmental Concern (BLM), Research Natural Areas (BLM, USFS) and other publicly owned areas specially managed for biodiversity.

Until recently, few data regarding avian reproductive success at many important riparian sites have been available. Similar data for non-riparian desert sites are generally not available. Government land managers should consider reproductive success data when designating and managing areas in support of biodiversity, including state wildlife areas and ecological reserves. This information complements ongoing efforts by agencies to evaluate and restore riparian areas, such as efforts by the BLM, USFS, and NRCS to assess proper functioning condition of riparian areas on public lands throughout the West.

10.2. When developing management practices for natural areas, government agencies, such as the USFWS and CDFG, should consider environmental impacts on local bird populations. Such evaluations should also occur when developing plans for habitat mitigation, habitat conservation, multi-species conservation, and natural community conservation.

The California Department of Fish & Game estimates that more than 89 habitat conservation plans, natural community conservation plans, and resource management plans were ongoing in California in 1998. Of these, 33 addressed the needs of one or more bird species. Additionally, the U.S. Fish & Wildlife Service constantly makes decisions regarding mitigation requirements for private and federally sponsored projects that affect the habitats of threatened or endangered species. By incorporating the conservation, restoration, management and monitoring recommendations of this Conservation Plan into their regulatory plans, agencies can implement the most effective conservation actions.

10.3. Incorporate the costs of limited-term (two–five years) or long-term bird monitoring into management endowments prescribed for conservation projects, including mitigation banks, habitat conservation plans and natural community conservation reserves.

The size of management endowments for preserves in Southern California, for example, varies substantially with management needs and staffing levels. In 1998, they varied from $70,000 at Dos Palmas (covering coordination meetings and management support to the BLM) to $2.5-$3 million at the Coachella Preserve (providing for 1.5 to 2 staff positions, buildings, vehicles, management activities and monitoring). Most endowments for unstaffed preserves are less than $1 million (usually less than $500,000). Most endowments for staffed preserves are greater than $2 million, depending upon the level of management, staffing, and partnerships at the site. Endowments of up to $510 million are common for sites requiring several staff, building maintenance, and active management, and that lack partners with whom to share costs.

Incorporating the long-term cost of bird monitoring into the management endowments of large-scale reserves is an efficient way to ensure that monitoring occurs. In 2000, a monitoring program costing $35,000 per year could provide extensive data from point count routes, mist-netting and two nest monitoring plots (see Appendix C for more information regarding methods). Using progressive investment strategies and a 5% capitalization rate, an endowment of approximately $700,000 would support this level of monitoring. Under these assumptions, one can calculate the cost for endowing monitoring at a site. A good rule of thumb is to add $150,000 to an endowment for every additional $7,500.00/year cost added to the long-term management (i.e., take the additional annual cost, e.g., $7,500, and divide by 5%) (Teresa, pers. comm. 1998).

OBJECTIVE 11

Increase protection and management actions to benefit severely declining or locally extirpated bird species in California.

Recommendations

11.1 Promote awareness, restoration and recovery of desert riparian gallery forest and mesquite woodlands.

California State Endangered Bell's Vireos, Gila Woodpeckers and Elf Owls populations once common in riparian forest and mesquite woodland transitions of the Lower Colorado River Valley have declined precipitously during the twentieth century. It is likely that Elf Owls have become extirpated from California (Rosenberg et al. 1991). The loss of these habitats has also factored in the demise of the federally-endangered Southwestern Willow Flycatcher, and has encouraged declines in other Desert Plan focal species such as Phainopepla, Lucy's Warbler, and Crissal Thrasher. These productive habitats are prime locations for urban development, conversion to agriculture, and large-scale water impoundments. Due to severely altered hydrology, these sites have largely converted to non-native tamarisk that, while beneficial to some species, is inhospitable to several others. In some cases on the Colorado River, habitat alteration is so complete that the local public often does not know what has been lost. Without appreciation for these diminishing habitat types, policy makers will not have the political will to further conserve these habitats.

OBJECTIVE 12

Foster policy initiatives that unite various land-use interests and extol the value of desert habitats.

12.1 Develop political partnerships to diffuse land-use differences.

While difficult, political leaders must find a way to unite land-use interests in the desert. Off-highway vehicle use will continue to increase in desert habitats, and even low-level use may have insidious effects, significantly altering fragile desert ecosystems into critical situations. Expensive policy disputes and legal action has resulted in the battle to preserve endangered endemic species of the Algodones Dunes in Imperial County, CA in the face of heavy recreation use of dune habitats. Intensive efforts at developing political partnerships, through mechanisms such as the California State Parks Off-Highway Motor Vehicle Recreation Commission, can help keep declining desert species from becoming threatened or endangered, saving time and resources for all parties.

Chapter 9. Implementation of Conservation Plan Recommendations

The implementation of the Desert Bird Conservation Plan is in development. It will be used to engage with local, bioregional conservation efforts and to better define bioregional priorities for acquisition, restoration, and conservation-focused efforts. Ideally, the implementation process would eventually include a series of local workshops to:

- Familiarize local organizations with the Conservation Plan and the Implementation Plan.
- Identify local initiatives, projects, and organizations capable of working as local partners to achieve habitat, restoration, and population targets.
- Develop conservation and restoration acreage objectives based on inventory, assessment and biological need.

The North American Bird Conservation Initiative

In 1998, participants at a meeting of the International Association of Fish and Wildlife Agencies developed a vision to link all of the major bird conservation initiatives in Canada, the U.S. and Mexico (CEC 1998). The participants represented each of the four major bird conservation initiatives already underway on the continent: The North American Waterfowl Management Plan (the oldest and most successful of bird conservation initiatives), Partners in Flight, the U.S. Shorebird Conservation Plan, and the Colonial Waterbird Conservation Plan. This new overarching program, known as the North American Bird Conservation Initiative (NABCI), seeks to synthesize the efforts of all these groups by creating "regionally based, biologically driven, landscape-oriented partnerships delivering the full spectrum of bird conservation across the entirety of the North American continent, including simultaneous, on-the-ground delivery of conservation for both game and nongame birds." See www.nabci.org for more information.

State, provincial, federal and non-governmental representatives from Canada, Mexico, and the U.S. adopted an ecological framework that facilitates coordinated conservation planning, implementation, and evaluation among major bird initiatives. These Bird Conservation Regions (BCRs) were defined by adopting the hierarchical framework of nested ecological units delineated by the Commission for Environmental Cooperation (CEC). Existing joint ventures as formed under the North American Waterfowl Management Plan (NAWMP) are recognized as important vehicles for local and regional delivery of bird conservation goals. Joint venture focus areas do not always correspond with BCR boundaries, but joint ventures are coordinating with the BCRs encompassed within their boundaries. Many joint ventures in North America have moved beyond waterfowl-only conservation and embrace the concept of "all-bird" conservation.

California is encompassed within five BCRs: the Northwestern Pacific Rainforest region, the Sierra Nevada region, the Coastal California region (which includes the Central Valley), the Great Basin region, and the Sonoran and Mohave Deserts region (see http://www.nabci-us.org/map.html for BCR boundaries). The state currently hosts five Joint Ventures: the Central Valley Habitat Joint Venture, the San Francisco Bay Joint Venture, and the Riparian Habitat Joint Venture (all located entirely within the state), and the Intermountain West Joint Venture and the Pacific Coast Joint Venture (both located partially within the state). Future bird conservation in priority habitats of California will be achieved by encouraging adoption of the all-bird conservation concept within existing joint ventures of the North American Waterfowl Management Plan and/or by expansion of the Riparian Habitat Joint Venture to include other habitat types.

Photo by Eric Preston, ericnpreston.com

Joint Ventures, originally created to protect North America's waterfowl like this Ring-necked Duck, are now embracing the conservation of all birds.

The following is only a partial list of programs and agencies with which CalPIF intends to interface in implementing this plan:

Non-governmental Organizations:
California Native Grass Association
California Native Plant Society
California Cattleman's Association
PRBO Conservation Science
Wildlife Conservation Society
National Audubon Society
National Fish and Wildlife Foundation
The Nature Conservancy

University Organizations:
University of California Cooperative Extension
(UC-Berkeley, UC-Davis, UC-Riverside)

State of California Organizations:
California Department of Fish and Game
California Department of Forestry and Fire Protection
California Department of Parks and Recreation
Resource Conservation Districts
Wildlife Conservation Board

Federal Organizations:
USDA Forest Service
US Fish and Wildlife Service
Bureau of Land Management
Natural Resource Conservation Service
Bureau of Reclamation
US Geological Survey - Biological Resource Div.

Private Organizations:
Certified Rangeland Managers

Chapter 10. Outreach and Education

Outreach and education are critical components of any effort to conserve desert birds and habitats. This chapter targets scientists, managers, communicators, and others seeking ideas for communicating desert bird conservation needs and actions to a variety of audiences. We hope that scientists, managers, and outreach practitioners from conservation groups, government agencies, Joint Ventures, nature centers, Audubon chapters, and private lands programs will reference this plan, and especially the tables within this chapter. This information will help guide the development and delivery of outreach and education programs that reflect the needs outlined in the Desert Bird Conservation Plan. As new programs and products are developed, they will be made available through future versions of the Plan and online through the CPIF resource directory at www.prbo.org/cpif.

The five key conservation threats for desert birds, as identified in this plan, are habitat loss and degradation, off highway vehicle use, and livestock grazing. For the purposes of communication, we have broken the broad category of habitat loss and degradation into three categories: urbanization, habitat fragmentation, and exotic/invasive vegetation. Using these threats to guide our education and outreach programs will ensure our programs address the needs of desert birds. Many times outreach and education programs miss the opportunity to directly contribute to bird conservation efforts at various levels. Outreach and education programs can address these threats by changing people's attitudes, behavior, and perceptions and increasing knowledge about desert bird conservation issues. Information in this chapter will help you tailor existing or new bird education and outreach programs to support desert bird conservation needs. It will also help you create outreach and education programs and products that directly support regional conservation objectives, making your program part of a larger effort to protect birds and bird habitat.

Chapter Highlights:

- ***A series of tables summarizing the five key conservation threats for desert birds and corresponding key concepts and target audiences.***
- ***A list of general concepts every person should understand for desert bird conservation.***
- ***A resource table listing existing groups and resources that promote desert conservation.***
- ***Guidelines for creating effective, targeted outreach and education messages for target audiences.***

Conservation Threat and Key Concept Tables

The following five tables present a summary of the primary threats to desert bird and desert ecosystem conservation. They key concepts provide the background needed to understand the core issues for desert birds. Further detail is contained in Chapter four.

Conservation Threat: Habitat fragmentation through suburban development, habitat conversion, catastrophic fire, or other means.
Key Concepts
In order to survive, birds require different sizes of territories that need to be intact and free from fragmentation.
Habitat fragmentation can lead to increased predation and nest parasitism.
Suburban/urban areas can provide important native habitat for migratory and resident birds.
Agriculture practices such as planting hedge rows and no-till agriculture can provide important habitat for migratory and resident birds.
Networks of green spaces within communities, towns, cities, etc. may help connect habitat patches.
Native plants require less water and are more tolerant of fire.
Native desert plants can be incorporated into landscaping for all new developments.
Altered fire cycles in desert scrub habitats from the introduction of non-native bufflegrass threaten habitat for Costa's Hummingbird.
Audiences to target:
Agencies
Agricultural producers
City planners
Farmers
Future Farmers of America, 4-H-type groups
Media

Conservation Threat: Off Highway Vehicle Use
Key Concepts
OHV use in the Sonoran Desert region is particularly destructive to **xeric riparian woodland habitat**.
Xeric riparian woodland accounts for only 5% of the area of the Lower Colorado River Valley section of the Sonoran Desert, yet it hosts 90% of its birds.
Xeric riparian habitats contain the highest breeding songbird diversity and abundance of any desert habitat except desert riparian. They are also critical stopover points during spring migration for songbirds to refuel.
OHV use may result in the abandonment and failure of songbird nests because vehicles deter birds from nesting.
OHV use degrades habitat through soil compaction, erosion, fragmentation by roads, spread of exotic vegetation, and direct disturbance to nesting birds.
OHV use conducted prior to March 1st has less of an effect on nesting desert birds because it is prior to the nesting season.
OHV use should be confined to designated areas only.
Closing certain areas to OHV use during the bird nesting season (March through mid-June) will help desert songbirds produce young, essential to maintaining healthy desert bird populations.
Audiences to target:
Agencies
Conservation Organizations
Legislatures
Media
OHV groups
Sonoran Joint Venture Partners

Conservation Threat: Urbanization
Key Concepts
Urban vegetation is tree and lawn dominated while natural desert vegetation is dominated by shrubs and forbs.
Desert birds nest largely in low growing shrubby vegetation, not trees and mowed areas.
Urbanization replaces desert scrubland communities, reducing foraging and nesting habitat for birds.
Urbanization results in increased predation to birds nesting in or near urban areas (e.g., cats, rats, raccoons, etc.)
Urbanization results in increased disturbance from human activities such as vegetation clearing, mowing, pets, roads, etc.
Gila Woodpeckers are threatened by habitat loss from development.
Gambel's Quail, Greater Roadrunner, and Black-throated Sparrows nest on the ground and are especially vulnerable to urban predation and human disturbance.
In areas where urban or agricultural development is imminent, working with developers to retain native Sonoran vegetation patches of greater than 1-ha, especially along washes and arroyos, is critical. These patches must be interspersed throughout the urban or agricultural matrix at a distance of less than 0.5 kilometers.
Audiences to target:
Developers
Land use planners
Landscaping companies and groups
Neighborhood associations
Urban residents

Conservation Threat: Domestic and Feral Livestock Grazing
Key Concepts
Grazing by feral burros significantly reduces palo verde and other understory vegetation in desert washes and decreases nesting habitat for desert birds.
Unsustainable cattle grazing practices have a wide range of negative impacts on desert ecosystems, including increased erosion, decreased water retention/infiltration, increase in exotic species, woody shrub encroachment, changes in fire regimes, and soil impaction.
Audiences to target:
Agencies
Future Farmers of America, 4-H- groups
Legislators
Media
Private Landowners: Farmers /Ranchers

Conservation Threat: Exotic Vegetation
Key Concepts
Exotic vegetation compromises the value of desert habitat for birds.
Disturbed soils without intact soil crusts are vulnerable to exotic plants.
Altered hydrological regimes facilitate the establishment of salt cedar and other invasive riparian species.
Invasive plants have been introduced as a byproduct of agriculture and recreation.
Invasive grasses, such as red brome and buffelgrass, increase fire by filling open spaces in desert scrub habitat and providing a vector for the spread of fire.
Desert birds cannot survive as well in an introduced plant community because it does not provide the same nutrition, host sites for insects, or nest sites.
Introduced plants spread quickly, reducing the diversity of vegetation and wildlife that inhabit the area.
Native desert ecosystems can be restored on public and private lands and there are existing programs, incentives, and resources available.
Native plants require less water and are more tolerant to fire than exotic plants.
Audiences to target:
Agencies
Conservation Organizations
Landscaping companies and groups
Land use planners
Private landowners
Recreation groups
School groups

These additional key concepts apply to desert bird conservation regardless of a particular threat.

Key Concepts for Desert Bird Conservation
Programs that communicate these general concepts about desert bird ecology will help to improve the knowledge and perception of a variety of audiences.
Desert birds and their habitats are unique, fascinating and inspiring to people.
Desert birds indicate a healthy desert ecosystem that provides ecosystem services such as water storage, water filtration, erosion control, and refugia during droughts.
Avoid conducting vegetation clearing activities during February - August, the bird nesting season of desert birds.
Eliminate outdoor sources of food (open compost piles, pet food, etc.) that might attract nest predators. Keep cats indoors. Pursue neighborhood ordinances calling for cats as indoor pets. Never feed feral cats.
People can give birds the food and shelter they need to survive by landscaping with native plants. Use native desert plants in landscaping for new developments. Native desert plants are drought tolerant and low maintenance.
Rare and threatened birds that live in natural desert habitat include the Burrowing Owl, Gila Woodpecker, Bendire's, Crissal, and LeConte's Thrasher, and Lucy's Warbler. See http://www.prbo.org/calpif/htmldocs/desert.htm for species profiles on all of the desert focal species.
Desert birds depend largely on shrub and forb dominated vegetation (scrubland).

Key Concepts for Desert Bird Conservation
A healthy native desert plant community supports many common and rare birds.
Different bird species place their nests in different locations, from directly on the ground to the tops of trees.
The breeding season is a vital period in birds' lives. Birds nest during the spring and early summer of each year, from February-August in the desert.
Natural predator-prey relationships are balanced, but human disturbance creates an imbalanced system.
Natural processes, such as flood and fire, are integral to a healthy ecosystem. They provide the natural disturbance needed in an area to keep the vegetative diversity high, an important factor for birds.
Reproductive success may be the most important factor influencing bird population health. If birds cannot reproduce the population will not sustain itself.

Designing Education and Outreach Programs

Guidelines for creating effective, targeted outreach and education messages for target audiences, adapted from: *Jacobsen et al, 2006 Conservation Education and Outreach Techniques. Oxford University Press Inc. New York.*

Answering these questions will help you plan an outreach program or tool that is truly effective.

Planning-
1. What is the conservation problem or issue being addressed?
2. What is the goal and objectives of the program/product/website?
3. Who is your targeted audience(s)?
4. What are the backgrounds, needs, interests, and knowledge level of the intended audience?
5. For each audience, what are the desired actions, changes, knowledge gains, etc.?
6. What are the key messages for each audience?
7. What communication tool(s) will best serve your audiences?

Implementation- Pilot and Final product
1. What subset of your target audience will be your pilot group?
2. What modifications are indicated by the results of pilot tests of programs/products/websites?
3. Is scheduling, funding, and staffing adequate to complete the final product?

Evaluation
1. How will you know if you met your goal and completed desired actions?
   - Choose one or more evaluation tools: feedback forms, surveys, interviews, observations, etc.

Example Communication Tools

(modified from Jacobsen et al, 2006)

Below is a list of commonly used education and outreach tools with some tips for maximizing their use:

Communication Tool/Program	Notes
Sign, poster, billboard	Raise awareness of an issue. Keep message short.
Brochures/Fact Sheets	Raise awareness, convey a needed action. Keep simple, catchy titles, pictures, color. Write for 8th grade level.
Web Pages	A good place to post resources, more information, or copies of brochures/fact sheets.
Press Release	Include Who, What, Where, When, Why
Press Interview	Present an issue to a large audience, provide reporter with background information as well as short sound bites
Letters to the Editor/Opinion Piece	Read by many people, good for presenting controversial issues. Keep short.
Advertisement	Raise awareness of an issue, provide testimonials. Can reach a large number of people.
Presentation	Raise awareness of an issue; good for reaching an existing group of people, especially if they meet regularly. Can be delivered by others.
Newsletter Articles	Raise awareness of an issue; convey a specific message. Articles in partner or audience group newsletters can be an effective way to reach a target audience.
Field Program/Bird Walk	Get people interacting with nature; excellent for building appreciation for birds and their habitats.
School Program	Increase knowledge of students; can also be an indirect way to reach parents in a community.
Festival/Community Event	Gets people out doing things, especially good for families. Can involve other conservation partners.

Existing Resources for Desert Bird Conservation Education and Outreach

Conservation Issue	Existing Resources
Urbanization	• American Bird Conservancy Cat's Indoors campaign materials www.abcbirds.org
Off Highway Vehicle Use/Recreation	• Poster on effects of OHV use on bird populations www.prbo.org/desertbirds • Arizona Game and Fish website for wildlife friendly tips for OHV use: http://www.azgfd.gov/outdoor_recreation/ohv_habitat_areas.shtml
Exotic/Invasive Species	• Arizona-Sonora Desert Museum *INVADERS* program (http://www.desertmuseum.org/invaders/) • Arizona Native Plant Society (http://www.aznps.org/invasives.html) • USGS/UA Desert Laboratory Buffelgrass Eradication and Outreach (http://wwwpaztcn.wr.usgs.gov/buffelgrass/) • Arizona Invasive Species Advisory Council (http://azgovernor.gov/AIS/) • Arizona Native Plant Society (http://aznps.org/invasives.html) • Buffelgrass Action Center (http://www.buffelgrass.org/) • California Native Plant Society (http://www.cnpssd.org/) • Center for Invasive Plant Management (http://www.weedcenter.org/) • Grow Native (http://aznps.org/invasives/GrowNative/invasives.html) • National Park Service Weeds Gone Wild (http://www.nps.gov/plants/alien/factmain.htm) • Sonoran Desert Weedwackers (http://aznps.org/invasives/weedwackers.html) • The Invasive Species Initiative (http://tncweeds.ucdavis.edu/methods.html) • USDA Invasive Species Initiative (http://www.invasivespeciesinfo.gov/) • U.S. Fish and Wildlife Service Invasive Species (http://www.fws.gov/invasives/)

Conservation Issue	Existing Resources
Exotic/Invasive Species (continued)	• USFWS National Wildlife Refuge: Volunteers and Invasive Plants (http://www.fws.gov/invasives/volunteersTrainingModule/index.html) • Sonoran Institute and Environmental Education Exchange have a bilingual (Spanish/English) book about exotic and invasive plants suitable for landowners, agencies, ranchers, land use planners, and developers. • The Master Watershed Steward program educates and trains citizens across the state of Arizona to serve as volunteers in the protection, restoration, monitoring, and conservation of their water and watersheds. (http://cals.arizona.edu/watershedsteward/)
Domestic and Feral Livestock Grazing	• Arizona Ranchers' Management Guide (http://cals.arizona.edu/AREC/pubs/rmg/ranchers.html • An Introduction to Erosion Control, by Bill Zeedyk and Jan-Willem Jansens (http://quiviracoalition.org/images/pdfs/73-Erosion_Control_Field_Guide.pdf) • An Introduction to Induced Meandering, by Bill Zeedyk (http://quiviracoalition.org/images/pdfs/75-Induced_Meandering_Field_Guide.pdf) • Rangeland Health and Planned Grazing, by Kirk Gadzia and Nathan Sayre (http://quiviracoalition.org/images/pdfs/77-Planned_Grazing_Field_Guide.pdf) • The Quivira Coalition (http://quiviracoalition.org) • The New Ranch Network (http://newranch.net/) • New Ranch Network Small Grants program (http://newranch.net/NRN_Small_Grants/index.html)
Habitat fragmentation and connectivity	• Science and Collaboration for connected Wildlands http://www.scwildlands.org
Groups/Programs that promote Desert Conservation	Sonoran Joint Venture www.sonoranjv.org Anza-Borrego Natural History http://www.abdnha.org/02bookstore_main.html Tuscon Audubon Society http://www.tucsonaudubon.org/education/index.htm CREEC RIM area: http://creec.edgateway.net/cs/creec9ap/query/q/3 (region 9a and 10) Bureau of Land Management Nevada – Environmental Education (http://www.blm.gov/nv/st/en/fo/lvfo/blm_programs/blm_special_areas/red_rock_nca/environmental_education0.html)

Conservation Issue	Existing Resources
Private land Incentive Programs:	• The Farm Security and Rural Investment Act of 2002 (Farm Bill) is landmark legislation for conservation funding and for focusing on environmental issues. The conservation provisions help farmers and ranchers meet environmental challenges on their land. This legislation simplifies existing programs and creates new programs to address high priority environmental and production goals. The 2002 Farm Bill enhances the long-term quality of our environment and conservation of our natural resources. • The Conservation Reserve Program reduces soil erosion, protects the Nation's ability to produce food and fiber, reduces sedimentation in streams and lakes, improves water quality, establishes wildlife habitat, and enhances forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filterstrips, or riparian buffers.

Photo by Laura Hughes

Ash-throated Flycatcher, a desert focal species

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Appendix A. Acronyms and Abbreviations

BBS:	Breeding Bird Survey
BLM:	U.S. Bureau of Land Management
Conservation Plan:	The California Partners in Flight Riparian Bird Conservation Plan
CalPIF:	California Partners in Flight
CDFG:	California Department of Fish and Game
GIS:	Geographic Information Systems
km:	kilometers
m:	meters
NRCS:	Natural Resource Conservation Service
PIF:	Partners in Flight
PRBO:	Point Reyes Bird Observatory
USFS:	U.S. Forest Service
USFWS:	U.S. Fish and Wildlife Service
USGS:	U.S. Geological Service
WHR:	Wildlife Habitat Relationships

Appendix B. Scientific and Common Names

Plants

Common Name	***Latin Name***
Acacia	*Acacia* spp
African buffelgrass	*Pennisetum ciliare*
Alkali goldenbush	*Isocoma acradenia*
Alkali rubber rabbitbrush	*Ericameria nauseosa*
Alkali sacaton	*Sporobolus airoides*
Allscale	*Atriplex polycarpa*
Anderson wolfberry	*Lycium andersonii*
Arrowweed	*Pluchea sericea*
Barrel cactus	*Ferocactus* spp
Beavertail cactus	*Opuntia basilaris*
Big galleta	*Pleuraphis rigida*
Big saltbush	*Atriplex lentiformis*
Blackbrush	*Coleogyne ramosissima*
Black greasewood	*Sarcobatus vermiculatus*
Bladdersage	*Salazaria mexicana*
Blue palo verde	*Parkinsonia florida*
Buckthorn	*Frangula* spp.
Bud sagebrush	*Picrothamnus desertorum*
Burrobush	*Ambrosia dumosa*
California buckwheat	*Eriogonum fasciculatum*
California juniper	*Juniperus californica*
Catclaw acacia	*Acacia greggii*
Cheesebush	*Hymenoclea salsola*
Cooper's goldenbush	*Ericameria cooperi*
Cooper's wolfberry	*Lycium cooperi*

Common Name	***Latin Name***
Cottontop cactus	*Echinocactus polycephalus*
Creosote bush	*Larrea tridentata*
Crucillo	*Randia rhagocarpa*
Desert agave	*Agave deserti*
Desert broom	*Baccharis sarothroides*
Desert globemallow	*Sphaeralcea ambigua*
Desert-holly	*Atriplex hymenelytra*
Desert lavender	*Hyptis emoryi*
Desert needle-grass	*Achnatherum speciosum*
Desert senna	*Senna armata*
Desert-willow	*Chilopsis linearis*
Fishhook cactus	*Sclerocactus* spp.
Foothills palo verde	*Parkinonia microphyllua*
Fourwing saltbush	*Atriplex canescens*
Fremont dalea	*Psorothamnus fremontii*
Goldenbush	*Ericameria* spp
Grizzlybear pricklypear	*Opuntia erinacea*
Red brome	*Bromus rubens*
Hedgehog barrel cactus	*Echinocactus* spp.
Hedgehog cactus	*Echinocactus* spp.
Honey mesquite	*Prosopis glandulosa*
Iodine bush	*Allenrolfea occidentalis*
Ironwood	*Olneya tesota*
Jojoba	*Simmondsia chinensis*
Joshua trees	*Yucca brevifolia*
Kochia	*Kochia* spp.
Littleleaf krameria	*Krameria* spp.
Longspine horsebrush	*Tetradymia axillaris*
Mediterranean grasses	*Schismus* spp.
Mesquite	*Prosopis* spp
Mojave yucca	*Yucca schidigera*
Nevada ephedra	*Ephedra nevadensis*
Nolina	*Nolina* spp.
Nuttall's saltbush	*Atriplex nuttallii*
Ocotillo	*Fouquieria splendens*
Organ pipe cactus	*Stenocereus thurberi*
Palmer's coldenia	*Tiquilia palmeri*
Palo verde	*Parkinsonia* spp.
Parry's saltbush	*Atriplex parryi*
Pencil cholla	*Opuntia arbuscula*
Pickleweed	*Salicornia* spp.
Rabbitbrush	*Chrysothamnus* spp.
Rabbit-thorn	*Lycium pallidum*
Red-spined sclerocactus	*Sclerocactus polyancistrus*
Saguaro	*Carnegia gigantean*
Sahara mustard	*Brassica tournefortii*
Saltcedar	*Tamarix* spp.
Saltgrass	*Distichlis spicata*
Sand verbena	*Abronia* spp.
Screwbean mesquite	*Prosopis pubescens*

Common Name	***Latin Name***
Seablite	*Suaeda esteroa*
Shadscale	*Atriplex confertifolia*
Singleleaf pinyon	*Pinus minophylla*
Smoketree	*Psorothamnus spinosus*
Snakeweed	*Gutierrezia* spp.
Spanish bayonet	*Yucca harrimaniea*
Spinescale	*Atriplex spinifera*
Spiny hopsage	*Grayia spinosa*
Spiny menodora	*Menodora spinescens*
Squawthorn	*Lycium torreyi*
Staghorn cholla	*Opuntia acanthocarpa*
Teddy-bear cholla	*Opuntia bigelovii*
Thurber sandpaper-plant	*Petalonyx thurberi*
Torrey's saltbush	*Atriplex torreyi*
Utah juniper	*Juniperus osteosperma*
White brittlebush	*Encelia farinosa*
White bursage	*Ambrosia dumosa*
Wiggins croton	*Croton wigginsii*
Winterfat	*Ceratoides arborescens*
Wire-lettuce	*Stephanomeria*
Birds	
American Crow	*Corvus brachyrhynchos*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Bendire's Thrasher	*Toxostoma bendirei*
Bewick's Wren	*Thryomanes bewickii*
Black-tailed Gnatcatcher	*Polioptila melanura*
Black-throated Gray Warbler	*Dendroica nigrescens*
Black-throated Sparrow	*Amphispiza bilineata*
Brewer's Sparrow	*Spizella breweri*
Bronzed Cowbird	*Molothrus aeneus*
Brown-headed Cowbird	*Molothrus ater*
Burrowing Owl	*Athene cunicularia*
Cactus Wren	*Campylorhynchus brunneicapillus*
California Thrasher	*Toxostoma redivivum*
Common Raven	*Corvus corax*
Costa's Hummingbird	*Calypte costae*
Crissal Thrasher	*Toxostoma crissale*
Elf owl	*Micrathene whitneyi*
European Starling	*Sturnus vulgaris*
Ferruginous Pygmy-Owl	*Glaucidium brasilianum*
Gambel's Quail	*Callipepla gambelii*
Gila Woodpecker	*Melanerpes uropygialis*
Greater Roadrunner	*Geococcyx californianus*
Green-tailed Towhee	*Pipilo chlorurus*
Hooded Oriole	*Icterus cucullatus*
House Finch	*Carpodacus mexicanus*
House Sparrow	*Passer domesticus*
Ladder-backed Woodpecker	*Picoides scalaris*
LeConte's Thrasher	*Toxostoma lecontei*

Common Name	***Latin Name***
Loggerhead Shrike	*Lanius ludovicianus*
Long-eared Owl	*Asio otus*
Lucy's Warbler	*Vermivora luciae*
Mourning Dove	*Zenaida aurita*
Northern Flicker	*Colaptes auratus*
Northern Mockingbird	*Mimus polyglottos*
Phainopepla	*Phainopepla nitens*
Pyrrhuloxia	*Cardinalis sinuatus*
Rufous-crowned Sparrow	*Aimophila ruficeps*
Rufous-winged Sparrow	*Aimophila carpalis*
Sage Sparrow	*Amphispiza belli*
Sage Thrasher	*Oreoscoptes montanus*
Scott's Oriole	*Icterus parisorum*
Verdin	*Auriparus flaviceps*
Western Screech Owl	*Otus kennicottii*
White-winged Dove	*Zenaida asiatica*

Mammals

Fox, Gray	*Urocyon cinereoargenteus*
Fox, Red	*Vulpes vulpes*
Raccoon	*Procyon lotor*
Skunk, Striped	*Mephitis mephitis*
Wild burro	*Equus asinus*

Amphibians and Reptiles

Desert tortoise	*Gopherus agassizii*

Appendix C. How to Monitor Bird Populations

Adaptive management requires the periodical gathering of information to ascertain whether management actions are achieving desired results. The most comprehensive and rigorous way of collecting this information is through a strategic program of monitoring using standardized methods that can be compared between years and between regions. Restoration and land stewardship programs need to build in long-term monitoring programs to assess the effectiveness of their activities. Such data are necessary to determine the need for continued funding.

Research and Monitoring

If habitat restoration or management is undertaken to benefit wildlife species, wildlife monitoring becomes the ultimate measure of success. There are many reasons that bird monitoring should be adopted as a basic component of long term stewardship in preserves with significant shrubland habitats or significant bird populations:

•Birds are highly visible and monitoring is cost effective.

•Birds can show relatively quick response in abundance and diversity to restored habitats (35 years).

•As secondary consumers (i.e., insectivores), birds are sensitive indicators of environmental change.

•By managing for a diversity of birds, most other elements of biodiversity are conserved.

•Bird monitoring can prevent future listing of declining species by identifying problems and solutions early.

•The only way to measure special-status bird species response to management and restoration is by monitoring bird populations.

•Because of the increasing popularity of birdwatching, there is great potential for public participation in bird monitoring.

•Birds are tremendously important culturally and economically and their popularity can help raise awareness of land-stewardship needs.

Monitoring Strategically

Monitoring can be conducted at varying levels of intensity, depending on the objectives to be achieved and the resources available. The standardization of protocols is critical to comparing results across space and time. Many recent programs (Ralph et al. 1995, Martin et al. 1997, DeSante et al. 1999a) and publications (Ralph et al. 1993, Geupel and Warkentin 1995, DeSante et al. 1995, 1998, 1999b, Nur et al. 1999) have summarized methods, objectives, and how to use results. Latta et al. (2005) present strategies and "tiers" for conservation monitoring of birds.

Monitoring programs should always include an analysis plan and identification of issues or site-specific projects to be assessed. The primary purpose of site-specific monitoring is to assess the effects on wildlife of natural and anthropogenic stressors or disturbances in the environment. This knowledge is critical in determining the relative priority of identified conservation problems and in developing effective measures to address those problems. Monitoring is an integral component of the adaptive management feedback loop, allowing land managers, conservation groups, and land owners to assess the effectiveness of their habitat management and restoration programs.

Standardized monitoring across many sites at varying scales can be analyzed to highlight broad changes or trends in species presence, diversity, abundance and productivity. Ideally, a series of reference sites with long-term monitoring, using most if not all protocols below, will be developed for each California bioregion. Other sites will be monitored more opportunistically, depending on the objectives of the landowner.

The following is a list of common monitoring regimes from least to most intensive.

1) Rapid assessment of habitat or designation of Important Bird Areas based on general vegetation characteristics and presence/absence of indicator species.

Method: area search or point count as little as one census per site per year.

2) Determine breeding status, habitat association, restoration evaluation and/or evaluation of changes in management practices.

Method: area search or point count two or more times per year for 3 years. For restoration evaluation every other year, censusing should continue for at least 10 years.

3) Determination of population health or source/sink status.

Method: census combined with demographic monitoring for a minimum of 3 years (4 years preferable).

Long-term Monitoring

Long-term monitoring provides a wealth of useful information about bird populations. In addition to parameters that can be determined by both short- and long-term monitoring (such as annual productivity, abundance, and diversity), patterns of variation in reproductive success and trends in abundance and diversity may also be described. Long-term monitoring is also the only method to monitor natural and human-induced changes in bird populations and adaptively manage in a time of rapid environment changes.

The Palomarin Field Station of PRBO Conservation Science provides an excellent example of the utility of a long-term monitoring program. Biologists have conducted mist-netting at the site for more than twenty years. With the data collected, they have documented a population decline of Warbling Vireos and linked it to reproductive failure on the breeding grounds (Gardali 2000).

Standardized Methods Adopted by the Western Working Group and Monitoring Working Group of Partners in Flight

These are listed from least to most intensity of effort. All are described in detail in Handbook of Field Methods for Monitoring Landbirds (Ralph et al. 1993).

Area Search
The Area Search, adopted from the Australian Bird Count, is a habitat specific, time constraint census method to measure relative abundance and species composition. It may also provide breeding status. While still quantitative, this technique is ideal for volunteers as it mimics the method that a birder would use while searching for birds in a given area, allowing the observer to track down unfamiliar birds.

Point Count
The point count method is used to monitor population changes of breeding landbirds. With this method, it is possible to study the yearly changes of bird populations at fixed points, differences in species composition between habitats, and assess breeding status and abundance patterns of species. The objective of point count vegetation assessment is to relate the changes in bird composition and abundance to differences in vegetation.

Mist Netting
Mist netting provides insight into the health and demographics of the population of birds being studied. Mist nets provide valuable information on productivity, survivorship, and recruitment. With these data, managers will have information on the possible causes of landbird declines or their remedies. This method is currently being used nationwide in the Monitoring Avian Productivity and Survivorship (MAPS) program (DeSante 1992).

Territory Mapping
Also known as "spot mapping," based on the territorial behavior of birds, where locations of birds are marked on a detailed map during several visits (a minimum of eight) in the breeding season. By counting the number of territories in an area, this method estimates the density of birds. Distribution of territories, species richness, and diversity is also documented. This is an excellent method for assessing areas with limited habitat. Standard methods are described by Robbins (1970) and used by The Cornell Laboratory of Ornithology's resident bird counts.

Nest Monitoring
Also called nest searching, this technique measures nesting success in specific habitats and provides information on trends in recruitment; measurement of vegetation associated with nests may identify habitat influences on breeding productivity. Examination of nests also allows collection of life-history data (e.g., clutch size, number of broods, numbers of nesting attempts), which provide important insight into vulnerability of species to decimation or perturbations (Martin and Geupel 1993).

EXHIBIT 428

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

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Aug 9, 2002

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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.

Reduce Tortoise Density

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.

Direct Effects

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.

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EXHIBIT 429

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

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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.

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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

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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.

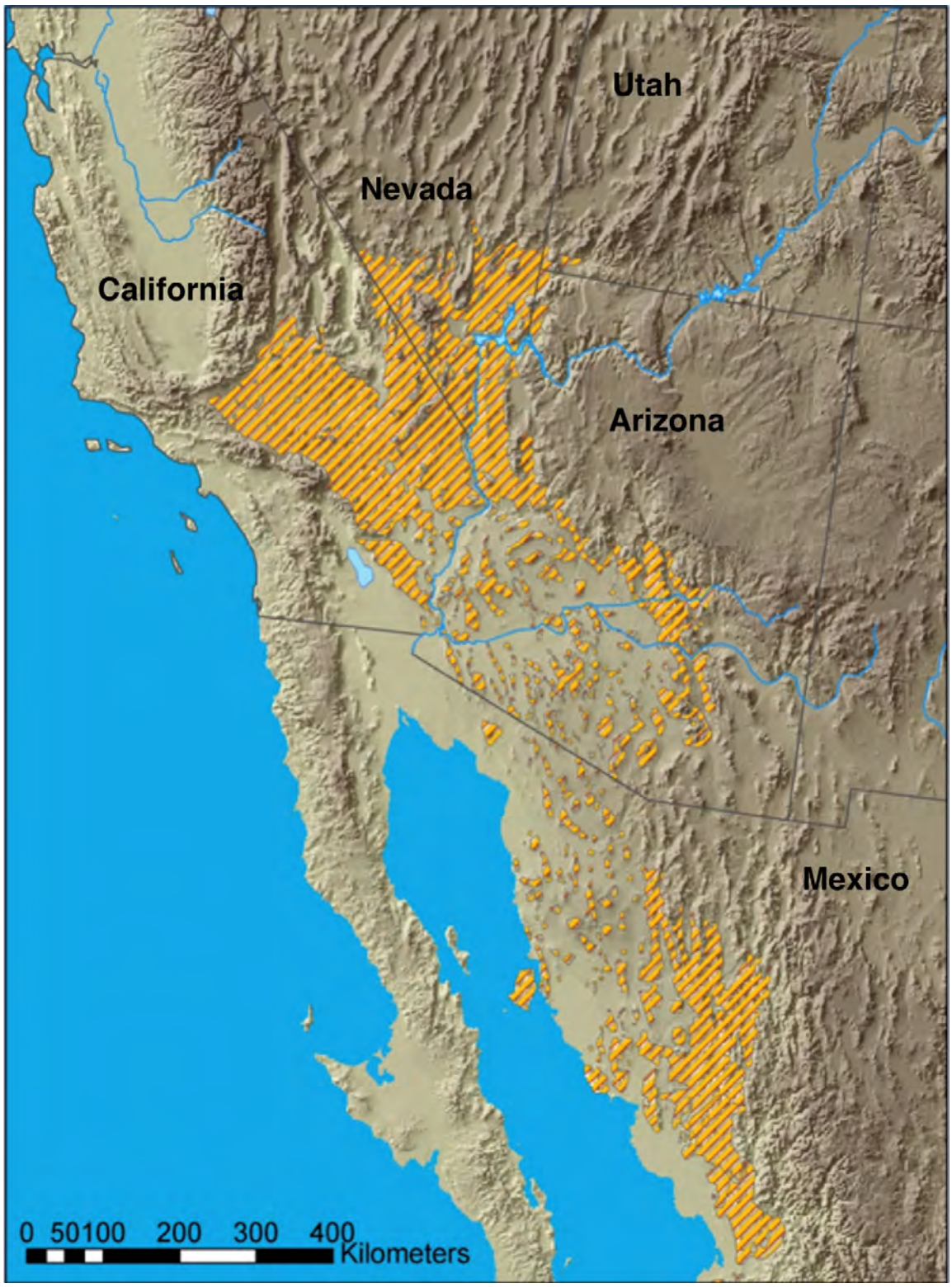

Figure 2. Map showing distribution of desert tortoise (*Gopherus agassizii*) in western North America (adapted from Germano and others, 1994).

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.

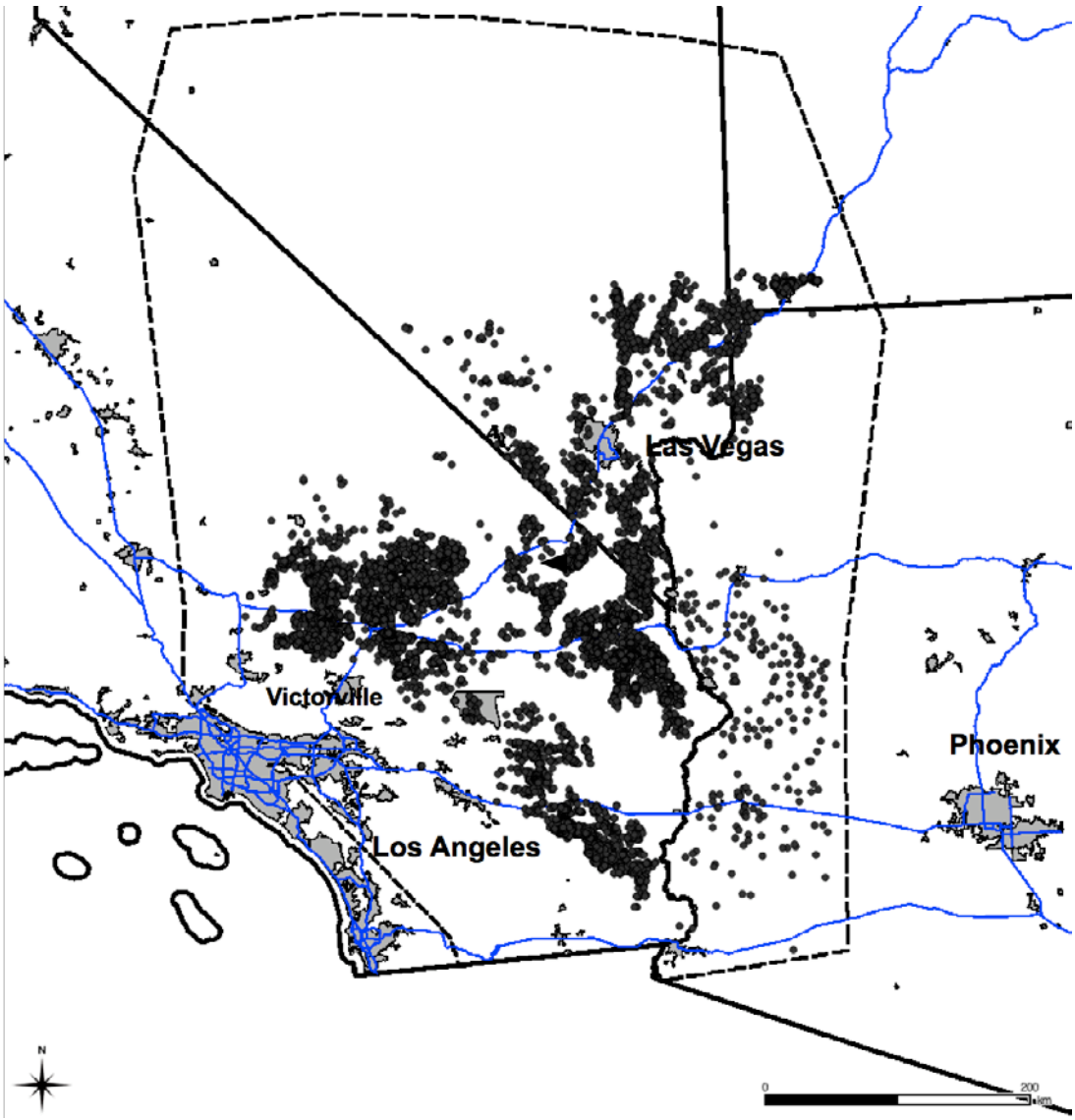

Figure 3. Distribution of desert tortoise (*Gopherus agassizii*) presence observations at sites in the Mojave Desert and parts of the Sonoran Desert of California, Nevada, Utah, and Arizona. *Solid circles* indicate records of one or more observations of live or dead tortoises. The dashed line indicates 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.

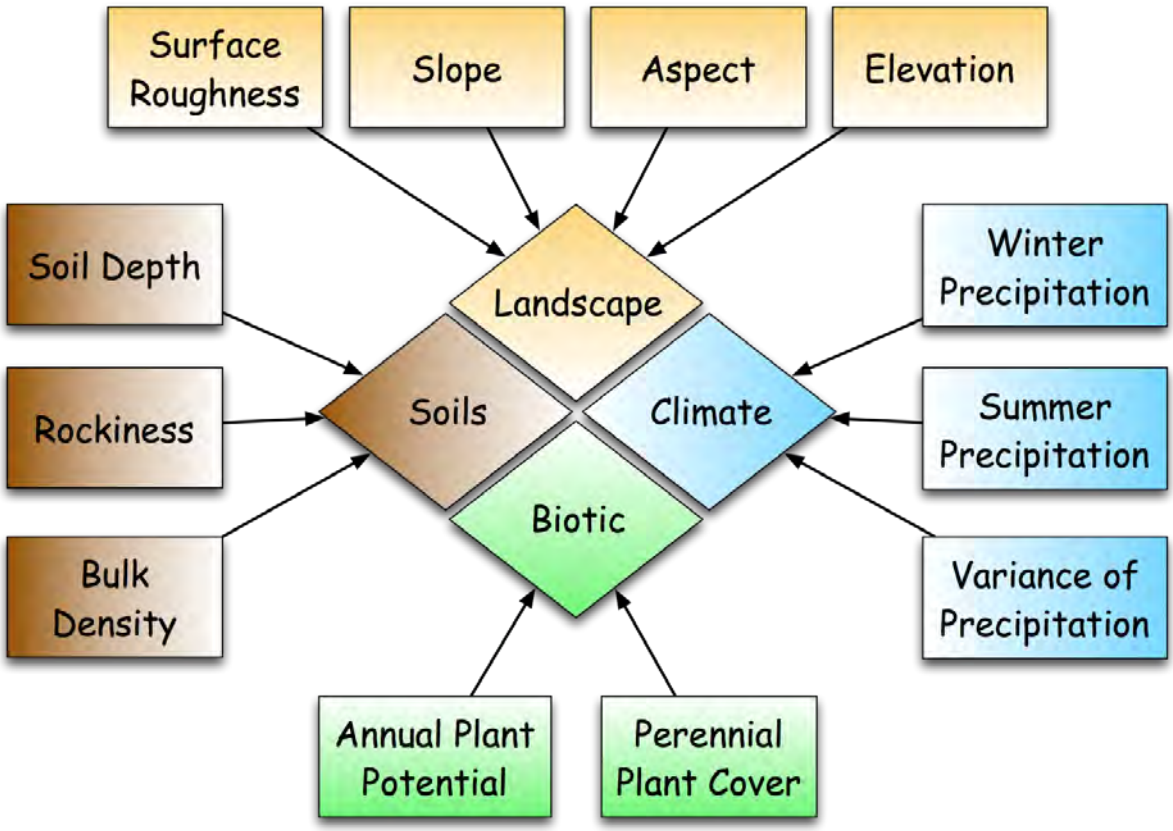

Figure 4. Array of variables used to predict desert tortoise habitat. Environmental variables were generally related to four categories of influence on the landscape and were hypothesized to influence tortoise ecology/habitat potential through a variety of mechanisms.

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).

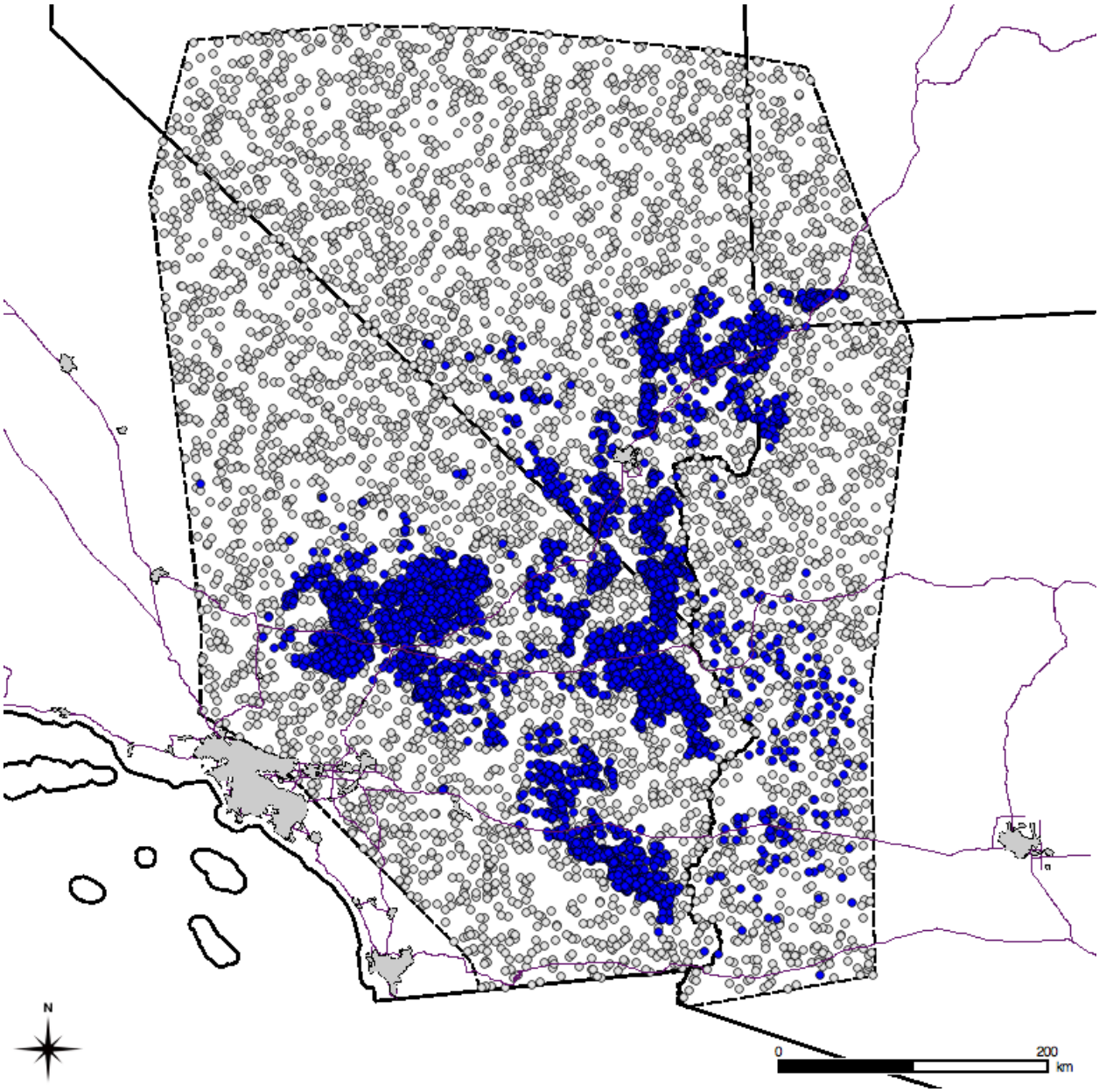

Figure 5. Distribution of presence data (blue circles) and random background data (gray circles) used in habitat modeling. Urban areas are defined by the gray shaded polygons.

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

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

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

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

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

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.

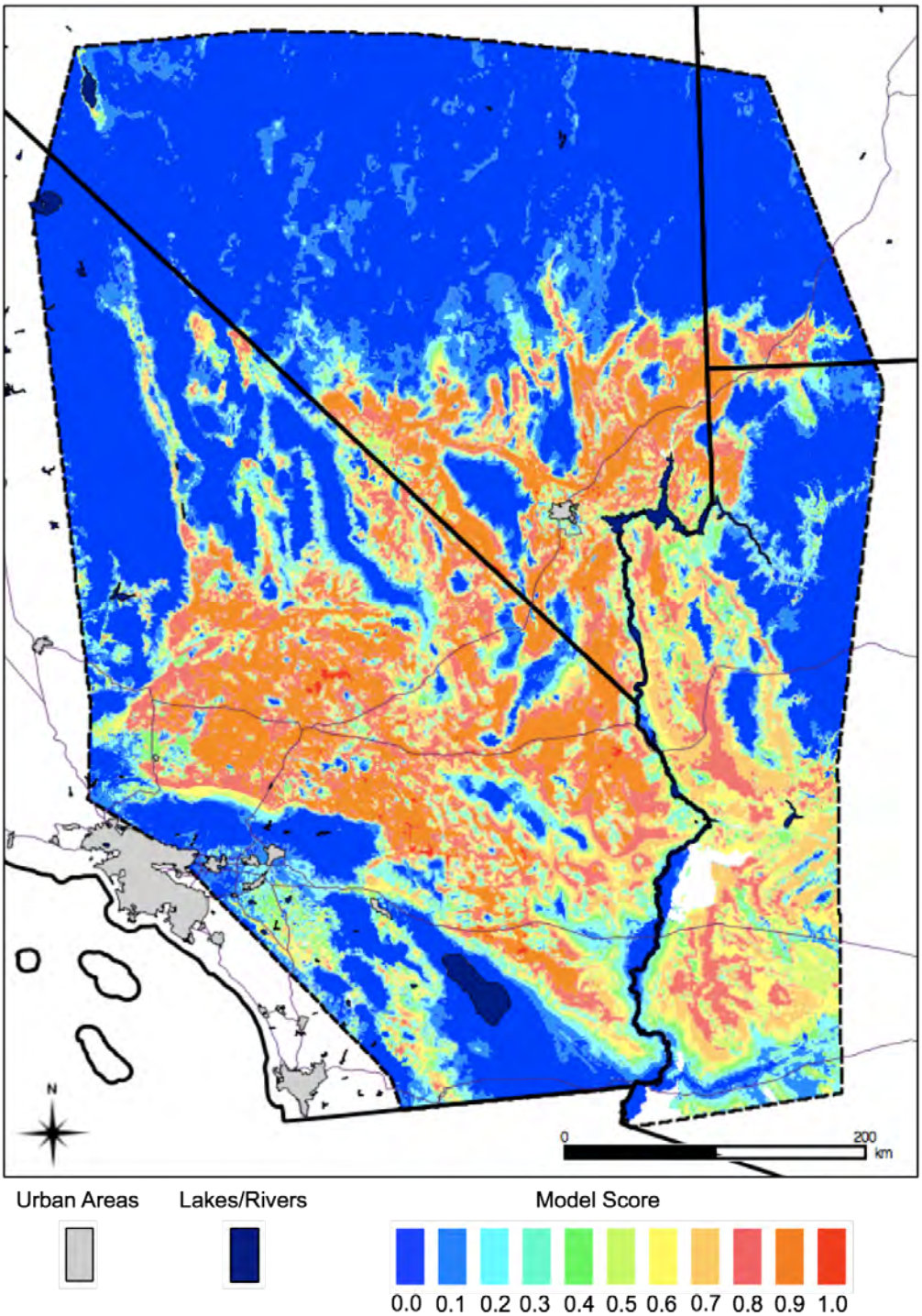

Figure 6. Spatial representation of the predicted habitat potential index values for desert tortoise (*Gopherus agassizii*) in the Mojave and parts of the Sonoran Deserts of Arizona, Nevada, Utah, and Arizona. White patches within the study area indicate areas where no environmental data were available 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

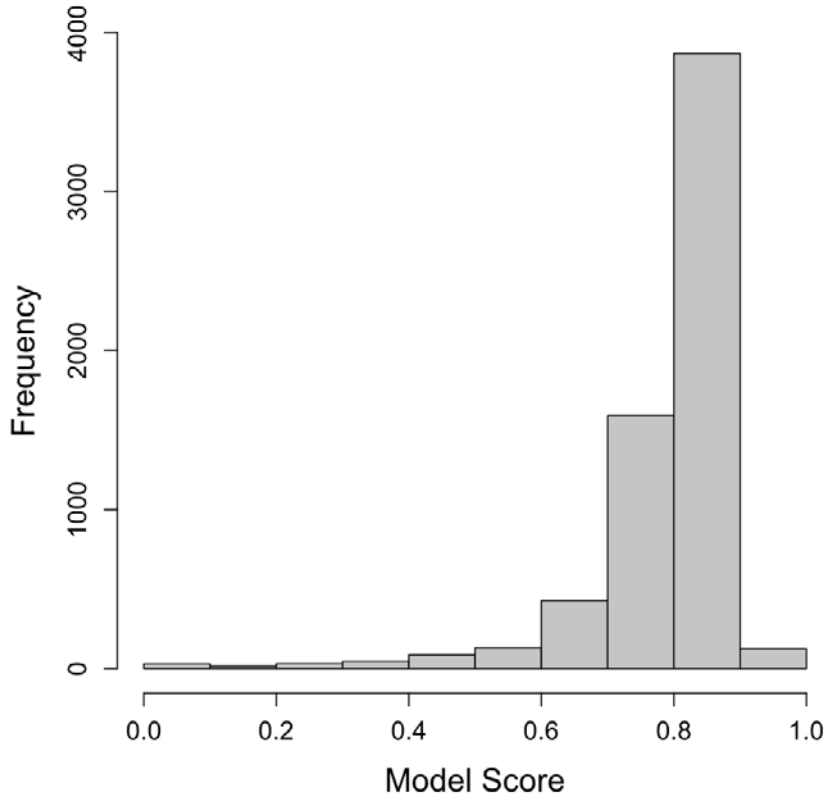

Figure 7. Frequency of the habitat potential index values for the 6,350 1-km^2 grid cells with known tortoise presence in the Mojave and parts of the Sonoran Deserts of California, Nevada, Utah, and Arizona.

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.

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EXHIBIT 430

Interim Golden Eagle Inventory and Monitoring Protocols; and Other Recommendations

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February, 2010

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Interim Golden Eagle Inventory and Monitoring Protocols; and Other Recommendations

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Recommended citation:

Pagel, J.E., D.M. Whittington, and G.T. Allen. 2010. Interim Golden Eagle inventory and monitoring protocols; and other recommendations. Division of Migratory Bird Management, U.S. Fish and Wildlife Service.

I. Purpose

This document identifies the minimum inventory and monitoring effort recommended for determining and evaluating potential Golden Eagle (*Aquila chrysaetos canadensis*) use of habitat including nest sites, roosts, and territories, as well as the rationale for identifying and evaluating foraging locations during breeding and non-breeding periods. It also outlines the minimum monitoring techniques to ascertain occupancy and reproductive success at territories. These field efforts are the mutual responsibility of agencies authorizing activities and their permittees (i.e. action agency; see Glossary). They are essential components for avoiding and minimizing disturbance and other kinds of take, including lethal take, and are a necessary component of short and long-term site specific monitoring and management of local Golden Eagles and regional Golden Eagle populations. The data gathered will provide information on the baseline circumstances for evaluation of permit applications and foundation for permit conditions, as well as assist planners so they may conduct informed impact analyses and mitigation during the National Environmental Policy Act (NEPA) process. Data collected via this effort will also help:

1. Determine the fate and reproductive trends of regional nesting populations via collating information from observed territories;
2. Document and list historical and unsurveyed habitat for future analysis to assist in determining local and regional population trajectories;
3. Provide information to document whether local Golden Eagle conservation efforts are meeting goals for improvements in the status of the species; and
4. Provide a foundation for evaluation of whether and which activities or conditions may be affecting Golden Eagles.

II. Background

Golden Eagles are protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (Eagle Act), both of which prohibit take. Take means *pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, destroy, molest,* or *disturb*. When the Bald Eagle (*Haliaeetus leucocephalus*) was delisted under the Endangered Species Act (ESA), and in order to improve management of both species of eagles under the Eagle Act, the U.S. Fish and Wildlife Service (Service) undertook a series of management actions, including:

- **Codifying a regulatory definition of "disturb"** under the Eagle Act (see 72 FR 31132, June 5, 2007). *Disturb* means to agitate or bother a Bald Eagle or a Golden Eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest

abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.

- **Proposing permit regulations** to (1) Create a new permit type to authorize take of Bald Eagles and Golden Eagles that is associated with, but not the purpose of, the activity; and (2) Create a second new permit type to authorize purposeful take of eagle nests that pose a threat to human or eagle safety (subsequently broadened to accommodate additional circumstances). The regulations were finalized on September 11, 2009 (74 FR 43686).

Summary of the new regulations.

Permits issued under 50 CFR § 22.26 authorize take of Bald Eagles and Golden Eagles, where the take is associated with, but not the purpose of the activity, and cannot practicably be avoided. Most take authorized under this section will be in the form of disturbance; however, permits may authorize lethal take that results from, but is not the purpose of, an otherwise lawful activity. Purposeful take will not be authorized under § 22.26.

The second new permit regulation, at 50 CFR 22.27, establishes permits for removing eagle nests where (1) necessary to alleviate a safety hazard to people or eagles, (2) necessary to ensure public health and safety, (3) the nest prevents the use of a pre-existing human-engineered structure, or (4) the activity, or mitigation for the activity, will provide a net benefit to eagles. Only inactive nests during the non-breeding season may be taken, except in the case of safety emergencies.

Regulations under § 22.27 authorize removal and/or relocation of active and inactive eagle nests in cases where genuine safety concerns for people, eagles, or both, necessitate the take. Examples include: (1) a nest tree that appears likely to topple onto a residence; (2) at airports to avoid collisions between eagles and aircraft; and (3) to relocate a nest built within a reservoir that will be flooded.

Both regulations are provided for by the Eagle Act which gives the Secretary of the Interior the authority to permit the limited take of Bald Eagles and Golden Eagles "for the protection of... other interests in any particular locality." Additionally, both new regulations:

- Are applicable to Golden Eagles as well as Bald Eagles.
- Authorize take only where it is compatible with the preservation of the eagle. For purposes of these regulations, "compatible with the preservation of the Bald Eagle and the Golden Eagle" means consistent with the goal of stable or increase of breeding populations.
- Authorize take only where it cannot practicably be avoided.

- Include provisions for programmatic take. Programmatic take (take that is recurring and not in a specific, identifiable timeframe and/or location) will be authorized only where it is unavoidable despite implementation of comprehensive measures developed in cooperation with the Service to reduce the take below current levels.

Additional needs for Golden Eagle information and evaluation.

As part of an adaptive management approach to the permits and eagle management, the Service will assess, at least every five years, overall population trends along with annual report data from permittees and other information to assess how likely future activities are to result in the loss of one or more eagles, a decrease in productivity of Golden Eagles, and/or the permanent loss of a nest site, territory, or important foraging area. Therefore, implementation of the new permit regulations will entail requirements for cumulative effects analyses and identifying the impacts of an activity. We include them here to provide the context and framework for the protocols and recommendations in this document.

Cumulative effect considerations.

Whether the take is compatible with eagle preservation includes consideration of the cumulative effects of other permitted take and additional factors affecting eagle populations. Cumulative effects are defined as: *"the incremental environmental impact or effect of the proposed action, together with impacts of past, present, and reasonably foreseeable future actions"* (50 CFR 22.3). Numerous relatively minor disruptions to eagle behaviors from multiple activities, even if spatially or temporally distributed, may lead to disturbance that would not have resulted from fewer or more carefully sited activities. The accumulation of multiple land development projects or siting of multiple infrastructures that may be hazardous to eagles can cumulatively reduce the availability of alternative sites suitable for breeding, feeding, or sheltering, resulting in a greater than additive risk of take to eagles.

To ensure that impacts are not concentrated in particular localities to the detriment of locally-important eagle populations, cumulative effects need to be considered at the population management level—*Service Regions* for Bald Eagles and *Bird Conservation Regions* for Golden Eagles—and, especially for project-specific analyses, at local area population levels (the population within the average natal dispersal distance of the nest or nests under consideration). Eagle take that is concentrated in particular areas can lead to effects on the larger management population because 1) disproportionate take in local populations where breeding pairs are 'high' producers may reduce the overall productivity of the larger population; and 2) when portions of the management population become isolated from each other the productivity of the overall management population may decrease.

Identifying the Impacts of the Activity

The applicant for an Eagle Act permit (who can be a project proponent or the agency preparing the NEPA), has four subtasks to determine the likely effects of a project or activity on eagles:

a. Collection and synthesis of biological data. The applicant is responsible for providing up-to-date biological information about eagles that breed, feed, shelter, and/or migrate in the vicinity of the activity that may potentially be affected by the proposed activity. Biological information can include locations and distribution of nests, delineation of territories, prey base, general composition and relative abundance, and productivity data.

b. Identifying activities that are likely to result in take. As part of the permit application, the applicant must include a complete description of the actions that: (1) are likely to result in eagle take, and (2) for which the applicant or landowner has some form of control. For most applications, the activity will be specific and well-defined (e.g., home construction; water use development) or land use activity (e.g., forestry). For larger-scale permits, each applicant will need to determine the extent of impacts to include in the permit authorization and, if necessary, which ones to exclude.

c. Avoidance and minimization measures. An application for a § 22.26 permit must document the measures to which the applicant will commit to avoid and minimize the impacts to eagles to the maximum degree practicable.

d. Quantifying the anticipated take. The take authorized under a permit will depend on a variety of factors, including: (1) the number of eagles that breed, feed, shelter, and or migrate within the activity area, (2) the degree to which the eagles depend on that area for breeding, feeding, or sheltering, or migration, and thus are more likely to be present and affected, (3) the potential of that type of activity in general to take eagles, (4) the scale of the activity, and (5) the measures the applicant will undertake to avoid and minimize the take.

Federal agencies have additional responsibilities to Golden Eagles under Executive Order 13186 (66 FR 3853, January 17, 2001), which reinstated the responsibilities of Federal Agencies to comply with the Migratory Bird Treaty Act of 1918. The Executive Order establishes a process for Federal Agencies to conserve migratory birds by avoiding or minimizing unintentional take and taking actions that benefit species to the extent practicable. Agencies are expected to take reasonable steps that may include restoring and enhancing habitat. Environmental analyses of Federal actions required by NEPA or other environmental review processes must evaluate the effects of actions and Federal agency plans on migratory birds, including Golden Eagles.

Golden Eagle populations are believed to be declining throughout their range in the contiguous United States (Harlow and Bloom 1989, Kochert and Steenhof 2002, Kochert et al. 2002, Good et al. 2007, Farmer et al. 2008, Smith et al. 2008, 74 FR 46836-46879). The Service has modeled current data (USFWS 2009, Appendix C), employing Moffat's equilibrium (Hunt 1998) and Millsap and Allen's (2006) analysis of anthropogenic demographic removal, and estimated that the floating (non-breeding and surplus) component of the Golden Eagle population in some areas may be limited at this time. Data from the Western EcoSystems Technology Inc. surveys from 2006 through 2009 suggest a decline since 2006 in the total Golden Eagle population within the area covered by the surveys (Neilson et al. 2010, USFWS 2009, Appendix C). Significant Golden Eagle breeding failures have been reported in some areas of the southwestern United States (WRI 2009), and declines in counts of migrating Golden Eagles have been reported in most areas in the western United States (Farmer et al. 2008, Smith et al. 2008), although it is unclear if the latter is linked to a decrease in the number of eagles.

III. Management Need

Prior to initiating inventory and monitoring efforts, land management agencies and/or proponents of land use activities should first assess all existing recent and historical data available on eagles, including their nests, reproductive activity and chronologies, natal dispersal, pertinent data from VHF and satellite telemetry, winter roosts, migration corridors, and foraging habitats contained by and 4 - 10 + miles of areas slated for development or authorizations for increased human activity. This background search of available information may yield few data, but is necessary to alert project proponents and regulatory staff about data gaps, and existing knowledge of Golden Eagles for that area. Inventory, monitoring, and research activities may then be identified and funded to fill in site specific information gaps to avoid take of Golden Eagles. Specific recommendations for the number of years needed for baseline data and measures to avoid take should be developed in coordination with the Service, and, to reduce redundancy between management and permitting requirements, consistent with permit requirements outlined in the Draft Implementation Guidelines for the new rules (expected fall 2010).

Projects in Golden Eagle breeding home ranges on federal, state, and private land possibly will have direct, indirect, and cumulative effects associated with or exacerbated by, factors such as: recreation disturbance, electrocution, urbanization, illegal shooting, invasive species altering prey densities, lead poisoning, other contaminants, climate change, and prolonged drought which affects predator and prey abundance and distribution. In many cases, existing data may not be adequate for NEPA, planning, or permitting purposes. Therefore, inventory and subsequent monitoring of Golden Eagles and components of their habitats are important to 1) develop a baseline prior to project planning and prior to project development in Golden

Eagle habitat, 2) analyze impacts to the species, 3) continue to evaluate and report on the effects of the action and mitigation on Golden Eagles, 4) essential to adaptive management approaches, and 5) provide information that may be required for permits.

Project design, type, and siting of project footprint and infrastructure are critical to avoid disturbance and take of Golden Eagles. In the Final Environmental Assessment on the rule and in the draft Implementation Guidance, the Service recommended that when planning locations of infrastructure and project boundaries, action agencies and project proponents consider life-history components such as productivity, age-class survival, dispersal, migration, winter-concentration behavior, and foraging behavior during breeding and non-breeding seasons to avoid lethal take. The Service recommends use of the best available or gathered information applicable to the location of the project or plan, but also encourages efforts to conduct further research. For permitting purposes however, and to determine the likelihood and magnitude of take, as well as effectiveness of mitigation, monitoring will need to yield productivity information.

Note: This document does not address site specific observations for transitory or wintering eagles; these protocols will be forthcoming. Although the life history for transitory and wintering eagles is not discussed at length here, that does not imply a lack importance for site-specific observations from the Service's perspective. The document provides general recommendations for factors to consider outside nesting, until more specific protocols are developed.

IV. Basic Golden Eagle Ecology

This account is not intended as a compendium of Golden Eagle natural history, biology, ethology, or ecology; please refer to Watson (1997), Palmer (1988) and Kochert et al. (2002) for more detailed information.

Where they exist, Golden Eagles are an upper-trophic aerial predator, and eat small to mid-sized reptiles, birds, and mammals up to the size of mule deer fawns and coyote pups (Bloom and Hawks 1982). They also are known to scavenge and utilize carrion (Kochert et al. 2002).

Golden Eagles nest in high densities in open and semi-open habitat, but also may nest at lower densities in coniferous habitat when open space is available, (e. g. fire breaks, clear-cuts, burned areas, pasture-land, etc.). They can be found from the tundra, through grasslands, woodland-brushlands, and forested habitat, south to arid deserts, including Death Valley, California (Kochert et al. 2002). Historically, Golden Eagles bred in the Plains and Great Lake states. Golden Eagles currently breed in and near much of the available open habitat in North America west of the 100th Meridian, as well as in eastern United States in the northern Appalachian Mountains (Palmer 1988, Kochert et al. 2002). The Lee and Spofford (1990) review

of the literature for the eastern portion of the United States suggested historical nesting Golden Eagles south of New York in the Appalachians was unlikely. Nesting of introduced Golden Eagles has been reported in Tennessee and northwestern Georgia (Kochert et al. 2002), but we do not know if those territories are still extant.

A nesting territory for the purpose of this monitoring protocol is an area that contains, or historically contained, one or more nests within the home range of a mated pair. It is a confined locality where nests are found, usually in successive years, and where no more than one pair is known to have bred at one time (Steenhof and Newton 2007).

Golden Eagles avoid nesting near urban habitat and do not generally nest in densely forested habitat. Individuals will occasionally nest near semi-urban areas where housing density is low and in farmland habitat; however Golden Eagles have been noted to be sensitive to some forms of anthropogenic presence (Palmer 1988). Steidl et al. (1993) found when observers were camped 400 meters from nests of Golden Eagles, adults spent less time near their nests, fed their juveniles less frequently, and fed themselves and their juveniles up to 67% less food than when observers were camped 800 meters from nests. In studies of Golden Eagle populations in the southwest (New Mexico and Texas) and the Front Range of the Rocky Mountains (New Mexico, Colorado and Wyoming), Boeker and Ray (1971) reported that human disturbance accounted for at least 85% of all known nest losses. Breeding adults are sometimes flushed from the nest by recreational climbers and researchers, sometimes resulting in the loss of the eggs or juveniles due to nest abandonment, exposure of juveniles or eggs to the elements, collapse of the nest, eggs being knocked from the nest by startled adults, or juveniles fledging prematurely. However, Golden Eagles rarely flushed from the nest during close approaches by fixed-wing aircraft and helicopters during various surveys in Montana, Idaho, and Alaska (Kochert et al. 2002).

Golden Eagles nest on cliffs, in the upper one third of deciduous and coniferous trees, or on artificial structures (windmills, electricity transmission towers, artificial nesting platforms, etc.; Phillips and Beske 1990, Kochert et al. 2002). Golden Eagles build nests on cliffs or in the largest trees of forested stands that often afford an unobstructed view of the surrounding habitat (Beecham 1970, Menkens and Anderson 1987). Usually, sticks and soft material are added to existing nests, or new nests are constructed to create a strong, flat or bowl shaped platform for nesting (Palmer 1988, Watson 1997, Kochert et al. 2002). Sometimes Golden Eagle will decorate multiple nests in a single year; continuing to do so until they lay eggs in the selected nest. The completed nest structure(s) can vary from large and multi-layered; or a small augmentation of sticks in caves with little material other than extant detritus (Ellis et al. 2009). Most Golden Eagle territories have up to 6 nests, but they have been found to contain up to 14 nests (Palmer 1988, Watson 1997, Kochert et al. 2002).

Onset of courtship and nesting chronology

Courtship for Golden Eagles involves stick-carrying, display flights, and vocalization (Ellis 1979, Kochert et al. 2002). Golden Eagles partake in undulating flight, however undulating flight has been observed year-round and is thought to be associated more with aggression and territory defense than with courtship (Newton 1979, Harmata 1982, Collopy and Edwards 1989, Watson 1997).

Nesting chronologies vary however there are some generalities. In California and in Texas, courtship at territories start in mid to late December (Palmer 1988, Hunt et al. 1997, D. Bittner pers. com); in Texas eggs have been detected as early as November (Olberholser and Kincaid 1974, *in lit.*). In Utah, courtship can commence in January. In northern tier states at upper latitudes and higher elevation sites, egg laying can occur as early as February and March, before late winter snows and storms have abated (Palmer 1988).

Golden Eagles lay 1 to 4 eggs, with 4 egg clutches rare. Most nests have 2 eggs. The laying interval between eggs ranges between 3 to 5 days. Incubation commences as soon as the first egg is laid, and hatching is asynchronous and can begin as early as late January in southern California (Dixon 1937, Hickman 1968), mid April to late May in southwest Idaho (Kochert et al. 2002) and late March–early May in central and northern Alaska (McIntyre 1995, Young et al. 1995; Fig. 3). In Texas, eggs have been noted from November to June (Oberholser and Kincaid 1974, in lit.). In the northeast United States, eggs have been laid in March/April (Palmer 1988). For more detail, please refer to Kochert et al. (2002, Appendix 2).

Migration and Wintering

Golden Eagles will migrate from the Canadian provinces and northern tier and northeastern states to areas that are milder in the winter and/or may have less snow cover. Wintering Golden Eagles have been noted in all states in the continental U.S. (Wheeler 2003, 2007). Some segments of the population can be found near their nest sites throughout the year. See Kochert et al. (2002) for detailed listing of winter range.

Roosts or gathering behavior

Golden Eagles are not known to roost communally as is common with wintering Bald Eagles in some areas of the United States, but will gather together if local food sources are abundant. A caveat to this is that Golden Eagles have perched with bald eagles where there have been large concentrations of waterfowl or carrion (Palmer 1988).

V. Golden Eagle Responses to Disturbance

Golden Eagles,visibly display behavior that signifies disturbance when they are stressed by anthropogenic activities; whether it is a lone hiker walking 1000 meters or more from a nest, or extended construction or recreation activities 2000 – 5000 meters from a territory. These postures, movements and behaviors can be overt. However with Golden Eagles, disturbance behaviors are often subtle and require an experienced observer. Olendorff (1971), Fyfe and Olendorff (1976), and Olsen and Olsen (1978) identified considerations when human interactions may disturb nesting activities, and how to ascertain critical distances to avoid agitating nesting, roosting, and foraging raptors. Factors affecting critical distances included:

1. Mannerisms of intruder,
2. Size of intruder,
3. Stage of breeding cycle, and
4. Topography and exposure of intruder in relation to bird.

Golden eagle behavior varies among individuals and can be affected by previous experiences. However, some behavioral generalities relative to direct and indirect disturbance include the following:

1. Agitation behavior (displacement, avoidance, and defense),
2. Increased vigilance at nest sites,
3. Change in forage and feeding behavior, and/or
4. Nest site abandonment.

Of the preceding behaviors, nest-site abandonment constitutes take under the Eagle Act, as it is specifically cited in the definition of 'disturb'. The other behaviors, when considered cumulatively, may be evidence that activities are interfering with normal breeding behavior and are likely to lead to take. Human intrusions near Golden Eagle nest sites have resulted in the abandonment of the nest; high nestling mortality due to overheating, chilling or desiccation when young are left unattended; premature fledging; and ejection of eggs or young from the nest (Boeker and Ray 1971, Suter and Joness 1981).

VI. Overall Objectives of the Golden Eagle Survey Protocol

This survey protocol is intended to standardize procedures to inventory and monitor Golden Eagles within the direct and indirect impact areas of planned or ongoing projects where disturbance or lethal take from otherwise permitted human activities is possible. This protocol will identify eagle use areas and identify and minimize potential observer-related disturbance to Golden Eagles by surveys when conducted by qualified and experienced raptor biologists.

Additionally, data collected using this protocol may be used for, at a minimum, 1), sampling other geographic areas where suitable habitat may be present; 2) short and long-term analysis of Golden Eagle occupancy and productivity at known nest sites, and historical locations where observation to determine occupancy maybe necessary; 3) identification and evaluation of potential disturbance factors. This protocol will standardize data collection for potential local and regional analysis of long-term occupancy, productivity and eagle use trends. It was developed as minimum standards, and as such may require additional area-specific detail if used for research purposes.

Objectives of inventory and monitoring

The first objective of these surveys is to provide methods to identify areas occupied by Golden Eagles and select factors their behavior ecology. Additional objectives of these surveys include the following.

1. Record and report occupancy and productivity of local Golden Eagle territories.
2. Document and list historical and unsurveyed habitat for future analysis to assist in determining local and regional population trajectories.
3. Determine nesting chronologies.
4. Provide information to document whether local Golden Eagle conservation efforts meet permit conditions or goals for improvements in the status of Golden Eagles.
5. Provide a foundation to evaluate whether and which activities or conditions may be affecting Golden Eagles.
6. Document foraging behavior, diet and habitat use within breeding and non-breeding home ranges.

VII. Inventory Techniques

CAUTION

Golden Eagles are one of several cliff and tree dwelling species sensitive to human disturbance. Monitoring eagles in a manner that 'disturbs' them, and causes them to be 'agitated or bothered' can cause nesting failure, and permanent site abandonment, constituting take under the Eagle Act.

These monitoring protocols should facilitate observer caution and identify techniques that will minimize potential for take of Golden Eagles. For additional information regarding preventing observer disturbance while surveying raptors, please refer to Fyfe and Olendorff (1976).

Inventory

Inventories for Golden Eagles should occur if nesting, roosting, and foraging habitat are contained within the project boundary and exist within 10 miles of the project boundary. Local and regional Golden Eagle habitat variability will dictate the distance from the project boundary where surveys will occur; distances will be greater in xeric or other habitats where local prey may not be abundant. The Service will be basing its site-specific evaluations and final determinations on local conditions, not national averages.

Nesting habitat

This account is not intended as a compendium of Golden Eagle habitat available and used in North America; please refer to Palmer (1988) and Kochert et al. (2002) for more detailed information.

Golden Eagles use a wide variety of habitat throughout North America. Small xeric mountain ranges in the Mohave and Great Basin deserts, forested habitat in the Pacific coastal, southern desert, Great Basin, Rocky, Sierra, and Cascade Mountain ranges are also key nesting areas. Local and regional variation of nesting habitat should be considered prior to surveys; however should include cliff, desert scrub, juniper woodland, and forested habitat. For example, in the northern Great Basin, Golden Eagles nest on cliff and in scrub-forest habitat; surveys of both types of substrates are urged prior to projects that have a potential to affect eagles. Identification criteria for nesting habitat at the local scale should take place in coordination with the Service, State, or Tribal wildlife agencies, and raptor experts.

VII.a. Procedures for aerial and ground inventory and monitoring surveys

Golden Eagles generally show strong fidelity to the nesting area annually. Occupancy determination is the most important goal of nest searches. Considerable suitable habitat exists in western North America that has never been adequately surveyed. Inventory surveys should examine habitat where Golden Eagles are not currently known to exist but habitat may be present, as well as previously inventoried areas to detect new activity. Monitoring surveys examine all historical and extant territories where Golden Eagles have been detected either previously or in the current survey.

A nesting territory or inventoried habitat should be designated as unoccupied by Golden Eagles ONLY after at least 2 complete aerial surveys in a single breeding season. In circumstances where ground observation occurs, at least 2 ground observation periods lasting at least 4 hours or more are necessary to designate an inventoried habitat or territory is unoccupied as long as all potential nest sites and alternate nests are visible and monitored. These observation periods should be at least 30 days apart for inventory, and at least 30 days apart for monitoring

of known territories. Intervals between observations at occupied nesting territories may need to be flexible and should be based on the behavior of the adults observed, the age of any young observed, and the data to be collected (see below, Section IX). Dates of starting and continuing inventory and monitoring surveys should be sensitive to local nesting (i.e. laying, incubating, and brooding) chronologies, and would be conducted during weather conditions favorable for aerial survey and/or monitoring from medium to long range distances (+ 300 – 700 meters).

The first inventory and monitoring surveys should be conducted during courtship when the adults are mobile and conspicuous. When survey of historical territories is conducted, observers should focus their search on known alternative nests, and also carefully examine the habitat for additional nests which may have been overlooked or recently constructed. A 'decorated' nest will be sufficient evidence to indicate the probable location of a nesting attempt. If a decorated nest or pair of birds is located, the search can then be expanded to inventory likely habitat adjacent to the discovered territory to see if additional golden eagle territories can be observed.

Note: Identification of alternate nests will be required by the Service for determination of relative value of individual nests to a territory in cases of applications for permits to take 'inactive' nests, and when determining whether abandonment of a particular nest is likely to result in abandonment of a territory. The Service has determined that territory loss or permanent abandonment of a territory is a greater impact to populations than temporary abandonment of a nest.

Weather: Avoid searching potential and known nesting locations during periods of heavy rain, snow, high winds, or severe cold weather. Golden Eagles should not be induced to flush at any time during the survey period. Flushing when the adults are incubating or have small young can be particularly hazardous for successful nesting, and could constitute lethal disturbance take. High temperatures also may cause problems for successful viewing over long distances due to heat waves. Further, observer related incidences of causing flight of adults that are shading young to prevent overheating during high temperatures may cause mortality of the young. Observation for Golden Eagles during inclement weather is impractical, uncomfortable, and unsafe for Golden Eagles and observers. Weather will be recorded by the observer.

Time of day: Aerial surveys should be conducted at the beginning of the day if winds permit. Likewise, ground surveys should be initiated, where possible, in morning hours when the air is still to avoid heat waves. Prime observation periods are around dawn, or shortly thereafter. In some cases the angle of the sun in relation to the cliff can be a more important issue, and some cliffs are better observed in

afternoon light, however observations of adult behavior that are used to determine nesting chronologies may be conducted during most of the day. Observers should be aware of the angle of the sun in relation to the observation post and the nest. Some sites are plagued by afternoon winds, heat waves, or dust storms; local observation conditions should be taken into account prior to establishing viewing periods. Time of day will be recorded by the observer.

Time of year: Breeding surveys for Golden Eagles are latitude and elevation dependent; however, their nesting season ranges in the contiguous United States from 01 January to 31 August (Kochert et al. 2002). Nesting failures and seasonal variations should be considered as potential anomalies to 'normal' behavior and nesting chronologies. Dates to be used as a cut-off period for observation and reporting of nesting failures or non-nesting status will vary per region. The dates listed below are to be used as general guides, and should not be used as final nest site failure survey determination dates. Location-specific determination dates should be developed in coordination with the Service, State, or Tribal wildlife agencies, and raptor experts.

Duration of stay at observation points: Ground observers will survey from observation points for a minimum of 4 hours, unless observations yield Golden Eagle presence, or Golden Eagle behavior indicate eggs or young, or observation suggests the observer is disturbing the birds. Slowly walking and observing all potential nesting substrate can be used to completely inventory potential habitat. Observation periods may last longer as longer observation periods may be necessary to accurately determine nesting chronologies. Duration of stay at known or suspected territories during helicopter reconnaissance, or during ground observation periods will be recorded by the observer.

VII.b Aerial surveys

Helicopters are an accepted and efficient means to monitor large areas of habitat to inventory potential habitat and monitor known territories only if accomplished by competent and experienced observers. They can be the primary survey method, or can be combined with follow-up ground monitoring. Disturbance to eagles is minimal only WHEN accepted aerial practices and techniques are followed. NOTE: Ground surveys can be used when their use is more efficient, or when other circumstances (e.g. bighorn sheep lambing areas) require this method.

Coordination between state and federal agencies is an important aspect of aerial surveys to develop acceptable search criteria to be used for identifying likely suitable nesting habitat and

locating nests, as well as to be become acquainted with potential hazards and air space restrictions. Survey pilots should be aware of potential ground hazards within the habitat to be examined, including marked and unmarked transmission and wires. Other hazards to surveyors include rock-fall or tree fall from above the helicopter, raptors or other birds colliding with the helicopter, and collision with other aircraft. Although pilots are often the first to note a flying raptor during surveys, some accidents involving wildlife researchers have been attributed to the pilots focusing on the survey, rather than giving their complete attention to flying the helicopter.

Helicopters used for surveying Golden Eagle habitat should be light utility, small to medium sized (such as the MD-500/520, Eurocopter 145, Bell Jet-Ranger 206, or UH-72). The aircraft should be capable of vertical mobility in warm temperatures and at higher elevations. Inventories for raptors can be conducted with the main observer door(s) removed (which may provide more lateral and horizontal visibility), or with the doors closed. The decision regarding observer doors should remain a personal choice, with the safety of pilots and observers as the primary determinant.

Cliffs should be approached from the front, rather than flying over from behind, or suddenly appearing quickly around corners or buttresses. Inventories should be flown at slow speeds, ca. 30 – 40 knots. However, detection of nests may require slower speeds, e.g. 20 knots, while between nest speeds can be higher (+ 60 knots). All potentially suitable nesting habitats (as identified in coordination with the Service) should be surveyed; multiple passes at several elevation bands may be necessary to provide complete coverage when surveying potential nesting habitat on large cliff complexes, escarpments, or headwalls. Hovering for up to 30 seconds no closer than a horizontal distance of 20 meters from the cliff wall or observed nests may be necessary to discern nest type, document the site with a digital photograph of the nest, and if possible, allow for the observer to read patagial tags, count young, and age young in the nest (Hoechlin 1976). Confirmation of nest occupancy may be confirmed during later flights at a greater horizontal distance.

Re-nesting is rare, but Golden Eagles may fail at their first nest attempt, and move to, or create, an alternate nest site. Multiple visits to known or potential nesting habitat may be necessary to provide complete observation and coverage of habitat.

To inventory for the purpose of documenting presence/absence of Golden Eagles in potential habitat, at least 2 aerial observation flights of habitat are necessary. These flights will be spaced no closer than 30 days apart. Additional inventory work in the territory is not necessary after nests have been located where Golden Eagles are found incubating, or where eggs or young and number of eggs or young are noted. At this point, the observation effort should

switch to monitoring of the known territory. The nest location should be documented (see territory/nest naming convention, pp. 20.

Inventory and monitoring flights will be based on local knowledge of known nesting chronologies for that latitude and elevation, and should be timed to be the most efficient to reduce the number of visits to the nest site. Flights may occur preferentially during a) late courtship, b) egg-laying though hatch, and/or c) when the young are between 20 and 51 days old. Productivity surveys are best scheduled when the young are 51 days old or more, but prior to fledging. Aerial visits at known nests may be augmented or replaced by ground observation (see below).

Other raptors or special status species may be observed during the flight, and should be recorded/reported. Coordination with state and federal agencies will be necessary when state or federally listed Threatened, Endangered or special status (species of concern, sensitive, etc.) species are present in the flight survey area (i.e. big-horn sheep, peregrine falcons, etc.). Bighorn sheep share the same type of cliff complexes Golden Eagles use for nesting, and are hyper-sensitive to helicopters (Weyhausen 1980, Bleich et al. 1990). Specifically for bighorn sheep lambing areas, helicopter reconnaissance and surveys for Golden Eagles are not possible as these flights will induce unpermitted take during the lambing season; all helicopter survey work for Golden Eagles should be avoided in known lambing areas. Ground observation will be necessary for inventory of cliff complexes and monitoring of potential and known Golden Eagle territories in bighorn sheep lambing areas.

Most Golden Eagle respond to fixed wing aircraft and helicopters by remaining on their nests, and continuing to incubate or roost (DuBois 1984, McIntyre 1995). Perched birds may flush. During aerial surveys, deference to flying eagles should be given at all times. Flights at nest sites should be terminated and the helicopter should bank away and move to the next location if Golden Eagles appear to be disturbed; i.e. behavior that indicates the birds are agitated by the presence of the helicopter. In short, observers should obtain their data, and leave as soon as possible.

Any disturbance behavior observed should be noted so that consecutive aerial surveys would be sensitive to Golden Eagles at that location. Aerial reconnaissance to inventory/survey for potential habitat and additional visits at known nests may be augmented/replaced by ground observation from a safe distance (see below). Ground observation may be the recommended alternative to additional survey flights due to convenience or necessitated by other sensitive wildlife species. Follow-up ground observation from a safe distance may also be the recommended alternative for additional nest site monitoring.

Observers in helicopters have specific duties. At least two observers may be best for aerial surveys; one the lead observer, the other(s) supplement survey effort. One observer is assigned to record data on a recorder (unless the verbal interchange can be recorded on the helicopters internal communication system), and the other briefly records data on hard-copy and with digital photographs. Aerial observation routes should be recorded, downloaded, and reported using Global Positioning System track routes or applicable software programs. Observation locations and time-on-site should be recorded on applicable maps to ascertain coverage of cliff systems and other potentially suitable habitat.

Summary:

- Qualified observer(s) (as defined in section VIII).
- No closer than 10-20 meters from cliff; no farther than 200 meters from cliff (safety dependent).
- Close approach and extended hovering is allowed when there are no birds on the nest to allow observers to count eggs, dead young, or confirm nest failure.
- Multiple passes or 'bands' (back and forth at different elevations above ground level) of observation across cliff habitat may be necessary to achieve complete coverage of a large cliff complex.
- Occupied territories and current and alternative nest sites will be documented; nests containing fresh branches should also be delineated.
- After a nest with eggs, young, or an incubating adult has been located, there is no need to search for other nests within the territory.
- Minimal hovering time at a known or potential nest should be less than 30 seconds.
- At least 2 surveys of previously unsurveyed habitat will be spaced at least 30 days apart.

VII.c. Ground Surveys

Ground surveys of potential habitat

Ground surveys for Golden Eagles in potential habitat may be achieved without aerial support, or may be used to augment extant aerial surveys. Ground surveys to detect Golden Eagle nests and the selected nest at known territories are effective in habitat where observation points are established to observe areas on cliffs, utility towers, or in trees suspected to be nesting habitat. As with aerial surveys, identification criteria for nesting habitat should take place in coordination with the Service, State or Tribal wildlife agencies, and raptor specialists.

Observation posts (OPs) are established during initial reconnaissance of potential or known nest cliffs, and are established in locations that are far enough from the potential nest site to

effectively observe the behavior of the adults (if present) without disturbing nesting behavior. Well-placed OPs provide unobstructed viewing of the potential nest location or of the area to be surveyed; including a broad panorama of the surrounding habitat. Multiple OPs or walking surveys may be necessary to observe potential nest sites. OPs located in front of, and below the potential nest cliff or tree are best. Placing OPs below the potential nest cliff reduces stress if an incubating adult may be present. The distance from an OP to the potential nest site may range from 300 – 1600 meters (latter represents extreme circumstances) from the cliff base to the observer, and generally no greater than 700 meters.

Golden Eagles may use alternative nests. Detection of previously unknown alternate nests and observation of all known alternative nests will become important if Golden Eagles fail in their initial nesting attempt, or are not observed at the probable nest location.

Ground monitoring; known territories

Monitoring to document nesting success at known territories may occur solely via ground observations. Observation of known territories should use the methodology described for ground monitoring of potential habitat (see section VIIc). Dates of all visits to the nesting territory will be recorded; date of confirmation of nesting failure will be key data for site specific and regional analysis.

Nesting outcomes

Fledging success will be determined via the observation of young that are at least 51 days of age, or are known to have fledged from the observed nest. If there is whitewash (Golden Eagle defecation) and a well worn nest, young were previously observed in the nest to be > 4 weeks old during a previous visit, and the young would have been > 51 days old at the time of the visit, and no dead young are found after a thorough ground search, the nesting attempt can be deemed successful.

Nesting failure occurs when a nest where eggs were laid or where incubation behavior was observed fails to have any young reach 51 days of age. If necessary, nesting failure will be confirmed by using a spotting scope to view the nest to determine if dead young are observed. Nesting failures may also be determined if observations of the nest prior to the projected fledge date yields no young or fledglings where eggs or young were previously observed. In these instances observation periods should last 4 hours (consecutively), or are confirmed by aerial survey. If dead young are observed in the nest (i.e. all young are dead), monitoring efforts may cease. Nest failures may also be confirmed by an approach (walk-in) to the nest no more than 4 weeks after fledging was scheduled to occur. Observers will look for dead chicks at the base of the nest cliff or tree, where access is reasonable and safe.

Observers must document the criteria they use to conclude that success or failure occurred.

Summary

- Observation posts for monitoring known territories will be no closer than 300 meters for extended observations, and generally no further than 700 meters, where terrain allows. Maximum OP distance would be 1600 meters.
- To inventory and determine occupancy of cliff systems, there will be *at least* 2 observation periods per season. To determine fledging success, additional observations may (or may not) be necessary.
    - Observation periods will last at least 4 hours for known nest sites, or until territory occupancy can be confirmed.
    - Observation periods will last for at least 4 hours per 1.6 km of cliff system, based from the center point of that cliff complex.
    - Observation periods will be at least 30 days apart for monitoring efforts.
- To collect monitoring data at a known nest territory, there will be at least 2 observation periods per season.
    - Observation periods from ground observation points will last at least 4 hours for known nest sites or until nesting chronology can be confirmed per visit. Observation periods will be at least 30 days apart.

VIII. Observer qualifications

Surveyor experience affects the results of protocol-driven raptor surveys. All observers should have the equivalent of 2 seasons of intensive experience conducting survey and monitoring of Golden Eagle and/or cliff dwelling raptors. That experience may include banding, intensive behavioral monitoring, or protocol-driven survey work. Experience should be detailed and confirmed with references, and provided to action and regulatory agencies. All surveyors should be well-versed with raptor research study design and Golden Eagle behavior and sign, including nests, perches, mutes, feathers, prey remains, flight patterns, disturbance behavior, vocalizations, age determination, etc. **Aerial surveys will be conducted by raptor specialists who have at least 3 field seasons experience in helicopter-borne raptor surveys around cliff ecosystems.**

In lieu of limited or no Golden Eagle experience, ground surveyors should attend at least a 2-day Golden Eagle training session convened with classroom and field components; trainers will be designated by the USFWS/USGS. Inexperienced or limited experience surveyors will be mentored by Golden Eagle specialists for at least 1-2 field seasons, depending on their experience level, and should assist with the preparation of at least 3 surveys and reports over at least 3 years. A Golden Eagle specialist is defined as a biologist or ecologist with 5 or more years of Golden Eagle or cliff dwelling raptor research/survey experience, possession of

state/federal permit allowing capture, handling, and/or translocation of Golden Eagles and/or cliff dwelling raptors; and/or relevant research on raptors published in the peer reviewed literature.

IX. Documentation and accepted notation of territory/nest site and area surveyed

Data for each territory/nest site(s) and area visited will be reported annually to the applicable regional office of the USFWS Division of Migratory Bird Management for collation into a national database.

Minimum data collected at known Golden Eagle territories

Observation of potential sites and known nest territories will produce data helpful to determine territory occupancy, productivity, and fate of the nesting attempt. Each observation and all site specific data collected should include at least;

a) Date of observation,
b) Time of observation(s),
c) Weather during observation,
d) Duration of observation,
e) Name of observer(s),
f) Location of observation,
g) Description of observation.

Data collected during inventory and monitoring will include (at least) the following:

- Territory status [Unknown; Vacant; Occupied-1 eagle; Occupied-2 eagles- laying or non-laying; Breeding successful (chick observed to be at least +51 days-fledging), Breeding unsuccessful (failed-nesting attempt failed after eggs were laid)].
- Nest location (decimal degree lat/long or UTM).
- Nest elevation.
- Age class of Golden Eagles observed.
- Document nesting chronology;
    - Date clutch complete (estimated). Describe incubation behavior observed to derive this date, and/or use backdating from known nestling age);
    - Hatch date (estimated from age of nestlings);
    - Fledge date (known or estimated; see nesting outcomes, pp. 18);
    - Date nesting failure first observed and/or confirmed;
    - Number of young at each visit and at >51 days of age;
    - Digital photographs; a) landscape view of area inventoried, b) landscape view of territory, and c) nest(s); and
    - Substrate upon which the nest is placed (tree species, cliff, or structure).

Additional data that can be collected include (but are not limited to):

- Presence or absence of bands (USGS and VID), patagial tags (number and color), or telemetry unit;
- Forage location (if known);
- Prey items noted (if discerned);
- Height of nest on cliff or in tree, and description of technique used to estimate height;
- Species of tree, type of rock, or type of structure used to support the nest;
- Overall cliff or tree height, and description of technique used to estimate height;
- Nest aspect; and
- Other nesting raptors present nearby.

Each area surveyed under the requirements of this protocol, including surveyed habitat, occupied nesting territory, historical territory, and suspected/alternative nests will be recorded in a standardized manner to allow local, regional, and national data analysis.

Recommended Golden Eagle Territory/site naming convention:

XX^1-XXX^2-XXXXX/XX^3-XXX^4-XX^5 Territory name

XX^1 = State (two letter alpha)

XXX^2 = County (three letter alpha)

XX^3= USGS Quad [five numeric/two letter alpha] (when the territory straddles adjacent quad maps, the quad in which the first nest was found will be used to describe the territory; XX^5 is used to document the locations of alternate nests within a territory)

XXX^4=Assigned Territory number within USGS quad (three numeric)

XX^5=Assigned Nest number within territory in instances of alternate nests (two numeric)

Site name=traditional site name, or if new, use local naming convention (e.g. Upper fork Amundsen Creek, Fort Peck flatland, Farmer Jane's back 40)

Example CA-KER-38512/DG-03-02 Abbot Creek

X. Additional considerations

This interim document primarily contains methods for inventorying and monitoring at nest sites, but the prohibitions against take and the new regulations apply at nest sites and foraging areas, as well as during migration and other non-breeding times. The Service will develop or adopt recommendations for surveys applicable to non-nesting in other documents.

Suitable foraging habitat

Golden Eagles forage close to and far from their nests, i.e. < 6 km from the center of their territories, but have been observed to move 9 km from the center of their territories in favorable habitat (McGrady et al. 2002). These distances may be further in xeric habitat.

Suitable wintering habitat

During winter, Golden Eagles are found throughout the contiguous United States. Inventories for wintering Golden Eagles will encompass all habitat where Golden Eagles have been known to nest, roost, and forage. Refer to Wheeler (2003, 2007) for maps elucidating suitable wintering range.

Winter surveys

Survey information gathered during the non-breeding period is needed to identify foraging areas and determine numerical estimates of use by Golden Eagles. Presence of Golden Eagles during winter surveys does not necessarily mean that breeding individuals are present; however follow-up surveys during the breeding season are necessary to denote occupancy at suspected or known territories.

Migration surveys

The location of migration routes or areas in relation to a proposal that are likely to take Golden Eagles through injury or mortality may have critical implications. Therefore, evaluations should assess whether migratory or transient Golden Eagles are likely to be present during the construction and the life of the project. Other factors to consider include numbers of Golden Eagles moving through the project area, movement patterns (including a three-dimensional spatial analysis), time of day, and seasonal patterns. In the case of wind development, surveys will need to identify the locations of migration routes and movements during migration in relation to proposed turbines and rotor-swept area.

XI. Acknowledgments.

The authors are indebted to the expertise, experience, effort and kindness expended on all phases of this protocol by Dr. Mark Fuller (USGS), Mike Kochert (USGS Emeritis), and Karen Steenhof (USGS Retired). We greatly appreciate the time they took to review multiple drafts, and provide sound advice and guidance where necessary regarding all aspects of Golden Eagle inventory and monitoring. Robert Murphy's comments on earlier drafts were also appreciated. We also appreciated Peter Bloom's input and good humor regarding his observations of Golden Eagle natural history and monitoring, and the cover photograph of a Golden Eagle taken from beneath a calf carcass while he was in a southern California pit trap.

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XIII Glossary

Action agency – an agency or entity authorizing an action or plan, or providing funding for actions and plans.

Active nest (from the regulations**)** — a Golden Eagle nest characterized by the presence of any adult, egg, or dependent young at the nest in the past 10 consecutive days immediately prior to, and including, at present. Applies only to applications for permits to take eagle nests.

Breeding home ranges - the spatial extent or outside boundary of the movement of individuals from Golden Eagle pairs during the course of everyday activities during the breeding season.

Inactive nest (from the regulations**) —** a Golden Eagle nest that is not currently being used by eagles as determined by the continuing absence of any adult, egg, or dependent young at the nest for at least 10 consecutive days immediately prior to, and including, at present. An inactive nest may become active again and remains protected under the Eagle Act.

Inventory –systematic observations of the numbers, locations, and distribution of Golden Eagles and eagle resources such as suitable habitat and prey in an area.

Local area population — the population within the average natal dispersal distance of the nest or nests under consideration (43 miles for bald eagles, 140 miles for golden eagles). Effects to the local area population are one consideration in the evaluation of the direct, indirect, and cumulative effects of take, and the mitigation for such take, under eagle take permits.

Migration corridors - the routes or areas where eagles may concentrate during migration. Golden Eagles begin migrating across a broad front, but tend to concentrate along leading lines (geographical features such mountain ridges) as they move between geographic locations. Golden Eagles are observed in largest numbers along north-south oriented mountain ranges where they soar on mountain updrafts. The species typically avoids lengthy water-crossings. In North America, migrating Golden Eagles concentrate along the Appalachian Mountains in the East and Rocky Mountains in the West.

Management agency - see Action Agency.

Monitoring - inventories over intervals of time (repeated observations), using comparable methods so that changes can be identified. Monitoring includes analysis of inventory data or measurements to evaluate change within or to defined metrics. Monitoring also includes repeated observations of a known nesting territory.

Occupied Nest – a nest used for breeding in the current year by a pair. Presence of an adult, eggs, or young, freshly molted feathers or plucked down, or current years' mutes (whitewash) suggest site occupancy. Additionally, for the purposes of these guidelines, all breeding sites

within a breeding territory are deemed occupied while raptors are demonstrating pair bonding activities and developing an affinity to a given area. If this culminates in an individual nest being selected for use by a breeding pair, then the other nests in the nesting territory will no longer be considered occupied for the current breeding season. A nest site remains occupied throughout the periods of initial courtship and pair-bonding, egg laying, incubation, brooding, fledging, and post-fledging dependency of the young.

Unoccupied Nests - those nests not selected by raptors for use in the current nesting season. Nests would also be considered unoccupied for the non-breeding period of the year. The exact point in time when a nest becomes unoccupied should be determined by a qualified wildlife biologist based upon observations and that the breeding season has advanced such that nesting is not expected. Inactivity at a nest site or territory does not necessarily indicate permanent abandonment.

Productivity — the mean number of individuals fledged per occupied nest annually.

Survey –is used when referring to inventory and monitoring combined.

EXHIBIT 431

The Auk 114(4):673–687, 1997

SPATIAL USE AND HABITAT SELECTION OF GOLDEN EAGLES IN SOUTHWESTERN IDAHO

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ABSTRACT.—We measured spatial use and habitat selection of radio-tagged Golden Eagles (*Aquila chrysaetos*) at eight to nine territories each year from 1992 to 1994 in the Snake River Birds of Prey National Conservation Area. Use of space did not vary between years or sexes, but did vary among seasons (home ranges and travel distances were larger during the nonbreeding than during the breeding season) and among individuals. Home ranges were large, ranging from 190 to 8,330 ha during the breeding season and from 1,370 to 170,000 ha outside of the breeding season, but activity was concentrated in small core areas of 30 to 1,535 ha and 485 to 6,380 ha during the breeding and nonbreeding seasons, respectively. Eagles selected shrub habitats and avoided disturbed areas, grasslands, and agriculture. This resulted in selection for habitat likely to contain their principal prey, black-tailed jackrabbits (*Lepus californicus*). Individuals with home ranges in extensive shrubland (n = 3) did not select for shrubs in the placement of their core areas or foraging points, but individuals in highly fragmented or dispersed shrublands (n = 5) concentrated their activities and foraged preferentially in jackrabbit habitats (i.e. areas with abundant and large shrub patches). As home ranges expanded outside of the breeding season, individuals selected jackrabbit habitats within their range. Shrubland fragmentation should be minimized so that remaining shrub patches are large enough to support jackrabbits. *Received 1 May 1996, accepted 6 May 1997.*

IN SOUTHWESTERN IDAHO, the demography and behavior of Golden Eagles (*Aquila chrysaetos*) are closely associated with variation in the abundance of black-tailed jackrabbits (*Lepus californicus*). Jackrabbit populations fluctuate, peaking at 7-to-12 year intervals (Johnson and Peek 1984). More eagles lay eggs and produce more offspring when jackrabbits are abundant than when jackrabbit populations crash (Steenhof et al. 1997), and eagles use alternative prey when jackrabbits decline (Steenhof and Kochert 1988). The importance of jackrabbits to eagles suggests that eagles should locate territories and concentrate foraging activities in habitats most likely to contain jackrabbits. We tested this hypothesis by relating spatial-use patterns of eagles to habitats associated with black-tailed jackrabbits. We then could indirectly describe habitat use by eagles relative to their main prey and quantify habitat characteristics meaningful to land managers.

Although descriptions of average behavior may be most easily understood by biologists and translated into management policy, they do not capture variation among individual animals. If such variation is substantial and ignored by focusing on population averages, conservation strategies and biological descriptions will be inaccurate and rarely effective. Describing individual variation, attempting to understand it, and using this to provide context-specific management recommendations would be preferable. Furthermore, many animals select and use resources at various scales (Allen and Starr 1982, O'Neill et al. 1988, Wiens 1989).

Here, we explore individual variation in Golden Eagle diet, spatial use, and habitat selection and show that, although certain habitat types are consistently preferred, the scale at which individuals exhibit selection for them is variable and dependent on landscape attributes and possibly individual experience. This is likely to be common in long-lived, permanent residents that maintain year-round, all-purpose territories, such as Golden Eagles (Beecham and Kochert 1975, Dunstan et al. 1978,

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TABLE 1. Golden Eagle territories where behavior, productivity, and home-range characteristics were studied, Snake River Birds of Prey National Conservation Area, 1991 to 1994.

Number of eagles		Individuals used in home-range estimation			Years locations were used in home-range estimation			
Captured	Instrumented	Sex	Age	Capture date	1991	1992	1993	1994
				Black Butte				
2	1	M	Ad	12 Nov 91		X	X	X
				Beercase				
2	2	M	Ad	18 Jan 92		X	X	X
				Wildhorse				
2	2	F	Ad	14 Oct 91		X	X	X
		M	Ad	16 Dec 92			X	X
				PP&L 119				
5	4	M	Ad	19 Feb 91	X	X	X	
		F	Ad	23 Oct 92		X	X	X
		M	Subad	11 Mar 94				X
				Pole 369[a]				
0	0	F	Subad	17 Dec 91			X	
				Grand View Sand Cliff				
2	2	F	Subad	17 Dec 91	X			
		M	Ad	24 Oct 92		X	X	X
				Ogden				
1	1	M	Ad	14 Dec 92		X	X	X
				Beecham				
1	1	M	Ad	22 Nov 91	X	X	X	X
				Cabin				
12	2	F	Ad	06 Dec 91	X	X	X	X
		M	Ad	12 Apr 94				X

[a] Individual moved from Grand View Sand Cliff to Pole 369.

Collopy and Edwards 1989), because learning and experience may shape behavior (Mayr 1974).

METHODS

Site selection and trapping.—We studied Golden Eagles on 9 of 20 historically occupied territories (defended areas including nesting and foraging sites) along a 140-km stretch of the Snake River canyon (from Walter's Ferry to C. J. Strike Reservoir) within the Snake River Birds of Prey National Conservation Area (NCA). Approximately 75% of historically occupied territories were actually occupied during our study. We selected our subsample of territories to provide a representative sample of currently occupied landscapes in the NCA (none was inactive for more than 5 years from 1970 to 1991, four had >50% of the area within a 2.66-km radius circle centered at traditionally used nests burned by wildfires during the previous 10 years, and four had <30% of this area burned). One territory was added in 1993 when a radio-tagged female left her territory and joined an untagged eagle at a new site.

From 1991 to 1994, we captured 27 individuals in target territories (Table 1). Sex was determined by observations of copulation and measurements of body mass and footpad length (Edwards and Kochert 1986). Thirteen birds were instrumented with 65-g, solar-assisted transmitters secured by a 10-g harness of 19-mm wide Teflon webbing and a leather sternum patch; two were instrumented with 15-g tail-mounted transmitters. Transmitters may have reduced productivity in one year of study but did not influence behavior and spatial use (Marzluff et al. 1997). More than one individual was captured and radio-tagged in some territories because of transmitter failure or removal, eagle dispersal, and deliberate attempts to catch both breeders.

We monitored the behavior and productivity of radio-tagged Golden Eagles at eight territories during 1992, nine during 1993, and eight during 1994 (Table 1). Both the male and female were tagged in one of the eight territories in 1992, in two of the nine terri-

tories in 1993, and in three of the eight territories in 1994. To avoid concerns over pseudoreplication, we used the territory, not the individual on the territory within a year, as the experimental unit unless otherwise noted.

We captured eagles with radio-triggered bow nets (1991 and 1994), noosed lures (1991), and padded leghold traps (1991, 1992, 1993, 1994; Bloom 1987). We observed traps from 1 to 2 km away and broadcast noises from two-way radios buried near traps to reduce the frequency of catching nontarget species.

Location estimates and behavior.—Instrumented eagles were selected randomly and followed for 6-h observation periods, three to four days per month. Eagles in each territory were followed approximately weekly to balance observation effort across territories. We located eagles for visual observation, then continuously recorded time and activity data, particularly noting where hunting forays occurred and characterizing habitats in those areas. Locations were plotted (± 100 m) in the field on 1:24,000 scale topographic maps assisted by aerial photographs. Locations were obtained for all perched birds, all extreme points used by birds each day, and most points where birds soared. Perched locations included roost sites as well as hunting and resting sites. We also estimated the location of all copulations, undulating flights, and hunting attempts. Travel routes among perches or soaring areas were recorded, but estimates of point locations along these routes were not made. We used all observations on both members of the pair to determine the location of hunting attempts and prey captures. Hunting forays were any flights that included an attempt to capture prey (i.e. a steep dive or chase of potential prey).

Breeding status and habitat.—We considered eagles to have laid eggs if one member of the pair was seen in an incubating posture, or if eggs were seen. In 1992 and 1993, nestlings at sites tended by radio-tagged parents were banded and marked with uniquely numbered patagial tags to aid in observations within territories during the winter and to identify these birds within their parents' territories.

In a concurrent study, Knick et al. (1997) determined areal coverage of habitats from Landsat thematic mapper satellite imagery classified into big sagebrush (*Artemisia tridentata*)/green rabbitbrush (*Chrysothamnus viscidiflorus*), winterfat (*Ceratoides lanata*), salt-desert shrub (*Atriplex confertifolia, A. canescens, Sarcobatus vermiculatus*), grassland (*Poa secunda, Bromus tectorum, Sitanion hystrix*), cliff, and water. They also delineated all areas used for agriculture since 1979 (including fallow fields) from a composite of the 1979 Snake River Birds of Prey vegetation map (USDI 1979), 1993 Bureau of Reclamation agriculture maps, and the classified satellite imagery. Resolution of the habitat map was 50 m (resampled from 30-m pixels in the satellite image). Knick et al. (1997) used >5% ground cover of shrubs to separate shrub and grassland classes. Accuracy of the classification in separating shrub and grassland areas was 80%; accuracy in separating individual habitat classes was 64% (Knick et al. 1997).

Knick and Dyer (1997) developed an index of black-tailed jackrabbit habitats from a multivariate analysis that included number of agriculture cells, a habitat diversity index, number of shrub cells, shrub patch characteristics, and an index of landscape patchiness. The habitat index, scaled into 10% intervals, represented the probability of similarity of the habitat at each 50-m gridded cell in a Geographical Information System map to the mean habitat vector associated with jackrabbits. We used habitat associations of jackrabbits during low population phases and spring/early summer seasons. These were the conditions during the majority of our eagle observations, but jackrabbit population phases and season have little effect on jackrabbit habitat associations (Knick and Dyer 1997). We emphasize that the map of the jackrabbit habitat index did not predict the actual presence of jackrabbits, but rather the similarity of a given cell to habitats used by jackrabbits.

Analyses.—We used all unique locations visited by eagles during an observation session in home-range analyses rather than using a time interval to select "independent" locations. Use of unique locations reduced dependency by removing repeatedly visited locations within a sampling day, but it did not reduce the estimation of the maximum area used by an eagle. However, because many locations within a range were visited repeatedly each day and these tended to be near the center of the range, the exclusion of repeat locations resulted in an expansion of core areas. Because different radio-tagged individuals breeding within a given territory showed similar ranging habits, we used all unique locations from both eagles to define the home range associated with a territory. The nest site constituted a single observation for home-range analyses, even though it was visited multiple times.

We separated our locations into two seasons, breeding and nonbreeding. We defined breeding as the time from when eagles were first observed building nests or incubating until the end of the postfledging dependency period or the breeding attempt failed; nonbreeding included all times not within the breeding period. Therefore, seasons were of different duration for each individual territory.

We analyzed all four years of data using a two-factor repeated-measures ANOVA, with travel distances by year and season as the repeated measures. In this analysis we used only the five territories that were observed every year and where transmitter failure did not limit observations. Mean seasonal travel distances did not differ among years ($P = 0.95$); therefore, we pooled data across years and used data from eight territories to examine seasonal and ter-

ritorial differences in travel distance using a two-factor (season and territory) ANOVA.

We used Ranges V software (Kenward and Hodder 1995) to calculate a variety of home-range estimates for comparative purposes, but we used only selected methods for analysis of habitat use and seasonal differences in home-range size. We used concave polygons with edge length restricted to half the minimum range diagonal to represent eagle home ranges. Concave polygons were most appropriate for estimation of habitat available to foraging eagles within their home ranges because they minimized territory overlap, included all known locations of eagles, and did not rely upon statistical distributions of locations. Harmonic-mean and convex-polygon methods were less satisfying because their reliance on the statistical distribution of locations resulted in extrapolation beyond locations we knew eagles visited, and, as a consequence, included extensive overlap between adjacent territories that we did not observe in the field.

We investigated habitat selection at three scales. First, we determined if eagles selected or avoided certain habitats in establishing a home range by comparing habitat used in concave polygon home ranges with habitat available within the study area. We defined available habitat as that area on either side of the Snake River canyon within the maximum travel distances observed for radio-tagged birds. Buffer areas, derived from maximum travel distances, were determined separately for the breeding and nonbreeding seasons. Second, we determined if eagles selected or avoided certain habitats within their home range by comparing the habitat used within core areas defined by hierarchical, incremental cluster analysis with a "nearest neighbor" joining rule (Kenward 1987) with habitat available within each individual's concave home range. We examined habitat in clusters that included 90 and 95% of locations separately. Most territories showed little change in the rate of area increase for cluster polygons that included from 20 to 90% of the locations but typically increased sharply thereafter, both in area within ranges and size variation between ranges, which indicated that the remaining 5 to 10% of locations were outliers. Third, we determined if foraging habitat was selected from within high-use areas by comparing the habitat within 100 m of locations where we saw eagles attempt to capture prey with the habitat available within core areas.

We determined the importance of habitat use with selection ratios (proportion of habitat class used/proportion of habitat type available) for each habitat type (Manly et al. 1993). We normalized selection ratios by using their natural logarithm. We viewed the individual territory as our sampling unit and calculated average selection ratios for our sample of territories. We calculated a 95% confidence interval around each ratio average after a Bonferroni adjustment for multiple comparisons. Selection ratios that did not include 0 in their confidence interval were evidence of significant ($\alpha = 0.05$) avoidance (ratio < 0) or selection (ratio > 0). We used compositional analysis (Aebischer et al. 1993) to test for individual differences in selection or avoidance of habitats.

RESULTS

SPATIAL-USE PATTERNS

Travel distance.—Distance traveled from the nest varied among individuals and between seasons. Eagles traveled farther from their nests outside of the breeding season ($\bar{x}$ = 3,036.1 ± SE of 241.6 m, n = 248) than during the breeding season ($\bar{x}$ = 1,046.8 ± 366.6 m, n = 121; repeated-measures ANOVA, F = 9.1, df = 1 and 4, P = 0.04). Annual variation in distance traveled was not significant (multivariate F = 0.05, df = 2 and 3, P = 0.95). However, individuals differed in travel distance between seasons (interaction of individual and season in two-way ANOVA without repeated measures, F = 2.29, df = 7 and 353, P = 0.03). Males ($\bar{x}$ = 1,963.7 ± 251.0 m, n = 253) and females ($\bar{x}$ = 2,094.2 ± 401.0 m, n = 116) traveled similar distances (F = 0.08, df = 1 and 365, P = 0.78).

An individual's travel distance from the nest was related to behavior (Fig. 1). Most of the extreme travel distances were hunting forays or undulating flights. A few individuals did most of their hunting (n = 2) and undulating (n = 2) near the nest.

Home range.—Similar patterns of travel also were reflected in individually and seasonally variable home ranges. Home-range estimators in Table 2 are for comparative purposes; we limited our discussion to concave polygons, which best described the total area used by eagles, and to clusters that removed extreme travels and defined high use (i.e. "core") areas.

Eagle breeding ranges encompassed 190 to 8,330 ha and expanded to 1,370 to 170,000 ha outside of the breeding season (Table 2). The average size of ranges was 2,280 ± SD of 2,625 ha (n = 8) during the breeding season and 30,484 ± 59,909 ha (n = 8) during the nonbreeding season. The large standard deviations resulted from extreme variation among individuals.

Home-range boundaries have remained fairly consistent for many years. Three of the territories we studied (a, b, i) also were studied

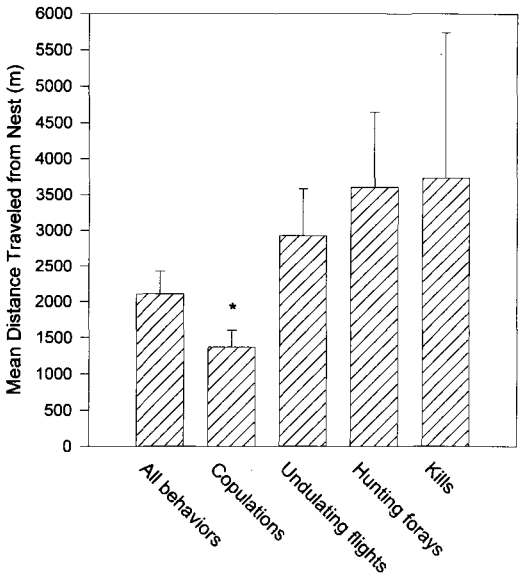

FIG. 1. Distances traveled by adult Golden Eagles where copulations, undulating flights, hunting forays, and kills were observed. Travel distance was calculated for each individual (n = 9) and averaged (± SE) across individuals. Significantly (*, $P < 0.05$) extreme average travel distances are indicated when the 95% confidence interval around the travel distance for a particular activity does not include the average travel distance to all locations.

with radiotelemetry in the 1970s (Dunstan et al. 1978). Home-range sizes in the 1970s and 1990s were similar (two ranges were larger and one was smaller in the 1970s than in the 1990s; $\bar{x}$ absolute difference in convex polygons = 1,256 ± SE of 413 ha), and ranges in the 1990s overlapped those from the 1970s by an average of 57.6 ± SE of 15.8%.

Breeding ranges of neighboring pairs overlapped only slightly ($\bar{x}$ = 3.7 ± 1.7%, n = 10; Fig. 2A), suggesting territorial behavior. Interactions between neighbors were rarely observed because of the mutually exclusive territories. Expanded ranges outside of the breeding season overlapped neighboring ranges more than during the breeding season ($\bar{x}$ = 22.1 ± 9.4%, n = 10; Fig. 2B) and included foraging areas frequented by wintering and nonbreeding eagles.

Nonresidents were captured in three territories (a, d, i) outside of the breeding season. Ten were captured in one territory (i), and only two offspring of residents were among those captured (one in territory d and one in i). Aggression between residents and nonresidents was extremely rare within and outside of the breeding season.

Eagles concentrated their activity within several frequently used cores. Cores defined by clusters of similar use indicated that 95% of the eagle locations were within 14.4 ± 3.1% of their breeding ranges and 25.3 ± 5.8% of their nonbreeding ranges (Fig. 2A, B). Ninety percent of the locations were within 6.9 ± 1.7% of breeding ranges and 12.6 ± 3.2% of nonbreeding ranges.

PREY

Black-tailed jackrabbits, Townsend's ground squirrels (*Spermophilus townsendii*), and Rock Doves (*Columba livia*) were the most commonly observed prey taken by eagles during our years of study (Fig. 3). Prey taken within and outside of the breeding season differed, with ground squirrels dominating the breeding season and jackrabbits dominating the nonbreeding season (comparing numbers of jackrabbits, ground squirrels, Rock Doves, and other prey for 1992 to 1994; Fisher's exact test, P = 0.02). Use of jackrabbits peaked in 1992 and then declined. Rock Doves, reptiles, yellow-bellied marmots (*Marmota flaviventris*), and Nuttall's cottontails (*Sylvilagus nutallii*) were taken more frequently as jackrabbit use declined.

Jackrabbits varied in importance among individual eagle pairs (pooled data from 1992 to 1994; Fisher's exact test, $P < 0.001$ for six pairs with $n \geq 6$ captures). One pair (b) took predominantly (8 of 10 captures) jackrabbits. However, the other pairs took jackrabbits much less frequently (jackrabbits comprised ≤7% of the prey taken by pairs a, f, g, and h). Rock Doves, waterfowl, and marmots comprised the remainder of the prey taken.

HABITAT SELECTION

Vegetation.—Eagle territories occurred along a gradient of shrubsteppe habitats from big sagebrush, winterfat, and green rabbitbrush to salt-desert shrubs. Additionally, wildfires burned significant portions of some territories prior to our study, resulting in varying amounts of grassland among territories (Fig. 2A, B).

Selection of habitat classes.—The variation in

TABLE 2. Estimated areas (ha) of home ranges (concave and convex polygon, harmonic mean) and core areas (cluster analysis) of Golden Eagle territories (letters denote territories in Figures 2 and 5). Data combined across years and birds but analyzed separately for nonbreeding (N) and breeding (B) seasons.

Season	*n*	Concave 100%	Convex 100%	Harmonic 100%	Harmonic 95%	Core 95%	Core 90%
				Black Butte (a)			
N	489	1,376	1,610	2,373	847	485	102
B	312	1,071	1,175	2,670	827	289	161
				Beercase (b)			
N	298	11,261	18,541	61,792	10,110	2,581	938
B	325	8,331	9,759	22,929	5,536	1,535	565
				Wildhorse (c)			
N	261	36,925	36,925	109,280	29,073	2,729	2,115
B	96	663	875	1,314	1,021	127	74
				PP&L 119 (d)			
N	250	6,076	6,762	16,621	6,110	1,535	755
B	112	1,032	2,290	13,686	4,206	254	120
				Pole 369 (e)			
N	22[a]	318	450	559	254	159	136
B	94	506	985	2,331	446	53	35
				Grand View (f)			
N	297	176,010	207,069	614,675	86,810	6,387	2,035
B	116	194	336	877	94	30	5
				Ogden (g)			
N	233	4,443	4,697	9,135	3,352	1,125	738
B	121	2,576	4,304	15,046	3,251	658	366
				Beecham (h)			
N	453	3,721	4,625	16,582	2,001	487	194
B	277	3,055	3,471	29,818	323	86	31
				Cabin (i)			
N	167	4,061	4,332	9,721	3,698	1,314	494
B	95	1,321	3,793	11,155	1,311	337	127

[a] Range sizes suspect owing to small sample size.

vegetation among territories was evident when we compared habitat classes found within breeding and nonbreeding ranges with available habitats within 4.5 km (the average maximum travel distance during the breeding season) or 9.5 km (the average maximum travel distance during the nonbreeding season) of the canyon rim. Most eagle home ranges had more sagebrush/rabbitbrush, more cliff/rock outcrop, less grassland, and less agriculture than expected from availability (see Table 3). Variation in selectivity among eagles was large (Table 3), and the resulting habitat composition of home ranges varied significantly among individuals (compositional analysis; breeding season, $\lambda = 0.16$, $\chi^2 = 16.5$, df = 5, $P < 0.01$; nonbreeding season, $\lambda = 0.20$, $\chi^2 = 14.4$, df = 5, $P < 0.05$). Most variation was due to varying amounts of sagebrush/rabbitbrush, salt-desert shrubs, grassland, and rock outcrop in home ranges. Individuals were more consistent in including less winterfat, agriculture, and water than expected based on availability in their ranges, especially during the breeding season (Table 3).

Eagle selection for shrubland and avoidance of grassland and agriculture was accentuated when we compared habitats in core areas with those available within each individual's home range (see Table 3). Avoidance of agriculture was significant and consistent among individuals during both seasons, especially within 90% core areas. Most individuals avoided grassland and selected shrubland, but individual variation precluded overall significance (Table 3).

Use and availability of habitats.—Selection coefficients are proportions and can mistakenly

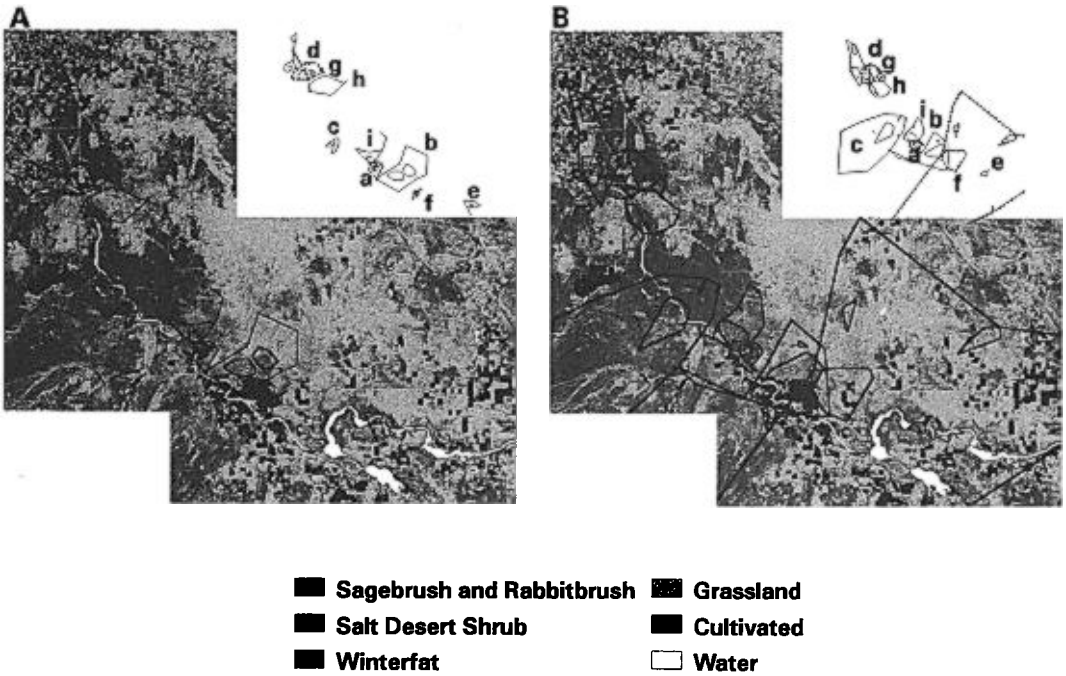

FIG. 2. Home range (solid lines, concave polygons) and core area (polygons within home ranges, 95% use area, cluster analysis) of eagles during (A) and outside of (B) the breeding season. Habitat of the study area is shown in the background to illustrate variation in shrub, grassland, and agriculture among territories. Small letters denote territory identification.

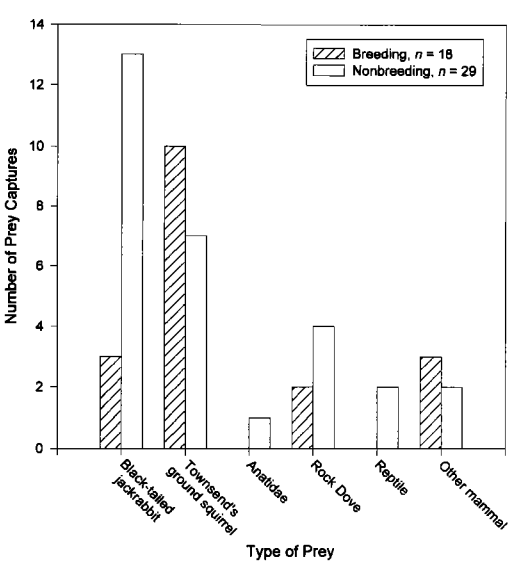

FIG. 3. Prey items captured by Golden Eagles, 1991 to 1994.

indicate strong selection or avoidance of very rare habitats because small absolute differences in use and availability are proportionately much larger than are similar absolute differences between common habitats. This potential problem contributed to the general avoidance of winterfat and water, and selection for cliff habitats (Table 3). The availability and use of these three habitats were very low (Fig. 4A, B, C).

Avoidance of agriculture was unlikely to be an artifact of habitat rarity (Fig. 4). Agriculture was avoided by all but one eagle, even though it represented as much as 24% of the available habitat. The individual that selected a core area with a relatively large amount of agriculture during the breeding season (Individual d) appeared to select agriculture because its territory had a substantial amount (18%) of agriculture available. Selection for agriculture in the nonbreeding season (Fig. 4A, B) and around foraging points (Fig. 4C) was suspect because the availability of agriculture used to compute those selection coefficients was very small.

TABLE 3. Average selectivity ($\bar{x}$ ± SE) by nine Golden Eagles for habitat types at three scales. The mean selection coefficient (ln[habitat use/habitat availability]) indicates general avoidance (negative values) or preference (positive values) for each habitat class. The number of eagles selecting each class (use > availability) is shown to indicate consistency of habitat selection among individuals.

Habitat class	Nonbreeding season		Breeding season	
	Selection coefficient	No. eagles	Selection coefficient	No. eagles
Home range				
Sagebrush/rabbitbrush	−0.03 ± 0.23	6	0.12 ± 0.21	7
Salt-desert shrub	−0.49 ± 0.42	4	0.05 ± 0.53	3
Winterfat	−0.84 ± 0.55	4	−1.92 ± 0.82	2
Grassland/disturbed	−0.13 ± 0.09	3	−0.14 ± 0.13	3
Agriculture	−1.84 ± 0.96	3	−2.27 ± 0.94	3
Cliff	0.75 ± 0.48	5	0.29 ± 0.62	6
Water	−0.49 ± 0.42	3	−1.73 ± 0.85	2
95% Core area				
Sagebrush/rabbitbrush	0.13 ± 0.12	6	0.22 ± 0.16	7
Salt-desert shrub	0.24 ± 0.14	7	0.24 ± 0.32	5
Winterfat	−0.66 ± 0.31	2	−1.07 ± 0.51	2
Grassland/disturbed	−0.03 ± 0.09	5	−0.10 ± 0.09	2
Agriculture	−0.40 ± 0.21	1	−2.43 ± 0.80*	1
Cliff	0.55 ± 0.29	7	0.72 ± 0.21*	7
Water	−0.85 ± 0.80	6	−0.68 ± 0.91	3
90% Core area				
Sagebrush/rabbitbrush	0.26 ± 0.12	7	0.17 ± 0.22	7
Salt-desert shrub	0.20 ± 0.28	6	0.54 ± 0.40	5
Winterfat	−1.34 ± 0.51*	3	−1.69 ± 0.77	2
Grassland/disturbed	−0.13 ± 0.08	2	−0.20 ± 0.20	3
Agriculture	−3.16 ± 1.01*	0	−3.11 ± 0.85*	0
Cliff	0.86 ± 0.45	7	0.26 ± 0.70	7
Water	−1.72 ± 0.99	3	−1.93 ± 1.16	3

*, $P < 0.05$ (avoidance or preference different from availability).

Our evidence that sagebrush/rabbitbrush and salt-desert shrub habitats were selected was strengthened because these habitats were common yet included in home ranges, core areas, and around foraging points at frequencies that exceeded general availability. Sagebrush/rabbitbrush appeared to be more important than salt-desert shrub because it comprised a larger percentage of used habitats at all levels of comparison (Fig. 4).

Individual variability in selectivity for sagebrush/rabbitbrush tended to be correlated with the availability of those shrubs within a home range. Individuals tended to be more selective for sagebrush/rabbitbrush when it was relatively rare within their home range (depending upon season and level of comparison, r values ranged from −0.68 to −0.39, $n = 9$ in each case), but this relationship was only significant during the breeding season when selectivity within the 95% core area was compared with availability in the home range ($P = 0.04$, all other P-values < 0.29).

Avoidance of grassland by most individuals at all levels of comparison, especially during the breeding season, was not due to the rarity of grassland. Grassland was the most common habitat type regardless of season or level of comparison (Fig. 4). Even though it was used less than expected based on availability, grassland remained a dominant feature of eagle home ranges, core areas, and foraging locations, regardless of season. Individual variability in avoidance of grassland was not correlated with the abundance of grassland within home ranges. In most seasons and levels of comparison, eagles with the largest amount of grassland in their home range avoided it, but these relationships were weak (all r-values < 0.50, P-values > 0.17).

Selection for jackrabbit habitat.—Jackrabbit habitats varied significantly among territories (compositional analysis; breeding season, $\lambda = 1.29 \times 10^{-16}$, $\chi^2 = 329.3$, df = 9, $P < 0.001$; nonbreeding season, $\lambda = 2.57 \times 10^{-14}$, $\chi^2 = 281.6$, df = 9, $P < 0.001$). Five territories (a, b, f, h, i)

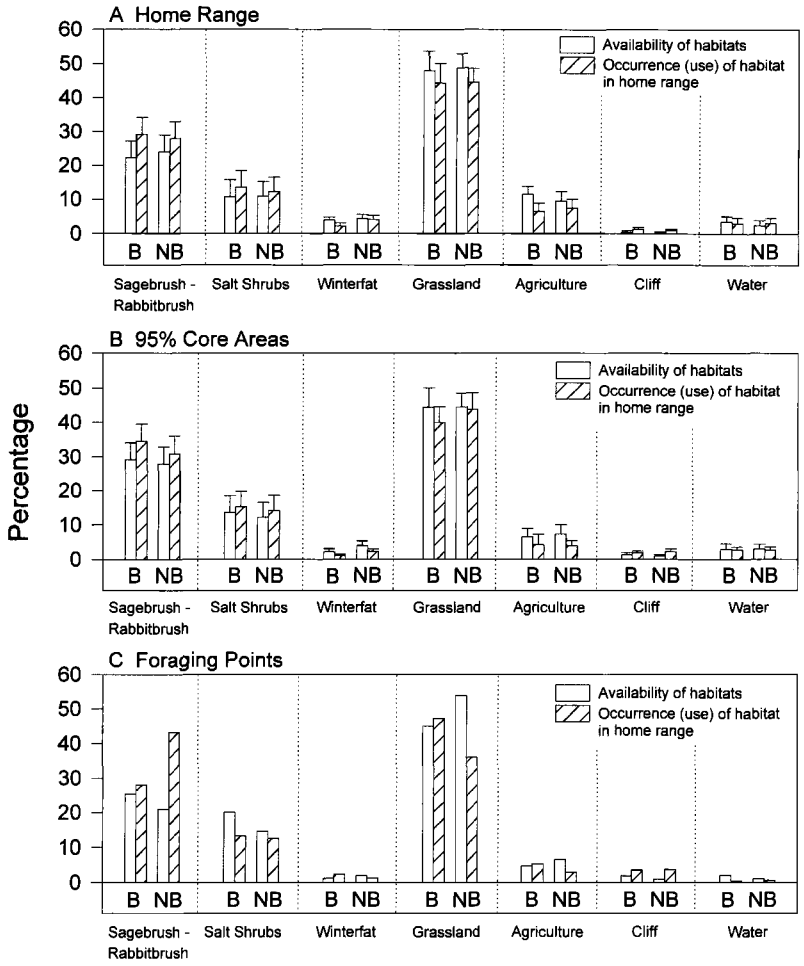

FIG. 4. Availability and use of habitat classes during the breeding and nonbreeding season. Use and availability is plotted for all nine territories in comparisons of home ranges with the study area (A) and of core area with home range (B). Data were insufficient to analyze habitat around foraging points separately for individuals, so all individuals were pooled (C). Values are $\bar{x} \pm$ SE.

contained lower indexes of jackrabbit habitat, three territories (c, d, g) contained higher indexes, and one territory (e) contained intermediate indexes compared with availability in the study area (Fig. 5A, B).

Overall, eagles in the nine territories studied did not select or avoid habitats based on the probability of supporting jackrabbits (Table 4). However, some individuals were more selective than others. Five pairs (a, b, c, f, i) centered their 95% core areas within the best jackrabbit habitat available within their home range during the breeding season (Fig. 5A). All five pairs had territories containing less sagebrush/rabbitbrush than expected based on availability ($\bar{x}$ selection coefficient = $-0.23 \pm$ SE of 0.29) and less absolute occurrence of sagebrush/rabbitbrush ($\bar{x}$ = 20.8 ± 5.95%) than the other four pairs ($\bar{x}$ selection coefficient = 0.56 ± 0.12; Mann-Whitney $U = 19$, $P = 0.03$; $\bar{x}$ abundance = 39.6 ± 4.08%; $U = 19$, $P = 0.03$). Territories of pairs that selected for jackrabbit habitat had lower jackrabbit habitat indexes ($\bar{x}$ index = 0.34 ± 0.07) than territories of other eagles ($\bar{x}$ = 0.48 ± 0.06), but this difference was not significant ($U = 14$, $P = 0.33$).

In contrast to the breeding season, few eagles selected for jackrabbit habitats within core areas outside of the breeding season. Only one pair (i) had a 95% core area that included the best jack-

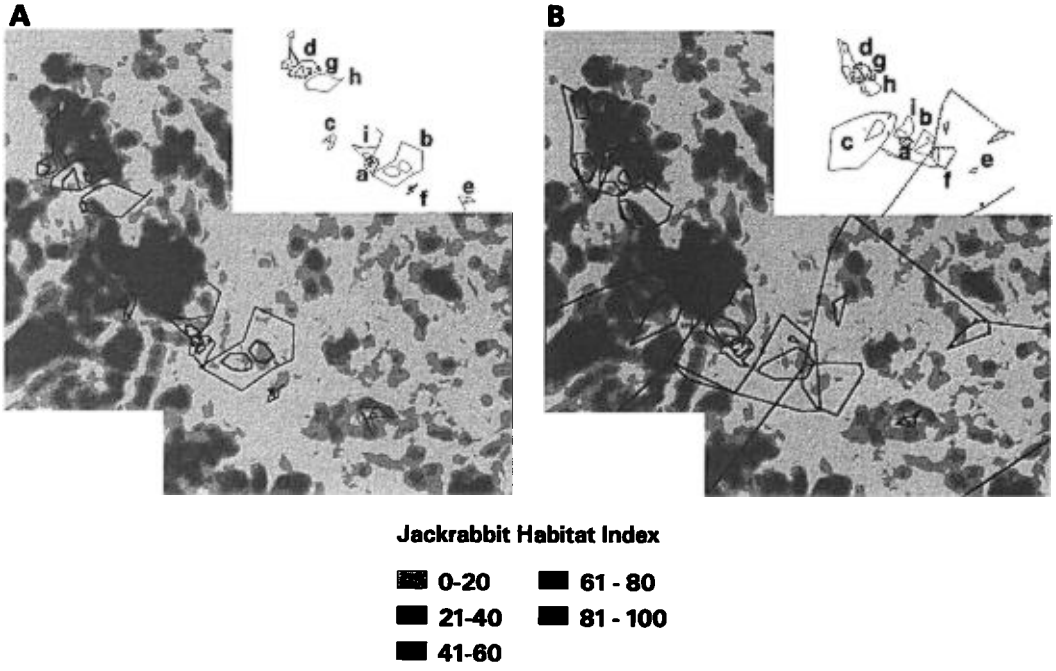

FIG. 5. Occurrence of black-tailed jackrabbit habitat in Golden Eagle home ranges (solid lines, concave polygons) and core areas (polygons within home ranges, 95% use area, cluster analysis) during (A) and outside of (B) the breeding season. Shading indicates the similarity of habitat at a given location to habitat used by jackrabbits. Progressively darker shading indicates habitats of progressively higher quality for jackrabbits. Small letters denote territory identification.

TABLE 4. Average selectivity ($\bar{x} \pm$ SE) by nine Golden Eagles for black-tailed jackrabbit habitat types at three scales. The mean selection coefficient (ln[habitat use/habitat availability]) indicates general avoidance (negative values) or preference (positive values) for each habitat class. The number of eagles selecting each class (use > availability) is shown to indicate consistency of habitat selection among individuals.

Jackrabbit index class	Nonbreeding season		Breeding season	
	Selection coefficient	No. eagles	Selection coefficient	No. eagles
		Home range		
Highest 30%	−2.50 ± 1.15	3	−2.43 ± 1.23	3
Middle 40%	−0.03 ± 0.18	5	−0.64 ± 0.64	3
Lowest 30%	−0.16 ± 0.23	5	−0.23 ± 0.29	5
		95% Core area		
Highest 30%	−0.98 ± 0.65	1	−1.59 ± 1.00	2
Middle 40%	−0.02 ± 0.24	4	0.03 ± 0.28	5
Lowest 30%	0.01 ± 0.17	6	−0.61 ± 0.86	4
		90% Core area		
Highest 30%	−1.15 ± 0.64	1	−2.23 ± 1.23	2
Middle 40%	−0.58 ± 0.82	6	−2.00 ± 1.19	2
Lowest 30%	−0.01 ± 0.13	4	−0.48 ± 0.86	7

rabbit habitat available in its home range, and one other (b) had a 90% core that included some of its best jackrabbit habitat (Fig. 5B).

Foraging locations.—Selection of foraging locations within core areas differed between the breeding and nonbreeding season (Fig. 6). During the breeding season, individuals used winterfat shrublands, cliffs, and agriculture more frequently than expected; sagebrush/rabbitbrush was used in proportion to availability. As a result, eagles did not select foraging points in jackrabbit habitat within core areas during the breeding season. In contrast, during the nonbreeding season foraging points were primarily in sagebrush/rabbitbrush and along cliffs. Eagles also foraged within the best jackrabbit habitat inside their core areas during the nonbreeding season.

Interrelationships of Habitat Quality, Range Size, and Eagle Productivity

Home-range size was not significantly related to eagle productivity. Breeding-range size tended to increase as the total number of young fledged from 1992 to 1994 increased ($r = 0.56$, $n = 9$, $P = 0.12$). Size of the nonbreeding range and size of core areas, regardless of season, were less closely correlated with productivity (all Ps > 0.25).

Two distinct groups of territories were evident during the breeding season. Pairs a, b, f, h, and i had a scarcity of shrubland associated with jackrabbits in their territories (Figs. 2, 5). In contrast, pairs c, d, and g had an abundance of shrubland associated with jackrabbits (Figs. 2, 5). Variation in habitat quality was not significantly related to differences in home-range size during the breeding season (high-quality territories, $\bar{x} = 1{,}423 \pm 586$ ha, $n = 3$; low-quality territories, $\bar{x} = 2{,}794 \pm 1{,}460$ ha, $n = 5$; $U = 5$, $P = 0.46$) or during the nonbreeding season (high-quality territories, $\bar{x} = 15{,}814 \pm 10{,}566$ ha, $n = 3$; low-quality territories, $\bar{x} = 39{,}286 \pm 34{,}221$ ha, $n = 5$; $U = 10$, $P = 0.46$). Territories in poor jackrabbit habitats had similar productivity compared with those in good jackrabbit habitats (total number of young fledged from 1992 to 1994; high-quality territories, $\bar{x} = 0.67 \pm 0.67$, $n = 3$; low-quality territories, $\bar{x} = 2.4 \pm 0.81$, $n = 5$; $U = 3$, $P = 0.17$).

Discussion

Golden Eagles in our study varied considerably in patterns of spatial use. Size of the home range, size of the core area, and travel distances for various activities varied by two orders of magnitude among individuals. Habitat composition, potential prey abundance, and individual preferences developed by long-lived, permanent residents likely account for much of this variation. Eagles do not simply maximize home-range size, nor should they, because their breeding success was only weakly correlated with range size. Rather, eagles adjusted their ranging and foraging behavior to take advantage of the types and configuration of prey habitat found in the vicinity of their nest. Where high-quality jackrabbit habitat was abundant, pairs foraged evenly throughout the shrublands and had relatively small home ranges (e.g. pairs c, d, g; Figs. 2, 5). However, pairs in territories with little sagebrush/rabbitbrush (where jackrabbits were expected to be scarce) showed two patterns of space use that may reflect individual experiences: they either ranged over large areas and concentrated their use in the better habitats for jackrabbits (pairs b, f; Figs. 2, 5), or they restricted their activities to a small area of cliff and riparian habitat around their nests (pair a; Figs. 2, 5). Pairs that maintained small territories took fewer jackrabbits and more alternate prey, notably Rock Doves, waterfowl, and marmots found in the cliff and riparian habitats. Thus, quality of habitat is more important than quantity, but "quality" habitat comes under a variety of guises depending upon habitat availability and eagle prey selection (riparian habitat [Pair a], agricultural lands [Pair d], or shrublands [other pairs]).

Consistencies in habitat selection became more apparent as we refined our assessment of selection from the scale of the territory, to the scale of the core area, to the foraging point. This may indicate the scale at which eagles actually select habitats, or it may reflect the progressive reduction in use of excursive travels in our analysis. At progressively finer scales, where excursions are not included in the analysis, the majority of eagles selected shrubland and avoided grassland and agriculture. Sagebrush/rabbitbrush was the most important shrub type. Thus, habitat selection by resident

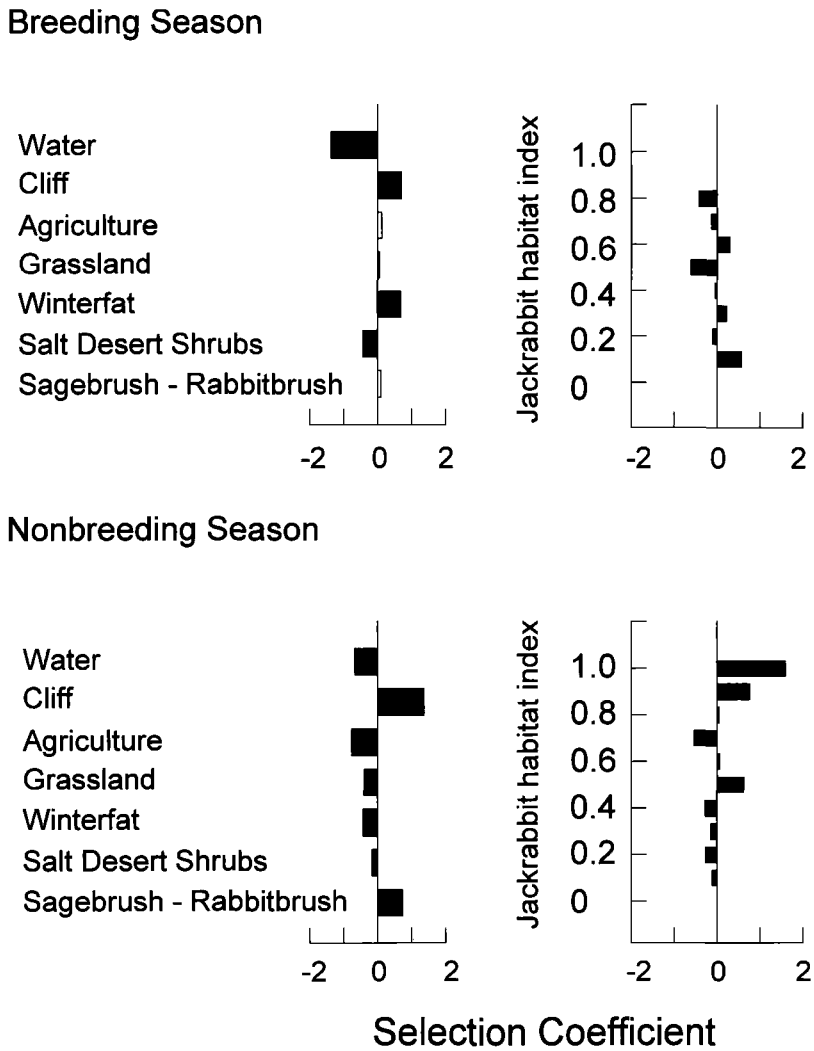

FIG. 6. Selection of foraging habitat within core areas by Golden Eagles. Selection coefficients (ln [percent habitat used / percent habitat available]) compare habitat within 100 m of foraging points with habitat available in 95% core areas during and outside of the breeding season. Selection is plotted separately for habitat classes and habitat quality for jackrabbits (0 is worst habitat, 1 is best habitat for jackrabbits). Vertical histograms show the relative preference (selection coefficient > 0) and avoidance (selection coefficient < 0) of each habitat or jackrabbit habitat-index category.

eagles was similar to selection previously documented for wintering vagrants (Craig et al. 1986).

Selection for sagebrush/rabbitbrush and the avoidance of agriculture and grassland resulted in most eagles foraging in habitats that had the potential to contain jackrabbits. Although our measure of habitat potential to support jackrabbits comes from the spring/summer season during a low population phase of jackrabbits, this is unlikely to influence our assessment of habitats because jackrabbits are found in the habitats rated as highest quality throughout the year, regardless of population cycling (Knick and Dyer 1997). However, the scale at which eagles selected jackrabbit habitats differed depending on the season and the characteristics of the home range. Outside of the breeding season, when even core areas were large, eagles selected foraging points in the

best available jackrabbit habitat. During the breeding season, when ranges were smaller, entire core areas were in jackrabbit habitat, and foraging points within cores were in cliff, winterfat, and agriculture where other prey types (notably Townsend's ground squirrels and Rock Doves) occurred. Jackrabbit habitat was used frequently within breeding-season core areas, but use at the scale of foraging points was not selective because territories or core areas were already in the best jackrabbit habitat available. Eagles may be selective in good jackrabbit habitat, but our inability to partition habitat quality more finely precluded testing selection within the best jackrabbit habitat. The importance of selection at one scale to selection at other scales was further illustrated by the lack of selectivity for sagebrush/rabbitbrush within territories that already had a high percentage of sagebrush/rabbitbrush. Habitat selection needs to be investigated at several levels to understand fully how animals allocate their time among various habitats (Wiens et al. 1986, Aebischer et al. 1993).

Although the use of area varied widely among individuals in the nine territories, the use of area by eagles in a given territory varied little regardless of nest location, prey abundance, or identity of breeders. All of these factors varied among years, but home range size and range boundaries did not vary significantly among years. In fact, home-range boundaries changed little from the 1970s to the 1990s. Continued residency by at least one, and usually both, members of the pair, their individual use of perching and foraging habits, and the constraining effects of neighboring pairs on territory shape likely contributed to the stable patterns of spatial use within a territory. Long-term studies of marked individuals are necessary to accurately contrast variation in use of space between territories with variation within territories.

Despite annual stability in territory size and shape, physical defense of territories was rarely observed. Defense of boundaries against neighboring breeders was adequately accomplished by undulating flights (Harmata 1982, Collopy and Edwards 1989). Undulating flights were most often given at the edge of territories, rather than near nests (Fig. 1) and were least frequently given by pairs that had just formed (territory d, e; individuals were banded), suggesting that their function was territory maintenance rather than pair bonding. We routinely captured eagles that were not the tagged offspring of the present territory owners at food items we placed in territories during the nonbreeding season for trapping. Rather, these eagles were vagrant nonbreeders or winter residents. Lack of defense against nonterritorial eagles also was observed in Wyoming (Phillips and Beske 1982) and may be rare because eagles are not breeding and the risks of injury from fighting (Harmata 1982) outweigh any costs of losing foraging opportunities.

We documented the largest home-range sizes reported for this species. Many of the ranges in our study were within values previously reported for this study area and elsewhere (i.e. 500 to 9,000 ha; Dixon 1937, Tjernberg 1977, Dunstan et al. 1978, Phillips and Beske 1982, Collopy and Edwards 1989), but three individuals occupied much larger areas (individuals b, c, f; Fig. 2A, B). Increased size of home ranges often resulted from excursions, especially during the nonbreeding season. Core areas and 95% harmonic-mean ranges, which exclude excursions, are more similar in size to published home ranges. Excursions may have been accentuated during our study, which included a period (winter 1992–93 through 1994) when jackrabbit numbers were low and declining (Steenhof et al. 1997). However, excursions also may represent searches for breeding, as well as foraging, opportunities. They were not synchronized forays by the pair, and in one case the female from territory "f" included territory "e" in her travels; she settled and bred there the following spring. Like any estimate of home range, ours is dependent upon decisions made during data collection and selection of individual points for inclusion in analyses. However, our intensive, long-term observations that include several individuals occupying a given territory allowed us to make realistic estimates of actual space use by eagles.

Management Implications

Management of a healthy population of Golden Eagles in shrubsteppe habitats must focus on maintaining the native shrub community. Stands of sagebrush/rabbitbrush interspersed with grassland harbor sizeable populations of an important prey item, black-tailed

jackrabbits (Knick and Dyer 1997). Our analysis demonstrates that eagles forage in areas without shrubs less than expected based on availability. Eagles were especially dependent upon shrub habitats when these shrub habitats were rare in the landscape.

Managers must recognize that although eagles range over large areas (>170,000 ha were used by one eagle), many concentrate their foraging in shrub habitats. Shrub (especially sagebrush/rabbitbrush) patch size appears to be an essential feature of all home ranges. Mean patch size for jackrabbit use of this habitat type was 5,000 ha, and the likelihood of observing jackrabbits increased with both increasing patch size and number of patches in the landscape (Knick and Dyer 1997). In managing the remaining large shrub areas in the landscape for eagles, we recommend that fragmentation by any disturbance not reduce the size of shrub patches below the mean patch size selected by jackrabbits. Patches slightly larger than this also should be maintained to accommodate maximum core areas during the nonbreeding season (6,387 ha; Table 2) and to provide habitat for vagrant and wintering eagles (observed in patches averaging 2,117 to 3,502 ha; Atkinson et al. unpubl. data). Individual variation in space use by eagles argues against using average values of home-range size in management recommendations. Rather, a variety of large and small areas could be suitable for eagles if they are managed to provide large shrub patches or rich alternative foraging areas (e.g. riparian zones).

ACKNOWLEDGMENTS

This study was funded primarily by the Idaho Army National Guard (IDARNG) under U.S. Army contract DAAD05-90-0135 and numerous agreements administered by W. S. Seegar. The U.S. Bureau of Land Management (BLM) and the U.S. National Biological Service provided additional funding and support. This study was part of the cooperative BLM/IDARNG project. J. McKinley, R. Townsend, B. Kimsey, and M. McFadzen were invaluable with data collection and analysis. A. Harmata kindly guided our trapping efforts. K. Steenhof, M. Kochert, R. Kenward, J. Rotenberry, M. Collopy, and K. Martin made valuable comments on the manuscript.

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EXHIBIT 432

Survey Protocols Required for NEPA/ESA Compliance for BLM Special Status Plant Species

Policy

It is BLM policy to conduct inventories to determine the occurrence and status of all special status plant species on lands managed by BLM or affected by BLM actions. This includes pro-active inventories directed toward developing plans or determining the status of plant species, as well as inventories conducted to determine the impacts of BLM planned or authorized actions on any special status plants that might be within the area of a proposed project. Such inventories are to be conducted at the time of year when such plant species can be found and positively identified.

Definition and Purpose

Inventory is the periodic and systematic collection of data on the distribution, condition, trend, and utilization of special status plant species (BLM Manual 6600).

Inventories are conducted for many reasons; however, for the purpose of this document only one inventory "reason" is addressed:

> To ensure compliance with the National Environmental Policy Act and the Endangered Species Act by having sufficient information available to adequately assess the effects of proposed actions on special status plants. Assessments of the effects of these actions are documented in biological assessments (if the project involves Federally listed species and qualifies as a "major construction activity" as defined by the ESA).

Special status plants include plant taxa that are Federally listed as threatened and endangered, proposed for Federal listing, candidates for Federal listing, State listed as rare, threatened, or endangered, or BLM sensitive species. All plant species that are currently on List 1B of the California Native Plant Society's Inventory of Rare and Endangered Plants of California (http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi), are BLM sensitive species, along with others that have been designated by the California State Director. BLM is party to a Memorandum of Understanding with the California Department of Fish and Game to collect information for inclusion in the California Natural Diversity Data Base. Therefore, in addition to inventorying for plants formally recognized as special status species by BLM, contractors must also inventory for all plant, lichen, and fungi species recognized as "special" by the California Natural Diversity Data Base (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPPlants.pdf). Although the following discussion uses the term "special status plants," it should be interpreted to mean all of the plant taxa discussed above.

The inventory requirements below apply to energy rights-of-way applications on Federal lands managed by the BLM in California and northwestern Nevada. Projects that include State or private lands or require State approval will likely also require conformance with the rare plant

survey guidelines of the California Department of Fish and Game (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/guideplt.pdf).

Timing and Intensity of Inventory

Before conducting inventories, contractors for BLM or energy companies should research three valuable sources to see if BLM special status species are known from the project area: the California Natural Diversity Data Base (CNDDB), CALFLORA, and the Biogeographic Information & Observation System (BIOS). However, CNDDB and BIOS are positive occurrence databases only, the lack of data should not be used as verification that the species does not exist in a given location. Inventories must be timed so that contractors can both locate and positively identify target plant species in the field. Inventories must be scheduled so that they will detect all special status species present. A single inventory on a single date will seldom suffice. For example, when one special status plant species suspected to be in the inventory can only be found and identified in April and another species can only be located and identified in August, at least two inventories are necessary. The first inventory can facilitate the second and/or third inventory, however, if potential sites for the late-flowering species are flagged during the first inventory. If sufficient information is available on the habitat requirements of potentially occurring species (substrate, plant community, etc.), and the site in question is believed to be unsuitable for those species, a field visit should still be conducted to document and validate the assumptions for believing that the species to be absent. In advance of the project site inventory, contractors should visit known populations of the target species in similar habitat conditions to determine current-year growth conditions and phenology. If, based on these visits to known populations, it appears likely that the project site inventory will fail to detect occurrences because of drought conditions (as may be the case for annual plant species or geophytic plants), BLM may require contractors to perform additional inventories in the following year.

Field Survey - Methodology

Field surveys will be floristic in nature, i.e., the contractor identifies every plant taxon observed in the project area to the taxonomic level necessary to determine rarity and listing status. Surveys will be conducted so that they will ensure a high likelihood of locating all the plant taxa in the project area. Depending on the size of the project area and the heterogeneity of the habitats within the project area, surveys will involve one or a combination of the following survey methods.

Complete Survey

A complete survey is a 100 percent visual examination of the project area (Figure 1) using transects. The length of the transect and distance between transects might change as the topography changes throughout the project area. Transects should be spaced so that all of the area between transects is visible and so that the smallest rare plant expected to occur is visible. The surveyor (1) compiles a species list while traversing the project area and keeps track of the plant community or habitat type where each taxon occurs; (2) maps the locations of all rare taxa

encountered using a GPS unit, and (3) fills out a CNDDB Native Species Field Survey Form for each location of each rare taxon encountered.

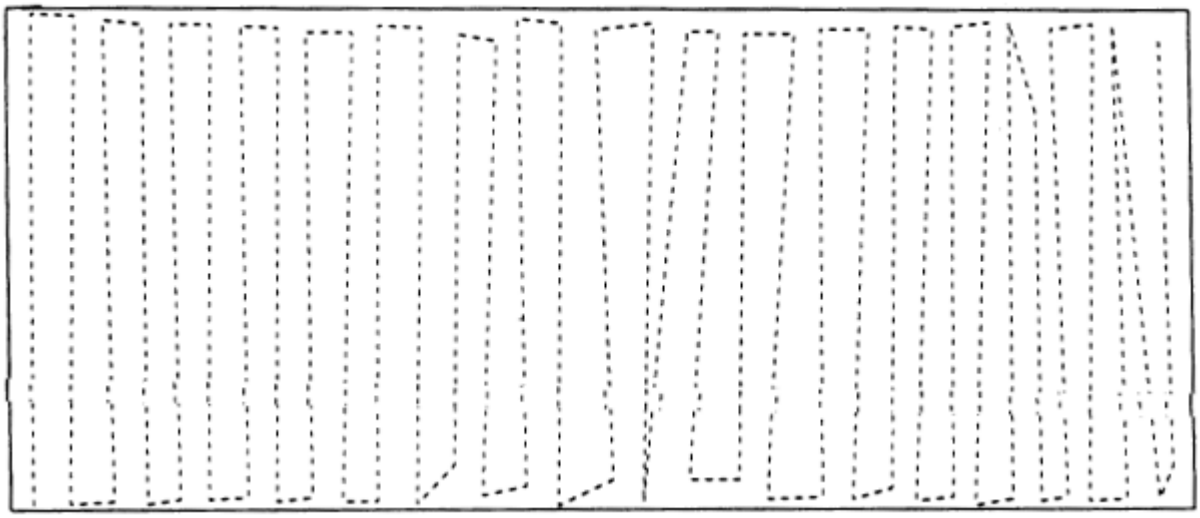

Figure 1. **Complete survey.**

Intuitive Controlled Survey

An intuitive controlled survey is a complete survey of habitats with the highest potential for supporting rare plant populations and a less intense survey of all other habitats present (Figure 2). This type of survey can only be accomplished by botanists familiar with the habitats of all the plant species that may reasonably be expected to occur in the project area. The botanist traverses through the project area enough to see a representative cross section of all the major plant habitats and topographic features. During the survey, the botanist compiles a species list of all plant taxa seen en route and keeps track of the plant community or habitat type where each taxon occurs. The surveyor maps the locations of all rare taxa encountered using a GPS unit and fills out a CNDDB Native Species Field Survey Form for each location of each rare taxon encountered. When the surveyor arrives at an area of "high potential" habitat, s/he surveys that area completely as described above and shown in Figure 1. High potential habitat areas include areas defined in a pre-field review of potential rare plants and habitat and other habitats where a rare species appears during the course of initial field work traversing the project area. Areas within the project area that are not the focus of a complete survey must be surveyed sufficiently so that is the botanist and BLM reasonably believe that few if any additional species would be added to the complete species list for the project area. The report must justify why the botanist did not consider these areas to have a high potential for supporting rare plant species and thus did not subject the area to a complete survey.

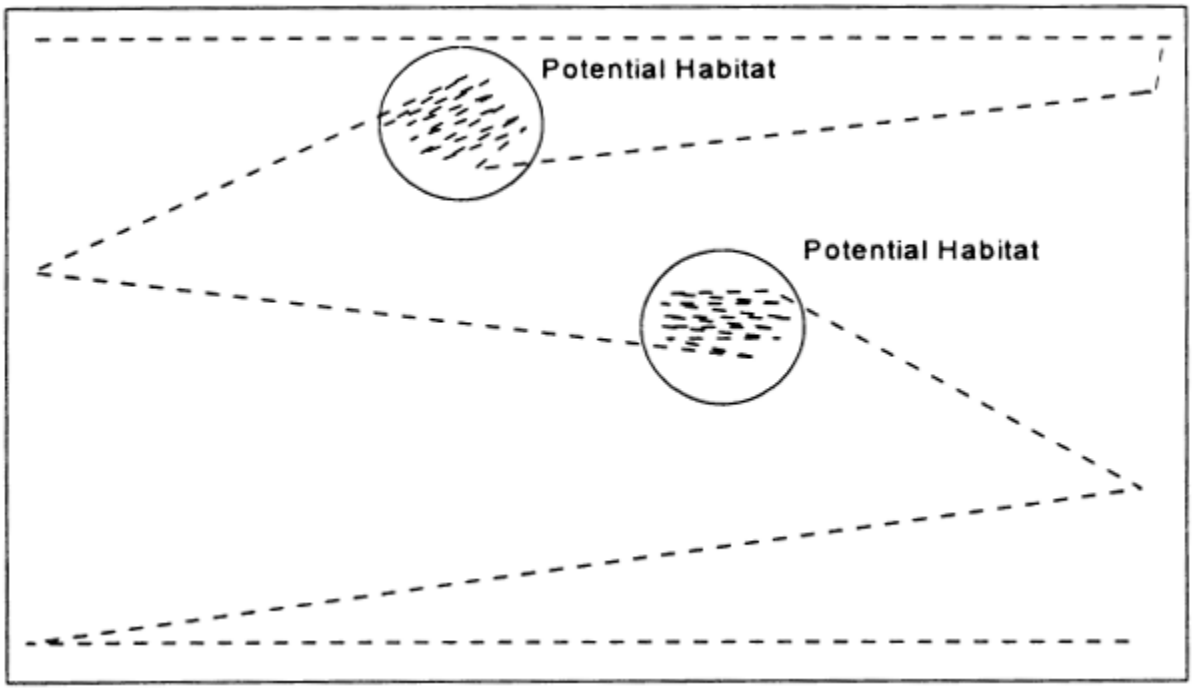

Figure 2. Intuitive Controlled Survey.

Documenting the Results of Inventory

The results of special status plant inventories should be well documented. This documentation must include as a minimum the completion and submission of Field Survey Forms and shapefiles/geodatabases of all special status plants found by BLM personnel or consultants. CNDDB defines occurrences as being separated from other plant locations by 0.25 mile. These forms are submitted to the BLM State Botanist and to the California Natural Diversity Data Base (CNDDB) at the following address:

CNDDB - Dept. of Fish and Game
1807 13th Street, Suite 202
Sacramento, CA 95811

Forms can be submitted electronically at: CNDDB@dfg.ca.gov
Copies of the Field Survey Form are available from the CNDDB at the same address. They will also provide photocopied parts of topo maps if needed.

If the inventory discovers any rare or unusual plant communities,[1] a Natural Community Field Survey Form must be completed for each such community and sent to the CNDDB at the address above.

[1] Rare or unusual plant communities includes those communities marked with asterisks in the most current list of California plant communities recognized by the California Natural Diversity Data Base, available at: http://www.dfg.ca.gov/biogeodata/vegcamp/pdfs/natcomlist.pdf, and Unusual Plant Assemblages as defined in

Most special status plant inventories of public lands conducted to assess the impacts of a project are performed by consultants hired by project proponents. These inventories must meet or exceed the intensity level required for the project by BLM. Personnel conducting the inventory must meet the qualifications outlined in this document. For BLM to adequately determine the quality of third party inventories, the following information must appear in a detailed report to BLM from the consultant or project proponent:

a. Project description, including a detailed map of the project location and study area.

b. A written description of the biological setting, including descriptions of the plant communities found in the project area and a vegetation map. Plant communities should be described and mapped to at least the alliance level using the vegetation classification system of the California Department of Fish and Game (CDFG). A list of the alliances currently recognized by CDFG can be found at: http://www.dfg.ca.gov/biogeodata/vegcamp/pdfs/NaturalCommunitiesList_Oct07.pdf. When the Manual of California Vegetation is published in 2009, the alliances recognized in that document should be used.

c. A detailed description of the inventory methodology, including techniques and intensity of the inventory and maps showing areas actually searched. This will also include areas searched but no special status plants found.

d. The results of the inventory.

e. The dates of the inventory.

f. An assessment of potential impacts and recommended mitigation measures to reduce impacts.

g. Recommended management actions to conserve any special status plants encountered should include both actions the BLM might take, as well as actions that might be taken by the FWS (listing or delisting of T/E plants, changes in candidate status, etc.).

h. A discussion of the significance of any special status plant occurrences found, with consideration for other nearby occurrences, and the distribution of the species as a whole.

i. Assessments of the health, population size, and protective status of any special status plants found.

j. A complete list of *all* plant species (not just special status species) identified within the project area, and a discussion of any range extensions discovered as a result of the inventory

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the California Desert Conservation Area Plan (http://www.blm.gov/pgdata/etc/medialib/blm/ca/pdf/cdd/cdcaplan.Par.15259.File.dat/CA_Desert_.pdf) or shown on Map 6 of the California Desert Conservation Area Plan, as amended (copies on file at the BLM California State Office, the California Desert District, and each of the field offices in the California Desert District).

k. Copies of all Field Survey Forms, for all special status plant occurrences found, or Natural Community Field Survey Forms, for any unusual communities found.

l. The name(s) and qualifications of the persons conducting the inventory.

m. A list of references cited, persons contacted and herbaria visited.

n. Additional data needs.

o. Other information as appropriate such as vegetation maps and photographs (see below).

Voucher specimens of special status plants should be collected if necessary to conclusively document the occurrence of the species and if the collection will not adversely affect the health of the population at the site. Collection of Federally listed plants on Federal lands requires a permit from the FWS. If voucher specimens are collected, they should be deposited in major recognized herbaria for future reference, preferably The University of California, Berkeley (UC), The Jepson Herbarium (JEPS), The California Academy of Sciences (CAS), or Rancho Santa Ana Botanic Garden (RSA).

Photographs should be taken of the areas inventoried, of all special status plants found, and of the habitat associated with each special status plant occurrence.

Data Collection – Data Submission

Data should be collected using a Mapping Grade GPS Receiver with an accuracy of < 3 meters Horizontal Root Mean Squared (HRMS).

All positions should be logged according to the following specifications:

- Maximum PDOP of 6
- Minimum of 5 Satellites
- Minimum elevation mask of 15 degrees
- Datum: NAD83
- Coordinate System: UTM Zone 10 or Zone 11, depending on where in California or northwestern Nevada the data is collected.
- ESRI compliant formats (Geodatabase, Coverage or Shapefile)

Metadata must be included with the data. The following must be included in the metadata:

- Project Name
- Purpose – Summary of the intentions with which the data set was developed
- Abstract Information – Brief narrative summary of the data set
- Location – What area(s) does your data cover? ie., list statewide, regions, city, county?
- Developer – Who collected the data?

Data Dictionary – A data dictionary must be used for all projects. The dictionary should include the data that is requested on the CNDDB forms. This ensures that the botanist is collecting (electronically) the same data as is requested by DFG. This also ensures that all inventories are collecting the same level/standard of data.

GIS Support Data: BLM California State Office Downloadable Data Sources

Index Page with BLM Data Naming Rules
http://www.blm.gov/ca/pa/gis/Data_Page/Data%20Page.html

Geospatial Data Downloads
http://www.blm.gov/ca/gis/index.html

All data collected in and referenced to the public land survey are required to conform to this version of PLSS published on the California BLM data download page.

In addition to the local Field Office; a copy of the Data (DVD or CDROM) must be submitted directly to:

BLM California State Office
Geographic Services, W1939
Attention: Chief Mapping Sciences
2800 Cottage Way
Sacramento, CA 95825

GIS Questions: Please Call
(916) 978-4343

Qualifications of Personnel Conducting Inventories

All personnel conducting special status plant inventories must have the following:

- strong backgrounds in plant taxonomy and plant ecology
- strong background in field sampling design and methods
- knowledge of the floras of the inventory area including the special status plant species
- familiarity with natural communities of the area

These qualifications help ensure that all special status plants in the inventory area will be located, including taxa that BLM or project proponents did not predict at the start of the inventory. All survey efforts must be coordinated with the responsible BLM Field Office botanist or biologist

EXHIBIT 433

Journal of Arid Environments (2000) **46:** 000–000
doi:10.1006/jare.2000.0711, available online at http://www.idealibrary.com on IDEAL®

Degradation of sandy arid shrubland environments: observations, process modelling, and management implications

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(Received 27 March 2000, accepted 25 August 2000)

Field remote sensing, and modelling observations from a degraded Mojave Desert shrubland were used to develop a model of the progressive degradation of areas adjacent to sites of direct anthropogenic disturbance. Aeolian removal and transport and dust, sand, and litter are the primary mechanisms of degradation, killing plants by burial and abrasion, interrupting natural processes of nutrient accumulation, and allowing the loss of soil resources by abiotic transport. It is concluded that any arid shrubland with wind-erodible soils is susceptible to degradation, and where possible development of these lands should be avoided.

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Keywords: desertification; wind erosion; Mojave Desert; shrublands; paleolakes; agriculture

Introduction

The Manix Basin in the Mojave Desert of south-eastern California is the site of ancient Lake Manix (Buwalda, 1914; Meek, 1989, 1990; Dohrenwend *et al.*, 1991). Far from being a unique geological setting, the fine-grained lacustrine sediments in the basin are part of the Pleistocene legacy shared by depressions throughout the entire basin and Range and Mojave provinces (Smith & Street-Perrott, 1983). Morrison (1991*b*, 1991*a*) has reported that 'nearly all closed or formerly closed basins in the Great Basin have ancient strandlines marked by lacustrine bars, spits, embankments, terraces, deltas, and wave-cut cliffs at elevations well above the playas or permanent lakes of today'. The lacustrine sediments of Pleistocene age that form the floors of these basins share qualities that make them amenable for agriculture and other human activities: very low slopes, little or o relief, subsurface water resources, and fine-grained sediments suitable for farming or other activities. The intersection of the human uses of Pleistocene paleolakes with their geological history creates opportunities for land degradation much greater than typically recognized.

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Wind erosion in the Mojave Desert is the principle mechanism of land degradation. Agriculture, urban development, military maneuvers, pipeline, road and powerline construction, and recreational vehicles all destroy vegetation cover and expose the soil to wind erosion (Sharifi *et al.*, 1999). These activities can result in increased dust emission, blowing sand, and damage of native vegetation.

Although the processes of arid land degradation have been well-established elsewhere in the south-western U.S. (see for example, Schlesinger *et al.*, 1990), no published process model exists for shrubland degradation in the Mojave Desert or other shrublands. In this paper, we report on the importance of human-induced wind erosion in initiating and propagating land degradation in the Manix Basin of the Mojave Desert. Based on these observations, we develop a model of wind-driven desertification in sandy arid shrublands.

Arid land degradation has received significant attention in the technical and popular media over the past several decades. Much of this interest has been practical in nature owing to the facts that: (1) desertification is widespread throughout the south-western United States and globally (Mabbutt & Floret, 1980; Walker, 1982; Warren & Hutchinson, 1984; Verstraete & Schwartz, 1991; Khalaf & Al-Ajmi, 1993; Dregne, 1995); (2) it has severe financial and societal consequences including property damage, increased health and safety hazards, and decreased agricultural productivity (Clements *et al.*, 1963; Bowden *et al.*, 1974; Fryrear, 1981; Hyers & Marcus, 1981; Leathers, 1981; Leys & McTainsh, 1994; Bach, 1998); and (3) some forms of desertification are irremediable on human timescales at reasonable cost (Whitford, 1992; Dregne, 1995). The increasing use of desert shrublands by humans for habitation, agriculture, industry, and recreation increases the amount of arid land directly impacted (Verstraete & Schwartz, 1991). Thus, it is important to understand the processes of arid land degradation in these environments. Improved process understanding will allow improved identification of areas at heightened risk of desertification before serious damage has occurred.

History and features of the Manix Basin, California

Our observations are drawn from the Manix Basin in the Mojave Desert, about 25 miles ENE of Barstow in south-eastern California (centred around 34°56·5′N·116°41·5′ W at an elevation of about 540 m). The basin has an area of 40,700 ha and was the site of ancient Lake Manix which existed during the peak pluvial episode of the last glaciation and drained through Afton Canyon to the east (Smith & Street-Perrott, 1983; Meek, 1989). Much of the basin is filled with lacustrine, fluvial, and deltaic sediments capped by weak armoring (Meek, 1990). There is clear evidence of pre-modern wind erosion, indicating that wind erosion, transport, and deposition has long been a dominant geological process in the area (Evans, 1992).

The modern climate of the Manix Basin is arid with an average annual precipitation of 100 mm, falling mostly in the winter, although there can be significant summer precipitation in some years (Table 1). The average annual temperature is 19·6°C, the average

Table 1. *Average precipitation (cm) by season at Daggett Airport*

	Jan–Mar	Apr–Jun	Jul–Sept	Oct–Dec	Annual
1944–1997	3·7	0·9	2·9	2·4	10·0
1980–1989	4·5	1·1	3·1	3·1	12·7
1990–1997	6·0	0·3	2·8	2·0	11·1

Source: National Climate Data Center, U.S. Precipitation by State, California: http://www.ncdc.noaa.gov/ol/climate/online/coop-precip.html

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winter temperature of 9·1°C, and the average summer temperature is 31·4°C (Meek, 1990). The average wind speed at the airport in Daggett is 5·5 m s^{-1} at a height of 6·1 m and is typically from the west (National Climate Data Center, 1993).

The vegetation in undisturbed areas of the basin in dominated by an association of *Larrea tridentata* and *Ambrosia dumosa*, with minor occurrence of *Atriplex polycarpa, Atriplex hymenelytra, Atriplex canescens, Ephedra californica,* and *Opuntia* spp. *Prosopis glandulosa* occurs in some areas of the basin. Areas that have been disturbed directly by human activity are dominated by *A. polycarpa* with total cover often greater than that in undisturbed desert. *Schismus*, an exotic annual grass, in ubiquitous, but grass cover varies significantly with yearly precipitation.

There has been extensive human activity in the Manix Basin with several phases of agriculture utilizing ground-water recharged by the Mojave River. The basin was used for dryland farming in the 1800s (Tugel & Woodruff, 1978). Limited irrigated farming started in the basin in 1902 with the acreage of irrigated land increasing sharply after World War II (Tugel & Woodruff, 1978). Today alfalfa hay is the major agricultural product. In the Coyote Dry Lake sub-basin, square flood-irrigated fields and abandoned flood irrigation equipment are seen in early Landsat images. After the mid-1970s, central-pivot agriculture became the dominant form of land use in the area, but many fields have since been abandoned throughout the northern part of the basin due to increasing costs of ground-water pumping (Ray, 1995).

Methods

In this study a series of Landsat Multispectral Scanner (MSS) and Airborne Visible Infrared Imaging Spectrometer (AVIRIS) images from the Manix Basin from 1979, 1982, 1985, 1988, 1997, and 1998 were used in order to identify areas of blowing sand associated with central-pivot agriculture in the basin. AVIRIS measures the total upwelling spectral radiance in 224 bands from 400 to 2500 nm in 20-m ground pixels from a NASA ER-2 aircraft flying at 20-km altitude. Landsat MSS measured upwelling radiation in four visible-near infrared broad multispectral bands in 80-m ground pixels. Geographical information about the extent and locations of blowing sand were the object of the remote sensing analysis. Simple spatial information is readily available from uncalibrated remote sensing images. Therefore, no attempt was made to calibrate the images or correct for atmospheric scattering. The images were incorporated into a geographical information system.

A series of field trips between 1996 and 1999 were undertaken to the Manix Basin in order to verify remote-based observations of sand blow-outs. In 1998 and 1999, perennial vegetation cover was estimated at several sites in the Manix Basin by measuring individual plant diameters in circular plots with 5-m radii (12 replicates each) and assuming full, circular shrub canopies.

Finally, a quantitative assessment of observed wind erosion and deposition rates was undertaken in order to link observed phenomena with physical and mathematical wind erosion models.

Results and discussion

Remote observation from the Manix Basin

The Landsat MSS and AVIRIS images taken in Fig. 1 clearly indicate the growth of sand blow-outs downwind of abandoned agricultural fields in the Manix Basin. Deposition of sand downwind of the fields is a progressive process, with sand plumes lengthening in each successive image. No regrowth of perennial vegetation was observed in these

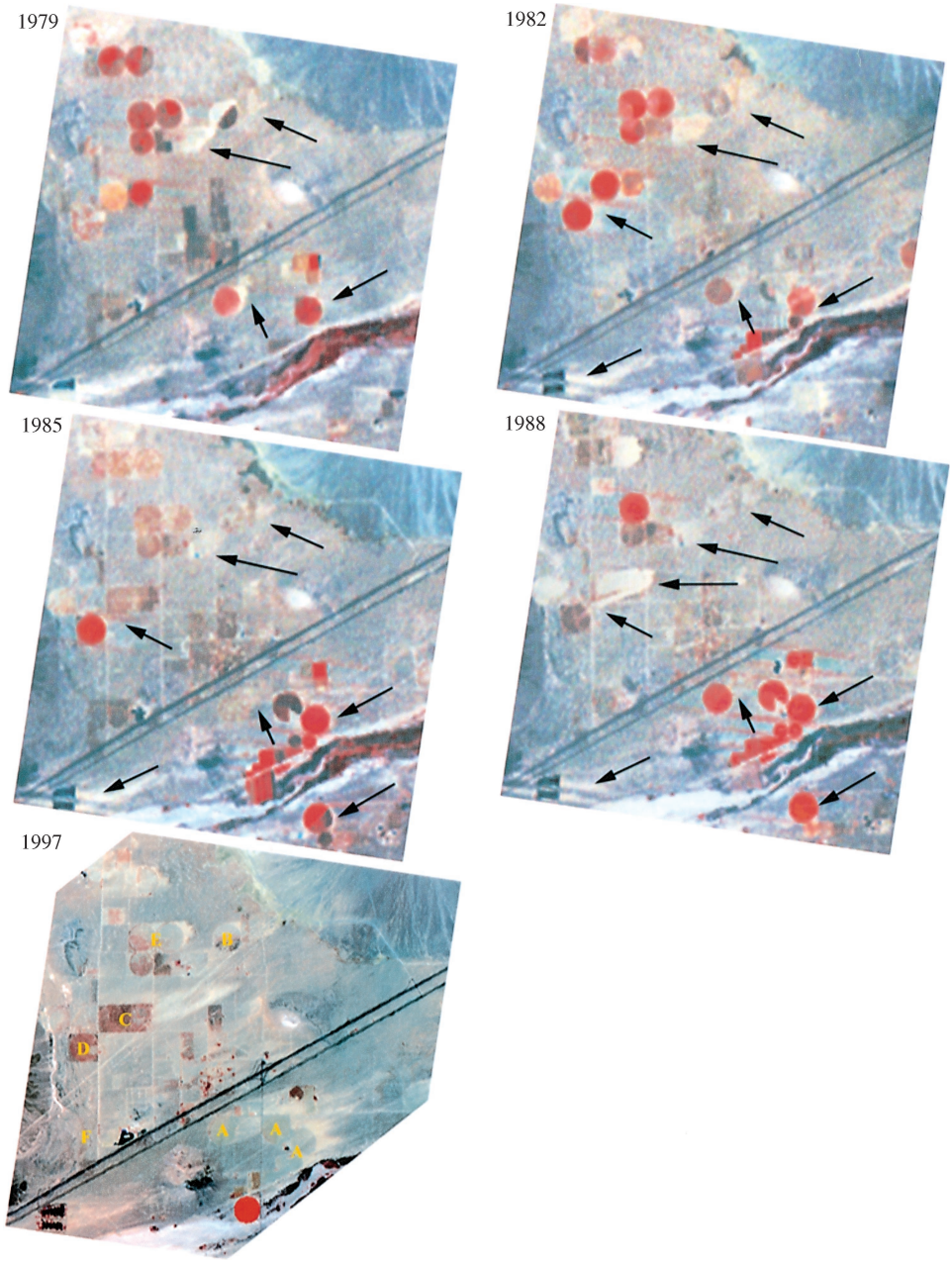

Figure 1. 1979–1988: Landsat Multispectral Scanner (MSS) images of the Manix Basin. Red is MSS band 4 (800–1100 nm), green in MSS band 2 (600–700 nm), and blue is MSS band 1 (500–600 nm). Interstate 15 goes diagonally through the centre of the images. North is up and active fields appear bright red in these images. The wind blows from west to east across the basin causing sand blowouts to appear as bright areas east of the fields. Arrows indicate the progressive appearance of sand mobilized from agricultural fields. 1997: An Airborne Visible Infrared Imaging Spectrometer (AVIRIS) image of the same area taken in 1997, and processed to display colours in the same way as in the MSS images. The relative sharpness of this image is due to the higher spatial resolution of the AVIRIS instrument. The dark-red area C consists of two fields covered with *A. polycarpa* while area A is an abandoned field with very little shrub cover. Both areas exhibit dramatic sand blowouts downwind.

Table 2. *Direct and indirect disturbance for some selected fields in the Manix Basin*

Location (see Fig. 1)	Total time cultivated (years)	Time since abandonment (years)	Soil Texture	Area subject to direct disturbance (ha)	Area subject to indirect disturbance (ha)	Indirect/direct (area ratio)
A	> 7	< 10	Sand/loamy sand	185	518	2·8
B	1	26	Sand/loamy sand	62	109	1·8
C	5	15, 17	Sand	182	241	1·3
D	6	11	Loamy sand	79	91	1·2
E	6 to 8	10, 14	Loamy sand	124	33	0·3

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sand plumes. Thus, the occasional darkening of the sand blow-outs is inferred to be due to annual vegetation related to winter rainfall. Annual cover can be relatively high in wet years, but seldom lasts through the spring and summer months.

Anthropogenic disturbance in the Manix Basin may be separated into two types: direct and indirect. Direct anthropogenic disturbance refers to human activities and the consequence of those activities in the area in which they were performed. This includes the actual fields, roads, pastures, corrals, trails, and so on that are affected by land use practices. Indirect disturbance refers to the consequences of direct disturbance in areas not directly disturbed. Our observations demonstrate that both direct and indirect disturbance are extensive in the Manix Basin, and that they are coupled by wind erosion and redeposition of wind-blown sediment.

Ray (1995) has reported that in 1985 agriculture in the Manix Basin reached its greatest extent with 37 active central-pivot irrigated fields accounting for 3062 ha of land in cultivation. Agricultural activity in the basin has decreased in the last decade. Thus, at least 3000 ha of land have been directly disturbed in the Manix Basin. By areal analysis of 1998 AVIRIS data, the relative areas of direct and indirect disturbance were identified in the form of sand blow-outs, for some of the fields in the Manix Basin (Table 2). No clear relationship was found between time of abandonment nor of cultivation with the magnitude of indirect disturbance. All fields were located in soils with sandy or loamy sand soils, the dominant soil textures in the basin (Tugel & Woodruff, 1978).

Sand may be blown several kilometres beyond the downwind boundary of a field and therefore the area of indirect disturbance can exceed the directly disturbed area by several-fold. With 3000 ha of land directly disturbed in the basin, 3000 to 9000 ha of land may be expected to be indirectly disturbed by agriculture. This sums to 6000–12,000 ha total disturbance or 15–30% of the total basin floor area, and approximately 23–45% of the non-playa area of the basin. Other disturbances, such as housing developments and roads are also present in the basin, while large areas of the basin are taken up by the Coyote and Troy playas. Anthropogenic degradation appears to have a major impact on land quality and status in the Manix Basin.

Field observations in the Manis Basin

Direct disturbance

Before the fields of the Manix Basin could be cultivated they were cleared of vegetation. Vegetation cover shelters the soil from the erosive force of the wind by: (1) reducing the force of the wind near the ground; (2) extracting momentum above the surface (Wolfe & Nickling, 1993); and (3) trapping soil particles in transport (Lancaster & Baas, 1998). Tillage destroys fragile surface armours, thereby reducing the threshold shear velocity (Gillette *et al.*, 1980; Gillette, 1988; Tegen & Fung, 1955; López, 1998). Vegetation removal and soil cultivation, therefore, have the combined effect of dramatically increasing soil erodibility in the Manix Basin (as seen in Fig. 1). Mechanical agriculture itself visibly mobilizes dust and sand on windy days and ensures that the soil surface is exposed for at least part of the year. Active fields, therefore, become sustained sources of material for aeolian transport immediately upon clearing.

The magnitude of deflation associated with wind erosion of agricultural fields in the Manix Basin is difficult to quantify. However, in one agricultural field in the Manix Basin abandoned about 30 years ago (Fig. 1, area F), wind erosion has led to an average deflation rate of more than 1·5 cm per year, as evidence by wind excavation of buried irrigation pipes. These pipes provide a rare field constraint on deflation, as the vertical feeder sections were once flush with the ground.

Areas that have been cleared to vegetation and then abandoned follow one of two principal trajectories with respect to their vegetative cover. Areas may be recolonized

Table 3. *Percent cover by species in undisturbed desert compared with areas on abandoned central-pivot agriculture fields*

	Undisturbed	On-field (low-cover)	On-field (high cover)
Larrea tridentata	4·8%	0·8%	0·0%
Ambrosia dumosa	1·1%	0·4%	0·0%
Atriplex polycarpa	0·8%	8·3%	32·5%
Total fractional cover	6·7%	9·5%	32·5%

Plant counts were carried out in February 1998 and April 1999 in 5-m radius circles.
The 'Undisturbed' plant cover data represent three sites with 12, 4, and 12 replicates, respectively.
The 'On-field (low cover)' data represent two sites with 12 replicates each. The 'On-field (high cover)' data represent one site with 8 replicates.

principally by *A. polycarpa*, a perennial shrub, and annual exotic grasses such as *Schismus*. Perennial vegetation cover estimates from various sites in the Manix Basin are shown in Table 3. We found 8 to 30% cover a *A. polycarpa* on abandoned fields, while undisturbed areas typically have approximately 5 to 7% cover, dominated by *L. tridentata*. In some cases, only the upwind portions of abandoned fields support a low cover of *A. polycarpa*, even after a decade or more of disuse. This may be due to the fact that fetch, and therefore, mass transport rate of the wind, is lowest here, minimizing plant abrasion and seed removal. These fields have only been abandoned for at most 30 years, and are nowhere near the 65 years Carpenter *et al.* (1986) estimate for a creosote bush scrup community to approach climax conditions nor the several hundred years estimated by Vasek *et al.* (1975). Stylinski & Allen (1999) have suggested that in arid shrublands, altered stable states can occur if a community is pushed beyond its threshold of resilience by anthropogenic disturbance. The dramatic differences between abandoned agricultural fields and undisturbed desert in the Manix Basin after several decades certainly argue for centuries for recovery, if it occurs at all.

Some of the abandoned fields in the Manix Basin do not support any native perennial vegetation, even after a decade or more of disuse. This may be explained by: (1) transport of sand by wind over the exposed soil surface killing young seedlings; and/or (2) absence of climatic or soil conditions suitable for plant germination (Lovich & Bainbridge, 1999). In an experiment aimed at restoring Mojave Desert farmland by seeding native plants in order to reduce dust emissions, Grantz *et al.* (1998) found *A. canescens* could be established in areas without deep sand. However, 'this revegetation was achieved in an anomalous year with above average and late rainfall that eliminated early competition from annual species and later fostered abundant shrub growth. This success was not reproducible in more normal years'. Thus, natural germination of native perennial vegetation on abandoned fields may be rare, explaining the lack of cover on some abandoned fields in the Manix Basin. The importance of germination conditions highlights the dramatic role of interannual climate variability and long-term regional climatic conditions on the response of these ecosystems to human disturbance. Bare fields in the Manix Basin may be expected to take much longer than the vegetated fields to approach climax conditions, if they recover at all.

Once fields are abandoned, they serve as sources of wind-borne sediment at least until a deflationary soil pavement is re-established or they are some how crusted (López, 1998). Landsat MSS and AVIRIS imaged in Fig. 1 depict the mobilization of sand from abandoned agricultural fields in the Manix Basin. Area C, which appears as dark red in the 1997 AVIRIS image, is a set of two fields abandoned in the early 1980s according to Landsat images of the basin from 1973 to 1992; area A was abandoned in 1988 (Ray,

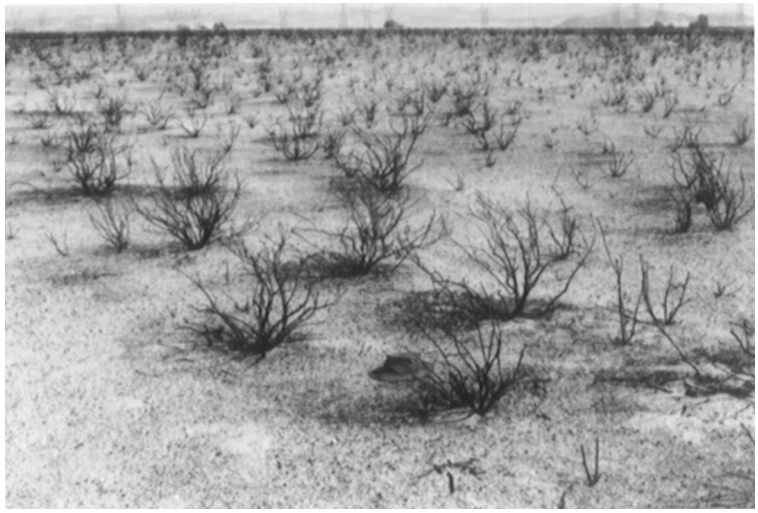

Figure 2. Photograph taken in an abandoned field in the Manix Basin after a fire in the summer of 1998 showing the response of highly disturbed areas to fire. Prior to the fire, this abandoned field had been covered with approximately 30% cover of *A. polycarpa*. Most individuals in the path of the fire in the area of high *A. polycarpa* cover were killed as shown here. Nearby, in adjacent undisturbed desert, only the annual grasses burned and perennial plant mortality was low.

1995). Areas downwind of both fields show significant sand encroachment even though area A has almost no cover and C has relatively high (~30%) *A. polycarpa* cover. Thus, even after regrowth of *A. polycarpa*, abandoned fields remain sources of aeolian sand. High *A. polycarpa* cover may increase roughness length and decrease boundary layer velocity, but once the soil crust was removed, these soils clearly remained.

A notable consequence of the trajectory that areas of direct disturbance follow is their potential response of fire. Lovich & Bainbridge (1999) have reported a 10-year average of 175 fires in the Mojave and Colorado deserts of California that affected an average of 10,927 ha annually. Besides this, there are no published definitive studies of fire return intervals or typical areas burned in individual fires in the Mojave Desert. Nonetheless, it is clear that fire has only recently become a factor in shaping the structure and dynamics of plant communities in the Mojave Desert. In prehistoric times, limited biomass, large intershrub spacing, low combustibility of some native plants and sparse ground cover to support and propagate combustion are thought to have led to very low fire frequencies. The recent proliferation of exotic annual plants has increased the fuel load and fire frequencies in many ecosystems around the world have increased in recent years (Lovich & Bainbridge, 1999).

A fire in the Manix Basin that occurred in June 1998 indicates that areas of high *A. polycarpa* cover have different fire responses than undisturbed areas or abandoned areas of direct disturbance with little or no vegetation regrowth. After the 1998 Manix Basin fire, the mortality of nearly all shrubs on the *A. polycarpa*-covered abandoned field was observed. The same fire burnt a nearby undisturbed area dominated by *L. tridentata* and *A. dumosa*. Here, the fire killed few shrubs and was only sustained in areas with a dense cover of exotic annual grasses as a type of under-storey fire. A fire in an abandoned field covered with *A. polycarpa*, therefore, re-exposed the soil surface to wind erosion while a fire in an undisturbed area has little effect on the landscape (Fig. 2). Disturbed areas that are subsequently burned therefore are likely to have much longer recovery times than their unburned neighbours, both due to fire mortality and the enhanced vulnerability of burnt landscapes to wind erosion.

Figure 3. Photograph taken downwind of an abandoned field in the Manix Basin in the spring of 1988 displaying evidence of active sand movement (sand ripples) and plant mortality. The plants in the foreground are *L. tridentata* and *A. dumosa* individuals that have been buried, abraded and ultimately killed by the encroaching sands.

Indirect disturbance

Indirect disturbance in the Manix Basin primarily takes the form of redeposition of wind-borne sediments onto previously undisturbed adjacent lands. Three types of material are removed from abandoned agricultural fields by wind erosion: saltation-sized particles, suspension-size particles, and organic litter. The removal of all three contributes to indirect disturbance. Saltation of large particles results in their redeposition wherever wind velocities drop, typically in adjacent, downwind vegetated areas or in the lee of plants growing on the field itself.

The encroachment of blowing sand into adjacent shrublands has dramatic consequences for the landscape. Field observations indicate that blowing sand abrades plants, resulting in leaf stripping and damage to the cambium and therefore to the plant's ability to distribute and use water. Young plants are especially vulnerable to the effect of blowing sand as they lack woody tissue. This results in the suppression of revegetation in bare areas and the loss of vegetation on adjacent lands. Nitrogen-fixing microbial communities and cryptobiotic crusts are buried by sand, reducing inputs of nitrogen to the soil (Belnap *et al.*, 1993; Evans & Belnap, 1999).

Blowing sand creates dunes in the wind-shadows of plants. Inspection reveals that these dunes typically have a coarser texture than the material from which they were derived, a result of the progressive removal of fines in a continual process of winnowing (Gibbens *et al.*, 1983; Hennessy *et al.*, 1986; Lyles & Tatarko, 1986). Dunes can grow and coalesce resulting in: (1) burial of large plants not able to grow fast enough to keep up with dune growth; (2) burial of all vegetation including very young shrubs in inter-shrub spaces; and (3) complete blanketing of the soil surface by sand. The persistence of branches and twigs from buried or abraded vegetation decreases the erodibility of the surface, but with time these disintegrate (Fig. 3). Since new vegetation growth is inhibited by blowing sand, the ability of vegetation in stem erosion is limited.

Anthropogenic additions

Chemical fertilizers or other soil amendments are often added to agricultural fields to increase productivity or soil workability. Inorganic salts also may be added inadvertently to the soil as irrigation water evaporates. The transportation of materials from an area of direct disturbance may be accompanied by the dispersal of these soil additives across the landscape. The dispersal of salts by wind onto adjacent undisturbed areas may contribute to the decreased plant growth on these areas by increasing osmolyte concentrations in soil solutions. Okin *et al.* (in press) have reported that Cl^-, SO_4^{-2}, and Na^+ are significantly elevated on and downwind of an abandoned field in the Manix Basin relative to the upwind areas as salts have spread with the moving sands. On the field, Cl^-, SO_4^{-2}, and Na^+ accumulated at average rates of approximately 9·9, 30, 29% per year, respectively over 7 years. This represents a dramatic addition of ions to the soil and may limit the usability of these areas for extended agriculture or influence the recovery of agricultural fields after abandonment.

Soil additives (including nitrate and phosphate) act as chemical tracers of mass flux and determine the relative effects of physical abrasion and nutrient loss in propagating desertification in arid shrublands. Okin *et al.* (in press) have reported significantly elevated concentrations of plant-available N and P on and downwind of an abandoned field in the Manix Basin. Fertilizer has been broadcast across the landscape as the soil from the field has been transported by wind. Despite elevated nutrient concentrations on the abandoned agricultural field at Manix, the absence of shrubs on this field indicates that recolonization of fields by native shrubs after their abandonment is not simply related to nutrient content of the soils, but is dependant more on germination conditions as suggested by Grantz *et al.* (1998). The area immediately downwind of the fertilized field has seen an increase in plant mortality and not a bloom in response to increased nutrient concentrations. This indicates that abrasion and burial of vegetation may dictate a landscape's response to wind erosion, especially in years without favourable germination conditions.

Quantitative assessment

Are the observed rates of deflation and burial of adjacent lands that are suggested quantitatively plausible in the Manix Basin? Using published threshold shear velocities and equations for the flux of wind-borne sediments, we conclude that observed deflation rates at the Manix basin are reasonable in light of literature values and theoretical considerations. Our quantitative assessment thus provides insight into the magnitude of deflation, redeposition of saltation-sized particles, and emission of nutrient-laden dust.

With erosion and transport processes have been reviewed many times in the literature (see for example Greeley & Iversen, 1985; Table 3·5). Here, the analysis of Bagnold (1941) will be followed because it is still prevalent in the modern literature of aeolian transport and because it provides a simple method for determining the magnitude of sand transport. From momentum considerations and simplifying assumptions about the path of saltating grains, Bagnold derived a relationship for the horizontal mass flux of saltating grains integrated over all heights:

$$q = C\sqrt{\frac{d}{D}}\,\frac{\rho_a}{g}\,U_*^3, \tag{1}$$

where q is the horizontal mass flux in g cm^{-1} s^{-1}, U_* is the shear velocity, d is the grain diameter of the sand in question, D is the grain diameter of a standard 0·25-mm sand,

ρ_a is density of air, g is the acceleration due to gravity, and C is 1·8 for a naturally graded sand. Assuming that $d = D$, Bagnold's equation simplifies to

$$q = 1{\cdot}5 \times 10^{-9}\,(U - U_t)^3, \tag{2}$$

where U is the wind velocity and U_t is the threshold wind velocity measured at 1 m height. U and U_t are related to shear velocity, U_*, and threshold shear velocity, U_{*t}, respectively, by Bagnold's formula:

$$U_z = \frac{U_*}{k} \ln\left(\frac{z}{z_0}\right), \tag{3}$$

where U_z is wind speed at height z, k is von Karmann's constant taken to be 0·4, and z_0 is the roughness length (Bagnold, 1941).

Shao & Raupach (1993) have shown from energetic considerations that vertical dust flux due to suspension, F, in mass per area per unit time is linearly related to q. Based on this, Gillette *et al.* (1997) have obtained a value for F/q of $5{\cdot}4 \times 10^{-4}\,\mathrm{m}^{-1}$ from wind tunnel experiments, which is of the order of that for sandier soils (Gillette, 1977; Shao & Raupach, 1993; Gillette *et al.*, 1997) and is therefore applicable here.

For a field with cross-wind diameter, x, and area, A:

$$\Delta\tau_{saltation} = \frac{q}{\rho_B}\frac{x}{A}, \tag{4}$$

where ρ_B is the bulk density of the soil and rate of deflation due to saltation, $\Delta\tau_{saltation}$, is expressed as cm year^{-1}. ρ_B is taken to be $1{\cdot}25\,\mathrm{Mg\,m}^{-3}$ for a dry, medium-texture mineral soil (Brady & Weil, 1999), x is taken to be 750 m, and $A = \frac{\pi}{4}x^2$ for a circular field. A/x is a equivalent to erosive fetch. The total average mass rate of erosion is:

$$F_{Total} = q\left(\frac{x}{A}\right) + F \approx q\left(\frac{x}{A}\right), \tag{5}$$

and the total deflation rate (in cm year^{-1}) is given approximately by:

$$\Delta\tau_{total} = \Delta\tau_{saltation} + \Delta\tau_{suspension} = \frac{q}{\rho_B}\left(\frac{x}{A} + \frac{F}{q}\right), \tag{6}$$

where the mass flux due to saltation, q, depends on a detailed wind record, z_0, and U_{*t} by equations (2) and (3).

The threshold shear velocity required to account theoretically for $\Delta\tau_{Total} = 1{\cdot}5$ cm year^{-1} in the Manix Basin was found iteratively using equation (6), Gillette *et al.*'s (1997) value for $F/q = 5{\cdot}4 \times 10^{-4}\,\mathrm{m}^{-1}$, $z_0 = 0{\cdot}04$ cm (an average of values reported by Gillette *et al.* (1980) for non-playa, uncrusted soil), and the wind conditions at Daggett Airport in the Manix Basin where wind speed has been collected hourly since 1961. U_{*t} was found to be 103 cm s^{-1}, well within the bounds of reported values for arid agricultural soils of 20–132 cm s^{-1} (Gillette, 1988). These results indicate that empirically-understood processes can account for observations in the Manix Basin and, therefore, that it is reasonable to invoke these processes to drive indirect disturbance in the conceptual model developed here.

The value $q = 8{\cdot}56$ Mg m^{-1} year^{-1} calculated from $U_{*t} = 103$ cm s^{-1} by equation (2) implies that the equivalent of 10^8–10^9 sand grains saltate through each metre of width per year. In fact, considering that the majority of wind erosion occurs during storms of a few days in duration, this constitutes an extremely concentrated attack on vegetation and is capable of overwhelming plants' self-healing capabilities.

The effect of abrasion acts in tandem with redeposition and dune formation to compromise vegetation in adjacent downwind areas. The total volume, V in m^3 $year^{-1}$, of soil moved by saltation from an abandoned agricultural field is given by:

$$V = \frac{qx}{\rho_B} T, \tag{7}$$

where T is the time in years before the re-establishment of an armoured surface. If the density of the soil is approximately the same after redeposition downwind, volume is conserved and the average depth of burial is given by V/A_b, where A_b is the area buried by the mobilized sand, which can be estimated from remote sensing imagery. Area C in the Manix Basin (Fig. 1, Table 2) has been abandoned for 16 years and has a sand plume downwind with an area of 241 ha. Using the value of q calculated above, we estimate that the average depth of this sand plume is 6·8 cm. However, mobilized sand usually accumulates in the wake of plants, leading to dunes larger than the average depth of burial. In the Manix Basins we have observed dunes greater than 1 m in height. There is currently no theory for determining dune height based on flux measurements or calculations.

Using Gillette *et al.*'s (1997) value for F/q, and reasonable values for x/A, $q(x/A)$ should always be greater than F, indicating that sand mobilization is more important as a wind erosion process than dust emission is terms of mass loss. However, dust emission represents the permanent removal of material from the regional ecosystem due to its potential for long-range transport. Nutrients, especially P, are often concentrated on small particles in soils (Avnimelech & McHenry, 1984; Leys & McTainsh, 1994). Assuming constant suspension flux, the removal of nutrient i from the bulk soil at time t may be written as:

$$F_i^d(t) = C_i^d(t) F, \tag{8}$$

where $C_i^d(t)$ is the concentration of soil nutrient i on the emitted dust and has units of mass of nutrient per mass dust. $F_i^d(t)$, therefore, is in units of mass of nutrient i lost per unit area per unit time. The mass per unit area of soil in a layer of depth, D, is:

$$M^D = \rho_B D, \tag{9}$$

and therefore, the reservoir of nutrients in this layer is $C_i^s(t) M^D$, where $C_i^s(t)$ is the concentration of nutrient i in the soil.

Conservation of mass gives:

$$M_i^{s,D}(t + \mathrm{d}t) - M_i^{s,D}(t) = C_i^d(t) F \mathrm{d}t, \tag{10}$$

where $M_i^{s,D}(t)$ is the mass of nutrient i at time t in a layer of soil of depth, D. Under the approximation that M^D is constant with time, we can divide equation (9) by M^D yielding:

$$C_i^{s,D}(t + \mathrm{d}t) - C_i^{s,D}(t) \approx C_i^d(t) \frac{F}{M^D} \mathrm{d}t, \tag{11}$$

where $C_i^{s,D}(t)$ is the concentration of nutrient i at time t in a layer of soil of depth, D. The ratio of $C_i^d(t)$ to $C_i^{s,D}(t)$ is assumed to be a constant, k_i, that is analogous to a chemical fractionation factor for nutrient i between dust and the bulk soil.

Rearranging equation (10) yields:

$$\frac{\mathrm{d}C_i^s}{\mathrm{d}t} \approx -k_i \frac{F}{\rho_B D} C_i^s. \tag{12}$$

Therefore, the time for the concentration of nutrient i in a layer of soil of depth D to drop by $1/e$ times its original value is given by t_i^D:

$$t_i^D = \frac{\rho_B D}{k_i F} = \frac{t^D}{k_i}, \tag{13}$$

where t^D is the time it takes to completely excavate a layer of depth D with a mass flux rate equal to F. For $D = 0{\cdot}05$ m (a typical sampling depth), $F = 4{\cdot}62$ kg m^{-2} year^{-1} (at $U_{*_t} = 103$ cm s^{-1}) and with a bulk density of 1·25 Mg m^{-3}, t^D is approximately 14 years. Reported values of nitrogen enrichment in Australian arid zone soils are in the order of 10 (Leys & McTainsh, 1994; Carter *et al.*, 1999), although Larney *et al.* (1998) have reported values as low as 1·1.

Talbot *et al.* (1986) have reported concentrations of water-soluble N and P in Saharan dust of 2·58 mg g^{-1} and 123 μg g^{-1} respectively. Using the inferred threshold shear velocity of 103 cm s^{-1} and equation (7), we calculate N and P losses of 1200 μg cm^{-2} year^{-1} (120 kg N ha^{-1} year^{-1}) and 57 μg cm^{-2} year^{-1} (5·7 kg P ha^{-1} year^{-1}), respectively. Typical concentration of N and P reported by Schlesinger *et al.* (1996) in undisturbed Mojave Desert soils are approximately 2 μg N g^{-1} and 0·66 μg P g^{-1}, respectively. Comparing these values with those of Talbot *et al.* (1986) implies that k_N and k_P may be as high as 10^1–10^3 and therefore that t_i^D may be as small as a few years.

Available N and P concentrations at a site in the Jornada Basin measured by Okin *et al.* (in press) indicate approximately a 5-fold net loss of available N and a 3-fold net loss of plant-available P in the 8 years since the establishment of the site. Thus, the e-folding times of N and P, t_N^D and t_P^D, in this surface soil undergoing active deflation and aerosol emission are inferred to be approximately 5–10 years. Wind erosion, therefore, impacts soil fertility in areas of both direct and indirect disturbance on short timescales. This has dramatic implications for nutrient availability in disturbed areas, especially for seed germination in surface soils where the degree of nutrient depletion will be greatest.

Conclusions

Anthropogenic desertification of arid shrublands

Extensive remote sensing, field, and quantitative assessment of arid land degradation in the Manix Basin leads us to conclude that in arid shrublands direct anthropogenic disturbance resulting in the destruction of soil crusts and vegetation cover can cause indirect disturbance of adjacent areas by initiating the disintegration of islands of fertility. Figure 4 illustrates a proposed model for the degradation of arid shrublands based on these observations. The inferred sequence can be visualized as:

(1) Transport of sand from disturbances resulting in deflation of the disturbed surface.
(2) Mobilization of dust and plant litter by wind, depleting the soils of nutrients in areas of direct disturbance.
(3) Damage to and burial of plants by saltating sand in adjacent downwind areas.
(4) Reduction of vegetation cover downwind, leading to an expanding area in which wind removes dust and litter material, depleting the soils of nutrients.

A feedback threshold may be reached when these mechanisms act to dramatically reduce shrub cover in previously undisturbed areas. The accessibility of this threshold is related to allogenic changes in regional climate and interannual variability. Reduced precipitation or increased temperature may exacerbate landscape vulnerability and cooler, wetter conditions may aid amelioration.

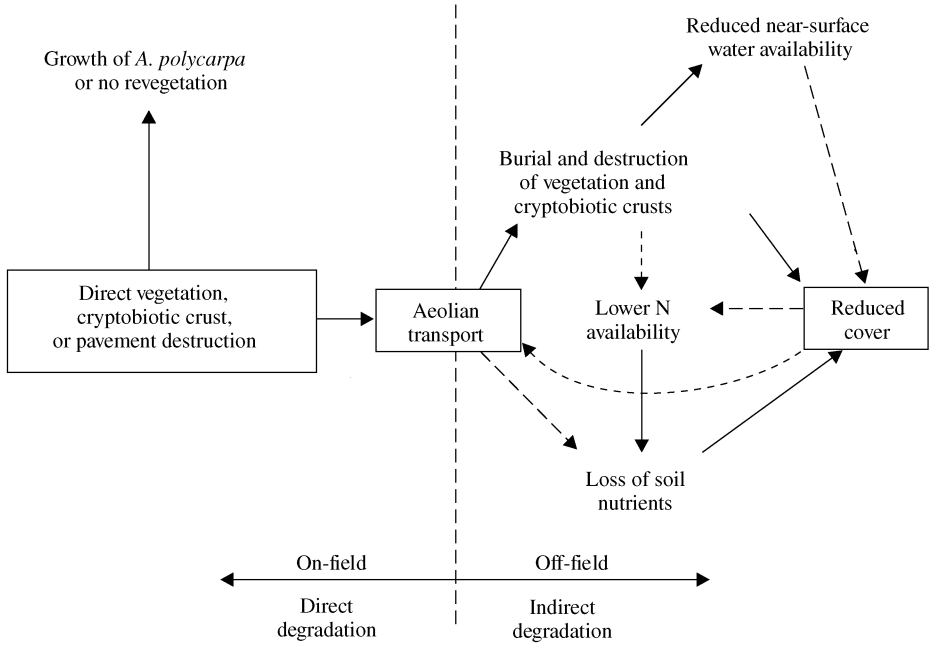

Figure 4. Process model for shrubland degradation developed from observations at the Manix Basin, California. Direct disturbance through vegetation, crust, or pavement destruction drives aeolian transport which leads to indirect degradation in the form of reduced cover in adjacent areas.

Nutrient relations and soil resources

Shrubs are the loci of nutrient accumulation and represent islands of fertility in shrubland ecosystems (Schlesinger *et al.,* 1990). How then does wind erosion affect soil resources in degraded shrublands?

Nutrient removal from islands of fertility has three main mechanisms: (a) physical removal of litter and organic matter by the wind; (2) wind suspension of dust particles with a high concentrations of plant nutrients (Leys & McTainsh, 1994); and (3) retarded accumulation of organic N due to increased surface and air temperatures (Post *et al.*, 1985). In areas of indirect disturbance, the mantle of winnowed dune sand may lead to decreased fertility of the surface soil, which is vital for seedling establishment. Areas of direct disturbance which are the sources for dune sand will also become less fertile through preferential removal of fines by wind. Removal of litter beneath shrubs limits the future availability of organic N and C to plants (Lyles & Tatarko, 1986; Schlesinger & Pilmanis, 1998).

Islands of fertility associated with shrubs are normally sites for recolonization by seedlings (Schlesinger & Pilmanis, 1998). These young plants are more vulnerable to sand abrasion and burial than their mature predecessors and their establishment may be limited. In many areas adjacent to abandoned agricultural fields in the Manix Basin, shrub sites are generally not recolonized and become areas of soil nutrient removal, effectively dismantling the islands of fertility. Schlesinger & Pilmanis (1998) have reviewed field experiments in which shrubs have been removed by cutting, herbicides, or fire. These studies show variable rates of soil degradation, but in each case, 'a loss of the local biogeochemical cycle associated with shrubs has allowed physical processes to

disperse soil nutrients across the landscape'. Thus, the progressive reduction in fertility acts in tandem with the mechanical action of sand to further decrease shrub cover which, in turn, increases the susceptibility of the land of wind erosion. The permanent removal of suspension-sized particles from the soil by wind erosion results in a change of the soil texture, which may also reduce soil binding properties, resulting in increased wind erodibility.

In a study aimed at determining the effect of wind erosion on nutrient availability, Okin *et al.* (in press) have measured available N and P at a disturbed site in the Jornada LTER site in south-central New Mexico. Their results indicated that surface soils upwind of the disturbance are richer in available N and P than those from downwind, if the soils from the upwind transect are considered representative of the original conditions throughout the study site. This indicates approximately a 5-fold net loss of available N and a 3-fold net loss of plant-available P from the soils blown off of the disturbed area. In addition, the site itself lost nearly 94% of its available N and nearly 79% of its plant-available P. Similar results have been reported by Leys & McTainsh (1994) in Australia.

The nutrient cycle may be further disrupted when soil microbial communities are buried or destroyed by blown sand, minimizing their ability to fix atmospheric nitrogen and add it to the nutrient reservoir of the soil. The burial of cryptobiotic crusts also reduces their ability to enhance infiltration of water leading to decreased near-surface soil moisture (Belnap *et al.*, 1993; Belnap, 1995).

It has been suggested by Gibbens *et al.* (1983), Lyles & Tatarko (1986), Hennessy *et al.* (1986), and Leys & McTainsh (1994) that permanent removal of suspension-size particles from the soil by wind erosion may reduce water-holding and cation-exchange capacities. This may result in less water in the surface soil, marginalizing the water balance of desert shrubs and increasing their susceptibility to drought and climate change. On short timescales, this may be particularly important for the establishment of annual grasses. In wet years, these grasses form a carpet that reduces the susceptibility of soils to wind erosion (Lancaster & Baas, 1998). In dry years, decreased near-surface soil moisture makes the landscape more vulnerable to wind erosion. Dust storm frequency has been correlated with reduced soil moisture, indicating that soil erosion and nutrient removal are accelerated by decreased soil moisture (Brazel & Nickling, 1987).

Lessons for land managers

Several aspects of the arid shrubland degradation observed at the Manix Basin can provide lessons for land management in these environments. Wind erosion is the principle mechanism of degradation in arid shrublands on basin floors. The principle consequences of land degradation are therefore:

(1) sand blasting of vegetation and equipment;
(2) burial of vegetation and equipment;
(3) dust emissions leading to decreased nutrient availability, cation-exchange capacity, water-holding capacity, and atmospheric pollution.

For virgin lands, not already converted to human uses, we stress that if possible, arid shrublands with sandy wind erodible soils should not be used for many activities. These are extremely fragile lands, the degradation of which could easily upset marginal economic gains from their cultivation or make recreation and habitation impossible. Furthermore, disturbance of arid shrubland landscapes may disturb successional processes, resulting in permanent landscape change. Where development is deemed necessary, planning must precede plowing. The principle consideration must be the wind erodibility of soils. In the United States, county-wide soil surveys typically provide information on soil texture. Soils of sandy or loamy sand textures, even when covered by

a thin layer of protective crust (deflationary crust, desert pavement, or cryptobiotic crusts), are very vulnerable to wind erosion. Activities which break up soil crusts and destroy vegetation are best avoided. High-risk activities include agriculture, grazing, ORV recreation, and military training. Roads, when necessary, should be situated to minimize the area of wind-erodible soils affected. The location of natural wind breaks such as trees, hills, and mountains should also be used to determine the location of planned developments.

For land already under cultivation or used for recreational purposes, we suggest technological and logistical methods for minimizing the effects of wind erosion in local vegetation, crops, and infrastructure. Equipment, sheds, and other buildings should be situated upwind of fields so that they are not sandblasted or buried. Fields, likewise, should not be situated such that one is close to and downwind of another, or else sand eroded from one will be deposited on another. Talbot (1947) has observed that uncultivated areas between fields in the extremely sandy western lowlands of the Cape Province, South Africa, may stem wind erosion and keep redeposition of sand from occurring in undesirable places. Other wind breaks, preferably indigenous plants which do not need to be watered after establishment, will also help stem erosion. Attempts must be made to keep vegetation on fields as much as possible. In light of this, nitrogen-fixing cover crops may be planted which would minimize erosion and add nitrogen when tilled back into the soil. Fallow periods, especially in the windiest time of the year should be avoided, and cover crops planted instead. Fertilizers may need to be added every few years, when significant nutrient loss is detected and when nitrogen-fixing cover crops are not sufficient to renew the soil resources. When abandoned, fields should be planted with a final, long-lived perennial indigenous cover that will help minimize wind erosion for years to come, and will allow natural succession processes to take place.

Novel management techniques may provide the best opportunities for sustainable management of arid shrublands. We suggest yearly monitoring of soil nitrogen and phosphorous in order to identify times or places where dust emission has significantly depleted the soil of nutrients. Where possible, use should be made of remote sensing and precision farming technologies to ascertain soil condition and to respond appropriately. Carter *et al.* (1999) have reported success in stemming erosion and improving soil conditions by adding clays of sub-soil origin to sandy soils in Western Australia. These and other techniques could be used to dramatically improve the sustainability of agriculture in arid lands.

Agriculture in the Manix Basin is a good example of unregulated and unmanaged human activities for short-term gain leading to long-term loss of value. As farming in the basin has became less profitable, farmers, simply abandoned the land to natural degradation processes without implementing long-term remediation strategies. A principal lesson from this area, therefore, is that policy mandates and financial incentives need to be put in place which promote soil conservation initiatives during land-use and require restoration of the landscape after cultivation stops. Efforts at remediation do not need to focus on restoring the environment to its pristine condition, although this is preferable. Instead, they can focus on halting or slowing soil erosion of planting long-lived, native, and perennial shrubs that will partially protect the surface. Funds for post-agriculture remediation should be earmarked before cultivation begins, and must be considered a part of the cost of business in vulnerable lands. In this way, remediation becomes the responsibility of the short-term land-user and not someone else's long-term problem.

Regional drivers and effects

In addition to the increasing intensity of human disturbance, arid lands are affected by changes in regional climate. How might climate change affect arid shrubland degradation?

The 1980s and 1990s—the decades in which large areas of the Manix Basin were abandoned from agriculture and in which the greatest land degradation has been seen—were neither unusually windy nor dry. The annual average wind speed for the period 1961 to 1990 was 5·5 m s^{-1}, identical to the period of 1980–1989 (National Climate Data Center, 1993). Annual precipitation was only slightly higher between 1970 and 1990 than for the period 1941 to 1997 (Table 1). When the decadal-scale regional climate in the Manix Basin shifts to a windier or drier period, the area affected by nutrient loss and aeolian sand mobilization may be expected to increase dramatically.

There has been much discussion about the relative importance of human *vs*. indirect climate drivers of desertification. Both can have a dramatic impact on the landscape (Schlesinger *et al*., 1990; Brown *et al*., 1997). Climate change may either increase or decrease anthropogenic effects on a landscape. For example, during wetter than average years, the presence of annual grass cover greater than about 15% halts wind erosion, and increased soil moisture leads to higher threshold shear velocities (Brazel & Nickling, 1987; Lancaster & Baas, 1998). In drier than average years, threshold shear velocity may be lower due to decreased soil moisture, and annual cover is greatly reduced leading to accelerated degradation. In the northern Mojave Desert, Schultz & Ostler (1993) have reported a dramatic decrease in total plant cover after only 4 years of drought. Clearly, resistance to climate-induced changes is dependent on the degree of anthropogenic disturbance and *vice versa*. Thus, regional decadal-scale climate conditions may be expected to dramatically influence the rate of arid shrubland degradation.

Extrapolation to other areas

The primary driving mechanism in the process model developed from observations in the Pleistocene paleolake Manix is the aeolian mobilization of sand, dust, and litter material as initiated by anthropogenic disturbance of the surface crust and vegetation cover. Any process that destroys the surface crust in an arid or semi-arid shrubland and increases the boundary layer velocity over a soil with saltation- and suspension-size particles will result in the progressive devegetation of the downwind area. Thus, our model can be extended to incorporate any arid or semi-arid shrubland with a source of wind-erodable material.

Other land forms in the arid south-west

Any arid shrubland with a source of wind-erodable, fine-grained material at the surface may be susceptible to anthropogenic degradation. Our study of the Manix Basin indicates that arid shrublands on Pleistocene paleolake beds are especially susceptible to anthropogenic degradation. Pleistocene lacustrine deposits are common in basin floors throughout the arid south-western United States, where large, shallow pluvia l lakes existed during the Last Glacial Maximum (Smith & Street-Perrott, 1983; Morrison, 1991*a*, *b*). Closed basins that were once Pleistocene lakes exist in many now-arid areas throughout the globe. The degradation observed in the Manix Basin is simply an example which can be applied to similar geological environments globally. They exhibit qualities that make them amenable for many human uses, such as very low slopes, little or no relief, subsurface water resources, and fine-grained sediments suitable for farming or other activities. Thus, the areas of greatest potential usefulness are also susceptible to serious degradation.

The armoured soils of desert bajadas—defined as broad, gently inclined alluvial surfaces extending from the base of mountain ranges to inland basins—may also be susceptible to a similar process of human-induced degradation. Although these soils are typically too gravelly or steep to be used for agriculture, these landforms may be wind

erodible when disturbed by human activities. When present, the soil armour has been argued to develop through the 'born at the top' model of McFadden *et al.* (1987), wherein fine, wind-mobilized particles are trapped by surface cobbles that float atop the accumulation of fine-grained material. Removal of the very stable desert pavement therefore exposes a layer of extremely wind-erodable wind-derived material, sometimes metres thick. Anthropogenic disturbance in these areas is likely to have profound consequences. Certainly, 'born at the top' pavements downwind of areas of active dunes will be at high risk of degradation should be cover of protective pebbles be disturbed. Other soils of aeolian origin, including stabilized dunelands, will similarly be susceptible to anthropogenic degradation of the type discussed here.

Cryptobiotic soil crusts—communities of cyanobacteria, lichens, and mosses—are found throughout the world's deserts. These crusts bind fine soil particles by linked cyanobacterial fibres which protect the soil from wind erosion. Belnap (1995), Williams *et al.* (1995), and Marticorena *et al.* (1997) have suggested that the presence of cryptobiotic crusts dramatically decreases wind and water erosion. When disturbed, cryptobiotic crusts lose most of their protective qualities allowing mobilization of the underlying mineral soils. Shrubland areas with widespread cryptobiotic crusts are thus also vulnerable to progressive degradation should human activities disturb these fragile soil crusts.

Global implications

The problem of wind-induced land degradation is not limited to the south-western United States. Greater use of mechanized agriculture in arid regions throughout the world, as well as other land-use demands, is increasing the amount of arid and semi-arid shrublands brought into cultivation or under human influence (see, for example, Luk, 1983; Kealah, 1989; Khalaf & Al-Ajmi, 1993; Zha & Gao, 1997; Kasusya, 1998; Khresat *et al.*, 1998; Koch & El Baz, 1998; Mitchell *et al.*, 1998). This trend, linked with political/economic instability or the marginal and water-limited nature of arid land agriculture, makes sustainable arid region agriculture especially challenging.

Nations with a large proportion of their territory situated in arid environments with wind-erodible soils are particularly vulnerable to the consequences of land degradation. Great care needs to be employed in the responsible stewardship of these lands to promote sustainable agricultural, and economic and social development.

Summary

Aeolian mobilization of dust, sand, and litter triggered by anthropogenic disturbance contributes to the destruction of islands of fertility by killing shrubs through burial and abrasion. This interrupts nutrient-accumulation processes and allows the loss of soil resources by abiotic transport processes. The resulting reduction of vegetation cover, in turn, increases susceptibility to wind erosion.

Land degradation processes necessarily exist in the context of regional climate and can either be bolstered or hindered by climatic conditions and changes, a fact that makes the rate of degradation ultimately climate-related. The process model developed here suggests various remediation techniques to halt shrubland degradation, but ultimately indicates that development of landscapes susceptible to wind erosion should be avoided where possible.

In the face of largely unsustainable socioeconomic factors, the vulnerability of arid lands to degradation argues for the development of linked degradation process models and monitoring strategies in order to minimize environmental damage and to promote sustainable management of human activities in arid lands. The dramatic landscape

changes that accompany arid shrubland degradation can be monitored using present and future remote sensing techniques and technologies. When informed by process models, such as the one presented here, remote monitoring tools may be used in the future to identify areas at risk of runaway degradation before large areas are adversely affected.

Globally, degradation of already-marginal arid lands represents a dramatic threat to local populations, food resources, and regional stability. Presently, the United Nations Convention to Combat Desertification is before the United States Senate for ratification. This treaty provides for scientific and technical exchange to combat desertification. The processes of arid land degradation must be understood, effective monitoring techniques developed, and effective remediation and management techniques implemented to avoid costly and prolonged environmental crises. The model presented here represents a small step in attaining these goals.

The authors wish to thank Drs Lancaster, Gillette, Monger, and Meek for their useful comments on the manuscript.

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JARE 20000711

HARCOURT PUBLISHERS

JOURNAL TITLE: JARE DATE: 6/11/2000
ARTICLE NO. : 20000711

Queries and/or remarks

Manuscript Page/line	Details required	Author's response
Page 16/line 8	Okin *et al.* (in press) — pl. update.	
Page 46/line 20	Ref. 50 — National Climate Data Center. (1997). — not in text.	
Page 50	Is figure. 1 to be colour? If not, change caption.	

EXHIBIT 434

BLM

Record of Decision

West Mojave Plan

Amendment to the

California Desert Conservation Area Plan

March 2006

California Desert District

BLM/CA/GI-2006-011+ 1790-1600

Public Lands USA; Use Share, Appreciate

These assurances can be issued only to incidental take permittees. They do not apply to federal lands, nor can they be issued to federal agencies, such as the BLM. Should conditions change, federal agencies can be required to take additional actions to protect a species.

The 2081 permit authorizes the take of species listed by the State of California. Should an unlisted species that is covered by the Plan become listed, the species could be authorized for take but only if the CDFG makes an independent finding that the species protection measures in place under the permit still provide for full mitigation of impacts to the species, and that the conservation measures continue to be adequate given the status of the species at the time of listing.

In the event that a species not covered in the Plan is subsequently proposed to be listed as threatened, rare, or endangered under FESA or CESA, USFWS and CDFG shall provide at least sixty (60) days notice to the permittees and meet with them prior to taking action on the listing proposal to ascertain whether this Plan and the environmental documentation for it shall be deemed to be adequate and appropriate documentation to support an application for a takings permit. USFWS and the permittees shall deem the Plan and accompanying environmental documentation adequate for the species so long as the species' habitat is adequately protected in the conservation areas, and the Plan is being properly implemented. CDFG would need to determine that the Plan meets all of the permit issuance criteria for that particular species, and that the permit would need to be amended to authorize incidental take. In that event, the application for revised incidental take permits to cover the additional species shall be treated by USFWS and CDFG as a Draft HCP that has been prepared in compliance with applicable state and federal laws, and shall treat the environmental assessment as an adequate environmental document under CEQA and NEPA to support the issuance of incidental take permits. If the finding is made that the species proposed for listing is not adequately protected by the conservation areas, USFWS and CDFG shall cooperate with the permitees to identify additional conservation measures that would be necessary to amend the Plan and incidental take permit applications to include the proposed species.

2.2.3.3 Take Authorized by Incidental Take Permits

Table 2-11 indicates the take to be authorized for each covered species and the conservation measures that are intended to minimize and mitigate the take. Take for all listed species other than desert tortoise is specified as either acres of habitat or number and location of known occurrences. Take would also be permissible for new occurrences found on private land outside the Habitat Conservation Area. Conservation efforts would keep pace with take, and habitat losses will not be allowed to outpace on-the-ground mitigation work. This will require tracking new ground disturbance. A mechanism to ensure that take does not outpace conservation will be included in the Implementing Agreement.

The permits would authorize take of listed species on private land outside the Habitat Conservation Area, subject to provisions of monitoring and adaptive management. Species not

2.2.4.8.5 Western Snowy Plover

Because the current occupied nesting habitat for snowy plover is not well known, much of the conservation for this species would be a result of adaptive management. The known important nesting sites on Searles Lake are protected through an agreement between IMC Chemical Corporation, BLM, Lahontan Regional Water Quality Control Board and CDFG.

Biological surveys of several playas in the western Mojave Desert in 2001 did not detect this species. However, reports from Harper Dry Lake in 2004 indicated the plovers were nesting. The following conservation measures apply to Harper Dry Lake and any newly detected nesting areas.

- (B-16) If nesting populations are discovered, human and vehicle disturbance would be restricted for a distance of 1/8 mile from nest sites during the nesting season (April 1 - August 1).

- (B-17) Projects in nesting habitat should allow the birds to complete the nesting season before construction begins.

- (B-18) BLM would continue working towards provision of a permanent water supply to the marshes at Harper Dry Lake ACEC.

2.2.4.9 Reptiles

2.2.4.9.1 Mojave Fringe-toed Lizard

Conservation of the Mojave fringe-toed lizard requires protection of the dune, hummock, and sand sheet habitat occupied by this species as well as of the sand sources and sand transport system. The ecological process of sand transport by flooding followed by sand sorting into smaller particle sizes and deposition onto occupied habitat by wind must be maintained where these processes are still present. In some cases, blowsand habitat along the margins of playas and lakes was formed in the Pleistocene era, and active sand transport is no longer present.

A conservation area composed of four parts is proposed for the fringe-toed lizard (see HCA-3). Three of these involve designation of ACECs on BLM managed lands, and one, Big Rock Creek, requires acquisition of private lands and cooperation by BLM, California Department of Parks and Recreation, Caltrans and Los Angeles County. BLM would retain public lands within the Mojave River wash and change the multiple use class from Unclassified to L. In addition, three other areas would be managed for compatibility with fringe-toed lizard conservation. These are the slope of Alvord Mountain and the Manix and Cronese Lakes ACECs.

The new proposed conservation area for the Mojave fringe-toed lizard is located at (1) Saddleback Butte State Park, including Big Rock Wash, Piute Butte, Alpine Butte and potential park expansion lands; (2) Dale Lake; (3) Mojave River east of Barstow, which consists of several separate parcels of public land; and (4) the Pisgah area.

Specific conservation actions are listed below:

- (R-1) Prohibit flood control structures that would impede sand transport at Big Rock Creek, Sheep Creek, and the Mojave River.

- (R-2) Aggregate mining in these drainages would be regulated to assure continued passage of sand downstream during flood flows.

- (R-3) Widen the bridge over Big Rock Creek when Highway 138 is improved to allow better sand and water flow and enhance the wildlife corridor between the desert and the San Gabriel Mountains. The existing double channel divided by fill material should be converted into a single long and high span.

- (R-4) Acquire occupied habitat adjacent to the northeast and west edges of Saddleback Butte State Park. BLM would retain scattered parcels within the Big Rock Creek blowsand ecosystem.

- (R-5) Suggest that the boundaries of the Big Rock Creek Significant Ecological Area in Los Angeles County be changed to the consultant's recommendations for the new Antelope Valley Significant Ecological Area.

- (R-6) Acquire specific lands on the slope of Alvord Mountain. Designate routes in this area, part of the Coyote subregion, as closed within the occupied habitat.

- (R-7) Amend the Cronese Basin and Manix ACEC Plans to include protection of the Mojave fringe-toed lizard as a primary goal.

- Designate portions of the Pisgah Crater area as an ACEC (see HCA-3).

- Designate a new conservation area near Dale Lake consisting of public lands within Joshua Tree National Park, the Sheephole Wilderness, and BLM managed lands adjacent to the Wilderness (see HCA-3).

- (R-8) Designate vehicle use on the conserved public lands with occupied habitat as closed.

- (R-9) Restrict the construction of windbreaks upwind of occupied habitat.

EXHIBIT 435

National Park Service
U.S. Department of the Interior

Organ Pipe Cactus
National Monument

10 Organ Pipe Drive
Ajo, Arizona 85321

520 387-6849 phone
520 387-7144 fax

Effects of the International Boundary Pedestrian Fence in the Vicinity of Lukeville, Arizona, on Drainage Systems and Infrastructure, Organ Pipe Cactus National Monument, Arizona

Prepared August 2008

On July 12, 2008, a summer storm delivered 1–2 inches of rain in about 1.5 hours in the south-central portion of Organ Pipe Cactus National Monument (OPCNM). The flash flooding that ensued tested the ability of the newly constructed pedestrian fence along the U.S./Mexico border to accommodate flood flows. The purpose of this report is to document the July 12 storm event, the performance of the pedestrian fence during the flash flood, the effects of the flood on floodplains and channel morphology of south-flowing drainage systems of OPCNM, and the implications for infrastructure maintenance.

Background

The pedestrian fence in the vicinity of Lukeville, Arizona, is 5.2 miles long. It was completed during the spring and summer of 2008. The fence is located within the 60-ft strip of land adjacent to the international boundary known as the 'Roosevelt Reserve,' set aside for public highways by presidential proclamation in 1907. The fence is located several feet north of the existing vehicle barrier, which is several feet north of the international boundary. Adjacent to the pedestrian fence is a dirt patrol road about 45 feet wide that was constructed as part of the pedestrian fence project.

The U.S. Army Corps of Engineers (USACE), in cooperation with the U.S. Department of Homeland Security (DHS), designed the pedestrian fence. A typical fence section is 15 feet tall and is composed of wire mesh panels (Figure 1).

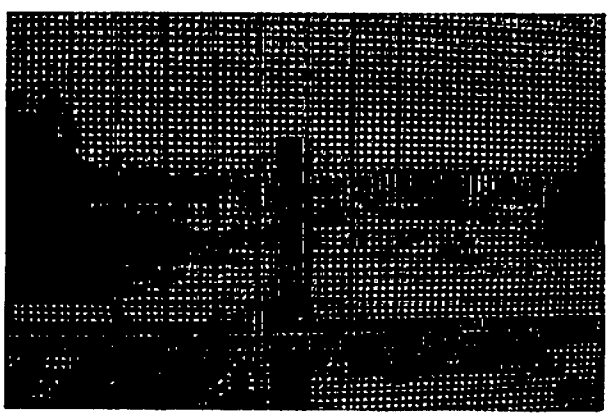


Figure 1. Close-up view of wire mesh on a typical fence panel.

Panels at drainage crossings have grates that were designed to accommodate a flood event (Figure 2). Grate openings are 6-inches (in) high and 24-in wide, with 1-in by 3-in bars.

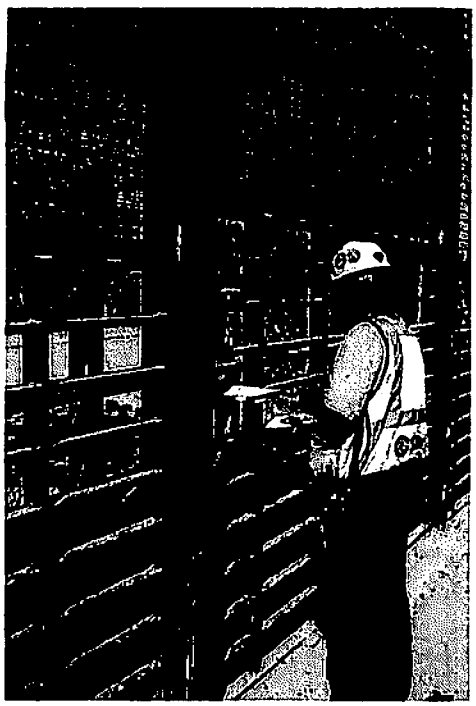


Figure 2. Fence panels at drainage crossings (above) have wire mesh above larger grate openings intended to accommodate flood flows.

Summer Thunderstorms and the 12 July 2008 Storm Event

The area experiences two annual rainfall periods that, in part, define the Sonoran Desert. The winter season is driven by westerly or northwesterly winds bringing moisture from the Pacific Ocean. Winter storms typically occur between November to April, and are gentle rains that rarely cause flooding. The Arizona or Mexican monsoon typically lasts from July to September in southwestern Arizona. The summer rainy season is driven by southerly or southeasterly winds that bring moisture northward from the Pacific Ocean and the Gulf of Mexico into the desert southwest. Extreme surface heating, combined with the moist air, powers monsoon thunderstorms. These violent storms are often accompanied by strong winds, lightning and flash flooding. Summer thunderstorms are the regional flood source (USGS 1999). On July 12 in the late afternoon, a monsoon thunderstorm occurred over south-central OPCNM. The radar rainfall estimate for that day from the National Oceanic and Atmospheric Administration (NOAA) shows the thunderstorm centered north of Lukeville, in the vicinity of the OPCNM headquarters (Figure 3). The map shows a very small area receiving rain in excess of 2.5 inches (in red, Figure 3).

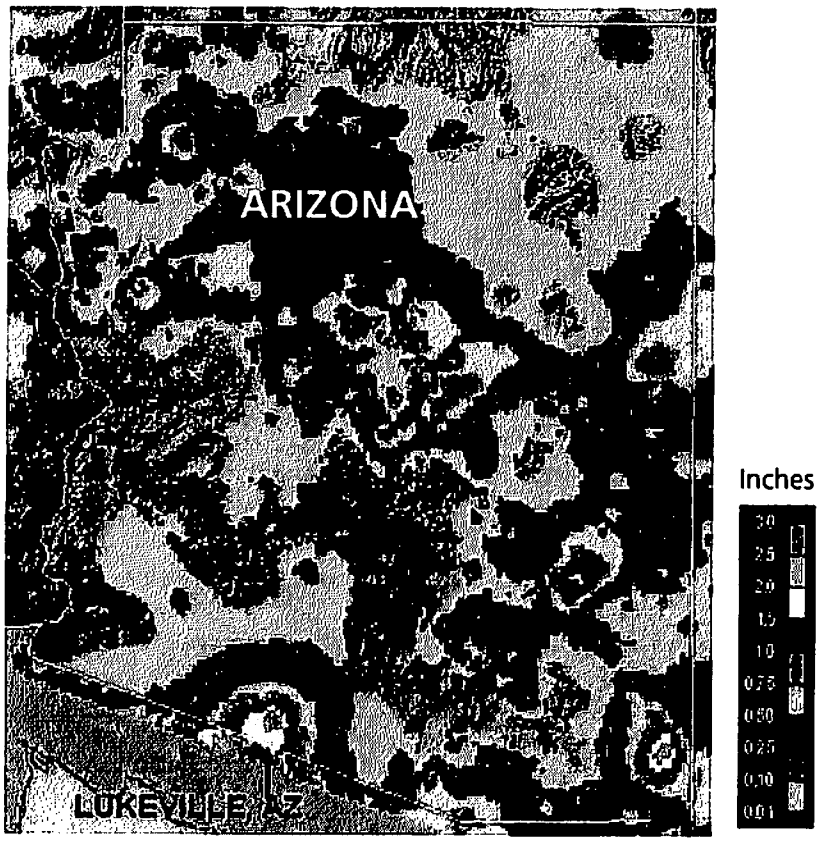


Figure 3. The radar rainfall estimate (in inches) for a 24-hour period from 0500 Mountain Standard Time (MST) July 12 to 0500 MST July 13, 2008, Arizona (NOAA, 18 July 2008). Data is truncated just south of the international boundary.

A different radar rainfall estimate map for the 6-day period July 9 to July 15 shows that monsoonal storms of the magnitude of the July 12 storm are a widespread and normal occurrence across southern Arizona (Figure 4) (NWS, July 15, 2008). At the headquarters climate station, light rain occurred on July 9 and July 10 as well as the heavy rain of July 12. The cumulative total of these rains is shown on Figure 4.

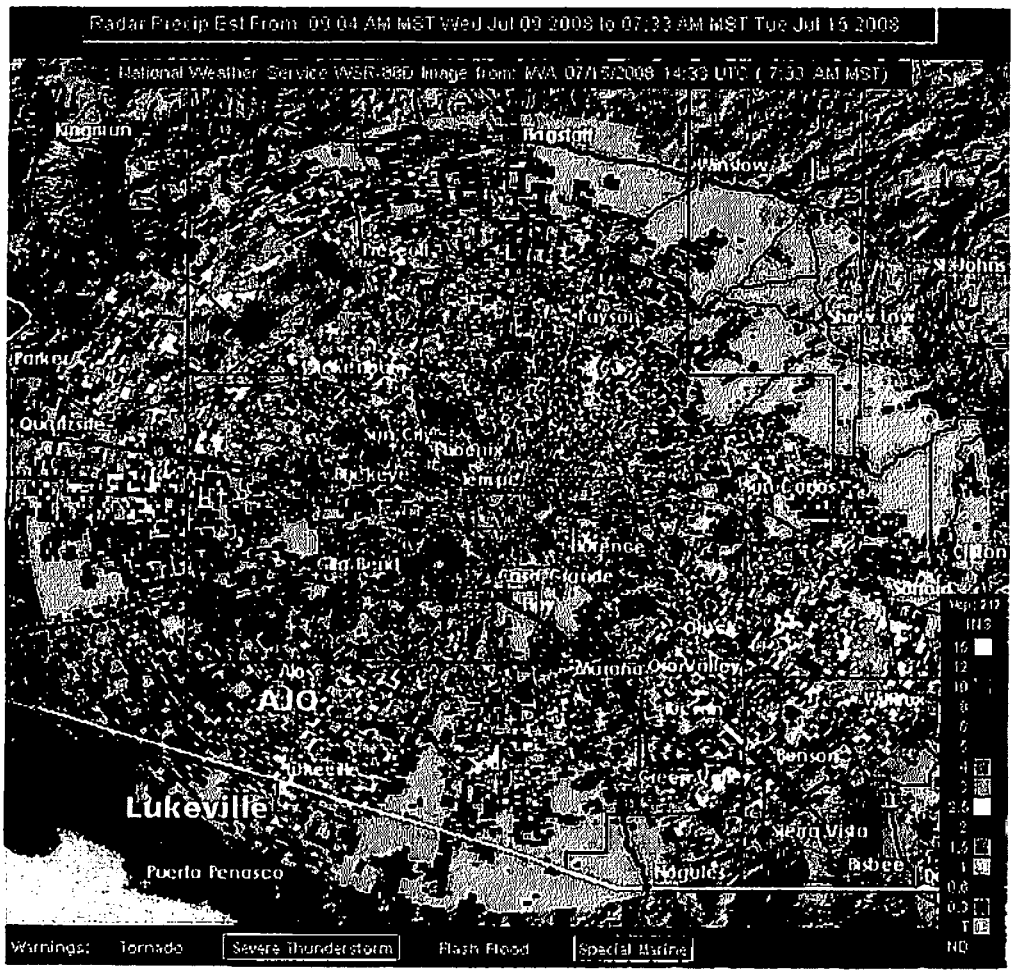


Figure 4. Regional radar precipitation estimates for 9:04am MST July 9, to 7:33am MST July 15, 2008 (NWS, 15 July 2008).

Typical of monsoon thunderstorms, the rainfall event of July 12 was intense and brief. Weather instrumentation near OPCNM headquarters recorded 1.99 inches of rain in about 1.5 hours. This climate station is part of the National Atmospheric Deposition Program (NADP) and is operated by the NPS. A few miles south of headquarters, another rain gauge recorded 1.28 inches of rain in about one hour and 45 minutes, or 0.71 inch per hour. Rainfall at this site, located about 1.5 miles west-northwest of Lukeville, was measured by a tipping bucket with Hobo recorder. Figure 5 shows the locations of the climate station and rainfall gauge.

Summer storm events such as the July 12 storm occur regularly within OPCNM. Based on a 60 year record of daily rainfall at OPCNM headquarters, rainfall events in excess of 2 inches occurred

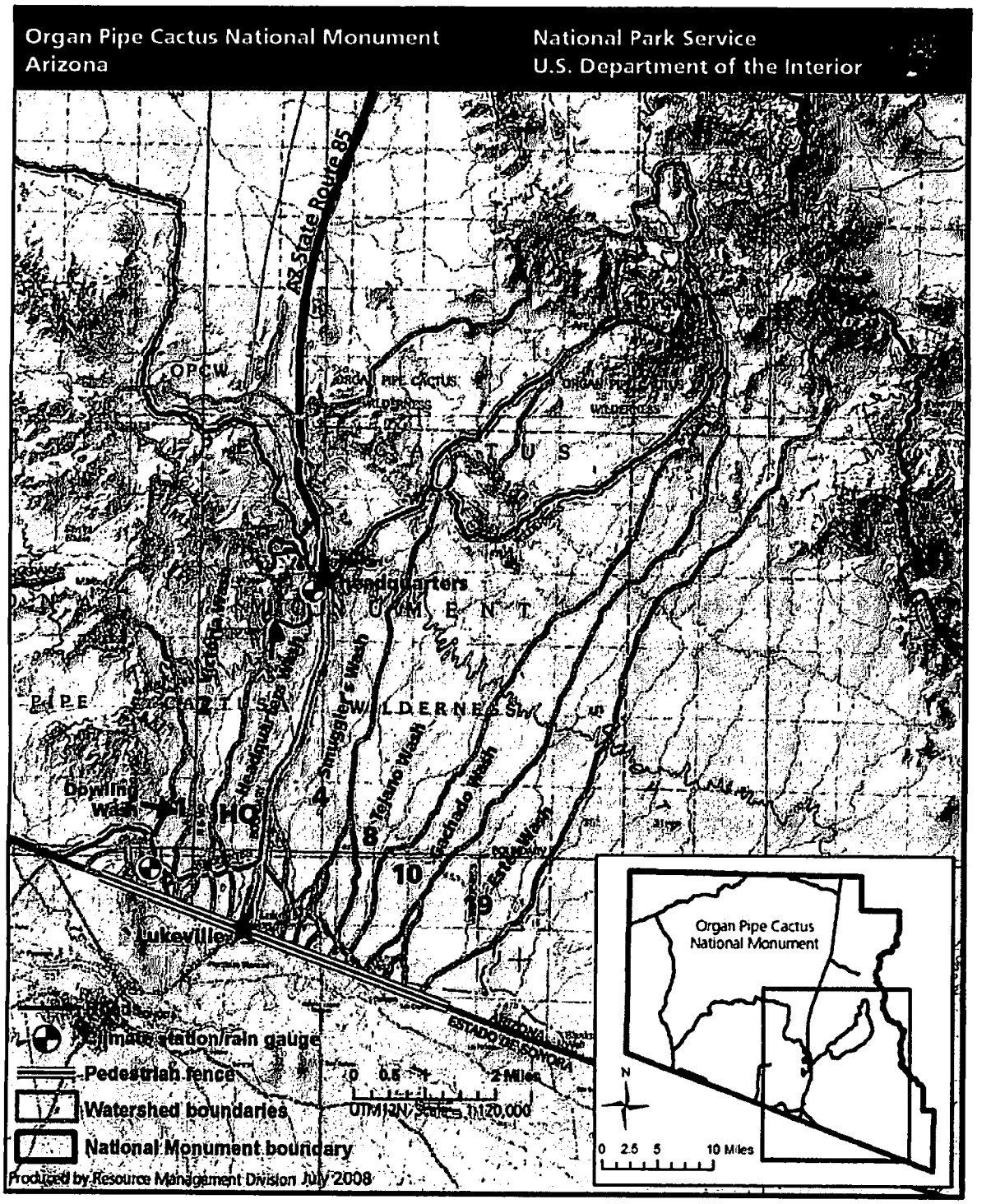


Figure 5. Extent of watersheds draining into Mexico and crossing the pedestrian fence. NPS drainage numbers and names are also listed in Table 1. The drainage area numbers and sizes calculated by OPCNM are different from those used in the hydrologic analysis (USACE/Kiewit 2008a).

12 times, or once every five years. Events between 1.50 – 1.99 inches occurred about once every 3 years, and events between 1.0 – 1.49 inches occurred nearly every year.

The probability that flash flooding will occur due to a monsoonal storm event in the Sonoran Desert is determined by many factors, including the total amount of rainfall, the rate of rainfall (intensity), extent of the storm, the size of the affected watersheds, how much of the area of each drainage area receives rain, and soil saturation preceding the event.

Nearly all drainages crossing the international boundary at the pedestrian fence flow from north to south. The seven largest drainage basins range in size from nearly 1 square mile (sq mi) to over 16 sq mi (Table 1). Drainage areas as determined by OPCNM (Table 1) were derived from an accurate GIS database and were different than estimates in the drainage report (USACE 2008a, p15-16). The latter estimates for Estes and Victoria Wash were significantly underestimated.

The headwaters of Smugglers, Tejano, Gachado, and Estes drainages are located in the Diablo/Ajo Mountains complex. These higher-elevation headwaters located on the eastern side of OPCNM—including Mount Ajo (4,808 ft), the highest point in the Ajo Mountains—typically receive more rainfall during the monsoon than lower-elevation sites (Holm & Conner 2006). The Victoria, Dowling and Headquarters drainage basins have headwaters located in the Puerto Blanco Mountains.

Table 1. The names of drainages crossing the international boundary at the pedestrian fence and the extent of the watersheds above the pedestrian fence.

Drainage Name	NPS Drainage Number	USACE/Kiewit Drainage Number	Drainage Area Estimate (acres)	
			NPS	Kiewit
Tejano Wash	8	E16	10,500	9,384
Smugglers Wash	4	E8	9,548	9,491
Estes Wash	19	E31	7,988	3,741
Headquarters Wash	HQ	W1	4,938	4,754
Victoria Wash	2	W13	3,613	2,839
Gachado Wash	10	E20	3,464	3,419
Dowling Wash	1	W17	593	591

Fence Design and Performance Criteria

Fence design addressed security performance criteria as well as those relating to hydrology. The following discussion addresses only the design and performance criteria that relate to hydrology.

OPCNM's early concerns about the effect of the pedestrian fence on floodwaters, floodplains, ecosystem function and infrastructure were based on first-hand knowledge of flash flooding and its frequency at OPCNM. Additionally, the vehicle barrier has afforded NPS staff the opportunity to observe how this very porous structure can cause scour and collect debris during a flood event. During scoping meetings and in comments on the draft Environmental Assessment (EA) for the pedestrian fence project (Baiza, *in litt.*, 9 October 2007, USDHA 2007a, USDHS 2007b, Kiewit 2007, *et al.*), OPCNM expressed concerns that:

- The fence would impede the conveyance of floodwaters across the international boundary.
- Debris carried by flash floods would be trapped by the fence, resulting in impeded flow and clean-up issues.
- Backwater pooling would occur due to impeded flow.
- Lateral flow due to backwater pooling would cause environmental damage as well as damage to patrol roads.
- Significant increase in surface water depths (or rise in water elevation) would occur as a result of impeded flow, causing adverse affects on downstream and upstream resources and infrastructure in OPCNM and Mexico.

Addressing OPCNM's concerns, the Final Environmental Assessment (FEA) and Finding of No Significant Impact (FONSI) stated that, in addition to security criteria, the fence would "...not impede the natural flow of water" (U.S. Border Patrol 2007a). It would be "...designed and constructed to ensure proper conveyance of floodwaters and to eliminate the potential to cause backwater flooding on either side of the U.S.-Mexico border" (U.S. Border Patrol 2007a). Further, Customs and Border Protection (CBP) "...will remove debris from the fence within washes/arroyos immediately after rain events to ensure that no backwater flooding occurs" (U.S. Border Patrol 2007a).

The Department of Homeland Security (DHS), OPCNM, USACE and Kiewit met in December 2007 to discuss how the fence design met the required performance standards. In the meeting handout, Kiewit stated the design would "...permit water and debris to flow freely and not allow

ponding of water on either side of the border" because the drainage crossing grates "...met hydraulic modeling requirements" (Kiewit 2007).

The hydrologic design criteria included in the final drainage report (USACE 2008a) were as follows:

- Rise in water elevation due to the fence for a 100-year frequency event would be limited to 6 inches in rural areas.
- Design would consider and protect against scour or long-term degradation at or downstream of the fence location.
- Design would protect against ponded water along the fence.

The drainage report stated that the final fence design satisfied all performance criteria (USACE 2008a).

The USACE/Kiewit based the fence design on a hydrologic analysis that used a 100-year storm as the base storm for determining peak discharge in all drainage basins (USACE 2008a). Two methods were used to determine the 100-year water surface elevations. For drainage areas greater than 10 square miles the 100-year water surface elevations were determined by using equations recommended by the U.S. Geological Service (USGS), even though the USGS advised that the method is not applicable at average elevations below 1,730 feet. (USACE 2008a, USGS 1999). The USGS method for estimating peak discharges from rural streams uses four variables: drainage area (in square miles), average annual precipitation, average basin elevation, and average annual evaporation (USGS 1999). Drainage areas were calculated using a GIS dataset of unknown source, rather than the more accurate OPCNM dataset. USACE/Kiewit's final calculations for 100-year water surface elevations included considerations given to elevation rise due to the fence posts and grates.

For drainage areas less than 10 square miles, the Natural Resource Conservation Service 'curve number method' was used to estimate discharge (USACE 2008a). USACE/Kiewit used the NOAA Atlas 14 to determine precipitation frequency estimate for the project (Bonnin et al. 2006). Atlas 14 for the Ajo, Arizona, area predicts that a storm lasting 1.5 hours with a rainfall intensity of 0.71 inches per hour would occur once every 5 years (based on a partial duration series). Hourly rainfall data from the headquarters climate station confirms a slightly more frequency occurrence (once every 3 years).

Performance of the Pedestrian Fence

This section of the report compares the performance standards set by the FONSI (USBP 2008) and those set by the final drainage report (USACE 2008a) with the actual performance of the fence, as documented by OPCNM. As the USBP performance standards are different from the USACE standards, each will be addressed separately.

FONSI Standard: The pedestrian fence would "...not impede the natural flow of water" and would allow "...proper conveyance of floodwaters." It would "...eliminate the potential to cause backwater flooding on either side of the U.S.-Mexico border."

The pedestrian fence impeded the natural flow of water and did not properly convey floodwaters during the July 12 storm. Mainstem drainage channels contained flood flows until reaching the proximity of the pedestrian fence. Debris blockages formed at the upstream side of the fence, restricting water flow and causing significant water elevation rise (Figure 6). The foundation wall of the pedestrian fence stopped subsurface sediment flow, which added to the water elevation rise. Backwater flooding occurred in most washes.

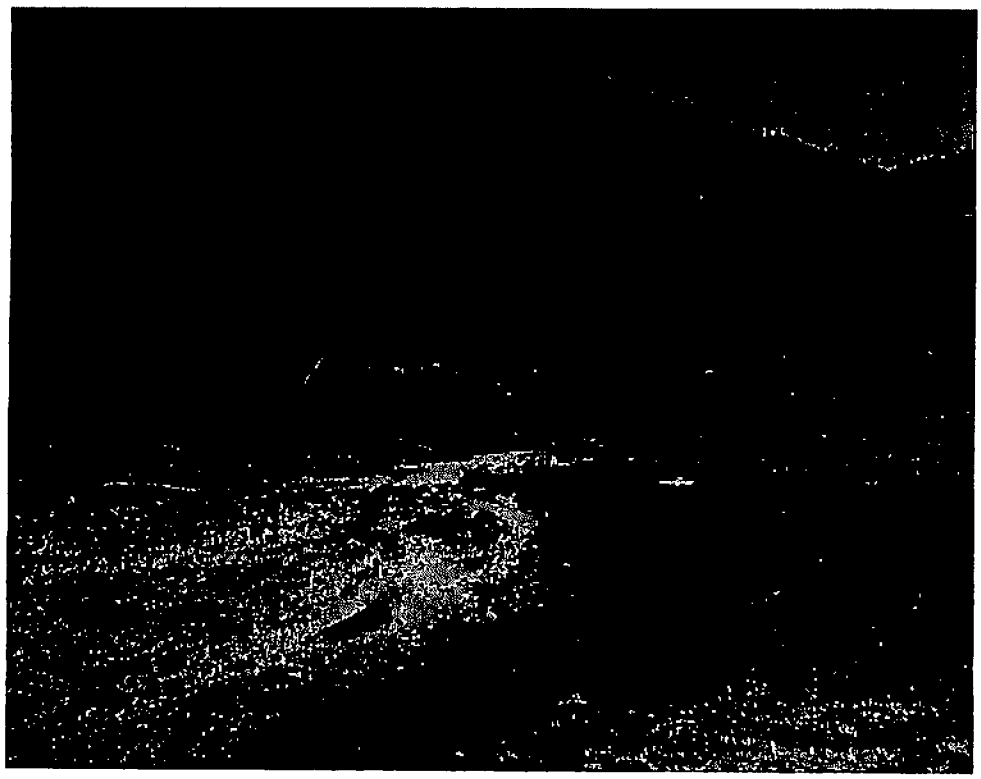


Figure 6. At this drainage crossing west of Lukeville, debris filled most of the length of the drainage grate, causing backwater pooling of 1-2 feet depth. Photograph was taken on July 15, 2006.

FONSI Standard: Flood debris would be removed "...immediately after rain events to ensure that no backwater flooding occurs."

Removing debris after a flood is ineffectual at stopping backwater flooding while a flash flood is occurring. Backwater flooding occurs during a flood. Removing debris after a flood will reduce the pooling that would take place during the next flood, compared with leaving the debris in place.

USACE Performance Standard: Rise in water elevation due to the fence for a 100-year frequency event would be limited to 6 inches in rural areas.

The storm of July 12 has a return frequency of about once every three years (OPCNM data), or once every five years according to NOAA (2006, partial duration series). According to the design criteria, the fence should not have caused the extensive significant water elevation rise, backwater pooling, or lateral flows from a relatively frequent storm event.

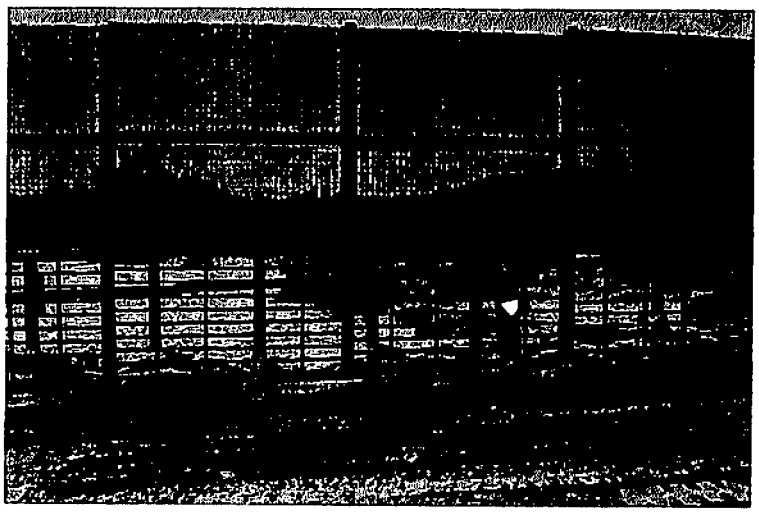
Floodwaters at the pedestrian fence were several feet deep in all the drainages listed in Table 1 as well as in a number of moderate-sized drainages. Since floodwaters were contained within natural channels except at the pedestrian fence, we can deduce that the fence caused a significant portion of the rise. The foundation wall likely contributed to backwater pooling by stopping subsurface flows, adding to water elevation rise.

During the July 12 event, water elevations at nearly all major drainages crossed by the fence rose so significantly that backwater pooling occurred and floodwaters flowed laterally (east-west or west-east) along the fence. Among the more significant lateral flow events were:

- Victoria Wash, with a drainage area of 5.6 square miles, rose against the pedestrian fence and flowed over 1,100 feet to the west into a minor channel. Fine sediment deposits on the fence between the two washes reached a height of 1-2 feet. Where the main channel crossed the fence, the high water mark was about 7 feet above the foundation wall of the fence (Figure 7). It is uncertain how much of this rise was due to the fence.
- Smugglers' Wash, with a watershed of nearly 15 square miles, left its channel at the pedestrian fence and flowed more than 500 feet to the east. It discharged into a channel that normally drains a 0.15 square mile basin.

Figure 7. The floodwaters of Victoria Wash (W13) were blocked by debris and rose to a depth of about 7 feet.

About 2 feet of coarse debris were deposited against the fence (upper photo, July 14, 2008). A band of fine sediment marks the high water line at flood stage.



The same site as above, after flood debris was cleared (middle photo, July 16, 2008). Distance from the foundation wall of the fence to the high water line is over 7 feet.

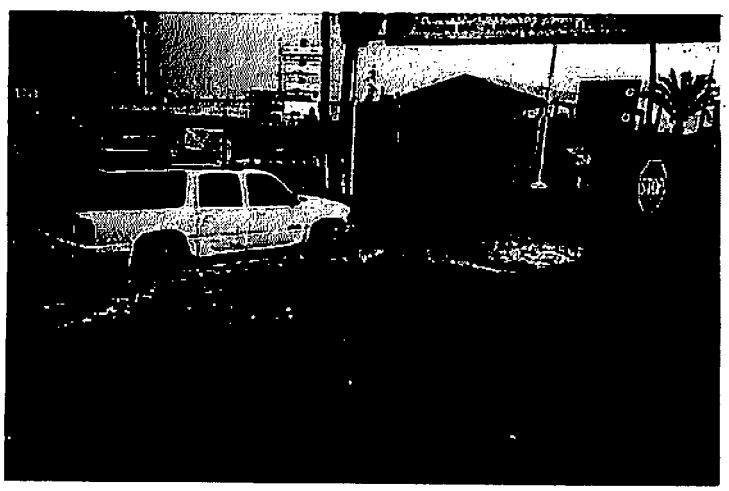


Figure 8 (left). Impounded by the pedestrian fence, floodwaters from Headquarters Wash, which normally flows from north to south, flowed to the east along the fence and into the Mexican Port of Entry in Sonoyta, Sonora. The white SUV is southbound into Mexico.

- Gachado Wash, which drains an area of 5.4 square miles, also flowed over 300 feet to the west into another channel. Coarse woody debris was deposited on the patrol road as far as 400 feet west of Gachado Wash. Wash bed sands were deposited on the road surface between these two drainage channels, indicating that the velocity of floodwater was sufficient to carry sand particles.
- Estes Wash travelled more than 500 feet to the west along the pedestrian fence foundation. Prior to the construction of the pedestrian fence, lateral flow of floodwaters along the international boundary had never been documented in the project area.
- Headquarters Wash flowed over 200 feet to the east along the pedestrian fence and through the international port of entry. It caused flood damage to private property, government offices and commercial businesses in Lukeville, Arizona, and Sonoyta, Sonora, Mexico (Figure 8).

Backwater pooling against the fence caused sedimentation to occur, at least in stream reaches near the fence. Sedimentation occurs when floodwater velocity decreases or is stopped by an impoundment. Evidence of sedimentation due to the pedestrian fence would include the presence of fine sediments in stream reaches normally having only sand and gravel. The flood of July 12 deposited a thick layer of fine sediments on the lower reaches of major washes. We could not determine the depth of sediments deposited on the patrol road because on July 16 they were either covered with debris or they had been removed prior to our visit.

Fine sediment deposits were documented in stream reaches above the patrol road. Accumulation of fine sediments in these stream reaches will, over the long term, change the hydrology of these drainage systems upstream. Downstream from the fence in Mexico, drainages will be affected eventually by the decrease in sedimentation.

Notable fine sediment deposits were documented in Tejano Wash (Figure 9), Estes Wash, Dowling Wash, Victoria Wash, and Smugglers' Wash upstream from the patrol road on July 16, 2008. These deposits were also observed at Gachado and Headquarters washes, but the observation was not photographically recorded, as repeat photography did not occur at this sites.

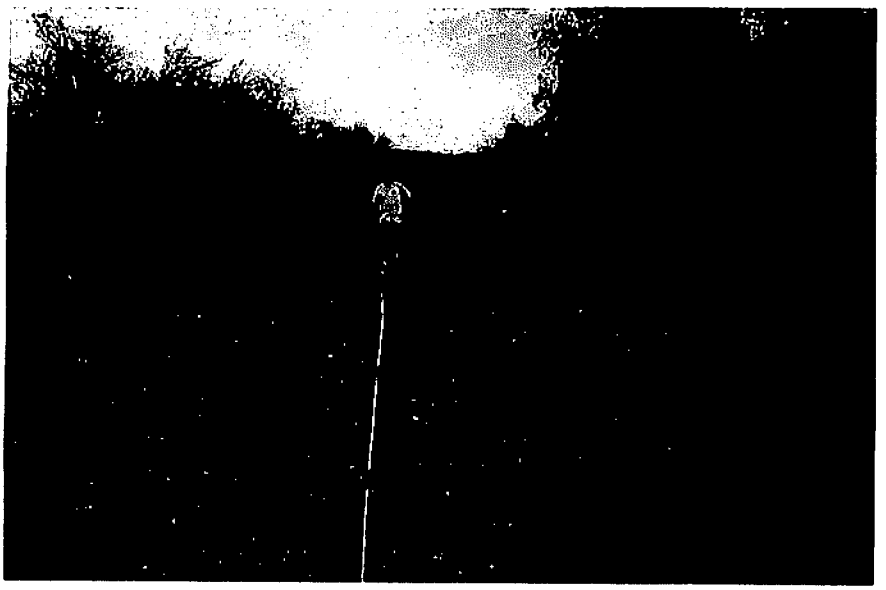


Figure 9. Prior to fence construction (above), the bed of Tejano Wash (E16) was composed of coarse sand and gravel (NPS photo, 9 July 2008). After the flood (below), flood debris can be seen in the foreground of the same scene, and a new deposit of fine sediment can be seen in the midground (NPS photo, 16 July 2008).

USACE Performance Standard: Design would consider and protect against scour or long-term degradation at or downstream of the fence location.

Considerable scour occurred downstream from the pedestrian fence. Some of this scour can be attributed to the pedestrian fence, while some sites will require addition time and study to determine if the pedestrian fence accelerated scour or not.

Scour that can be attributed to the pedestrian fence include areas where lateral flows or backwater pools crossed the fence outside of natural drainages. Scour also occurred at the upstream side of the foundation wall (Figure 10).

Figure 10. Floodwaters flowed laterally along the pedestrian fence, causing scour at the foundation wall and erosion of the patrol road in places. (NPS wash 17, east of Lukeville, July 16, 2008).

A water elevation rise of up to 7 feet at the pedestrian fence caused significant scour at the foundation wall and vehicle barrier on the downstream side. Erosion control fabric was displaced and in most large wash crossings is no longer functional (Figure 11).

Figure 11. Left: Downstream from the pedestrian fence, a 7-ft tall cascade of water caused downstream scour at Victoria Wash (NPS photo July 16, 2008). A Kiewit photo taken before construction (USACE 2008a) shows no scour at this site.

Right: At Estes Wash, floodwaters flowed along the foundation wall on the downstream side, causing scour at the vehicle barrier. At this site, the erosion control fabric remained in place, although exposed.

USACE Performance Standard: Design would protect against ponded water along the fence.

We assume this design standard was written to protect against ponded water on the patrol road during and after rainfall events. The design appears to have met this standard for the patrol road. Some ponding did occur, however, in areas upstream from the patrol road where road elevations are above the natural surface elevations, especially where small drainages are impounded by the road or where road berms block runoff. During the next few decades, vegetation change will occur in those areas along the northern edge of the patrol road that receive and retain runoff.

Conclusion

Our data and observational information show that the pedestrian fence did not meet the standards set by the FONSI (USBP 2008) or the USACE's hydrologic performance standards (USACE 2008a). As a consequence, natural resources of OPCNM and NPS infrastructure will be impacted, as well as resources and infrastructure on neighboring lands in the U.S. and Mexico. Short- and long-term impacts that are expected due to the pedestrian fence include the following:

- Accelerated scour below the pedestrian fence will damage the structural integrity of the vehicle barrier along the U.S./Mexico boundary unless continued maintenance occurs.
- Floodwaters will flow laterally along the pedestrian fence and on the patrol road. These flows will result in erosion and scour above and below the foundation wall of the fence, including areas hundreds of feet outside existing drainage channels. As a consequence, the need for routine maintenance and repairs of the patrol road and vehicle barrier will increase.
- The patrol road associated with the pedestrian fence will change vegetation in OPCNM by changing rainfall retention or runoff along the northern road edge.
- Riparian vegetation will change in response to increased sedimentation.
- Channel morphology and floodplain function will change over time.
- Channelized waters will begin a gullying process that has the potential to transform land surfaces in the affected watersheds.

We recommend that third-party, objective experts should conduct a review of the performance of the fence with regards to hydrologic criteria. The fence needs to properly convey debris-laden flood flows. Significant pooling, lateral flows and scour should be minimized by improved fence design. The structural integrity of the vehicle barrier needs to be maintained because it continues to play a strategic role in border security and resource protection. Road-edge effects on vegetation should be minimized by better management of berms and road elevations.

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EXHIBIT 436

U.S. Fish and Wildlife Service

FINAL ENVIRONMENTAL ASSESSMENT
Proposal to Permit Take as Provided Under the Bald and Golden Eagle Protection Act

DIVISION OF MIGRATORY BIRD MANAGEMENT

FINAL ENVIRONMENTAL ASSESSMENT

Proposal to Permit Take

Provided Under the Bald and Golden Eagle Protection Act

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April 2009

Summary

- The U.S. Fish and Wildlife Service has removed the bald eagle (*Haliaeetus leucocephalus*) from the list of threatened and endangered species under the Federal Endangered Species Act in all areas except the range of the Sonoran Desert bald eagle population, which remains protected as a threatened species. The Bald and Golden Eagle Protection Act (Eagle Act) remains as the primary law protecting bald eagles in other parts of its range and the golden eagle (*Aquila chrysaetos*).

- The Eagle Act authorizes the Secretary to permit take of eagles "necessary for the protection of … other interests in any particular locality." In addition, there may be instances where take of eagle nests is necessary to protect public safety and welfare.

- In this assessment we consider three alternatives for regulations establishing new take permits under the Eagle Act, and authorizing take of eagle nests where necessary to protect public safety and welfare.

- The assessment looks at potential impacts that could result from the implementation of the proposed regulation or alternatives to the proposed regulation within the context of other take already authorized or otherwise occurring.

- This assessment also summarizes the biological foundation for defining take thresholds for bald eagles and golden eagles. Under the preferred alternative, the Service will define thresholds for take by adapting a published model used in other recent raptor regulations. The thresholds will guide annual take limits on a regional basis to ensure that we are consistent with the goal of stable or increasing breeding populations.

- The majority of authorized take will be non-lethal and will simply allow activities to disturb eagles in a way that will result in a loss or reduction of one year's productivity by a nesting pair.

- On-the-ground information and conditions will guide the actual amount of take authorized, which may be less than modeled, as long as the total does not exceed the modeled thresholds.

- Except for safety emergencies, the rule will give priority in permitting to Native American use for rites and ceremonies that require eagles be taken from the wild if requests for permits will likely approach the annual threshold. The next permit priorities will be for activities necessary to ensure public health and safety, renewal of programmatic nest-take

permits, and Non-emergency activities necessary to ensure public health and safety, and (for inactive golden eagle nests only) resource development or recovery operations (§ 22.25).

- The Service's preferred alternative, number 3, will: (1) authorize disturbance take of eagles; (2) authorize removal of eagle nests where necessary to protect public health and safety; and (3) provide for permits for take resulting in mortality in some limited circumstances. It will authorize take permits for both bald eagles and golden eagles.

- Alternative 3 is also the environmentally-preferred alternative. It is expected to have the least adverse impact on the human environment, with negligible effects on the natural and physical environment and the least adverse impact along with the most beneficial impacts to the socioeconomic environment.

- The criteria for issuance of permits would initially limit their issuance to only 5% of the Maximum Sustainable Yield for bald eagles, which is consistent with the recommendations in published literature for take of raptors where population monitoring may be limited or there are concerns about the vital rates for a species

- The best available data we have for golden eagles indicate modest declines in the four BCRs that constitute 80 percent of its range in the lower 48 states. Estimates of population size in Alaska are coarse, based upon even fewer data sources than in the lower 48 states, and juvenile survival may be far lower, so management would therefore need to be conservative. In addition, McIntyre et al. (2008) suggested that conservation strategies for migratory golden eagles require a continental approach. Therefore, until we have additional data to show that populations can withstand additional take, of those authorized under the new rule, we will only consider issuance of permits for safety emergencies and programmatic and other permits that will result in a net reduction in take or a net take of zero for golden eagles. We will continue to issue historically-authorized take permits under existing permit types at the level of take carried out under those permits (average over 2000-2007).

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Chapter 1: Purpose and Need for the Action

1.1 Introduction

This Final Environmental Assessment (FEA) has been prepared to analyze the U.S. Fish and Wildlife Service's (Service) proposal to create a permit or permits under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*) (Eagle Act) allowing the take of bald eagles and golden eagles and their nests when necessary to protect interests in particular localities. This FEA is an analysis of potential impacts that could result from the implementation of the proposed regulation or alternatives to the proposed regulation within the context of other take already authorized or otherwise occurring. It is to assist us in ensuring compliance with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 *et seq.*) (NEPA), and in making a determination as to whether any "significant" impacts could result from the analyzed actions. "Significance" under NEPA is defined by regulation at 40 CFR 1508.27, and requires short-term and long-term consideration of both the context of a proposal and its intensity, and whether the impacts are beneficial or adverse. An EA provides evidence for determining whether to prepare an Environmental Impact Statement (EIS) or a statement of "Finding of No Significant Impact" (FONSI). If the decision maker determines that this project has "significant" impacts following the analysis in the EA, then an EIS would be prepared for the project. If not, a FONSI would be signed for the EA approving the alternative selected and a Set of Findings may be prepared.

As with any NEPA process, if all components have undergone equal analysis, the final proposal may include all or some components of a single alternative. Or, it may include a combination of components from more than one alternative.

1.1.1 Background

In 2007, the Service removed the bald eagle from the list of threatened and endangered species under the Endangered Species Act (16 U.S.C. 1531 *et seq.*) (ESA) (72 FR 37345, July 9, 2007). However, on March 6, 2008, the federal district court for the District of Arizona enjoined removal from ESA protection of the population of "Desert bald eagles" of "the Sonoran Desert region of the American southwest" pending resolution of a 90-day petition to list a distinct population segment of bald eagles in that region. *Ctr. for Biological Diversity v. Kempthorne*, 2008 U.S. Dist. LEXIS 17517 at 42 (D. Ariz. 2008). Therefore, the bald eagle remains protected under both the Eagle Act and the ESA in the Sonoran Desert region as a threatened species pending the outcome of that case. The Bald and Golden Eagle Protection Act remains as the primary law protecting bald eagles outside the range of the Sonoran Desert population in the U.S. and golden eagles throughout their U.S. range. The Eagle Act would also become the primary law protecting bald eagles within the range of the Sonoran Desert population should the Service delist that population in the future. The

Eagle Act prohibits take of bald eagles and golden eagles and provides a statutory definition of "take," which includes activities that "disturb" eagles. Bald eagles and golden eagles are also protected under the Migratory Bird Treaty Act (MBTA) (16 U.S.C. 703–712).

To provide a consistent framework in which to implement the Eagle Act after bald eagle delisting, on June 5, 2007, the Service clarified its regulations implementing the Bald and Golden Eagle Protection Act. (72 FR 31131). The modifications to implementing regulations for the Eagle Act established a regulatory definition of "disturb," a term specifically prohibited as "take" by the Eagle Act. As per the regulatory definition, disturb means

> *to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, injury to an eagle; a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior; or nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.*

As stated, the regulatory definition of "disturb" also applies to golden eagles.

Also on June 5, 2007, the Service issued a Notice of Availability of the National Bald Eagle Management Guidelines (Guidelines). (72 FR 31156). These guidelines provide a roadmap for landowners and project proponents seeking to avoid violating the Eagle Act while conducting activities near eagles. For example, the guidelines recommend buffers around nests to screen nesting bald eagles from noise and visual distractions caused by human activities. We intend the clarifications and the guidelines give landowners, and others, guidance in ensuring that actions they undertake are consistent with the Bald and Golden Eagle Protection Act.

When Congress enacted the Eagle Act in 1940, it intended the Act to be the primary law protecting eagles from extinction, and as such it provided a broad prohibition in its definition of "take" by defining it to include "pursue, shoot, shoot at, wound, kill, capture, trap, collect, molest or disturb." (Pub. L. No. 76-567, §4, 54 Stat. 250, 251 (1940)). Congress later added "poison" to the definition. (Pub. L. No. 92-535, §4, 86 Stat. 1064, 1065 (1972)).

However, the Eagle Act also delegates to the Secretary the ability to permit take of eagles for several reasons, including when "necessary for the protection of "other interests in any particular locality" after determining the take is "compatible with the preservation of the bald eagle or golden eagle." In addition, there may be instances where take of eagle nests is necessary to eliminate a hazard to human or eagle safety. Most populations of the bald eagle have recovered sufficiently to be removed from the ESA list, while supporting take during recovery. Therefore, we can logically assume populations can continue to sustain limited take.

1.2 Current Proposal

The Service proposed new regulations to amend the current regulations at 50 CFR 22.26 and 22.27 as follows: to (1) establish an eagle take permit under the Eagle Act; (2) authorize take of eagle nests where necessary to protect public health and safety, (3) authorize take resulting in mortality (TRM)[1] under limited circumstances; and (4) establish new programmatic permits under the Eagle Act for disturbance, airfield eagle hazards, nest removal from power lines, and TRM (72 FR 31142, June 5, 2007). The take permit provisions will primarily authorize disturbance. However, the regulations analyzed in this document will also provide for authorization of other types of take of eagles under limited circumstances.

For example, take might be authorized, in the areas meeting prescribed standards, for a utility that does all of the following:

- establishes a mortality baseline through estimates or a sampling scheme;
- employs the best available techniques and mutually-approved standard practices for minimizing eagle mortalities;
- undertakes a system-wide risk analysis and retrofits a significant portion of hazardous locations within a reasonable time frame;
- implements an effective monitoring program and reports eagle mortality to the Service,
- uses only avian-safe practices on all new infrastructure in areas determined to be high-risk for eagles; and
- demonstrates it has eliminated eagle mortality except that which is unavoidable.

To prevent collisions, utilities might also need to ensure transmission lines, distribution lines and towers located in known eagle concentration areas, foraging areas, or nesting areas, have visual markers on the wires. Because even best practices cannot ensure that eagles will not be killed by electrocution or collision with power lines, the regulation could authorize this type of unavoidable take by a utility that has met all the requirements above. This is an example only. The specific requirements listed above may not be applicable should the Service issue such a permit in the future, but the standards to be met will be comparable.

1.3 Purpose and Need for Action

The purpose of this regulatory proposal is to: (1) provide authorization for take of bald eagles and golden eagles "necessary for the protection of "other interests in any particular locality" as provided for in the Eagle Act, while ensuring it is compatible with the preservation of the eagles, as mandated by the Eagle Act;

[1] TRM in this document refers to non-purposeful take that would result in mortality, despite all efforts to avoid it. We distinguish this from intentional lethal take permitted under 50 CFR 22.22 for Native American religious purposes.

(2) develop a management system that will simplify complex, long-term-eagle-management issues by allowing programmatic approaches; (3) provide a consistent approach to permitting between Service Regional offices; and (4) make take authorization available for removal of eagle nests where necessary to protect public health and safety and to protect eagles.

For purposes of this action, "compatible with the preservation of the bald eagle and the golden eagle" means consistent with the goal of stable or increasing breeding populations. Although take thresholds are based on regional populations, the regulation requires the Service to consider additional factors, such as cultural significance, that may warrant protection of smaller and/or isolated populations within a region. In the DEA and notice re-opening of the comment period on the rule (73 FR 47574, August 14, 2008), to elucidate the statutory standard of "preservation of the bald eagle or the golden eagle," we proposed the following terminology: "maintaining increasing or stable populations." We continue to support the essential meaning of that standard, but recognized that it could be misapplied to constrain any authorization of take because any take of a bald or golden eagle by some degree results in a population decrease, even if short-term and inconsequential for the long-term preservation of the species. Thus, if interpreted so narrowly, the word "maintaining" would render us unable to authorize any take. Therefore, we are revising our interpretation of "preservation of the eagle" to read "consistent with the goal of stable or increasing breeding populations." The phrase "consistent with the goal" will allow take that is compatible with long term stability or growth of eagle populations. Adding the word "breeding" clarifies the significance of the number of breeding pairs for maintaining or growing populations, versus floaters (non-breeding adults).

Under the Eagle Act as it has been applied to golden eagles, the Service relies on enforcement discretion and voluntary cooperation between the Service and other agencies and private entities to regulate take of eagles in the absence of an available permit for non-purposeful take. The resulting case-by-case enforcement and reliance on voluntary measures to eliminate and reduce take during otherwise-legal activities has made it difficult for the Service to ensure that such take is compatible with the preservation of eagles. The Service needs to provide a uniform legal framework for allowing take of eagles during the conduct of otherwise-legal and permitted activities. Creation of a permit or permits that all Service Regions can consistently administer will fulfill that need and improve the protection of eagles. The permit or permits created must be both feasible to implement and enforceable, and provide for the conservation of both species.

1.4 Authorities

The principal Federal authority for the actions analyzed in this FEA is the Eagle Act (16 U.S.C. 668–668d). The Service is the Federal agency with primary statutory authority for the management of bald eagles and golden eagles in the

United States. Regulations implementing the Eagle Act are in Subparts C & D of Part 22 of Title 50 of the Code of Federal Regulations.

Compliance with Federal Statutes, Regulations, and Orders Relevant to the Alternatives Considered

The proposal is in compliance with the following federal statues, regulations, Executive Orders, and Department of the Interior Departmental Policy:

Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*) (Eagle Act)

The Eagle Act provides that the Secretary of the Interior may authorize certain, otherwise-prohibited activities through promulgation of regulations. The Secretary is authorized to prescribe regulations permitting the "taking, possession, and transportation of [bald or golden eagles] . . . for the scientific or exhibition purposes of public museums, scientific societies, and zoological parks, or for the religious purposes of Indian tribes, or . . . for the protection of wildlife or of agricultural or other interests in any particular locality," provided such permits are "compatible with the preservation of the bald eagle or the golden eagle" (16 U.S.C. 668a). In accordance with this authority, the Secretary has previously promulgated Eagle Act permit regulations for scientific and exhibition purposes (50 CFR 22.21), for Indian religious purposes (50 CFR 22.22), to take depredating eagles (50 CFR 22.23), to possess golden eagles for falconry (50 CFR 22.24), and for the take of golden eagle nests that interfere with resource development or recovery operations (50 CFR 22.25). This rulemaking establishes permit regulations to authorize non-purposeful eagle take "for the protection of . . . other interests in any particular locality."

The analysis in this FEA evaluates whether the proposed permits and their implementation, including limits on annual take, are compatible with the preservation of the bald eagle and the golden eagle.

National Environmental Policy Act of 1969, as amended (NEPA) (42 U.S.C. 4321 *et seq*.)

Agencies must complete environmental documents pursuant to NEPA before implementing Federal actions. NEPA requires careful evaluation of the need for action, and that Federal actions are considered alongside all reasonable alternatives, including the "No Action Alternative." NEPA also requires the action agency to consider the potential impacts on the human environment of each alternative. The decision maker(s) must consider the alternatives and impacts prior to implementation, and must inform the public of these deliberations.

The Service has prepared this FEA in compliance with NEPA; the President's Council for Environmental Quality (CEQ) Regulations, (40 CFR 1500–1508); and the NEPA-compliance requirements in the Department of the Interior's Departmental Manual (DM) and the Fish and Wildlife Service's Manual (FW) (516 DM 8, 550 FW 1-3, 505 FW 1-5).

Pursuant to NEPA and CEQ regulations, this FEA documents the analysis of a proposed Federal action, and all reasonable alternatives, including the “No Action” alternative. The FEA evaluates impacts anticipated from all alternatives; informs decision-makers and the public; and serves as a decision-aiding mechanism to ensure that NEPA and CEQ regulations have been incorporated into Federal agency planning and decision-making. The Service prepared this FEA using an interdisciplinary approach to address all aspects of the natural and social sciences relevant to the potential impacts of the project. The FEA analyzes the direct, indirect, and cumulative effects of the proposed action.

Endangered Species Act of 1973, as amended (ESA) (16 U.S.C. 1531 *et seq.*)

It is Federal policy under the ESA that all Federal agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of the ESA (§ 2(c)). Action agencies must implement section 7 consultations with the Service to ensure that "any action authorized, funded, or carried out by such an agency … is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat of such species. Each agency shall use the best scientific and commercial data available" (§ 7(a)(2)). In addition to the Sonoran Desert population of bald eagles, there may be other listed species present when permitted take of eagles will occur. When deemed necessary, each Regional Permit Office may help coordinate intra-Service section 7 consultations at the permit stage.

Migratory Bird Treaty Act, as amended (MBTA) (16 U.S.C. 703 *et seq.*)

The MBTA provides the Service with the regulatory authority to protect species of birds that migrate outside the United States. Individuals of species that do not migrate outside of the United States are also protected with the exception of several introduced, non-native species, including mute swans (*Cygnus olor*), house sparrows (*Passer domesticus*), European starlings (*Sturnus vulgaris*), Eurasian collared-doves (*Streptopelia decaocto*), and rock pigeons (*Columba livia*). For eagle take, a separate authorization under the MBTA is not required. Many impacts authorized under the ESA that will require Eagle Act authorization will not “take” eagles under the MBTA because that statute does not contain a prohibition against disturbance (without injury) of the birds it protects. Therefore, activities that disturb an eagle will not require MBTA authorization unless the activity also results in injury or some other impact prohibited by the MBTA. Even where MBTA take will occur, a separate MBTA authorization in addition to the Eagle Act authorization is not required because 50 CFR 22.11(a) exempts those who hold Eagle Act permits from the requirement to obtain an MBTA permit.

National Historic Preservation Act of 1966, as amended (NHPA) (16 U.S.C 470 *et seq*.)

Section 106 of the NHPA requires Federal agencies to take into account the effects of their undertakings on historic properties. Federal agencies accomplish this by following the Section 106 regulations, "Protection of Historic Properties" (36 CFR Part 800). The Section 106 regulations set forth a process by which agencies: 1) evaluate the effects of any Federal undertaking on historic properties (properties included in, or eligible for inclusion in, the National Register of Historic Places (National Register)); 2) consult with State Historic Preservation Officers (SHPO), Tribal Historic Preservation Officers (THPOs), and other appropriate consulting parties regarding the identification and evaluation of historic properties, assessment of effects on historic properties, and the resolution of adverse effects; and 3) consult with appropriate American Indian Tribes (Tribes) and Native Hawaiian Organizations (NHOs) to determine whether they have concerns about historic properties of religious and cultural significance in areas of these Federal undertakings.

Some Tribes and tribal members may consider eagle nests sacred sites provided for in the American Indian Religious Freedom Act (42 U.S.C. 1996) (some are frequently referred to as Traditional Cultural Properties (TCPs)), and as potential historic properties of religious and cultural importance under the NHPA. Such sites are not limited to currently-recognized Indian lands, and they occur across the entire aboriginal settlement area. In addition, some tribes may consider all eagles and eagle nests as TCPs or sacred sites, and potential historic properties of religious and cultural significance which must be considered under Section 106 of NHPA. Properties of religious and cultural importance may be areas where eagles nest and have nested within living memory, their presence becoming a contributing element for determining eligibility under NHPA (King 2006, Tanji 2008)). Thus, a landform or landscape known for eagle habitation—a ridgeline, canyon, lakeshore, river valley, mesa, mountain, etc.—may be considered by Tribes as suitable for designation as a property of religious or cultural importance. A search of the database of historic properties listed on the National Register yielded eleven sites that may be associated with eagle habitat and that are likely to be considered properties of religious and cultural significance by Indian Tribes (Appendix A). We consider this list to be far from comprehensive, and include it primarily to illustrate the minimal information readily available. For other sites considered to have religious and cultural significance, the rigorous evaluation process for listing on the National Register has not been completed, or Tribes may not have initiated the process. According to the Section 106 regulations, a property is considered an historic property if it is listed on, or **eligible for** (emphasis added) listing on, the National Register. Thus, a lack of formal listing does not lessen the need to consider a property; instead, it emphasizes the need for close coordination with appropriate parties at the project planning stage.

Because an eagle or eagle nest may constitute or be considered a contributing feature or element of a property of religious or cultural importance or

sacred site (see discussion in Section 3.8, Societal Issues), issuance of the proposed permits for eagles could constitute an undertaking requiring compliance with Section 106 of the NHPA, and may also require government-to-government consultation with Tribes. Each Regional Permit Office will coordinate with the Service Regional Historic Preservation Officer to ensure necessary NHPA consultations take place with the appropriate parties. The FWS will comply with Section 106 on a case-by-case basis for permits that have the potential to affect historic properties. If it is determined to be more efficient for all parties, the Service may also consult with appropriate stakeholders to develop state or regional Programmatic Agreements that will govern and resolve the compliance with NHPA for the issuance of permits to take in specific states or regions.

American Indian Religious Freedom Act (AIRFA) (42 U.S.C. 1996)

AIRFA sets forth Federal policy to protect and preserve the inherent right of American Indians to express and exercise their traditional religions, including but not limited to, access to sites, use and possession of sacred objects, and the freedom to worship through ceremonials and traditional rites. Given the special trust relationship between the federal government and federally-recognized Indian Tribes, the accommodation of tribal religious practices is in furtherance of the duty of the federal government to promote tribal self-determination. AIRFA will be construed in conjunction with the Service's trust responsibility to federally-recognized Tribes. The Service, in proposing this regulation, has incorporated these principles into the proposal. To address the possibility that demand exceeds our scientifically-based take thresholds, the regulation contains permit-issuance criteria to ensure that requests by Native Americans to take eagles from the wild, where the take is necessary to meet the religious purposes of the Tribe, will be given first priority over all other take except, as necessary, to alleviate safety emergencies.

Religious Freedom Restoration Act of 1993 (RFRA) (42 U.S.C. 2000bb *et seq.*)

RFRA is aimed at preventing laws that substantially burden a person's free exercise of his or her religion. Regardless of the TCP designation under the NHPA, individual eagle nests and eagle areas may be regarded as "Sacred Sites" (AIRFA, EO 13007, and RFRA). The age or longevity of a sacred location has no bearing on its sacred quality, and questions of age or longevity might not be relevant to the community or religious practitioners who ascribe sacredness to a place. In keeping with our commitments under RFRA and AIRFA, the Service will place the highest priority upon Native American religious use for rites and ceremonies that require eagles be taken from the wild when allocating permits, except, as necessary, to alleviate safety emergencies, and we will conduct all necessary consultations (see discussion of Executive Order 13175 below).

Executive Order 13007, Indian Sacred Sites (61 FR 26771, May 29, 1996)

In managing Federal lands, each executive branch agency with statutory or administrative responsibility for the management of Federal lands shall, to the extent practicable, permitted by law, and not clearly inconsistent with essential agency function, (1) accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners and (2) avoid adversely affecting the physical integrity of such sacred sites. When deemed necessary, each Regional Permit Office will coordinate with the Regional Historic Preservation Officer and Regional Native American Liaison (NAL) to ensure implementation of the proposal is in compliance with this Order.

Executive Order 13175, Consultation and Coordination with Tribal Governments (65 FR 67249, Nov. 9, 2000)

This Executive Order emphasizes the need for regular and meaningful consultation and collaboration with tribal officials in the development of Federal policies that have tribal implications, the responsibility to strengthen the United States government-to-government relationships with Indian tribes, and the responsibility to reduce the imposition of unfunded mandates upon Indian tribes. Each Service Regional Director, in coordination with the Service Regional NAL, conducts government-to-government consultation with the tribes in their Region, and will do so on permits under this proposal. In order to ensure consistent, appropriate consultation, the implementation guidance for this proposal, which will also be available for public comment, will contain guidelines on government-to-government consultation. To facilitate coordination of our multiple responsibilities, our Tribal consultations will advise the Tribes that we are providing them notice under all applicable federal mandates, and we will list them: AIRFA, RFRA, the Eagle Act, E.O. 13007 (if applicable), E.O. 13175, and NHPA. We will also indicate that our notice and invitation to consult is being provided in an effort to carry out our trust responsibility to Tribes, with regard to the unique traditional religious and cultural significance of eagles to Native American communities, and in furtherance of the reserved rights of Native communities with respect to eagles.

Executive Order 13186, Responsibilities of Federal Agencies to Protect Migratory Birds (66 FR 3853, Jan. 17, 2001)

This Executive Order specifies the need to avoid or minimize adverse impacts on migratory bird resources when conducting agency actions, as well as the need to restore and enhance the habitat of migratory birds. The proposal, through its standards for incorporation of avoidance and minimization measures, is consistent with the goals of this Executive Order. The local Ecological Services and Regional Offices will review any mitigation proposals to ensure they do not adversely affect populations of other migratory bird species.

Department of Interior Departmental Manual 522 DM 1 Adaptive Management Implementation Policy

This policy from the Department of the Interior states that Bureaus should incorporate the operational components identified in the report, Adaptive Management: The U.S. Department of the Interior Technical Guide. These components are: the AM definition; the conditions under which AM should be considered; and the process for implementing and evaluating AM effectiveness. The proposal will be consistent with the Order.

Tribal and State Statutes

As of the writing of this document, 17 states consider the bald eagle endangered, and another considers it threatened under State statutes (See Appendix B). The Nez Perce, Mille Lacs Band of the Ojibwe, and Navajo Nation consider the bald eagle endangered. Three States consider the golden eagle endangered, and a single State protects it as a threatened species. The Navajo Nation and the Mille Lacs Band of the Ojibwe list the golden eagle as endangered. Nothing in the proposed regulation will prohibit individual Tribes or States from considering either eagle species as threatened or endangered according to their statutes. Nor will the proposed regulation prohibit Tribes or States from developing more stringent protection for either species.

Take of eagles may not be allowed without having obtained necessary tribal and State permits and/or certificates or registration. It is beyond the scope of this document to provide specific information regarding each Tribe's or State's permit requirements. However, it is the responsibility of each applicant to contact the respective tribal and State wildlife agency to determine permitting requirements. The Service will determine, upon application, whether there is a valid justification for the permit. In addition, the permit will include this proviso: "The authorization granted by permits issued under this section is not valid unless you are in compliance with all other Federal, tribal, State, and local laws and regulations that are required to conduct the permitted activity." Permittees found to be out of compliance with such other laws and regulations are subject to revocation of their permits under the Eagle Act.

Each Service Region will coordinate and consult with their respective Tribes and States on a case-by-case basis.

1.5 Scope of Analysis

The FEA considers alternatives for permits to take bald eagles and golden eagles "for the protection of … other interests in any particular locality" and where necessary to protect public health and safety. The document also provides evidence and analysis sufficient to determine whether an EIS is required.

This assessment evaluates the effects of various alternatives for permits to take eagles under the Eagle Act. Different permits have potentially different effects on bald eagles and golden eagles, and on societal aspects of the human environment. The potentially-affected human environment includes bald eagle and golden eagle populations, safety, the economy, cultural values, and Native

American religious and cultural practices. Since neither eagle addressed in this document occurs naturally in the State of Hawai`i, Hawai`i has been eliminated from the scope of analysis. In general, the analysis is either national or Service Regional in scale.

1.5.1 Scoping and Public Participation

The proposed permit regulation was made available to the public for a 90-day comment period (72 FR 31141, June 5, 2007), and we relied upon those comments as scoping under NEPA. The Service received approximately 21,500 comments. About 21,400 of the comments were essentially identical, but we summarized their substantive input. Thirty-four individual respondents provided additional substantive input that will be helpful in crafting final regulations, and have helped during the development of the FEA. The 34 individual respondents consisted of: one Federal agency, three Tribes, six State natural resources agencies, three Flyway Committees comprised of representative from State departments of natural resources, one State department of transportation, five environmental organizations, four industry associations, three law firms/consultants on behalf of developers, two power companies, one federal reclamation project, one airport, three rail transportation companies (commenting together), and three private citizens. In addition, we received 58 comment letters on the proposed revisions to the rule and the DEA as noted in our August 14, 2008, notice re-opening of the comment period on the rule and announcing the availability of the DEA. The respondents consisted of: three Federal Agencies, three Tribes, two Confederations of Tribes, one Tribal Department of Natural Resources, three Flyways, 13 State agencies, three Tribal members, one airport, three electric utilities, 10 individuals (non-tribal), five industry associations, nine environmental organizations, one conglomeration of railroad companies, and one transportation association. We have incorporated and responded to the majority of comments addressing our proposal in the preamble to the amended proposed regulation the Service will publish. In addition, the Affected Environment (Chapter 3) and Environmental Consequences (Chapter 4) portions of the FEA reflect a number of the comments, and Appendix K includes a summary of the substantive comments provided on the DEA, with our responses.

1.5.2 Related NEPA Documents

The Service has finalized two other NEPA documents analyzing the impacts from proposed regulations to take raptors. The Service published the Final Environmental Assessment for Take of Nestling American Peregrine Falcons in the Contiguous United States and Alaska for Use in Falconry in March 2004 (http://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/AmericanPeregrineFalcon/Final_EA_Peregrine.pdf). We finalized the Environmental Assessment for Take of Raptors from the Wild under the Falconry Regulations and the Raptor Propagation Regulations in June 2007 (http://www.fws.gov/migratorybirds/issues/falconry/Final%20Regulations%20EA.

pdf). For permitting disturbance under the Eagle Act, the Service will use the same modeling approach for determining take used in those NEPA documents.

1.5.3 Issues Discussed in Detail

The Service has used comments on the proposed regulation to help us develop this document. Some of the major topics on which comments focused, and which the FEA discusses, include the following:

- How populations will be delineated for management purposes.
- How the Service will be able to detect the threshold population declines.
- Whether the issuance criteria "where take cannot practicably be avoided" is appropriate.
- Whether "other interests in a particular locality" should be applied as a "catch-all" category.
- How permits will be prioritized if limited in quantity.
- The kinds of mitigation that will be required or effective.
- State coordination and relationship to State guidelines.

In addition, the FEA identifies resources that may either be affected by or may affect the alternatives. These include: (1) presently-occurring eagle mortality factors; (2) human safety concerns; and (3) cumulative effects to eagle habitat from human-generated and other environmental factors.

1.6 Decisions to be Made

- Whether to authorize take permits for both bald eagles and golden eagles.
- Whether to implement take permits for both bald eagles and golden eagles.
- Whether to authorize and implement take permits for removal of both bald and golden eagle nests when necessary to protect public health and safety.
- Whether to set thresholds for take employing a theoretical ecological model consistent with that used in other recent raptor regulations.
- Whether to authorize "disturbance" take only, or to authorize TRM under specific circumstances, and if so, under what circumstances.
- Whether the Service should authorize a permit for only one "disturbance" at a time, or authorize provisions for a programmatic approach.
- Whether, as our final preferred alternative, to adopt all of one proposal or components of more than one alternative.
- Whether, under NEPA, a Finding of No Significant Impact can be reached.

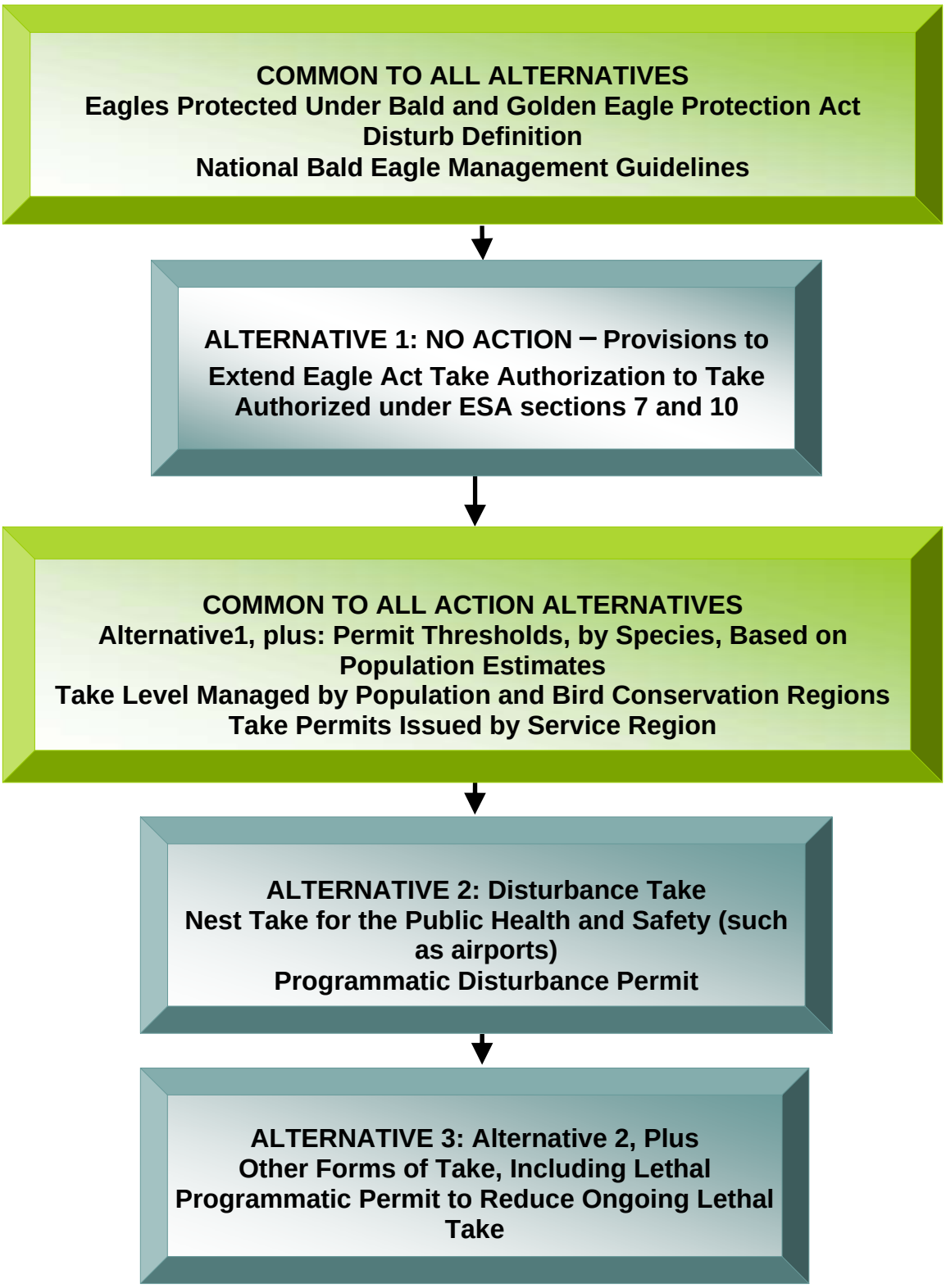

Figure 1 Outline of Alternatives

CHAPTER 2: ALTERNATIVES

2.1 Introduction

This chapter considers three alternatives that provide a reasonable range of options for a regulation permitting take of bald eagles and golden eagles that will occur while carrying out otherwise-legal activities. The alternatives provide different approaches to questions regarding the proposed take permit, such as the following:

- Whether the Service should allow a permit system with allocation based on prioritization.
- Whether the Service should only allow "disturbance" take.
- Whether the Service should allow TRM under certain circumstances, and if so, under what circumstances.
- If the Service will permit only for one "disturbance" at a time.
- Whether the Service will establish provisions for a programmatic approach.

The FEA presents the biological foundations for setting permit thresholds for bald eagles and golden eagles, and outlines a proposal for permit management according to populations, Bird Conservation Regions (BCRs), and Service Regions. The document also discusses whether and how to establish programmatic approaches to permitting, summarizes key aspects of the alternatives, and states the Service's preferred alternative.

The FEA has presented the alternatives in an order from the simplest to the most complex (Figure 1). In some cases, the alternatives are additive. For example, Alternative 3 includes all of the components common to all alternatives, Alternative 2, plus additional proposals, including TRM.

2.1.1 Comparison of Approaches to Take under the ESA and the Eagle Act

Although both the ESA and the Eagle Act prohibit take, there are some subtle, but distinct differences in how each Act defines and regulates take. One key distinction is that the ESA includes the term "harm" in its definition of take, which the Service has defined to include habitat modification and degradation, while the Eagle Act does not. Additional points to bear in mind throughout the discussions in this FEA are included in Table 1.

Table 1. Comparison of Approaches to Take under ESA and Eagle Act

Endangered Species Act Regulations, and Policies	Bald and Golden Eagle Protection Act Regulations, and Policies
Definition of "take"	
"Take" under the ESA means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Harass is further defined by the USFWS to include an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. Harm is further defined by the USFWS to include an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3).	*"Take" includes to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb (50 CFR 22.3). "Disturb" is defined as "to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.*
Actions that would significantly disrupt normal behavior patterns are **not limited to breeding, feeding, or sheltering behavioral patterns.**	Limited to "**substantially interfering with breeding, feeding, or sheltering behavior."**
May include significant habitat modification or degradation; therefore, there are provisions for habitat conservation measures.	The definition itself includes only nest abandonment, but the rule also talks about important eagle use areas such as communal roosts and concentration areas. Does not provide for habitat conservation measures, but habitat manipulation that would result in disturbance may be indirectly regulated.
Not specifically tied to decrease in productivity by individuals.	Specific to decrease in productivity of individual birds.

(Comparison of Approaches, continued)	
Endangered Species Act Regulations, and Policies	**Bald and Golden Eagle Protection Act Regulations, and Policies**
Reference for evaluation	
Not likely to jeopardize the continued existence of listed species or adversely modify designated critical habitats in the case of Federal agency actions.	Population-based. Goal of stable or increasing breeding populations. (Note: no designated critical habitat).
Thresholds	
Not routinely set or quantified at a population level.	Set and quantified at a population level.
Cumulative Effects	
Evaluation of cumulative effects under section 7 consultation does not include information on other future federal actions; they are assumed to be covered during consultations on the other actions (past activities addressed in baseline and cumulative).	Would include information regarding all past, present, and future actions, regardless of entity. However, for purposes of the FEA, past activities that continue to indirectly take eagles are addressed in the baseline.
Evaluation process	
Mandatory section 7 consultation on federal actions, sometimes requiring biological evaluation and biological opinion. Section 10 HCPs for non-federal actions, requiring plan and NEPA.	Optional discussions with Regional Permits Offices and/or Field Offices, and submittal of avoidance, minimization, and sometimes compensatory measures.
Authorities	
Both are federal statutes, with ultimately federal responsibilities.	
Streamlining	
'Streamlining' and 'batching' of section 7 consultations are encouraged and there is guidance available, as well as a recognized process.	Although not specific to the Eagle Act or its regulations, 'streamlining the permitting process' is mentioned in the Migratory Bird Strategic Plan. We will develop specific guidance in the implementation guidance for this rule.

2.2 Management Common to All Alternatives

The Service will continue the current management and permitting of bald eagles and golden eagles under the Eagle Act, including the finalized definition of disturb, and the National Bald Eagle Management Guidelines (USFWS 2007a), recognizing that the Guidelines are voluntary rather than regulatory. Each Service Regional Director, in coordination with the Service Regional NAL, conducts government-to-government consultation with the tribes in their Region, and will, where appropriate, do so on a case-by-case basis when issuing individual permits under this proposal.

2.3 Alternative 1– No Action: Permit Existing and Future Take Authorized Under ESA:

As part of the rulemaking in which the Service initially proposed eagle take permit regulations (72 FR 31141, June 5, 2007), the Service proposed to extend Eagle Act authorizations to persons previously granted authorization to take bald eagles under the Endangered Species Act. The Service has finalized those provisions in a separate final rulemaking, published on May 20, 2008 (see 73 FR 29075). The new regulations include the following:

- A new section at 50 CFR 22.28 (Eagle Take) providing for expedited permits for take of bald eagles exempted through section 7 incidental take statements; and
- New provisions at 50 CFR 22.11 extending Eagle Act take to HCPs that cover ESA section 10 incidental take of bald eagles and golden eagles.

The regulations extend Eagle Act authorization to persons authorized to take eagles under the ESA, provided the take occurs in compliance with the terms of the ESA authorization. Specifically, the regulations include revisions to 50 CFR 22.11 to provide Eagle Act authorization to persons with ESA section 10 permits that cover the bald eagle or golden eagle[2] for take of eagles that occurs according to the terms and conditions of the ESA permit, as long as the permittee fully complies with the terms and conditions of the ESA permit. The new provision at 50 CFR 22.11 also applies to take covered under future ESA section 10 permits, if, at some future time, either eagle species should become listed under the ESA. The regulations also establish an expedited process to issue Eagle Act permits for take that is in compliance with previously-granted ESA section 7 incidental take statements.

Alternative 1 includes the existing “incidental” take authorizations as well as the current management of bald eagles and golden eagles under the Eagle Act,

[2] Although an HCP is keyed to the section 10 permit provisions of the ESA, which only apply to listed species, HCPs may address both listed and unlisted species, such as the golden eagle. In the event that an unlisted species addressed in the approved conservation plan subsequently is listed under the ESA, no further mitigation requirements would be imposed if the conservation plan addresses the conservation of the species and its habitat as if the species were listed.

including the finalized definition of disturb, and the National Bald Eagle Management Guidelines ("Management Common to All Alternatives"). Required by NEPA, the “No Action” alternative, along with the conditions in the Affected Environment, serve in this document as the reference for comparing the action alternatives. The “No Action” alternative would not provide non-purposeful take outside that previously authorized under the ESA, and such take would continue to be illegal.

2.4 Management Common to Both Action Alternatives: Thresholds for Permits, Management by Population Regions for Bald Eagles, by Bird Conservation Regions for Golden Eagles

Management of eagles under all the action alternatives will include the “Management Common to All Alternatives,” the authorizations currently in place as described in Alternative 1—the “no action” alternative—plus the conditions outlined in this section. This section discusses how the Service will revise its eagle permitting regulations by establishing permit thresholds, and how the Service will establish a management framework. It discusses the biological and geographical foundations for permit thresholds and permit management.

As a result of compelling comments and recommendations from the public on the Draft EA, additional sensitivity analyses we conducted (see Appendix C), and new information suggesting the population growth rate averaged over the span of record of the WEST survey for golden eagles may be negative, the Service will initially place a cap on permitted take at 5% estimated annual productivity for bald eagles (following the approach recommended in Millsap and Allen 2006) and permitted new take at 0% estimated annual productivity for golden eagles. If, in the future, data and modeling suggest golden eagle populations can support take, we would begin to authorize take at no greater than 1% of annual productivity, unless information available at that time demonstrates that higher levels of take can be supported (again, following Millsap and Allen 2006 for species with high uncertainty). However, at this time, we will only consider issuance of "safety emergency take" and the Programmatic Take permits for golden eagles, the latter because it offers the most immediate potential for reducing ongoing take and improving populations.

The Service’s approach is consistent with the recommendations made by Millsap and Allen (2006) that advised that falconry harvest rates for juvenile raptors in the United States not exceed one-half of the estimated MSY up to a maximum of 5%, (depending on species-specific estimates of capacity to sustain harvest) and harvest rates of 1% for species without adequate demographic data. These new permits represent a somewhat different approach to eagle management and have significant policy implications and uncertainties. Those uncertainties and stochasticity (natural variability in vital rates affecting population trends) for both species support a more conservative approach than we proposed in our DEA, which proposed capping threshold at ½ maximum sustainable yield (MSY). The MSY is the greatest harvest rate over an indefinite

period that does not produce a decline in the number of breeding adults in the population. The original proposed cap did not adequately take into account known variability in vital rates, nor was it consistent with the recommendations in Millsap and Allen (2006).

In recent sensitivity analyses the Service conducted (incorporating stochastic events and documented normal variability in vital rates), our models showed, at 4% take there would be no potential for growth for a golden eagle population that may be declining, and there would be negative effects to the floater portion of the bald eagle population (using population trend data from Florida) at ½ MSY and even some minor effects at 5% take. Both the original application of the model and the sensitivity analyses for golden eagles calculated and used a positive growth rate for golden eagles. Incorporation of the new data from Good et al. (2009, pers. Comm.) into calculations for population demographics, yielded a declining growth rate for golden eagles. Floaters, for which monitoring is rarely conducted, serve to buffer populations from decline in times when productivity does not offset mortality, and also serve to provide a buffer for unforeseen effects to populations. Importantly, the models did not factor in the cumulative effects that were discussed in the DEA. Furthermore, the lack of annual monitoring to ensure we are not having a negative affect on populations, particularly when the thresholds we are proposing would be in effect for five years, compels us to adopt the more conservative approach. Some commenters, including eagle experts in various parts of the U.S. believe the DEA's population numbers and survival rates for bald eagles may have been too high for some areas of the country.

Furthermore, the caps recommended in Millsap and Allen were in the context of falconry, where removal of birds from the population has no associated impacts to habitat, whereas many permits issued under both these new regulations will have long-term or permanent habitat-related impacts that may lead to lost breeding opportunities or reduced suitable nest locations that would negatively affect the population. Therefore, we believe that caps should be no less conservative than those recommended for falconry take.

The approach taken also incorporates the cultural significance of both species (Section 3.8, Cultural and Religious). Cultural significance is not limited to Native American religious purposes, but encompasses a broad cultural regard for both species. Although collected by some Native American tribes for ceremonial purposes, the overall cultural value placed on bald eagles and golden eagles is, generally quite distinct from the value of harvesting them. This fact warrants a different, significantly more conservative approach than for managing game bird populations, where allowable take approaches MSY.

Definitions and Interpretations Used in This Document and Proposal

On June 5, 2007, the Service clarified its regulations implementing the Bald and Golden Eagle Protection Act and established a regulatory definition of "disturb," a term specifically prohibited as "take" by the Eagle Act. The final

definition defines “disturb” as “to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.” It is this form of take to which we refer in much of the FEA.

For the purposes of this action, in the associated “disturb” permit regulations, the Service will define “mitigation” as per the Service Mitigation Policy (46 FR 7644, Jan. 23, 1981), and the President’s Council on Environmental Quality (40 CFR 1508.20 (a–e)), to sequentially include the following:

- Avoiding the impact altogether by not taking a certain action or parts of an action;
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- Reducing or eliminating the impact over time by preservation and maintenance operation during the lifetime of the action;
- Compensating for the impact by replacing or providing substitute resources or environments.

The Service will adopt both new and modified definitions under 50 CFR 22.3. The Service will remove the definition of “golden eagle nest”; amend the regulatory definition of “take” as applied to bald eagle and golden eagle nests; clarify existing law by adding the term “destroy”; and add new definitions for “eagle nest” and for “important eagle use area.”

The definition of “eagle nest” is “a readily identifiable structure built, maintained, or used by bald eagles or golden eagles for breeding purposes.”

The definition of “important eagle-use area” is “an eagle nest, foraging area, or communal roost site that eagles rely on for breeding, sheltering, or feeding, and the landscape features surrounding such nest, foraging area, or roost site that are essential for the continued viability of the site for breeding, feeding, or sheltering eagles.” Not all foraging areas and communal roost sites are important enough such that interfering with eagles at the site will cause disturbance (resulting in injury or nest abandonment.) Whether eagles rely on a particular foraging area or communal roost site to that degree will depend on a variety of circumstances, most obviously, the availability of alternate sites for feeding or sheltering.

We interpret the standard of “compatible with the preservation of the eagle” as consistent with the goal of stable or increasing breeding populations. Although take thresholds are based on regional populations, the regulation requires the Service to consider additional factors, such as cultural significance, that may warrant protection of smaller and/or isolated populations within a region.

The Service has developed or included the following definitions in response to requests and recommendations for clarification of terms as used in the proposed rule and/or FEA.

Eagle Terms (FEA only):

Adult — an individual eagle capable of breeding.

Breeder — an adult eagle that defends a breeding territory.

Cohort — for purposes of the models used in the FEA, eagles of the same species born in the same year.

Fledgling — a juvenile eagle that has taken the first flight from the nest but is not yet independent.

Floater — an adult or subadult eagle without a breeding territory.

Juvenile — an individual eagle less than one year old.

Lambda (λ) — the annual rate of change in population size. The population is increasing if lambda is greater than (>) 1, is constant if lambda = 1, and is decreasing if lambda is less than (<) 1.

Natal dispersal distance — extent of movement between the place of birth and place of first breeding.

Nestling — an individual eagle between the time of hatching and the time it takes the first flight from the nest.

Productivity — the mean number of individuals fledged per occupied nest annually.

Subadult — an individual eagle greater than one year old, but typically not able to breed.

Vital rates — factors such as productivity, survival of juveniles, and annual survival of adults that influence population change.

Use Area Terms (To be defined by regulation except where noted):

Communal roost site — an area where eagles repeatedly in the course of a season gather and shelter overnight, and sometimes during the day in the event of inclement weather.

Foraging area — an area where eagles regularly feed during one or more seasons.

Inactive nest — a bald eagle or golden eagle nest that is not currently being used by eagles as determined by the continuing absence of any adult, egg, or dependent young at the nest for at least 10 consecutive days immediately prior to, and including, at present. An inactive nest may become active again and remains protected under the Eagle Act.

Territory — a defended area that contains, or historically contained, one or more nests within the home range of a mated pair of eagles.

Permit and Permit Evaluation Terms (To be defined by regulation except where noted):

Advanced Conservation Practices — scientifically-supportable measures that are approved by the Service and represent the best-available techniques to reduce eagle disturbance and ongoing mortalities to a level where remaining take is unavoidable.

Cumulative effects — the incremental environmental impact or effect of the proposed action, together with impacts of past, present, and reasonably foreseeable future actions. Cumulative environmental effects may be individually minor, but collectively significant over time.

Indirect effects — effects for which a proposed action is a cause, and which may occur later in time and/or be physically manifested beyond the initial impacts of the action, but are still reasonably likely to occur.

Necessary to ensure public health and safety — required to maintain society's well-being in matters of health and safety

Practicable — capable of being done after taking into consideration, relative to the magnitude of the impacts to eagles, (1) the cost of a remedy compared to proponent resources; (2) existing technology; and (3) logistics in light of overall project purposes. For programmatic permits, the comparable standard is "*maximum degree technically achievable*," defined as "the standard at which any take that occurs is unavoidable despite implementation of Advanced Conservation Practices.

Programmatic permit — a permit that authorizes programmatic take. A programmatic permit can cover other take in addition to programmatic take.

Programmatic take — take that (1) is recurring, but not caused solely by indirect effects (2) occurs over the long-term and/or in a location or locations that cannot be specifically identified.

Safety emergency — a situation that necessitates immediate action to alleviate a threat of bodily harm to humans or eagles

Techniques (FEA only) — within the context of Advanced Conservation Practices, includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

A question submitted on the original proposed regulation asked whether "other interests in a particular locality" should be applied as a "catch-all" category. Our interpretation of this phrase is that it is inclusive, in order to allow flexibility. As a practical example, "other interests in a particular locality" may apply to interstate transmission and transportation corridors as well as small communities and individuals. It may also apply to holders of economic, recreational, or other social interests in a particular locality who do not necessarily reside at that locality. For example, holders of mineral leases, rights-of-way, or vacation homes may not reside in the same State as the particular locality, but they have interests there. In addition, it is often the case that American Indian tribes and individual tribal members have an interest in a particular locality because of its aboriginal cultural, spiritual, religious or traditional values, but the locality is outside currently-recognized Indian lands.

2.4.1 Steps When Determining Potential for Take

By employing the Guidelines, State-specific guidance, and other appropriate avoidance and minimization measures, landowners and project proponents should be able to avoid eagle disturbance under the Eagle Act most of the time. In most parts of the country, the Service anticipates issuing relatively few permits for take associated with activities by proponents that have used the Guidelines because the majority of such activities will not take eagles. We routinely encourage project proponents to work with the Service during the early planning phases of their projects. If, after coordination with the Service, it is determined that avoiding disturbance is not practicable, acquisition of a permit may be needed to comply with the Eagle Act. In general, we anticipate that the first point of contact for many inquiries regarding whether or not a permit is advisable will be the Service Ecological Services Offices, Division of Habitat and Resource Conservation, Branch of Conservation Planning Assistance. However, applicants who have already incorporated avoidance and minimization measures into their project planning, and believe take is still likely, may wish to first contact the Regional Permit Office. No matter which office is first contacted, they will coordinate closely with each other.

Disturbance may also result from human activity that occurs after the initial activities. In general, however, the Service will not issue permits for routine activities where take is not likely to occur. New uses or uses that are greater in scope or intensity than pre-existing conditions (such as increased hiking, driving, or residential development) may raise the likelihood of eagle disturbance, and as such, could require authorization for take under these proposed regulations. When evaluating the take that may result from an activity for which a permit is sought (such as residential development), the Service will consider the effects of the preliminary activity (construction) as well as the effects of the foreseeable ongoing future uses (such as activities associated with human habitation).

The Service will not limit its consideration of the impacts and threshold distances to the footprint of the initial activity if it is reasonably foreseeable that the activity will lead to adverse, secondary prohibited impacts to bald eagles and golden eagles. We consider the direct, indirect, and cumulative effects of each activity. For example, when evaluating the effects of expanding a campground, in addition to considering the distance of the expansion from important eagle-use areas, the Service will consider the effects of increased pedestrian and motor traffic to and from the expanded campground. In many cases, the potential for take could be greater as a result of the activities that follow the initial project. For example, the installation of a boat ramp 152 meters (500 feet) from an important bald-eagle foraging area may not disturb eagles during the construction phase, but the ensuing high levels of boat traffic through the area during peak feeding times may cause disturbance. Trail construction 122 meters (400 feet) from a nest is generally unlikely to take bald eagles, but may disturb golden eagles, which have shown such responses as reduced feeding of juveniles in the presence of observers camped 122 meters (400 feet) from a nest (Steidl et al.

1993). Moreover, if the trail will be open to off-road vehicle use during the nesting season, the Service will need to consider the impacts of the vehicular activity as part of the impacts of the trail construction. The Service will evaluate permit applications for whether they had evaluated both direct and indirect impacts of the proposal, and addressed impacts through mitigation measures.

2.4.2 Modify Existing Certification of Compliance Language

All of the Service's migratory bird and eagle-related permits contain the standard condition that the Federal authorization is not valid unless the activity complies with all other applicable laws, including State and local laws. Permits issued under this regulation will include that condition and clarify that the activity must also be in accordance with "tribal" laws (if applicable). The application will therefore ask the applicant to state whether he or she has obtained the State, local, or tribal authorizations necessary to conduct the activity. This permit condition does not override or supersede the right of States or tribes to withhold authorization for take of eagles.

2.4.3 Eagle Management Units and Permit Administration Regions

The Service used available data for each species of eagle to identify appropriate regional population scales for management purposes, with the goal of ensuring the Service's permit program does not cause declines in eagle populations at a regional or national scale.

Bald Eagle

For bald eagles, we obtained locations of all known contemporary nest sites from State fish and wildlife agencies. We also obtained U.S. Geological Service Bird Banding Laboratory band recovery data for all bald eagles banded as nestlings and recovered at five or more years of age at times of the year when they could have been breeding (during the nest building and incubation stages of the breeding cycle of the individual's natal population). We used natal populations (eagles within the median natal dispersal range of each other) in our evaluation in order to look at distribution across the landscape. Being able to see where natal populations appear sparser, rather than concentrated, allows us to determine natural boundaries between regional eagle populations and thus reduces the risk that we will issue take permits in any one regional management area in a manner that is disproportionate to the population in the area. We will consider the natal dispersal distance of bald eagles when evaluating effects to local area populations.

Based on analysis of band recovery data for a subsample of states (AK, AZ, FL, MN, VA; 50 cases), we estimated the median natal dispersal distance for bald eagles to be 43 miles. We built a GIS database that incorporated all State nest locations, and then placed a 43 mile-radius buffer around each nest, effectively "linking" nests that were within the median natal dispersal distance of one another. We regarded aggregates of linked nests as components of the

same regional population for management purposes. Gaps (or areas of sparse nest distribution) in the buffered nest database were used to delineate boundaries between regional management populations. The bald eagle management areas derived using this method include most bald eagle nests in the United States, although a few highly-isolated nesting sites in Arizona, southern California, central Utah, southeastern Colorado, northeastern New Mexico, western Oklahoma, and eastern Texas were not clearly affiliated with any of the larger management areas. For purposes of this EA, we considered Alaska's bald eagles as one population, but Service Region 7 may manage by smaller management regions. Although most nests have been located in southeastern Alaska, extensive surveys have also been conducted on Kodiak Island, the Kenai Peninsula, Alaska Peninsula, Prince William Sound and several mainland rivers. (USFWS 2008). However, vast areas of interior Alaska and the Aleutians remain unsurveyed.

The Service acknowledges that this process was somewhat subjective, and that the regional management populations delineated are not, in most cases, genetically or even demographically isolated. However, we believe the approach does serve to identify biologically-based, regional populations at a scale meaningful for eagle conservation. The Service's goal in managing bald eagles at this scale is to ensure permitted take does not negatively affect the species' status in any regional management population.

The Service will manage bald eagles roughly by eagle populations within Service Regions (see Figure 3 for lower 48 states), referenced to the continental population. Currently, the Sonoran Desert population is still protected under the ESA, but if this population is eventually delisted, we will use the demographic parameters of the Sonoran Desert population in determining take under the Eagle Act in order to more closely monitor that population (Table C.3 in Appendix C). Permits will be administered by Service Regions in coordination with each other, especially where a management area lies in more than one Service Region. For example, the Southwest Region will closely coordinate with the Southeast Region regarding permitting of bald eagles in Texas and Oklahoma (see Figure 3). This management and administrative approach will be evaluated regularly, at least once every five years.

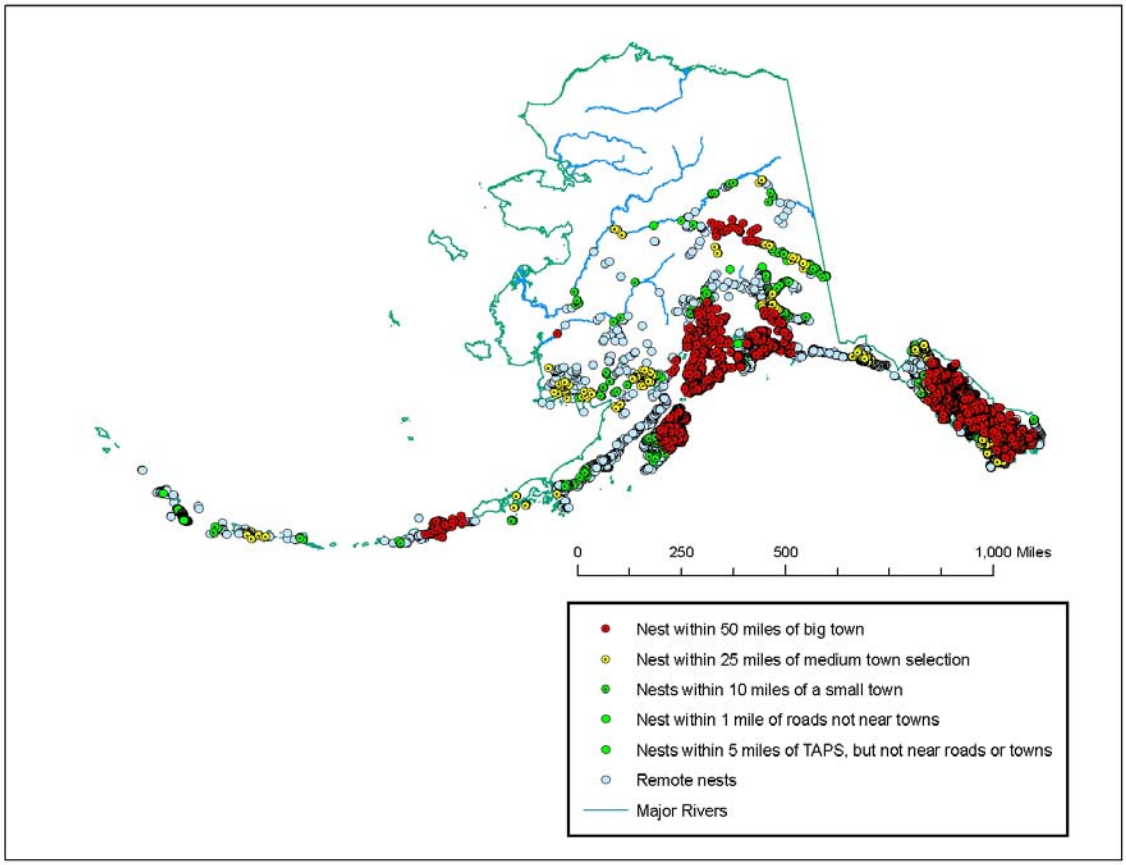

Figure 2 Locations of bald eagle nests catalogued in Alaska: Data collected from organized surveys, reports from biologists doing other work and incidental observations from biologists and the public (TAPS in the legend is the Trans-Alaska Pipeline System). Areas on the map that do not have nests reported may be because there are no nests, but more likely because no one has looked in that area for nests.

Golden Eagle

For golden eagles, available data on distribution are not as spatially precise. However, to estimate natal dispersal distances for golden eagles, an analysis of appropriate band recovery data provided by the U.S. Bird Banding Laboratory (BBL) comparable to that done for bald eagles. Our analysis of this data set showed that 90% of mature golden eagles reencountered during the breeding season were within 140 miles of their natal site. We will consider the natal dispersal distance of golden eagles when evaluating effects to local area populations.

The Service has funded transect-based aerial surveys of golden eagles in the interior west periodically since 2003 (Good et al. 2008). The goal of this survey is to provide statistically-rigorous estimates of population size and juvenile to non-juvenile age-ratios in Bird Conservation Regions (BCRs) 9, 10, 16, and 17.

In addition, the Partners in Flight landbird conservation planning process generated population size estimates for golden eagles in other U.S. BCRs, though these estimates are not as statistically rigorous, nor have the estimates been replicated. Because the BCR-scale population estimates are the only range-wide estimates available for the golden eagle, we used a BCR-scale management approach for this species. In other words, we will manage take of golden eagles according to thresholds set at the BCR level. Because Service Regions are not administered according to BCR boundaries, we will administer permits by Service Regional Permit offices. In those instances when a BCR occurs in more than one Service Region (such as Great Basin BCR 9 in Service Regions 1, 6, and 8, see Figure 4), Service Regions will coordinate closely regarding permit issuance to ensure that the threshold for that BCR is not exceeded. Because there are no breeding populations in the eastern United States that can sustain take (Section 3.4.2), the Service will not authorize take for golden eagles east of approximately 100° west longitude (Figure 4) except for take of nests for safety emergency situations. In addition, for most States west of 100° west longitude, there is little reliable recent data for breeding golden eagles. For example, Breeding Bird Surveys in Kansas and Oklahoma, which intersect the proposed management region by only a small proportion, do not report sightings of golden eagles, although it occurs in both states. It is important to note that failure to detect does not necessarily mean absence, because both States individually note small numbers of breeding pairs (NatureServe 2008). In addition, many states have not had the resources to conduct monitoring of golden eagle populations, in some cases for up to 20 or more years. The Service will therefore base thresholds upon existing data and modeling until better data become available.

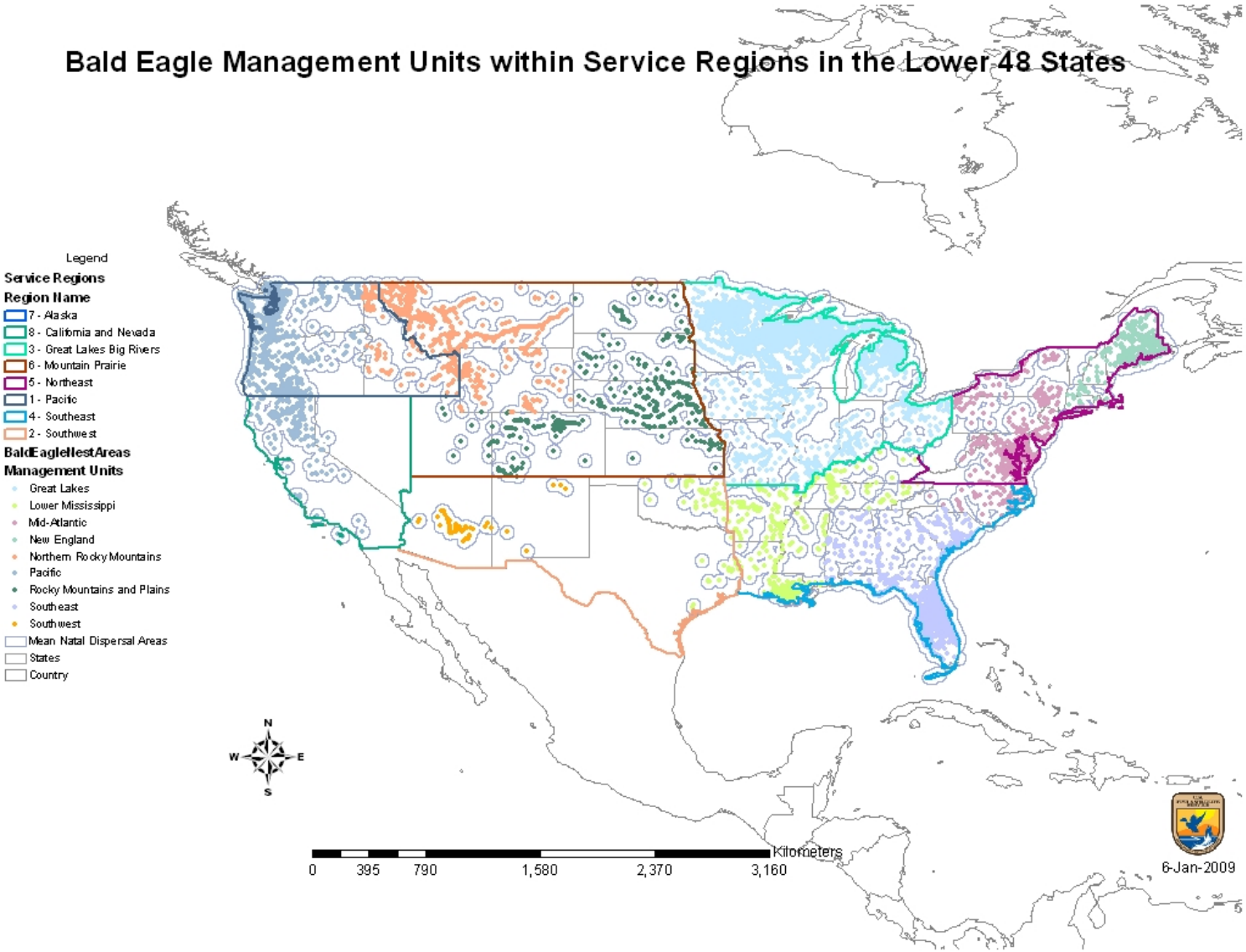

Figure 3 Bald eagle management areas

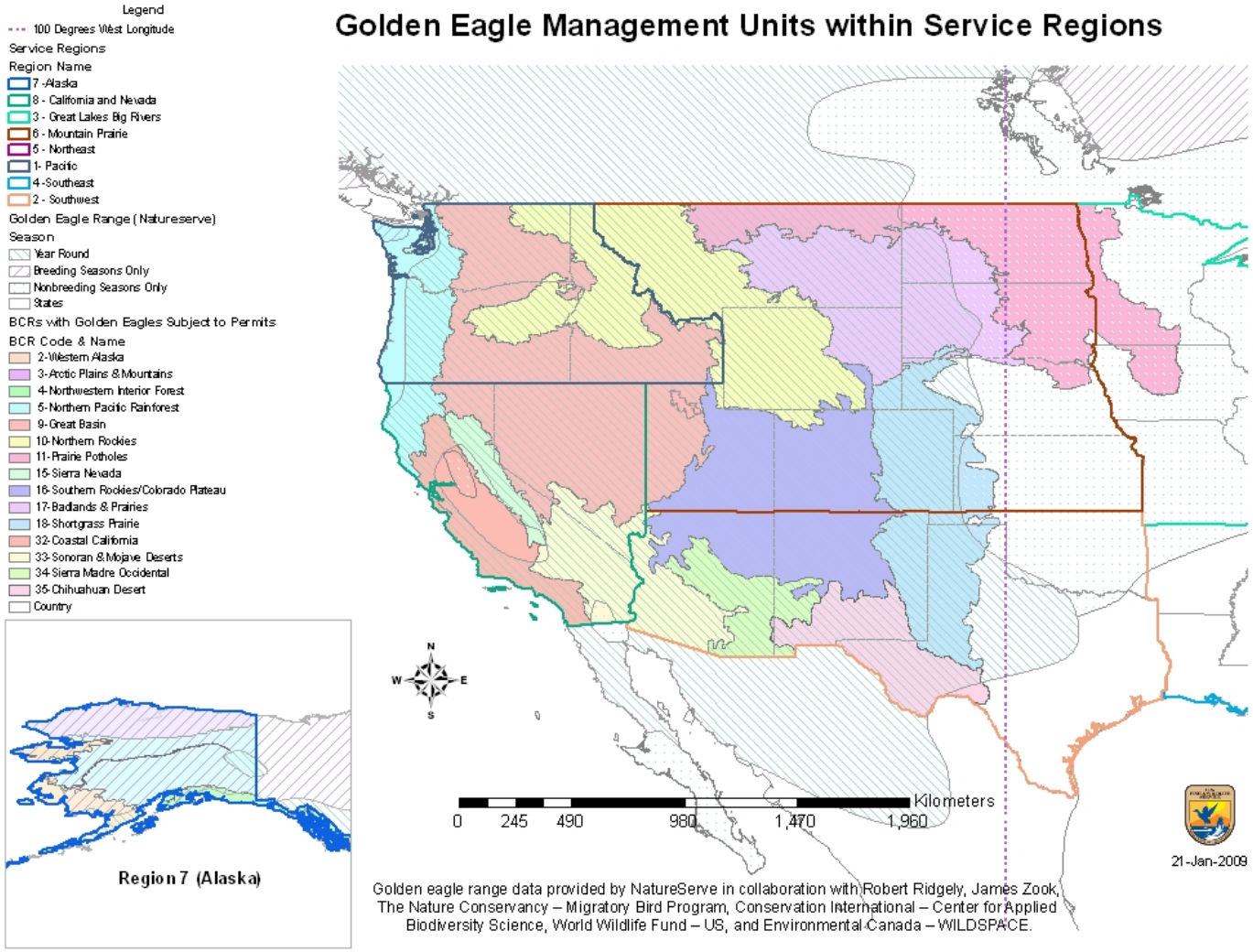

Figure 4 Golden eagle management areas

2.4.4 Permit Thresholds

The Service will base maximum levels of permitted take of bald eagles and golden eagles under both 50 CFR 22.26 and 22.27 on populations (see Appendices C and D for complete discussions of assumptions and methods). We will base take thresholds on regional populations for each species and estimates of their vital rates (see Millsap and Allen 2006), where there is information to substantiate different vital rates. Current, ongoing take from natural and unauthorized human causes contribute to the survival ratios used in the population models. The proposed thresholds will reflect acceptable take above that from natural and unauthorized take. Estimated take caused by currently-permitted activities under the Eagle Act, with the exception of certain ongoing take for Indian religious purposes, will, cumulative with the proposed permit, be subject to the proposed thresholds.

The thresholds proposed in this FEA will determine maximum annual take until new information warrants modification of the thresholds. The Service will base the limits on take upon:

- Models that use available data on population parameters such as juvenile, subadult, and adult survival.
- The number of nests and their occupancy as the information becomes available.
- Cumulative effects of other permitted take of eagles.

However, because the proposed thresholds are estimates and based in part upon models, they do not take into account such things as cumulative effects and site-specific conditions, factors which will become available during the permit-evaluation stage. The on-the-ground information and conditions will guide the actual amount of take that is authorized, as long as the total does not exceed the modeled thresholds. In fact, the actual take authorized may be less than the predicted threshold. The Service Regions, in coordination with adjacent Regions, will make the final decisions regarding the actual amount of take allowed each year.

Biological Foundation for Take Thresholds

The Service originally proposed managing take of eagles using the outer negative range of the regional Population Trend criteria established by Partners in Flight (PIF)[3] to define a stable population (Panjabi etal. 2005)

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[3] In the PIF species assessment, each species is assigned global scores for six factors, assessing largely independent aspects of vulnerability at the range-wide scale: Population Size (PS), Breeding Distribution (BD), Non-breeding Distribution (ND), Threats to Breeding (TB), Threats to Non-breeding (TN), and Population Trend (PT). Each of the scores reflects the degree of a species' vulnerability (i.e., risk of significant population decline or rangewide extinction) as a result of that factor, ranging from "1" for a low vulnerability to "5" for high vulnerability. Simplified scores for population trend on a continental scale (PT-c) evaluate trends in terms of % change over 30 years, or equivalent % annual change. A score of 1 means a ≥50% increase over 30 years with an equivalent % annual change of ≥1.36% (Large population increase). A score of 2 means a 15-49% increase, or <15% equivalent annual change (Possible or moderate population increase or population stable). A score of 3 means a Highly variable or Unknown change over 30

(http://www.rmbo.org/pubs/downloads/Handbook2005.pdf). That would have allowed an annual decline of up to 0.54%. There are several reasons why the Service has decided not to use that approach. First, managing to allow for an annual decline, no matter how small, will have a long-term, negative impact on eagle populations. Second, as noted in some comments on the proposal, the current monitoring proposal for the bald eagle and the limited monitoring for the golden eagle do not have the precision or accuracy to detect declines of that magnitude. Third, for golden eagles in particular, the Service requires key demographic, biological, and ecological information, particularly juvenile mortality rates and proportions of non-breeding adults to breeding adults. The original management scenario risked accepting declining populations as the norm, which is not compatible with the preservation of eagles. Finally, the Service wants to use consistent standards for management approaches for all raptors while taking into consideration species-specific natural history differences.

For the preceding reasons, the Service will use the same model for calculating take for eagles that we used in the recently-finalized falconry regulations. This FEA incorporates by reference the methodology presented in a peer-reviewed article (Millsap and Allen 2006, Appendix E) regarding the effects of falconry on wild populations of raptors in the United States, with the following exceptions: unlike the falconry regulations, the term "take" in the proposal does not always mean removal from the wild; and we are using juvenile survival rates of 0.79 instead of 0.84 for golden eagles. Millsap and Allen (2006) noted that the dynamics of most raptor populations make monitoring the short-term impact of take on them nearly impossible. However, it provided recommended strategies designed to account for uncertainties within the plan to manage take. Millsap and Allen (2006) also included an explanation of the deterministic model used to estimate how take likely affects raptor populations. Setting conservative take allocations (as discussed further in Section 2.4, Management Common to Both Action Alternatives and in Appendix C) will allow us to buffer the effects of the uncertainty inherent in using a deterministic model for populations with vital rates that may vary widely from one year to the next, particularly for the golden eagle. Increasing take rates further toward MSY will require us to implement robust population monitoring, a costly effort that will be extremely difficult logistically and financially.

The modeling will set the level of take the Service could permit that is compatible with the preservation of the eagle. The thresholds applied by the Service Regions will consider the cumulative effects of all permitted take, including other forms of lethal take permitted under regulation, against the backdrop of other causes of mortality and nest loss. The backdrop reflects the factors contributing to mortality and survival rates, and includes both natural

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years, and an equivalent % annual change is not available (Uncertain population trend). A score of 4 means a 15-49% decrease over 30 years with a <-0.54 to -2.28% equivalent annual change (Possible or moderate population decrease). Finally, a score of 5 means a ≥50% decrease over 30 years and an annual equivalent change of ≤-2.28% (Large population decrease). Under the PIF species assessment process, the PT-c score for bald eagles is 1, and the PT-c score is 3 for golden eagles.

mortality and human-caused mortality, purposeful and non-purposeful. Examples of illegal purposeful take, which are investigated by the Service's Law Enforcement (LE) program in coordination with State, tribal and international wildlife agencies, include deliberate persecution of eagles and killing of eagles for purposes of commercial gain from wildlife trafficking.

There are inherent limits to the ability of monitoring to detect precise fluctuations in bald eagle and golden eagle numbers. Take is not always discovered or may occur later, so there may be uncertainty as to whether individual actions being permitted will in fact result in a "take" of eagles. To reduce and compensate for uncertainties, we intend to use multiple sources of the best available data, including but not limited to data from post-delisting monitoring by States, the Breeding Bird Survey, golden eagle data from the previously mentioned west-wide surveys (WEST data), and fall and winter migration counts and any other reliable data that may become available, to assess the status of eagle populations, adjust the model based upon updated parameter information, and adjust permitting criteria on a five-year basis as appropriate. As noted in the introductory paragraph to this section, thresholds proposed in this FEA will determine annual take until new information warrants a modification of thresholds. If data confirm populations at either national or regional scales are declining, depending on the source and severity of the decline, the Service will either establish lower take permit thresholds where appropriate or suspend permitting until data confirm the populations can support take. Conversely, if a population at one or the other scale is increasing, the Service may set take thresholds at a higher level. If we have inadequate data to run our modeling and no other means of assessing the status of the population where the take will occur, we may not be able to determine that the take is compatible with the preservation of the species, and if we determine that take is not compatible, we will not authorize it.

The Service will assess, at least every five years, overall population trends along with annual report data from permittees and other information to assess how likely future activities are to result in the loss of one or more eagles, a decrease in productivity of bald or golden eagles, and/or the permanent loss of a nest site, communal roost site, or important foraging area. The Service will also assess how such outcomes will likely affect population trends, taking into consideration the cumulative effects of other activities that take eagles and eagle mortalities due to other factors. In addition, the assessment will incorporate estimates of illegal purposeful take of eagles from persecution or trafficking as well as unauthorized non-purposeful take, both of which LE will continue to investigate. This periodic assessment will provide additional information for: (1) establishing permit thresholds; (2) determining the efficacy and applicability of mitigation; (3) confirming or modifying permit information and issuance criteria; (4) confirming or modifying the recommendations provided in the Guidelines.

The impact to the population from permits (the cumulative take under all permits used/allocated) will include the following: (a) disturbance associated with a temporary loss of productivity; (b) disturbance resulting in a permanent loss of a nest or abandonment of a territory (in some cases leading to a decrease in the

breeding population); (c) Native American religious take which has been for either nestlings or, when take occurs in the fall, fledglings, juveniles, or adults; and (d) other permitted take (see Appendix C for a more extensive discussion relative to methods for setting thresholds). Recommended thresholds for take that results in a temporary loss of productivity will incorporate the total permitted disturbance of eagles at communal night roosts and important foraging areas. The Service will recommend greater take be deducted from the annual allocation when there is a permanent loss of a foraging area or roost for which there is no comparable alternate use area within an average home range distance of the applicable season. On the other hand, in the case of take occurring at nests, if there were other suitable nest locations or alternate nests used by the breeding pair, or they subsequently emigrated but were replaced by another pair, the Service will recommend take be allocated based upon a loss of productivity rather than loss of a nest. We will determine the amount of take incurred per location on a case-by-case basis by Service Region.

Accounting for Take

Because we will evaluate the effect of take on the basis of survival of juveniles rather than nest productivity, we will be able to set take in terms of individual eagles (see Appendix C for detailed discussion, including take calculations for bald eagle populations other than "standard").

For the standard bald eagle population:

- take affecting one individual = subtraction of one individual from the threshold;
- take resulting from disturbance at one nest on only one occasion = subtraction of 1.3 individuals from the threshold; and
- one nest take resulting in the permanent abandonment of a territory = subtraction of 1.3 individuals from the threshold the first year and a reduction of eight individuals from the annual individual permit limit until data show the number of breeding pairs has returned to the original estimated, or until it can be demonstrated that the predicted loss has not occurred.

For the standard golden eagle population:

- take affecting one individual = subtraction of one individual from the threshold;
- take resulting from disturbance at one nest on only one occasion = subtraction of 0.78 individuals from the threshold; and
- one nest take resulting in the abandonment of a territory = subtraction of 0.78 individuals from the threshold the first year, and a reduction of four individuals from the annual individual permit limit until data show the number of breeding pairs has returned to the original estimated, or until it can be demonstrated that the predicted loss has not occurred.

Destruction or loss of the use of a nest location, with no opportunity for replacement, may result in the loss of a territory, and a permanent decrease in the breeding population. The Service would not issue permits, except for safety emergency, if a permanent, unmitigable loss of a golden eagle territory is likely.

2.4.4 Mitigation

As noted in Section 2.2, Management Common to All, the Service will define "mitigation" to sequentially include: avoidance, minimization, rectification, reduction over time, and compensation for negative impacts to bald eagles and golden eagles. Prior to the submission of a permit application, potential applicants should consult with Ecological Services Field Offices to determine whether or not the proposed activity is consistent with eagle management guidelines. The Service will evaluate permit applications to determine whether, during the process of developing an activity, use of the eagle management documents and other methods for avoiding and minimizing the potential for take will be employed. Any requests for permits will need to cite these measures in their supporting documentation.

For most individual take permits resulting in short-term disturbance, the Service will not require compensatory mitigation. The population-based permitting the Service will propose is based on the level of take that a population can withstand. Therefore, compensatory mitigation for individual permits is not necessary for the preservation of eagles. However, the Service will advocate compensatory mitigation in the cases of nest removal, disturbance or TRM that will likely incur take over several seasons, result in permanent abandonment of more than a single breeding territory, have large-scale impacts, occur at multiple locations, or otherwise contribute to cumulative negative effects.

2.4.5 Relationship between Data Gathered and Setting Annual Thresholds

In its technical guide to adaptive management (AM) (Williams et al. 2007), page 4, the Department of the Interior adopted as the operational definition of adaptive management the definition by the National Research Council:

> *Adaptive management (is a decision process that) promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.*

AM is a structured approach to decision making that emphasizes accountability of decision outcomes, and is useful when there is uncertainty regarding the most appropriate strategy for managing natural resources. As set

forth in **522 DM 1**, consideration of AM is warranted when: (1) there are consequential decisions to be made; (2) there is an opportunity to apply learning; (3) the objectives of management are clear; (4) the value of reducing uncertainty is high; (5) uncertainty can be expressed as a set of competing, testable models; and (6) an experimental design and monitoring system can be put in place with a reasonable expectation of reducing uncertainty. Rather than simply monitoring the status of the resource of interest, a key component of AM is also monitoring the impacts of the management strategies. Although statutory requirements constrain the ability of the Service to propose an active (experimental) AM strategy, we believe the proposal is in keeping with a passive AM strategy. In a passive AM strategy, uncertainty is recognized, but the focus is on the achievement of management objectives. Monitoring is focused on the resource status and other factors that are useful for improved understanding through time (Williams et al. 2007).

The proposed eagle-take regulations are based on a number of assumptions and contain areas of uncertainty. Increasing our understanding of how disturbance actually affects eagles, and how loss of individuals and nests affects populations, will improve our ability to effectively conserve eagles with minimal impacts to eagles and socio-economic resources. The Service proposes to reduce uncertainty in the management of eagle take by requiring permittees to report back to us on the use of nests, roosts, or foraging areas by eagles for up to three years after the activity is completed (see draft forms in Appendix F). Permittees for most disturbance permits will only be asked to provide minimal information to allow the Service to assess whether or not the activity likely caused disturbance. However, this information will contribute to an AM process that will enable us to evaluate and revise thresholds for permits and to adjust the Guidelines.

The Service will also use results of the final bald eagle post-delisting monitoring program to help re-evaluate the size and status of regional populations at least once every five years for a total of 20 years. These data will increase the accuracy of our estimates of regional population size and nest locations, and will also allow us to recalibrate thresholds for take of nests and individuals based on actual population trends. The bald eagle post-delisting monitoring program will focus on nest-site occupancy. However, monitoring at nests is not sufficient to detect some types of population decline (Millsap and Allen 2006). The Service will use other eagle population data, as available, such as counts and age-ratio information from standardized migration count sites, to look for indications of population changes not detectable through any existing nest surveys.

For golden eagles, the Service will initially use data from available surveys such as that by WesternEcoSystems Technology, Inc. and information from the BBS. The Service also will use additional data, as available, such as counts and age-ratio information from standardized migration count sites, and the long-term monitoring data from the Snake River Birds of Prey National Conservation Area.

For both species, we will evaluate persistent changes in migration counts or age ratios, at least once every five years, to determine if eagle-take regulations

might be a contributing factor, and if changes are warranted. The Service will adjust the permitting thresholds and allocations by using the best data available at the time of each decision. We will use the updated data to apply the population model for estimating the number of permits to allocate.

2.5 Alternative 2– Eagle Take Permits, Structured Allocation Authorized, Nest Take for Public Health and Safety, and Programmatic Disturbance

Alternative 2 discusses regulatory proposals that will authorize the following: disturbance-related take of eagles; removal of eagle nests for reasons of "public health and safety"; and programmatic disturbance under a permit designed to avoid or minimize the ongoing and future risk of disturbance to eagles

2.5.1 Disturbance Take

The Service will add a new section at 50 CFR 22.26 (Eagle Take) to authorize disturbance take of bald eagles and golden eagles for the protection of other interests in any particular locality, where such permits are compatible with the preservation of the bald eagle and golden eagle, and the take cannot practicably be avoided.

These permits will be limited to disturbance, as opposed to take that results in mortality. They will require an initial determination that the permits will be compatible with the preservation of the bald eagle and golden eagle; that the take will be associated with, and not the purpose of, an otherwise lawful activity; and that it will occur even after impacts are minimized to the extent practicable by use of avoidance and minimization measures.

Short-term Disturbance

The Service will distinguish between levels of effects to the population in two separate evaluations of disturbance. A short-term disturbance reduces productivity in a given year, and there is a decrease in recruitment into the following year equivalent to the average number fledged per occupied territory. This assumes eagles in the territory become productive again after the activity ceases, which may not be as likely for golden eagles. If it appears likely that eagles in the territory will not become productive again after the activity ceases, the Service may classify the effect as a long-term disturbance as described below.

Permanent Abandonment of Territory, Important Communal Roost Site, or Important Foraging Area

Long-term disturbance may result in the permanent abandonment of a territory, important traditional communal roost site, or important foraging area. In terms of population effects, this permanent effect is the equivalent of annually authorizing disturbance at one location in perpetuity. For this reason, long-term disturbance will have larger impacts on the eagle population, and will result in a greater take being subtracted from the annual thresholds (Appendix C). Permit

information requirements and issuance criteria will be applied in the same manner as those for short-term disturbance, and will apply if the Service's Migratory Birds Office, local Ecological Services Office or the Regional Permit Office determines that a disturbance will be associated with the permanent abandonment or loss of a nest. However, the Service would also likely require compensatory mitigation in such cases. Destruction or loss of the use of nest location, with no opportunity for replacement, may result in the loss of a territory and a permanent decrease in the breeding population. The Service would not issue permits, except for safety emergency, if a permanent (unmitigable) loss of a golden eagle territory is likely.

2.5.2 Permitted Take of Nests for the Public Health and Safety

The Service will add a new section at 50 CFR 22.27 (Eagle Nest Take) to authorize removal of bald eagle and golden eagle nests where "necessary to ensure public health and safety." This will include nests that pose an imminent hazard to human safety or to the welfare of eagles. The proposal will authorize removal and/or relocation of both active and inactive eagle nests in what we expect to be the rare case where genuine safety concerns necessitate the take. This permit will also be available to remove or relocate inactive nests in situations where the take is necessary to ensure public health and safety, but the presence of the nest does not create an immediate safety emergency. Nest take permits may be issued for projects that will provide a net benefit to eagles (including projects where the net benefit is the result of compensatory mitigation measures). We may also issue permits to take eagle nests built on human-engineered structures where the nest interferes with the intended use of the structure. This permit is limited specifically to eagle nests and will not authorize intentional, lethal take of eagles.

Except for applications associated with safety emergencies, prior to authorizing nest removal, we will review the availability of potential alternative suitable habitat (nest substrate, foraging areas, etc.) and the distance to those areas, in order to reasonably assess the likelihood of total loss of the territory. When known, we will consider such factors as the number of nests in a particular breeding pair's nesting territory and the last known date the pair used the nest under consideration for take, in order to assess the relative value of the nest to the pair. Further, to assess whether the loss of a particular nest may have negative local population impacts, we will also consider the surrounding territories and the nests within those territories to evaluate the ability of the area to support a displaced pair. For example, if all the suitable nest locations are fully-occupied, impacts leading to abandonment of a territory (either through destruction of the nest substrate or through not being re-occupied by either the original nesting pair or a new pair from the floater population) may have a significant negative impact to the area population. Available prey base or intra-species competition may be additional relevant factors. For overall permit management, we will consider local area population effects within the species-specific natal dispersal distances (43 miles for bald eagles, 140 miles for golden eagles). However, we believe it will be too burdensome to ask the proponent to

provide data on that large a scale. We have found, in implementing the resource recovery permit for take of inactive golden eagle nests (50 CFR 22.25), that data within a 10-mile radius of the nest provides us with adequate information to evaluate many of the factors noted above.

The Service anticipates that permits authorizing take of nests for the public health and safety will be relatively few and will be subject to the thresholds and allocation process proposed in the Management Common to Both Action Alternatives. Take of inactive nests that pose a hazard to human safety or to the welfare of the eagles without emergency removal may not always need to be included in the calculations for permit thresholds if the eagles will likely be lost anyway due to the conditions prompting the safety emergency, or if the Service determines the removal of the nest would not result in an unmitigable loss of a breeding territory. Because of the time constraints associated with take that will be for emergency situations, these will not be immediately subject to the allocation prioritization and all bona fide applications will be authorized. However, we will conduct an after-the-fact evaluation of emergency-take authorizations. If data indicate there may be population effects from use of emergency take, the Service will reconsider whether the allocation for the safety take should be deducted from the permit thresholds. An example will be if there were no other suitable nest locations or alternate nests for the breeding pair, and they subsequently emigrated without being replaced by another pair. If the Service determines it is necessary, we will estimate potential take from this source, based on historical numbers for the applicable Service Region to that date and the formula used in **2.4.3 Permit Thresholds**, *Accounting for Take*, and deduct the number from the available permits at the beginning of the year.

Current regulations at 50 CFR 22.25 allow the removal by permit of golden eagle nests if the nest interferes with resource development or recovery operations.

2.5.3 Allocation of Individual Permits

Although unlikely to occur in most parts of the range of either eagle species, the Service anticipates that in a handful of regions there could be more requests for permits than the number of permits available. However, we will reserve some permits in order to authorize safety and emergency permits. In some cases, e.g., sampling under a scientific collecting permit to ascertain disease, pathogen, or contaminant issues, activities intended to protect eagles may result in a short-term disturbance. If there is a compelling need for this sampling, specific to the conservation of eagles, this kind of take will be considered emergency take for prioritization purposes. In keeping with our commitments under RFRA and AIRFA, the Service's Regional Directors will each be responsible for developing and implementing a structured-allocation process in each Region if there is evidence that demand for take will exceed take thresholds for either species of eagle. This process will ensure that authorized take of birds necessary to meet the religious need of a Native American Tribe will not be denied due to other take being authorized for another purpose. Each Regional structured-allocation process will also need to ensure that permits are available in case of public

safety emergencies. The next permit priorities, in order are, renewal of programmatic nest-take permits, and Non-emergency activities necessary to ensure public health and safety. The next permit priority (for golden eagle nests only) is for resource development or recovery operations (§ 22.25). Service Regions will be responsible for any necessary NEPA compliance regarding additional decisions for implementation procedures. If the Service receives more applications for permits than it can provide under the relevant regional threshold, applicants will need to reapply at a later date.

2.5.4 Permit for Programmatic Disturbance

Under this alternative, the Service will develop a programmatic disturbance permit at 50 CFR 22.26 that will be available to entities (industries, agencies, or authorities) at the private, federal, tribal, and State level undertaking activities that may result in a cumulative loss of bald eagles and golden eagles, eagle nests, foraging areas, and roost sites with potential for local population-level effects. "Programmatic" has several meanings in the proposal. Primarily, we use the term to mean dealing with take from the same source in a consistent manner. The sources may be practices or facilities common to one or more industries or agencies, e.g., road construction conducted by Federal, State, tribal, and local transportation departments, or power lines and infrastructure installed by power companies of all sizes, or other entities such as natural gas development companies. It can also refer to resource "programs" carried out by agencies at all levels, e.g., minerals, fire, and realty programs that conduct activities that may result in non-purposeful take of eagles. The entities conducting those "programs" may want to work with the Service to develop specific measures and standard practices to avoid and minimize take of eagles, with the goal of designing a permit for those "programs." In addition, "programmatic" may refer to a permit that comprehensively addresses long-term or widespread take.

The Service will work with the entities to develop scientifically-supportable standard practices and criteria for choosing the best-available techniques in projects and plans. Project design criteria will include requirements for applicants to reduce take and provisions to notify the Service when take occurs. These standard practices and plan specifications will then become permit conditions, in addition to monitoring and reporting requirements more comprehensive than those for permits allowing take of individual eagles. The Service will require that any mitigation or standard practices be designed to avoid or minimize the ongoing, future risk of disturbance to eagles. We expect most industry-wide or agency-wide standard practices for programmatic permits will be developed with the respective entities at the Service Washington Office level, in coordination with Service Regions, and, as requested, State and tribal jurisdictional agencies. They will serve as permit type templates that can then be adopted for use by individual practitioners or companies engaged in the covered industry or program. The permits will be issued by the Regions.

In cases where current industry practices are resulting in programmatic disturbance of eagles leading to the abandonment of important eagle-use areas and when the Service has limited permits based upon population models,

compensatory mitigation may be a suitable standard practice, as long as the mitigation will provide long-term protection from disturbance for nest sites, foraging areas, or roost sites within the area defined by the programmatic permit. In addition, under certain situations (e.g., multiple transportation corridors within eagle-use areas) it may be advisable to develop geographically-based programmatic permits involving more than one industry or agency.

Several of the comments the Service received on the proposed regulation suggested that the approval process should give "substantial weight to findings of consistency with a State management plan where such plans are consistent with the Eagle Act's goal of preservation of the eagle." One commenter specifically cited the Maryland Chesapeake Bay Critical Area Program (MCBCAP). The Service considered this a potential example suitable for a programmatic disturbance permit. However, we found that the MCBCAP emphasizes habitat conservation measures (which are provided for under the ESA), but is limited in preventing disturbance of eagles (which is the focus of the Eagle Act).

This permit could also be available to entities actively engaged in habitat enhancement that will provide long-term benefits for eagles but will entail short-term negative impacts. An example of such an activity is the shrub-steppe enhancement and renewal initiatives in the Great Basin ecosystem.

Depending upon site-specific conditions and the determination of the local Ecological Services Office and/or the Service Regional Permit Office, permitted take in programmatic permits that will lead to reductions in ongoing disturbance may not need to be subtracted from the calculated take thresholds because this EA considers such disturbance take to be part of the baseline environmental conditions. Programmatic permits for future activities will be subject to take thresholds and the annual allocation process. However, if we determine that entities proposing future activities have, through advanced conservation practices on existing infrastructure or activities, ensured that there will be no net loss to the breeding population from the combined existing action and new proposal, they would not be subject to take thresholds and the annual allocation process.

2.5.5 Combination Permits

Where appropriate, the Service will issue a single permit that combines authorizations provided under the various regulations. For example, an airport that meets the obligations of its Wildlife Hazard Management Plan, or comparable document, and adopts measures developed in cooperation with the Service to minimize the potential take of eagles, could be issued a programmatic permit under these proposed regulations (50 CFR 22.26). Based upon comments received on the proposal, the Service will extend the time period of such a permit to authorize take that occurs as the result of unavoidable collisions between eagles and planes. It will be valid for up to five years. A stipulation of the permit will likely be the requirement to haze eagles in the vicinity of airports, which could constitute disturbance (for example preventing eagles from re-nesting at a hazardous location). Because this hazing is intentional and the effects on the eagles purposeful, it does not meet the issuance criteria for the §

22.26 permit, which requires the taking to be associated with, but not the purpose of, the activity. Therefore, we will issue permits to intentionally remove nests or haze under the authority of § 22.23 (Depredating permits), which will be amended to clarify their application to the protection of health and safety as well as to depredating eagles. The regulations at § 22.23 limited permit tenure to 90 days because the need for programmatic authorization was not contemplated at the time that regulation was developed. In order to have the ability to extend this type of authorization to "Advanced Conservation" programmatic permittees, we will amend the regulations at § 22.23 to allow all depredation permits to be valid for up to five years.

2.6 Alternative 3– Alternative 2 Plus Take Resulting in Mortality (TRM) Individual and Programmatic Option (Preferred Alternative and Environmentally-Preferred Alternative)

Alternative 3 will encompass all of Alternative 2 and it will add permits for TRM of bald eagles and golden eagles where the take is associated with, but not the purpose of, the activity. The primary purposes of Alternative 3 are to reduce the ongoing occurrences of unauthorized and unregulated mortality contributing to eagle losses (currently affecting survival ratios in the population modeling) and to ensure that any authorized, programmatic TRM also include measures to reduce long-term risk of take.

Alternative 3 will also authorize programmatic permits for airfields that could include TRM. Programmatic permits for new and expanded activities are subject to take thresholds and the annual allocation process if it is determined that the predicted take, even where reduced to the point where it is unavoidable, will result in a cumulative loss to the eagle population. When there are no Service-approved measures to minimize take, we will issue no permits.

We will develop metrics for determining whether take is unavoidable and for determining industry- or agency-wide standard practices for programmatic permits with the respective entities at the Service Washington Office level, in coordination with Service Regions. The permits will be issued by the Regions, and will include permit conditions to ensure all recoverable eagle carcasses, parts, and feathers are sent to the National Eagle Repository.

We intend, through a structured coordination process with States and tribes (Section 2.6.4., Measures to Minimize Uncertainty), to develop monitoring and research adequate to both resolve current uncertainties in the data and to provide enhanced ability to detect the effects of the permit program. If, after implementation for a time period commensurate with the normal population cycles of the eagle, data then indicate take thresholds can be increased in certain regions, we will increase thresholds accordingly to allow more annual take. One factor that should allow us to increase take thresholds in some regions for both species, is implementation of advanced conservation measures through programmatic permits to reduce ongoing take that is currently unauthorized. (Section 2.5.4, Permit for Programmatic Disturbance, and Section 2.6.2., Permit for Programmatic Reduction and Minimization of TRM).

2.6.1 Permit for TRM on an Individual Basis

For standard, individual permits, the same issuance criteria will apply for disturbance and TRM. The Service anticipates these permits will be few, but historically, there has been a need to permit some unavoidable TRM of bald eagles. The sources of mortality could be related to such things as transportation, forest management, electric utilities, and home construction. In addition, if a safety-related nest take occurs while the nest is active, there may be a need for an additional permit to take eggs or juveniles if it is determined they cannot be successfully relocated. However, this will be a one-time individual permit and will not apply if the mortality is ongoing for the same location, entity, or system. Therefore, whenever possible, the Service will encourage development and use of programmatic permits.

2.6.1.1 Allocation of Individual Permits for TRM

Individual permits for TRM will be subject to the same allocation process as for individual disturbance permits. The consequence of TRM of individual eagles and the consequence of nest disturbance are the same - the loss of individuals from the population. In the case of TRM, the loss is of individual eagles and the consequences are easily calculated. As long as the rate of population growth (λ) is greater than 1, the loss of any individual eagle has the same demographic consequence to the population; even if the loss is of a breeding adult, surplus floating adults should be available as replacements. In the case of nest disturbance, the loss is the contribution to the annual cohort of juveniles from the affected nest. On average, that loss will equal the average productivity of breeding pairs in the impacted population since that is the number of young that will have been produced in the absence of the authorized disturbing activity.

2.6.2 Permit for Programmatic Reduction and Minimization of TRM

Under this alternative, the Service will also develop a “Performance-Based” programmatic permit designed to reduce ongoing TRM of bald eagles and golden eagles associated with industries such as electric distribution via power lines, transportation, and wind-power development. The list of examples is not meant to be exhaustive because other industries, agencies, or authorities at the federal, tribal, and State level may also be contributing to ongoing eagle mortality. The Service Washington Office will work with the entities to develop scientifically-supportable standard practices and protection plans which, when implemented, will reduce the occurrence of mortality to that which the Service determines meets the “unavoidable” criterion. These standard practices and plans will then become permit conditions, in addition to monitoring and reporting requirements more stringent than those for permits for take of individual eagles. The take authorized through programmatic permits will require quantified estimates of mortality, and the estimate will be specified in the permit authorization. Any mitigation or standard practices must be designed to be consistent with the goal of stable or increasing breeding populations. The Service will use the monitoring and reporting to determine effectiveness of the mitigation or standard practices.

Currently, the only industry example (of which the Service is aware) of standard practices that could, with reasonable modifications, be developed into conditions for a “Performance-Based” permit is that developed by the power-line industry and the Avian Powerline Interaction Committee (of which the Service is a member). As noted in Section 1.1.2 of the Introduction, suitable components of a permit for the power-line industry will include (but will not be limited to): establishment of a mortality baseline through estimates or a sampling scheme; employment of the best-available techniques and mutually-approved standard practices for minimizing eagle mortalities; undertaking a system-wide risk analysis and retrofitting a significant portion of hazardous locations within a reasonable time frame; implementation of an effective monitoring program; reporting eagle mortality to the Service; use of only eagle-friendly practices on all new infrastructure (60" spacing, raptor-safe poles and equipment) in areas identified as high-risk for eagle mortality; and a demonstration that the permittee has eliminated all avoidable eagle mortality in those high-risk areas. To prevent collisions, utilities will also need to ensure transmission lines, distribution lines, and towers that are located in known eagle concentration areas, foraging areas, or nesting areas, have visual markers on the wires.

Other industries or agencies interested in developing standards suitable as permit conditions, and which ensure any mortality meets the “unavoidable” criterion, will be encouraged to work with the Service to develop them. Once those permit types are developed, they can serve as permit type templates that can then be adopted for use by individual practitioners or companies engaged in the covered industry or program. Practitioners of the relevant industries could work to qualify for the programmatic permit. The key components for any permit in this category will need to meet the same high level of standards set for the power-line industry as described above.

The coverage for programmatic take will be limited to those portions or programs of an industry, company, or geographic area that have fully implemented the advanced conservation practices and can demonstrate acceptable reduced mortality. Prior to completion of the risk analyses, the determination of acceptable reduced mortality will be based upon the percent reduction in mortality, supported by documentation of the implementation of standard practices or use of best available technologies. Similar to the programmatic-disturbance take permit, it may be advisable in some cases to develop geographically-based programmatic permits involving more than a single industry or agency.

The Service will encourage industry and non-governmental entities to work with us to conduct scientifically-sound risk analyses to predict with acceptable accuracy the per-unit probability of eagle mortality from specific industry practices and technologies under varying conditions and situations. We will use the per-unit mortality predictions, among other factors, to help set permit thresholds for programmatic TRM. Monitoring and reporting of actual take will be required as a part of the adaptive management process.

This permit will not be required for activities to proceed, nor, in the case of the electric-power-line-utility industry, will it replace the current voluntary process for

instituting an Avian Protection Plan, which will still remain an option, but cannot legally absolve the utility from liability. It will be a performance-based permit for those industry operators, or portions of their programs, which demonstrate their actions have reduced ongoing mortality or have contributed to population stability or improvements.

This permit will initially be for reduction of ongoing take that is currently unauthorized, and which is reflected in the survival ratios of population models. Therefore, TRM permitted in programmatic permits that will lead to reductions in mortality will not be subtracted from the calculated take thresholds. If the reductions in mortality (or other factors) contribute to population increases over a period of five years or greater, then we will re-evaluate the permit thresholds to determine whether modifications are warranted. Programmatic permits for new and expanded activities may be subject to take thresholds and the annual allocation process if it is determined that the predicted take of new activities or combined predicted take of an expansion plus existing take, even where reduced to the point where it is unavoidable, will result in a net loss to the eagle population. .

2.6.3 Avoidance and Minimization for TRM Permits

As with all other permits under this proposal, the Service will evaluate permit applications to determine whether, during the process of developing an activity, use of the eagle-management documents and other methods for avoiding and minimizing the potential for take will be employed. Any requests for permits will need to cite these measures in their supporting documentation.

Proper siting and placement of infrastructure known to be lethal or injurious to eagles are essential to avoid take. In addition to measures to avoid disturbance take as noted in the eagle-management documents, siting to avoid lethal take needs to take into greater consideration such life-history components as dispersal, migration, winter-concentration behavior, and foraging behavior during breeding and non-breeding seasons. When evaluating requests for TRM permits (especially if programmatic in scope), the Service will first assess whether the proposal includes avoidance of migration corridors, winter-concentration areas, and home ranges during breeding and non-breeding seasons. Failure to site lethal infrastructure outside these areas will reduce the options available to qualify for a permit under this proposal.

2.6.4 Measures to Minimize Uncertainty

Our original DEA identified, and commenters provided, substantive information demonstrating there could be significant negative impacts to local area eagle populations without more specific provisions to minimize uncertainty and specific measures for coordination between the Service and jurisdictional wildlife agencies regarding permit issuance and program management. As a response to comments received on the DEA and proposed rule, and to minimize uncertainty regarding eagle demographics and populations and the effects of the proposed rule, the Service will develop and implement two improvements in coordination and consultation: 1) a structured coordination process with State

and tribal wildlife jurisdictional entities, and 2) improved implementation of Service Trust responsibilities to tribes. We will develop and refine these measures during the drafting of implementation guidance for this proposal. The implementation guidance will also undergo public review and comment. In addition we agree with comments we received that additional resources, e.g., monitoring that would support management of eagles at regional or local scales, would improve and further reduce the uncertainty in the eagle permit program. We have provided a list of the goals for which we will work, as resources allow.

2.6.4.1 Structured-Coordination Process with State and Tribal Wildlife Jurisdictional Entities

The implementation guidance for this proposal will contain guidelines for the Division of Migratory Bird Management on how to better implement coordination between the Service and State and tribal wildlife jurisdictional agencies. This implementation guidance will be designed to achieve the following: consistent and effective coordination; minimization of the effects our permit actions will have on local area populations; development of additional goals necessary for effective implementation; provide a forum to share monitoring reports and data, to help develop standard practices for programmatic permits; and to cooperatively develop the required components for more localized thresholds and management, We will use the coordination structure developed by the guidance to identify specific regions, e.g., the Chesapeake Bay, that are critical to the maintenance and continued recovery of continental bald eagle populations and to the long-term sustainability of golden eagle populations, and also to develop localized conservation measures for programmatic permits. We will also use enhanced coordination to identify areas that are critical foraging, roosting, and concentration areas. We intend to actively seek the assistance of States and tribes as we develop the guidance, and we will not limit our outreach to minimal compliance with NEPA.

While there are a number of ways to implement enhanced coordination, including operating through the existing flyway structures, there may be a need to create structures at different scales, national, Service Region, and/or State or tribal. The specific structures will be developed during the implementation guidance stage, and by the Service Regions, as appropriate. However, there are elements necessary for effective coordination that will be common to all agreed-upon structures. These elements include, but may not be limited to, the following:

- Formal agreements;
- Clear delineation of roles, responsibilities, and authorities;
- Coordination facets – Coordination between entities, applying guidance criteria, implementation teams that meet regularly;
- Action level points-of-contact;
- Liaisons;
- Issue resolution teams;
- Strategic Facets – Program Manager Team (monitoring implementation of streamlining and needed improvements, assessing and monitoring

programs and workload, determining need for additional criteria, consistency, training, and developing strategic recommendations);
- Dispute resolution process;
- Implementation plan; and
- Criteria for evaluation of efficiencies.

In some areas, processes for streamlining permits may be feasible if requested. We will only consider such requests if those States or tribes have eagle-management plans or statutes protecting eagles that have legally-enforceable provisions prohibiting take at least as protective as those in the Eagle Act (including prohibitions on disturbance), and contain comparable liability provisions.

2.6.4.2 Improved Implementation of Service Trust Responsibilities to Tribes

In order to better ensure consistent, appropriate consultation, and improve our compliance with NHPA, AIRFA, and RFRA, the implementation guidance for this proposal will contain guidelines for the Division of Migratory Bird Management on how to better implement government-to-government consultation on a permit-by-permit basis and on the program as a whole. We intend to actively seek the assistance of tribes as we develop the guidance, and not limit our outreach to the requirements of NEPA. The measures in the implementation guidance will provide direction on incorporating the results of government-to-government consultation into permit conditions, as necessary. In addition, the implementation guidance will also recommend that each Region work with their respective tribal governments or representative organizations to develop a practicable and mutually-agreeable framework for regular coordination meetings relative to the eagle permit program.

2.6.4.3 Identified Goals for Improved Ability to Manage Eagle Populations and Permit Program

The comments received on the DEA, in addition to uncertainties pointed out by the Service, have lead us to identify a number of needs that, when met, will reduce the uncertainty and improve the Service's ability to manage bald eagles and golden eagles, as well as the permit program. They will also support the improved coordination procedures and structures committed to in section 2.6.4.1, as well as efforts to develop more localized management. Drawing, in part, from recommendations for golden eagle conservation in Kochert and Steenhof (2002) and Whitfield et al. (2008), and the results of analysis in this document, we have identified the following non-comprehensive, but critical needs and goals as program goals towards which we will work:

- A national golden eagle-specific conservation and management plan to include, but not be limited to:
    - Identifying and assessing the influence of constraints, e.g., nest site availability, electrocution, agricultural and urban encroachment,

persecution, unintentional disturbance through recreation, energy development (including wind), lead poisoning or other contaminants, invasive species, climate change, drought, impacts to prey base, or other factors;
    - Establishing criteria for setting favorable conservation status targets. Criteria could include such things as: whether the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and whether there is, and will probably continue to be, a sufficiently large habitat to maintain populations on a long-term basis;
    - Identifying and developing management measures to achieve favorable conservation status;
    - Developing tests for determining achievement of favorable conservation status targets; and
    - Developing standardized protocols for surveys and monitoring to ensure the ability to compare and combine results.
- A satellite telemetry study to better determine age-specific mortality, and answer questions about dispersal, migration, and winter concentration areas.
    - Eagles radio marked to provide population data could also be used to simultaneously gather information about their association with environmental factors. Those data would help fill in at least two information gaps: 1) eagle use of the environment beyond the nest site and of the landscape in general; and 2) their current use of the environment as compared to historical data.
- Improved survey and monitoring for both species.
- A habitat-predictive model for golden eagles that could identify not only suitable habitat structure (e.g. slope, aspect, geologic strata that would provide shelves, or large nest trees in some areas) but also identify areas that are prone to invasives, altered fire frequency and intensity regimes, and subject to increasing pressures from urban and energy (including wind) development.
- Population goals for each species.

2.7 Alternatives Considered but Eliminated from Detailed Study

When the Service first proposed the eagle permit regulation, we considered permitting take of bald eagles and golden eagles based upon (1) the populations in Alaska and (2) the total populations in the lower 48 states for both species. The Service is interpreting the “preservation of the eagle” to mean maintaining bald eagle and golden eagle populations with no discernible population declines, nationally or regionally. Therefore, an alternative that would allocate permits solely at the larger scale probably would not be compatible with the preservation of eagles and would be difficult to implement. In addition, the Service believes that management of either species of eagle solely at the scale of the lower 48 states would not be feasible to implement because our Permit Program is largely administered from the Service Regional Offices. It will also limit the ability of the

Service to effectively coordinate with local entities such as tribes and States. For all the preceding reasons, the Service eliminated this as an alternative.

One comment letter recommended an alternative that would propose take for bald eagles but not for golden eagles. The Service believes that the measures and analyses specific to the golden eagle in Alternative 1, the “No Action” alternative are consistent with the approach proposed by the commenter, and that the recommended alternative would not change the management of either species. The measures also ensure that thresholds are compatible with the preservation of the eagle, and allow us to suspend take of either species if populations would not support take. In addition, we believe the programmatic permits proposed are needed to improve conditions for golden eagle populations, and that failure to take those steps would not be compatible with the preservation of the golden eagle. Furthermore, we do not believe that including the proposed approach as a fourth alternative would provide any additional substantive information that would change the information informing our decision. Thus, we have not added it.

CHAPTER 3: AFFECTED ENVIRONMENT

3.1 Introduction

The affected environment includes the environmental components (resources) that will be affected by the alternatives. It is important to note these resources may also affect the alternatives if the Service were to implement them. For example, large-scale changes in habitat supporting eagles may have population impacts that may require adjustment to the level of take compatible with the preservation of eagles. Although the chapter title includes the term "affected," this chapter does not present effects. Instead, the environment described is the reference point for the comparisons of impacts in Chapter 4, Environmental Consequences. The implementing regulations for NEPA (40 C.F.R. 1502.15) state that agencies shall avoid useless bulk in statements and shall concentrate effort and attention on the important issues. The proposed permit or permits will be national in scale; therefore the Service has identified those factors with the greatest importance at that scale, and has also concentrated on those issues identified in comments on the proposed rule.

3.2 General Information Regarding Raptor Population Biology

The Service considers the availability of nest sites and food as the limiting factors for raptor populations (Wilcove et al. 1986, Watson and Langslow 1989). Raptors compensate for the loss of foraging and nesting habitat by abandoning established territories and/or attempting to utilize less productive or already-occupied territories (Nelson 1979, Newton 1979). Without human intervention, population regulation in many raptor species comes through competition for breeding space assisted by the presence of surplus adults, which breed only when an existing breeding territory becomes vacant. In habitat where nest sites are widely available, breeding density fluctuates generally in synchrony with availability of preferred prey (Newton 1979, Smith and Murphy 1979, Ridpath and Booker 1986, Bates and Moretti 1994). The presence of alternate prey species may allow continued breeding success during periods when the availability of preferred prey species is low (Johnstone 1980, Thompson et al. 1982). In other areas, breeding-density levels may be influenced by the number of available nest sites rather than by available food supply (Edwards 1969, Boeker and Ray 1971). Consequently, in relatively undisturbed raptor habitat, breeding density is naturally limited primarily by food supply or nest sites, whichever is most limited (Newton 1979, 1991).

Local area adult and subadult eagle populations may be comprised of: pairs occupying a breeding territory; individuals that have secured a breeding territory but not a mate; and individuals that are unable to secure a breeding territory, or "floaters" (non-breeders). Although competition for nest sites and food between established breeders and floaters may reduce nest success, healthy populations over the long term typically depend upon the presence of many floaters. An emphasis solely on occupied territories may delay the detection of population declines (Kenward et al. 2000), but some researchers

suggest that tracking the proportion of immature breeders drawn from the floater population can be used as an early-warning sign of population decline (Ferrer et al. 2003). More recent modeling efforts cited by commenters (Katzner et al. 2006) suggest that this is not so much an early warning sign, as a sign of a population in extremely dire straits, and t hat adult turnover may be a more reliable indicator of short-term changes in eagle demography. Ensuring the availability of suitable settlement areas for dispersing floaters can increase the effectiveness of conservation efforts (Penteriani et al. 2005). For additional information regarding population dynamics and how we assessed them in this proposal, see Appendix C.

3.3 Bald Eagle

3.3.1 General Conditions

Bald eagles are an endemic North American species that historically occurred throughout the contiguous United States and Alaska. It historically ranged and nested throughout North America except extreme northern Alaska and Canada and central and southern Mexico. The largest North American breeding populations are in Alaska and Canada, but there are also significant bald eagle populations in Florida, the Pacific Northwest, the Greater Yellowstone area, the Great Lakes states, Maine, and the Chesapeake Bay region. Bald eagle distribution varies seasonally. Bald eagles that nest in southern latitudes frequently move northward in late spring and early summer, often summering as far north as Canada. However, in Arizona bald eagles typically stay in their breeding areas year round. Most eagles that breed at northern latitudes migrate southward during winter or to coastal areas where waters remain unfrozen. Migrants frequently concentrate in large numbers at open water sites where food is abundant and they often roost together communally. Wintering bald eagles occur throughout the United States but are most abundant in the West and Midwest (USFWS 1983) along major river systems and large bodies of water in the mid-western states, Chesapeake Bay region, Pacific Northwestern states, and states of the intermountain west, including Wyoming, Utah, Colorado, New Mexico, and Arizona. On their winter range, bald eagles may roost singly or in small groups but larger communal roosts are important and may predominate in many areas (Platt 1976). Bald eagles have been observed to fly over 24 kilometers (15 miles) from their feeding areas to roosting sites (Swisher 1964). In some cases, concentration areas are used year-round: in summer by southern eagles and in winter by northern eagles.

Breeding bald eagles occupy territories, many of which have been used continuously for many years. One breeding territory in Ohio was occupied continuously for nearly a century (Herrick 1924). Bald eagles generally nest near coastlines, rivers, large lakes, reservoirs, and streams proximate to an adequate food supply. They often nest in mature or old-growth trees, snags (dead trees), sometimes on cliffs or rock promontories, and rarely nest on the ground. They also nest with increasing frequency on human-made structures such as power poles and communication towers. Several alternate nests are built by a single

pair in a breeding territory, and in any given year, a new nest may be built or an old nest may be reoccupied (Greater Yellowstone Bald Eagle Working Group (GYBEWG) 1996). The start of the breeding season ranges from October in Florida, to late April or early May in the northern United States.

3.3.2 Population

The first declines in bald eagle populations in the past 250 years occurred due to habitat loss as early European immigrants settled on shorelines in the Chesapeake Bay and elsewhere on the East Coast. More significant declines began in the late 19th Century due to hunting for feathers, trophies, and bounty. In addition, eagles were killed by ingesting poisons used to bait and kill livestock predators. In 1940, Congress enacted the Bald Eagle Protection Act (amended in 1962 to protect golden eagles, and now called the Bald and Golden Eagle Protection Act). In the late 1940s, organochlorine pesticide compounds such as DDT (dichloro-diphenyl-trichloroethane) began to be used in large quantities. DDT metabolites accumulated in the fatty tissues of breeding bald eagles, resulting in production of eggs with abnormally thin eggshells, which cracked or failed to fully develop, causing a severe decline in bald eagle numbers. By 1963, a survey conducted by the National Audubon Society estimated the number of breeding bald eagles in the lower 48 states to be 417 breeding pairs.

Since DDT use in the United States was banned in 1972 and the bald eagle gained the protection of the ESA,[4] bald eagle numbers have rebounded.[5] In 1999, the Service proposed to remove the bald eagle from the list of threatened and endangered species, prompting some states to stop conducting annual surveys for bald eagles. The most recent national census in 2000 counted 6,471 breeding pairs in the lower 48 states. On February 16, 2006, the Service re-opened the comment period on its 1999 proposal to delist the bald eagle (71 FR 8238, Feb. 16, 2006), conservatively estimating at least 7,066 breeding pairs in the contiguous United States. As of February 2007, the Service estimates that number to exceed 9,700 (72 FR 37346, July 9, 2007). In July of 2007, the Service removed the bald eagle from the ESA list of threatened and endangered species. However, the bald eagle currently remains protected as a threatened species throughout the range of the Sonoran Desert population because the federal district court for the District of Arizona enjoined the removal of ESA protection for that population in *Ctr. for Biological Diversity v. Kempthorne*, 2008 U.S. Dist. LEXIS 17517 at 42 (D. Ariz. 2008).

3.3.3 Disturbance

Numerous studies have sought to measure the sensitivity of bald eagles to a variety of human activities (Mathieson 1968, Stahlmaster and Newman 1979,

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[4] The bald eagle was first protected south of 40° north latitude by the Endangered Species Preservation Act in 1967, then listed as endangered in 43 contiguous states and threatened in the other five under the ESA in 1978, then reclassified to threatened in the lower 48 states in 1995.

[5] Alaskan bald eagles were largely unaffected by DDT and were never protected under the ESA. Today, there are perhaps 50,000 to 70,000 bald eagles in Alaska.

Skagen 1980, Gerard et al. 1984, Fraser et al. 1985, Russell and Lewis 1993, Brown and Stevens 1997, Buehler 2000, Grubb et al. 2002), and have shown that bald eagle pairs may react to human activities very differently. Some pairs nest successfully just dozens of yards from human activity, while others abandon nest sites in response to activities much farther away. This variability may be related to a number of factors, including visibility, duration, noise levels, extent of the area affected by the activity, prior experiences with humans, and tolerance of the individual nesting pairs.

Human activities that cause prolonged absences of breeding adult bald eagles from their nests can jeopardize eggs or nestlings. Depending on weather conditions, this may cause the eggs to either overheat or cool down too much, and then fail to hatch. Unattended eggs and nestlings are subject to predation. Irregular feeding due to human disruption can harm nestlings and adults. Adults startled while incubating or brooding nestlings may damage eggs or injure their nestlings as they abruptly leave the nest. Older nestlings may be startled by loud or intrusive human activities and prematurely jump from the nest before they are able to fly.

Human activities near or within foraging areas and communal roost sites may prevent eagles from feeding or taking shelter, especially if no other adequate feeding or roosting sites are available. Human disturbances may constitute a threat to wintering bald eagle populations by causing displacement to areas of lower human activity (Stalmaster 1976, Stalmaster and Newman 1978, Brown and Stevens 1997). Human disturbances may also interfere with foraging behavior of eagles (Mathiesen 1968, Stalmaster 1976).

Additional information regarding the response of bald eagles to disturbance can be found in the final rule removing the bald eagle in the lower 48 states from the list of endangered and threatened wildlife (72 FR 37346, July 7, 2007).

3.4 Golden Eagle

3.4.1 General Conditions

Worldwide, the golden eagle is widely distributed, with five or six subspecies found throughout the northern hemisphere in Europe, Asia, and northern Africa and occasionally in the southern hemisphere (Kochert et al. 2002). In North America, golden eagles occur mainly west of the 100th Meridian and in western Canada, nesting and wintering from Alaska south to central Mexico. Historically, the breeding range of the golden eagle included most of North America (Bent 1937). Today, the golden eagle is primarily a winter resident in the eastern United States (Kochert et al. 2002), but in 1997 a nesting pair was documented in Michigan (Wheeler 2003).

In North America, northern breeding golden eagles migrate longer distances to wintering areas than do southern eagles, sometimes up to thousands of kilometers. Golden eagles south of 55° north latitude migrate smaller distances or not at all. More research is needed to establish migration routes or areas, but they appear to be concentrated along the Rocky Mountains and Appalachians (Kochert et al. 2002). In some western states golden eagles are year-round

residents on breeding territories. Golden eagles will occasionally roost communally during severe weather or when prey is abundant (Kochert et al. 2002; Craig and Craig 1984). Edwards (1969) observed in Utah that immature golden eagles often associate with one another during winter and they also may roost with bald eagles during winter.

Golden eagles usually occupy open areas (canyon land, open desert, grassland, and shrub habitat) where their preferred prey can be found. However, in southwestern Idaho, eagles selected shrub habitats and avoided grasslands in addition to disturbed areas and agriculture (Marzluff et al. 1997). Golden eagles feed primarily on small mammals, most commonly rabbits (*Sylvilagus* spp.), hares (*Lepus* spp.), ground squirrels (*Spermophilus* spp.), marmots (*Marmota* spp.), and prairie dogs (*Cynomys* spp.). They also eat carrion, birds, and reptiles, and less often fish and larger mammals. Millsap and Vana (1984) reported on the importance of waterfowl to wintering golden eagles in the eastern United States.

Nest sites are most often on cliffs or bluffs, less often in trees, and occasionally on the ground. Pairs establish and defend breeding territories that may contain multiple nests built and/or maintained by the pair, which are often re-used or attended in subsequent nesting seasons. Individual eagle nests left unused for a number of years may be reoccupied. In a review of the available literature and reports regarding nest use by raptors, Megown et al. (2007) reported an interval of over 22 years during which golden eagles did not occupy a nest.

3.4.2 Population

The golden eagle is a Bird of Conservation Concern in the Great Basin, Northern Rockies, Southern Rockies/Colorado Plateau, and Badlands and Prairies Bird Conservation Regions (numbers 9, 10, 16, and 17, USFWS 2002). The golden eagle is also ranked by NatureServe (2007) as critically imperiled in Georgia, Tennessee, and Vermont; breeding golden eagles as critically imperiled in Kansas and Maine; and the non-breeding population as critically imperiled in Indiana, Louisiana, Maine, Maryland, and Virginia (see Appendix B). Braun et al. (1975) estimated a North American population of perhaps 100,000 individuals in the early 1970s. United States Breeding Bird surveys show no trend for this species (P=0.39, Sauer et al. 2005). However, a report on a 2006 survey (Good et al. 2007a) showed decreasing populations in two Bird Conservation Regions (BCRs). A draft report of 2007 surveys in the same areas (BCRs 9, 10, 16, and 17, hereinafter WEST areas) found decreasing golden eagle populations in two BCRs, one of which was the same as the previous report (Good and others, 2008). The current PIF-based United States and Canada population estimate is 80,000, with a “fair” accuracy rating and a “very high” precision rating. Kirk and Hyslop (1998) suggested that golden eagle populations may be declining in some areas of Canada. Golden eagle productivity in Alaska may be lower than that for golden eagles in lower latitudes (Young et al. 1995; McIntyre and Adams, 1999). Good et al. (2004) estimated that there were just over 27,000 golden eagles in the 4 BCRs in which the species is of conservation concern. These

same BCRs encompass much of the western U.S. population and most of the North American population of this species. A preliminary report on the 2008 surveys in the WEST areas showed population declines in all four BCRs covered in the survey, an area which is believed to contain approximately 80% of the golden eagle population in the lower 48 states (Good et al., personal communication, January 14, 2009). Breeding bird surveys and migration counts are inconclusive but suggest lowered reproduction rates in the western United States, possibly due to habitat alteration and loss, with concomitant declines in prey (Kochert et al. 2002). Kochert and Steenhof (2002) noted that the status of nesting golden eagles in the western U.S. is less clear than that of golden eagles in Alaska and Canada, where information suggests that nesting populations are stable. In addition, McIntyre et al. (2006), provided evidence that estimates of annual productivity were not good predictors of first-year survival in migratory juvenile golden eagles. They further suggested more research is needed to determine whether productivity is an accurate predictor of survival in both non-migratory and migratory populations of golden eagles.

In addition to gaps in knowledge regarding post-fledgling mortality, there is a need to gather more information regarding dispersal patterns of juvenile golden eagles (Edwards et al. 1988) as well as adult female survivorship, a key population indicator. They remarked that an apparent male bias in fledgling sex ratios was less skewed than expected because, as Newton (1979) noted, female golden eagles usually suffer greater post-fledging mortality than males. They also suggested that, among golden eagles from the Snake River Birds of Prey area in Idaho, subadult males may either have lower survivorship relative to females or have greater dispersal tendencies. Greater knowledge regarding sex ratios of survivorship and dispersal tendencies can yield information relevant to adult sex ratios, important for evaluating monitoring results. In addition, skewed sex ratios in wild bird populations may have implications for conservation (Donald 2007).

Good et al. (2007b) noted that determining if the golden eagle population in the Western United States is increasing, decreasing, or stable is more important than knowing how many golden eagles are present. Harmata (2002) suggested that conservation and management of golden eagles may be better served if, in addition to productivity, efforts were focused on determining the number of breeding pairs and turnover of breeding eagles over multiple years. In a personal communication (September 25, 2007), Carol McIntyre, wildlife biologist and eagle specialist from Denali National Park and Preserve, reported a general concern among raptor biologists over the proposal to issue take for golden eagles, given the lack of data on population size, productivity, and survival. In addition, McIntyre et al. (2008) suggested that conservation strategies for migratory golden eagles require a continental approach.

3.4.3 Disturbance

Golden eagles appear to be sensitive to human activity, and may be much more sensitive to disturbance than bald eagles (Dr. M. W. Collopy, personal communication, May 15, 2007). They commonly avoid urban and agricultural

areas, but this is likely due at least in part to low availability of preferred prey species in those locations. Steidl et al. (1993) found when observers were camped 400 m from nests of golden eagles, adults spent less time near their nests, fed their juveniles less frequently, and fed themselves and their juveniles up to 67% less food than when observers were camped 800 m from nests. In studies of golden eagle populations in the southwest (New Mexico and Texas) and the Front Range of the Rocky Mountains (New Mexico, Colorado and Wyoming), Boeker and Ray (1971) reported that human disturbance accounted for at least 85% of all known nest losses. Breeding adults are sometimes flushed from the nest by recreational climbers and researchers, sometimes resulting in the loss of the eggs or juveniles due to nest abandonment, exposure of juveniles or eggs to the elements, collapse of the nest, eggs being knocked from the nest by startled adults, or juveniles fledging prematurely. However, golden eagles rarely flushed from the nest during close approaches by fixed-wing aircraft and helicopters during various surveys in Montana, Idaho, and Alaska (Kochert et al. 2002).

3.5 Biological and Physical Environment

3.5.1 General Habitat Factors

As described above, bald eagles typically occupy coastal areas and shorelines of rivers and lakes, while golden eagles favor the open, more arid habitat of the western states. However, in reality, both species use a variety of habitats and geographical areas. The breeding and wintering habitats of bald eagles and golden eagles together comprise a large portion of the United States. A detailed description of the biological and physical components of this large area is beyond the scope of this FEA. However, the Service can outline some factors in eagle habitat that may be related to population effects.

The Birds of North America accounts for both species make specific recommendations for research relating to eagle environments that is important for adequate and informed management. Buehler (2000) noted that research is needed to define tolerable limits of human development that will not compromise bald eagle population viability. In addition, information on the effects of habitat alteration on golden eagle populations is deficient for both breeding and wintering grounds (Kochert et al. 2002).

3.5.1.1 Climate Change

In a review of research evaluating the effects of recent climate change, McCarty (2001) noted that, while scientists have documented the response of species to interannual or geographic variations in climate, they lack sufficient information to understand or predict the responses to the kinds of long-term trends in climatic conditions that have occurred in recent decades. However, changes in the timing of avian breeding and migration and a northward expansion of the geographic range in North American birds have already been documented (McCarty 2001; Peterson 2003; LaSorte and Thompson 2007).

In the western U.S., there is evidence (Ziska et al. 2005) that increasing atmospheric CO_2 concentrations associated with climate change may have contributed to cheatgrass productivity and fuel load with subsequent effects on fire frequency and intensity, a factor in golden eagle habitat that is discussed further in Section 3.5.3, Golden Eagle Habitat Factors, page 44. In addition, elevated CO_2 concentrations may contribute to increased expansion of the exotic invasive hydrilla (*Hydrilla verticillata*) (U.S. EPA 2008) that, with an associated epiphytic cyanobacteria species, has been implicated as a link to avian vacuolar myelinopathy (AVM) (Wilde et al. 2005). First reported in 1994, AVM has caused the death of at least 100 bald eagles (Thomas et al. 1998).

3.5.2 Bald Eagle Habitat Factors

Habitat loss and encroachment from development has been a factor for bald eagles. For example, some of the states with high numbers of bald eagles have also experienced high rates of increased housing unit development from 2000 to 2004 (United States Census Bureau, 2007). Of the twenty states ranked highest in housing unit development, the following States with high concentrations of bald eagles: Florida, Georgia, North Carolina, Virginia, Michigan, Washington, Minnesota, Wisconsin, and South Carolina ranked, respectively, number 1, 4, 5, 7, 10, 14, 16, 17, and 19. In addition, 49 of the top 100 fastest growing counties from April of 2000 until July of 2006 (United States Census Bureau, 2007) have bald eagle breeding locations identified within them (Appendix G and Figure 5).

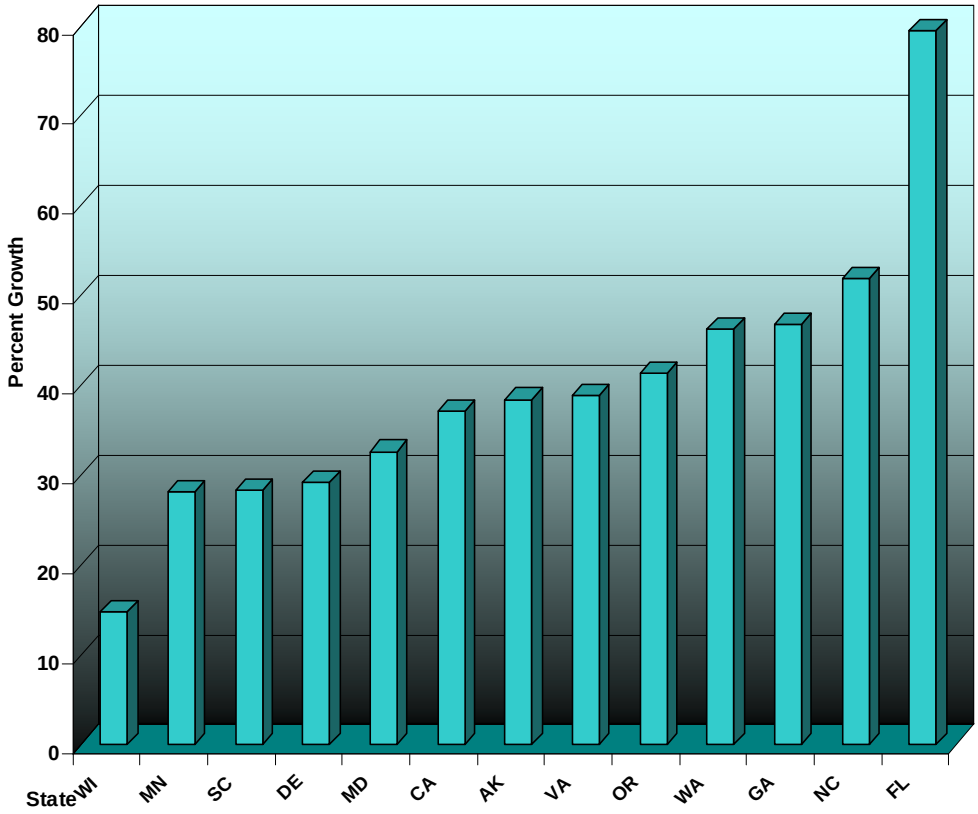

Figure 5 Expected human population growth in 10 fast-growing states with substantial bald eagle populations.

However, many of the fastest-growing counties still have relatively low human population densities and low counts of bald eagles. Bald eagle numbers in those areas are still increasing, so, while there may be impacts to individuals in local areas, the Service doesn't believe there have been adverse impacts to overall bald eagle populations so far.

Increased oil and gas (conventional and coal bed methane) development, and the increase of inter and intra-state pipelines in the Intermountain West is occurring in areas with bald eagle nest and winter roost sites, particularly along riparian corridors. The National Bald Eagle Management Guidelines ((USFWS 2007a))(p. 9), make specific note that in open areas where there are little or no forested or topographical buffers, such as in many western states, the distance alone must serve as the buffer, and that buffer distances may need to be larger than those in the Guidelines. In the commonly narrow riparian corridors in the Intermountain West, cottonwoods are predominantly used by bald eagles as nest and roost trees. Therefore, the decline of cottonwoods in the arid West (Miller etal. 1995; Lite and Stromberg 2005; Birken and Cooper 2006) has rendered the remaining cottonwoods more valuable as bald eagle habitat. The degree to which these activities result in impacts to habitat, either temporarily or permanently, can vary by reclamation potential in location of project, method of extraction, or success of reclamation. Quantification of these impacts is beyond the scope of this environmental analysis.

3.5.3 Golden Eagle Habitat Factors

Habitat loss and encroachment from urbanization and conversion of habitat to agricultural uses has negatively impacted golden eagles (Kochert et al. 2002). Golden eagle breeding territories were less successful in areas lacking a mosaic of native vegetation (Thompson et al. 1982) since the habitat was unable to support abundant jackrabbit populations, their preferred prey. Good et al. (2007b) noted that factors that could cause population declines such as habitat loss are increasing. In some areas, especially in southern California (Scott 1985) and the Colorado Front Range (Boeker 1974), urbanization and human-population growth have made areas historically used by eagles unsuitable for breeding. Widespread agricultural development in portions of the golden eagle range has contributed to reduction of jackrabbit populations and has been a factor in rendering areas less suitable for nesting and wintering eagles (Beecham and Kochert 1975; United States Dept. of the Interior 1979; Craig et al. 1986).

Another factor affecting golden eagle habitat has been the increasing number, frequency, and intensity of fires. In the Intermountain West, fires have caused large-scale losses of shrubs and jackrabbit habitat in areas used by golden eagles. Greater than 98,000 acres of shrub lands were consumed by wildfires between 1981 and 1987 in the Snake River Birds of Prey National Conservation Area, and adversely affected nesting populations. Nesting success at burned territories in Snake River Canyon declined after major fires. Kochert et al (1999) documented that burned territories abandoned by the original nesting pair were taken over by neighboring pairs increasing the size of their territories. This

resulted in a decreased number of nesting pairs in the initial area. Between 2001 and 2006, fire burned approximately 566,800 acres within the range of the golden eagle in the lower 48 States (USFWS 2007b).

The fires affecting golden eagle populations in the Snake River Birds of Prey National Conservation Area were associated with the presence of cheatgrass (*Bromus tectorum*) (Kochert et al. 1999). There is evidence that the widespread abundance of cheatgrass, red brome (*Bromus rubens*), and other non-native annual grasses has led to the establishment of a frequent annual grass/fire cycle in areas that had relatively low fire frequency prior to their invasion (Link et al. 2006, Brooks et al. 2004; Whisenant 1990). The interval of natural fires in sagebrush shrub habitat has been shortened via invasions of annual non-native grasses (Crawford et al. 2004).

Empirically-derived declines in populations of prairie dogs, a prey species for golden eagles (Kochert et al. 2002), have been suggested as a habitat-related factor affecting golden eagle populations. Most of the remaining prairie dogs in the southern grasslands are associated with playas (seasonally wet depressions or dry lake beds), which, although not plowed, are small and dispersed. While apparent declines in white-tailed and black-tailed prairie dogs may not currently be sufficient to result in listing of either species under the ESA, alterations in availability of prey species can still affect golden eagles (Dr. C. Boal, personal communication, 24 August 2007).

Both the 90-Day Finding on a Petition To List the White-Tailed Prairie Dog as Threatened or Endangered (69 FR 64889, Nov. 9, 2004) and the Finding for the Resubmitted Petition To List the Black-Tailed Prairie Dog as Threatened (69 FR 51217, Aug. 18, 2004) cited research suggesting that annual fluctuations in the respective prairie dog populations may have dramatically increased over historical patterns. In the Moreno Valley, New Mexico, Cully (1991) documented a steady decline leading to an apparent disappearance of golden eagles during a period from 1985 to 1987 that correlated with the declines of Gunnison prairie dogs resulting from plague. Boal et al. (2008) suggested that persistent prairie dog control may be one of several factors contributing to data that suggests that nesting Golden Eagles in the Texas Panhandle may have declined by 40%–71% since 1983.

Energy development also affects golden eagle habitat. Numerous types of energy development occur in golden eagle nesting and wintering habitat. Surface coal mines have impacted nesting sites in Wyoming (Phillips and Beske 1982), and subsidence from underground coal mines impact nests associated with cliffs in Utah. Efforts to construct replacement, artificial nest locations have met with some success in Wyoming's coal mine region (Postovit et al. 1982). However, the geomorphology in Utah's primary coal mine region has not been as conducive to the same techniques. There, nests are located on high, steep, cliff faces, and activities under a Part 22.25 permit to remove nests or temporarily exclude birds from nesting in a hazardous situation are often extremely hazardous to human safety.

Dramatically-increased oil and gas (conventional and coal bed methane) development in Colorado, Montana, Utah, and Wyoming is occurring in areas

centered within the golden eagle range in the lower 48 states. For example, drilling applications in Utah have increased by approximately 250% over the last five years compared to the previous five-year period (Utah BLM 2007). The degree to which these activities result in impacts to habitat, either temporarily or permanently, can vary by location of project, method of extraction, or success of reclamation, and quantification is beyond the scope of this environmental analysis. However, the introduction of new or improved roads into previously, poorly-accessible golden eagle habitat is a common factor in most oil and gas development. Even if roads and well pads are eventually reclaimed, the life of some field developments can extend for decades. In addition, reclamation times for vegetation (supporting prey and providing line-of-sight screening for nests) in semi-arid to arid areas where many golden eagles occur can be lengthy. For example, a cumulative effects analysis for one field development proposal in Utah noted that reclamation times ranged from 50 to 250 years. The analysis also predicted a net decline of 10-15 nesting pairs of golden eagles within the impact analysis area over the life of the project.

In addition, the Western United States, perhaps because of its combination of wide expanses of inexpensive real estate and high winds has been the focus of extensive wind energy development.[6] In 2007, installations of new wind turbine facilities increased the national wind-energy-generation capacity by 45%, and three of the top five States in terms of capacity were in the Western United States. One of those States, Colorado, recently experienced an increase from approximately 316 Megawatts (MW) to 1066 MW, an over 200% increase (AWEA 2007). In the 17 states west of 100° west longitude, including Alaska, wind power capacity has increased from 1952 MW in 1999 to 12425 MW at the end of 2007, an increase of over 600% (Figure 6) (Department of Energy 2008).

3.6 Eagle Mortality Associated with Human Activities

Raptors in general are killed by starvation, disease, predation, electrocution, shooting, trapping, poisoning, and vehicle/aircraft collisions (Newton 1979). Analyses of records of raptors brought in to veterinary hospitals frequently cite trauma as the leading source of morbidity and mortality, with a majority of cases directly related to human activity (Deem et al. 1998, Harris and Sleeman 2007, Richards et al. 2005, and Wendell et al. 2002). Some of the trauma is from persecution. Between 1993 and 2003, trauma was the most common reason (70%) for bald eagle admission to the Wildlife Center of Virginia, and 15% of the trauma was due to gunshot (Harris and Sleeman 2007). Six percent of the golden eagle admissions to the Colorado State University Veterinary Teaching Hospital during 1995 to 1998 were from gunshot. Another source of eagle mortality is illegal killing for purposes of commercial gain from wildlife trafficking. Annual reports from1999 through 2007 of the Service's LE program have examples in all years but one of enforcement actions against individual trafficking in eagles and eagle parts of both species. In a 2002 cooperative federal/State

[6] The Department of the Interior has chartered a committee, which will advise the Secretary on effective measures to avoid or minimize impacts to wildlife and their habitats related to land-based wind energy facilities.

investigation of the illegal killing and commercialization of eagles for the Native American pow wow trade, Service agents and Iowa conservation officers confiscated leg hold traps, a freshly killed eagle, and parts of at least 22 golden eagles and three bald eagles. A 1999 investigation resulted in seizure of eagle parts representing over 90 birds. A recent Service investigation documented the illegal killing and trade of bald and golden eagles and other protected birds, and well as their feathers and parts. One portion of the investigation revealed the illegal trafficking of over 300 eagles annually of which 60 percent were golden eagles and 40 percent were bald eagles. Illegal trafficking is a persistent source of eagle mortality and the Service is regularly engaged in detecting and apprehending individuals involved in these unlawful activities. While there is a legitimate use for eagle feathers in Native American religious practice and ceremonies, illegal trade undermines the effort to conserve eagles and will continue to be a high priority for the Service's law enforcement program.

Offsetting the adverse effects of human activity is considered the greatest conservation challenge in managing golden eagle populations (Kochert and Steenhof 2002). Estimates of mortality and causes of mortality vary with the methods of gathering data, and depend largely upon reporting to appropriate authorities. In this FEA, the Service is limiting the discussion of eagle mortality factors to those human-associated activities for which we expect eagle permits may be requested. Natural eagle mortality factors will not be discussed here, nor will we provide lengthy information on mortality from such unauthorized human-associated factors as vehicle collisions and lead poisoning, for which a permit could not practically be designed. Currently, under the Eagle Act, the Service relies on enforcement discretion and voluntary cooperation between the Service and other agencies and private entities to regulate take of eagles in the absence of an available permit for non-purposeful take.

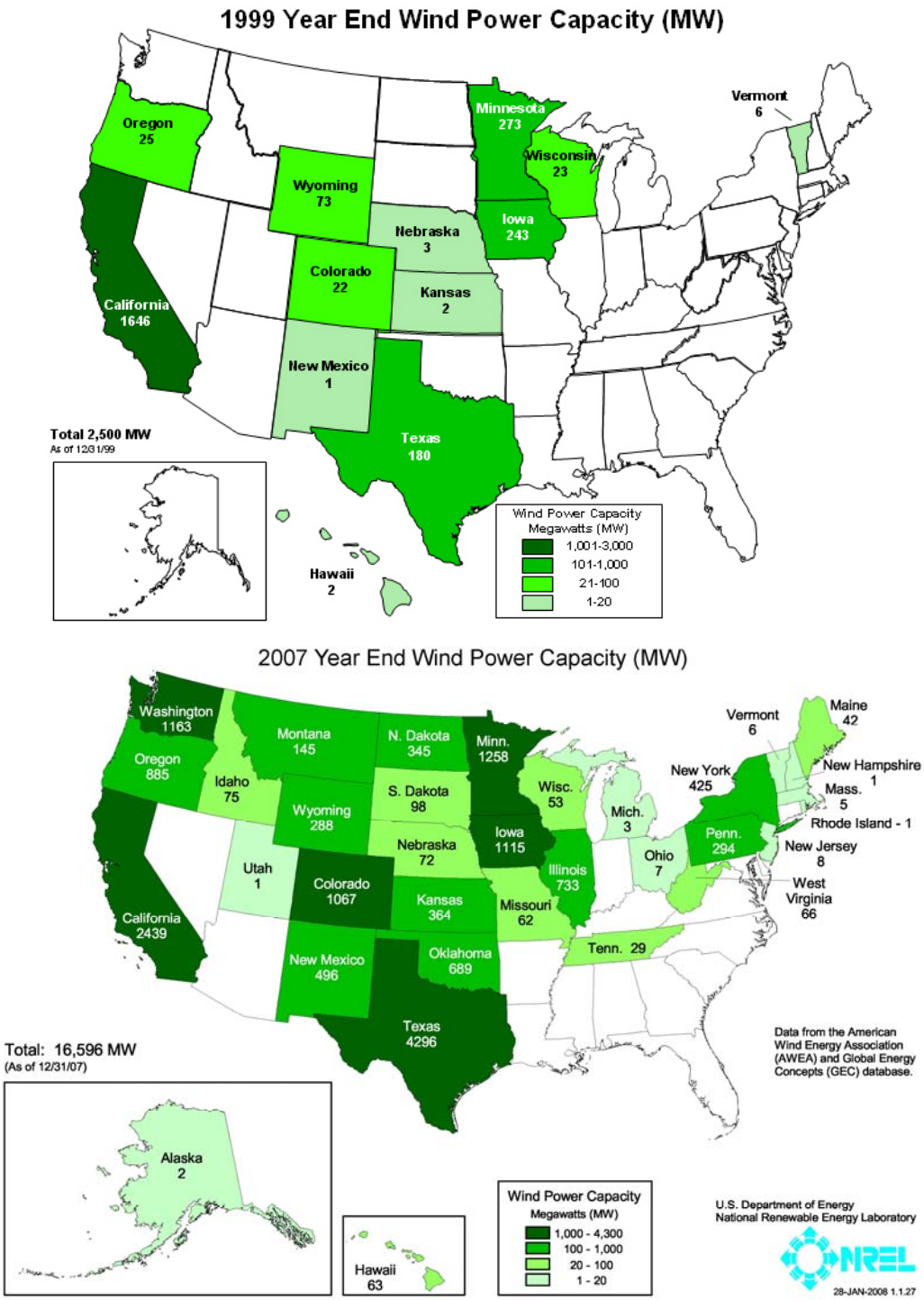

Figure 6 Installed wind power capacity from 1999 – 2007.

3.6.1 Power Lines

Improperly-constructed power lines, especially distribution lines, are one cause of direct mortality for both eagle species and can result in electrocution of birds attempting to utilize these structures for perching and nesting (Harness and Wilson 2001). Of 4,300 human-caused eagle mortalities investigated by the

Department of the Interior from the early 1960s to 1995, electrocution was reported as the second greatest cause of mortality in golden eagles and the third greatest cause for bald eagles (LaRoe et al. 1995). A separate review focused only on raptor mortality due to power lines asserted that electrocution is the fourth leading cause of human-caused death for bald eagles, following accidental trauma, poisoning, and shooting (Lehman 2001).

In 2000 and 2001, eagle mortality due to electrocution from, and collision with, small distribution power lines associated with oil and gas wells was documented within a small area in central Montana. Data were collected from 4,090 power poles in the preceding area. Of 273 raptor carcasses collected in 2000 and 2001, the cause of death of 23 raptors, 21 identified as golden eagles and one as a bald eagle, was attributed to mid-span collisions with power lines. In another study, electrocution was the identified cause of death of 280 raptors, 219 of which were identified as golden eagles, four as bald eagles, and 11 were either golden or bald eagles (Schomburg 2003).

3.6.2 Wind Turbines

Commercial wind turbine facilities and their impacts to birds are a recently-identified phenomenon. The problem in the U.S. surfaced in the late 1980s and early 1990s at the Altamont Pass Wind Resource Area (APWRA), a facility then containing some 6,500 turbines on 189 km^2 (73 mi^2) just east of San Francisco Bay, California (Davis 1995). Orloff and Flannery (1992) estimated that several hundred raptors were killed each year at Altamont due to turbine collisions, guy wire strikes, and electrocutions. Smallwood and Thelander (2005) estimated 28-34 golden eagle deaths per year at APWRA between March 1998 and September 2001.

3.6.3 Lead Poisoning

Lead shot and bullet fragments in the carcasses and viscera of game and other animals can pose a hazard to raptors. Diurnal raptors are one of the main avian groups affected by lead toxicosis (Miller et al. 2002), and lead poisoning accounts for an estimated 10–15% of the recorded post-fledging mortality in bald eagles and golden eagles in Canada and the United States (Scheuhammer and Norris 1996). Craig et al. (1998) noted that twelve of 16 (75%) eagles found in Idaho during a 9-yr period had lead exposure, and suggested that lead poisoning in golden eagles may be a greater problem than previously believed. Bald eagles and golden eagles admitted to The Raptor Research Center at the University of Minnesota had a 17.5% incidence of lead poisoning before the 1991 federal ban on lead shot for hunting waterfowl and a 26.8% incidence of lead poisoning after the ban (Kramer and Redig 1997).

3.6.4 Collision with Aircraft

Another source of mortality that results in fewer reported losses of individual eagles, but poses a greater risk to humans, is collisions with aircraft, as reported to the Federal Aviation Administration (FAA) (Figure 7 and Appendix I). Because commercial airfields in particular are generally built on flat areas, often in or

adjacent to natural wetlands, this habitat can provide shelter, nesting areas, and feeding areas for bald eagles that may not be present in surrounding metropolitan areas.

On the other hand, many of the United States Air Force's military training ranges, within which they are authorized to fly at low altitudes, are located in golden eagle habitat in the western United States. This combination of factors may contribute to the greater number of golden eagle collisions for military aircraft (28 collisions for military aircraft versus four collisions for civilian aircraft).

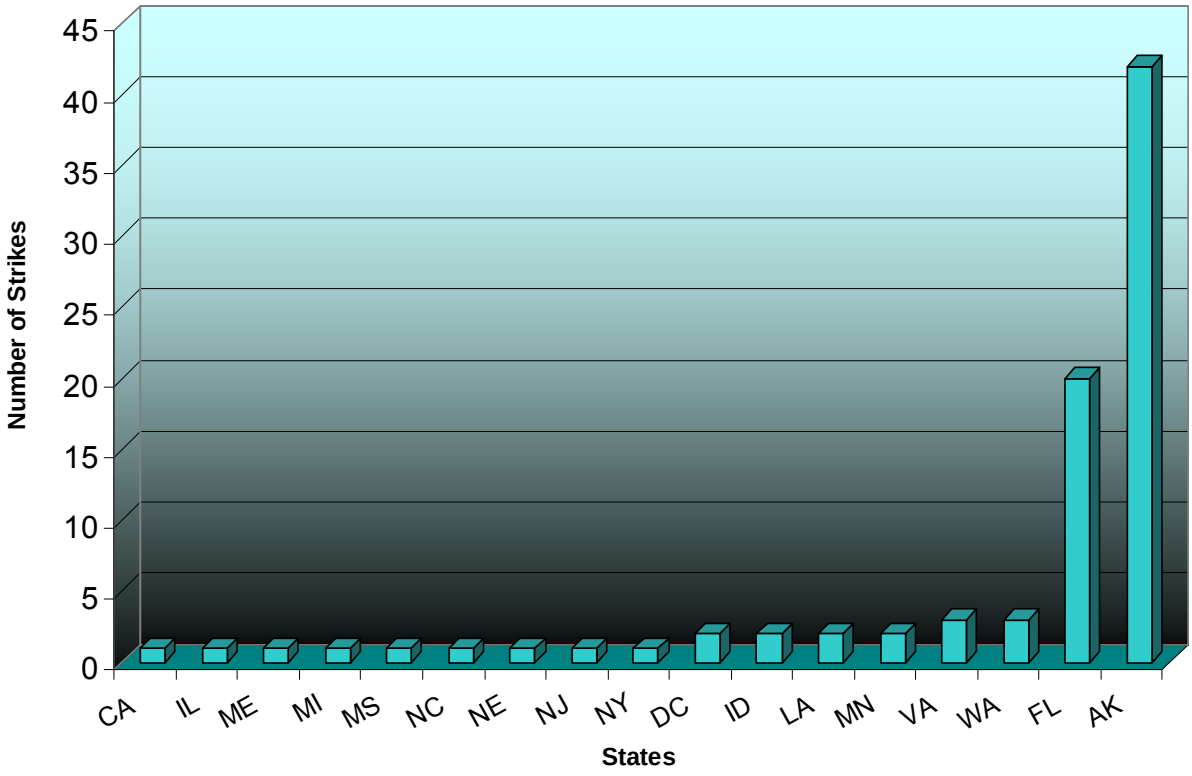

Figure 7 Bald eagle aircraft strikes reported by the FAA (January 1990-May 2007). (For 2 of the strikes, the State in which it occurred was not reported.)

There are a number of differences between commercial and military flying and associated airfields, including the proximity of fields to nesting habitat, location of activities relative to different species, and flight patterns (level and speed). Perhaps related to these differences, more commercial aircraft/eagle collisions seem to occur in the immediate vicinity of the airfield during take-off and landing operations. Although both species are involved in collisions with military aircraft, the relatively greater number of golden-eagle-related collisions may be related to training activities in the western U.S., during which pilots fly at low altitudes in more open areas.

3.7 Currently-Authorized Take of Eagles

This section of the document discusses the current take authorizations for both species under the Eagle Act as well as existing take authorizations for the

bald eagle under the Endangered Species Act (See Appendix C for detailed tables). Some permitted actions may authorize activities, for example, banding, that do not result in removal of an individual from the population or a loss of productivity and will not result in population effects. Others may result in loss of productivity for one year, and others may permanently remove eagles from the population. We are treating the estimated annual average level of all historical take from existing permits as baseline conditions for analysis and for future permitting. Because we need, at least initially, to limit take permits for golden eagles to historically-authorized take levels, we will use the prioritization issuance criteria from this rule to guide permit decisions with regard to allocating all golden eagle take permits. ,

3.7.1 Take Authorized under the Bald and Golden Eagle Protection Act

The Service already issues eagle permits under the Bald and Golden Eagle Protection Act through the implementing regulations at 50 CFR part 22. Permits enable the public to engage in legitimate eagle-related activities that will otherwise be prohibited by law. Permits are issued for scientific, educational, and Indian religious purposes, depredation, and falconry (golden eagles). We are treating the estimated annual average level of all historical take from existing Eagle Act permits as baseline conditions.

§22.21 Scientific and Collecting and Eagle Exhibition

The Service may, under the provisions of this section, issue a permit authorizing the taking, possession, transportation within the United States, or transportation into or out of the United States of lawfully-possessed bald eagles or golden eagles, or their parts, nests, or eggs for the scientific or exhibition purposes of public museums, public scientific societies, or public zoological parks. The Service will not issue a permit under this section that authorizes the transportation into or out of the United States of any live bald or golden eagles, or any live eggs of these birds.

The Service has not authorized any take from the wild for eagle exhibition. Scientific collecting permits that authorize take from the wild for bald eagles have only been authorized in Alaska, where they are numerous and have not been listed under the ESA. In addition, some scientific research was authorized under ESA Recovery permits. Within the last six years, 20 bald eagle eggs have been held under this permit, and 23 bald eagles have been sampled and released (Appendix J).

Similar to bald eagles, scientific collecting and exhibition permits for golden eagles are primarily issued within Service Region 6, where the greatest portion of breeding golden eagles occurs in the lower 48 states. Within the last six years, seven golden eagles have been trapped and released under the scientific collecting permit, and three have been relocated (Appendix J).

An estimated average annual take of 3 golden eagles (Table 2) and an estimated average annual take of 7 bald eagles (Table 3) under this section will be treated as baseline conditions.

§22.22 Eagle Parts for Native American Religious Purpose/Certification of Enrollment in a Federally Recognized Tribe

The Service may, under the provisions of this section, only issue a permit to members of Indian entities recognized and eligible to receive services from the United States Bureau of Indian Affairs (25 U.S.C. 479a–1), who are engaged in religious activities, and satisfy all the issuance criteria of this section. The permits discussed in this FEA are those for religious ceremony needs that require take of eagles from the wild, as opposed to permits under this same section for eagle carcasses, feathers, or parts acquired by another means such as gifting from one tribal member to another or obtaining from the National Eagle Repository. To date, the requests for take of eagles under this permit have been from tribal members wishing to take golden eagles from sites located on lands within Service Region 2 (Southwest Region) and approximately 23 golden eagles per year have been taken over the last six years (Table 2). All of the permits authorized have been limited to golden eagles.

The Hopi, to whom golden eagles are sacred and essential for religious practices, have been collecting eagles for centuries. The Hopi gathering practices have been authorized under annually-issued Eagle Act permits since 1986, and have been determined to be modest in scope and impacts. Because take has been occurring for some time, it is reflected in our baseline data. Therefore, the average annual take of golden eagles authorized to the Hopi nation under the Eagle Act over the last six years (23) will be considered part of the reference conditions for this document, and the Service will not count that take towards any threshold calculations for the Eagle Act permits being considered in this FEA. In addition, within Region 2, the historical baseline for take of golden eagles by other tribes includes approximately one golden eagle per year.

There are some limitations to take of wild eagles for religious ceremony. For example it is limited to tribes that can demonstrate a traditional religious need to take only live, wild eagles for which the Repository does not provide an adequate substitute. Notably, there is nothing in the regulation requiring tribal members to limit take requests to specific locales or Service Regions. If there are no permits available for take in the Service Region of residence for a tribal member's religious practices, if their own practices do not limit take to a specific location, and they have access to an eagle at a location in another Service Region, they may apply for a permit from the other location via the Permit Office in the Service Region in which they reside.

Federally-recognized tribal members may also apply for take of bald eagles for religious ceremonies, subject to the same criteria with regard to the tribe's traditional religious need to take eagles from the wild versus acquiring them from another source. To date, the Service has not received any applications for take of bald eagles that met the criteria.

§22.23 Take of Depredating Eagles

Under this provision, the Service may also issue permits to intentionally take eagles after the Service has determined that the take permit is necessary for the

protection of wildlife, agricultural, or other interests in a particular locality. Such take can either be lethal (limited to certain methods) or non-lethal (such as hazing). Criteria evaluated include: (1) The direct or indirect effect that issuing such permit will likely have upon the wild population of bald or golden eagles; (2) Whether there is evidence to show that bald or golden eagles have in fact become seriously injurious to wildlife or to agriculture or other interests in the particular locality to be covered by the permit, and the injury complained of is substantial; and (3) Whether the only way to abate the damage caused by the bald or golden eagle is to take some or all of the offending birds. The Service has also used this permit to authorize safety-related hazing activities intended to reduce the risk of eagle-aircraft collisions at airfields. Over the past six years, an average of twenty-five golden eagles per year (Table 2) and fourteen bald eagles per year (Table 3) have been permitted to be taken under this section, and that level of take will be treated as baseline conditions.

§22.24 Eagle Falconry

Under the provisions of this section, the Service may authorize the possession and transportation of golden eagles for falconry purposes. Only golden eagles from a specified depredation area may be trapped for falconry purposes. Over the past six years, an average of six golden eagles per year from Service Region 6 (Table 2) has been permitted for falconry purposes, and that level of take will be treated as baseline.

§22.25 Take of Golden Eagle Nests for Resource Development and Recovery

Under the provisions of this section, the Service may issue a permit authorizing any person to take inactive golden eagle nests during a resource-development or recovery operation, but only if the taking is compatible with the preservation of the area nesting population of golden eagles. For the purposes of the permit in existence under this section, the area nesting population has been defined as the number of pairs of golden eagles known to have a resting attempt during the preceding twelve months within a ten-mile radius of a golden eagle nest. The FEA includes more extensive information on this permit because under the current proposal the Service will apply comparable standards to permits for actions that would result in permanent loss or abandonment of a nest or territory, and for programmatic disturbance permits. An estimated average annual take of 6 inactive golden eagle nests has been authorized under this section (Table 2), and that level of take will be treated as baseline conditions.

The Service requires applicants to provide the additional information including, but not limited to the following:

- For each golden eagle nest proposed to be taken, the applicant must calculate the area nesting population of golden eagles and identify on an appropriately-scaled map or plat the exact location of each golden eagle nest used to calculate the area nesting population unless the Service has sufficient data to independently calculate the area nesting population. The map or plat

- A description of each activity to be performed during the resource development or recovery operation which involves the taking of a golden eagle nest.
- A statement with any supporting documents from ornithologists experienced with golden eagles or other qualified persons who have made on site inspections and can verify the applicant's calculation of the area nesting population.
- A statement indicating any proposed mitigation measures that are compatible with the resource development or recovery operation to encourage golden eagles to reoccupy the resource development or recovery site. Mitigation measures may include reclaiming disturbed land to enhance golden eagle nesting and foraging habitat, relocating in suitable habitat any inactive golden eagle nest taken, or establishing one or more nest sites. If the establishment of one or more nest sites is proposed, a description of the materials and methods to be used and the exact location of each artificial nest site must be included.

Additional issuance criteria that the permitting office must consider when determining whether to issue this permit include the following:

- Whether the applicant can reasonably conduct the resource development or recovery operation in a manner that avoids taking any golden eagle nest.
- The total number of golden eagle nests proposed to be taken.
- The size of the area nesting population of golden eagles.
- Whether suitable golden eagle nesting and foraging habitat unaffected by the resource development or recovery operation is available to the area nesting population of golden eagles to accommodate any golden eagles displaced by the resource development or recovery operation.
- Whether feasible mitigation measures compatible with the resource development or recovery operation are available to encourage golden eagles to reoccupy the resource development or recovery site. Mitigation measures may include reclaiming disturbed land to enhance golden eagle nesting and foraging habitat, relocating in suitable habitat any golden eagle nest taken, or establishing one or more nest sites.
- Whether the area nesting population is widely dispersed or locally concentrated.

3.7.2 Take Authorized Under the Endangered Species Act

Any take currently authorized under the ESA will be considered part of the reference conditions for this document, under the No Action Alternative, and the Service will not subject ESA-authorized take in any threshold calculations for the Eagle Act permits being considered in this FEA. This is consistent with our treatment of historical levels of average annual take authorized under the Eagle Act as baseline. Populations of the bald eagle have recovered sufficiently to be

removed from the ESA list, while supporting take during recovery. Therefore, it is logical to assume populations can continue to sustain some. Tables 2 and 3 summarize the reported take authorized under the preceding permits for an approximately six-year period.

Table 2. Estimated Average Annual Actions or Take Reported for the Golden Eagle (2002-2007)

Service Region	Number of Golden Eagle Technical Assistance Requests	22.21 (Scientific and Exhibition) Permits	22.22 (Religious Take) Permits	22.23 (Depredation) Permits	Taken for Falconry Under 22.23	22.25 (Nest Take for Resource Recovery) Permits
1	1	0	0	5	0	1[c]
2	12	1	24	0	0	3[d]
3	0	0	0	0	0	0
4	1	0	0	0	0	0
5	0	0	0	0	0	0
6	338	2	0	8	6	3
7	0	0	0	12	0	0
8	13	0	0	0	0	0
Annual Average (Total from all Regions)		3	24	25	6	6

[a] Since 2003, all 22.22 permits have been issued by Region 9, but take has occurred in Region 2.
[b] Only one nest reported destroyed, all others blocked or relocated.
[c] One nest authorized over six years.
[d] Where the permit did not specify a limit, reported take is provided.

Table 3. Estimated Average Annual Take Reported for the Bald Eagle (2002-2007)

Service Region	Endangered Species Act Authorizations (Reference for this FEA)					Eagle Act Authorizations	
	Actions Where Take Reported[a]	Total Individuals Reported	Estimated Average Individuals Reported Each Year	Total Nests or Roosts Reported	Total Territories Reported	22.21 Permits (Scientific and Exhibition) Reported[b]	22.23 Permit (Depredation/ Hazing) Reported[h]
1	49	53[c]	18	15	33	0	2
2	10	36	7	0	0	0	0
3[c]	6	4	1	0	0	0	8
4[c]	34	0	0	4	0	0	0
5	0	0	118	2	0	0	0
6	n/a [d]	112	22	6	6[f]	4	2
7[e]	0	0	0	0	0	3	2
8	24	85[g]	17	1	0	0	0
Estimated Average Annual National Total				27	39	7	14

[a] Under Biological Opinions and Habitat Conservation Plans.
[b] Permits authorized included take of eggs, trap and release of birds, and killing of birds.
[c] Information from Oregon did not differentiate among birds, nests, or territories, but total authorized take is estimated at an additional 40 birds, nests, or territories combined from 2001 through 2007.
[d] Notwithstanding their large populations of bald eagles, Service Regions 3 and 4 were by and large able to emphasize early coordination in order to avoid take.
[e] Information from Region 6 regarding the total number of actions authorizing take could not be extrapolated for comparison.
[e] The bald eagle was not ESA-listed in Alaska. Only Technical Assistance was provided, but estimated at 400 actions per year.
[f] Six adults, 12 juveniles authorized
[g] One programmatic Biological Opinion out of Ventura authorized one bald eagle per year over the life of the project, 25 years to date. That same opinion anticipated that any bald eagles on the installation could be taken by harassment over the life of the project by military maneuvers.
[h] Take authorized and reported hazing was primarily for airports and landfills.

3.8 Societal Issues

Cultural and Religious

The way in which cultural interaction takes place depends on the uniquely human capacity for using complex symbolic representation in the expression of meaning (Lamendella 1980). Ritual behavior, a human universal, is the quintessential form of symbolic expression through (largely nonverbal) action, and is often used for strengthening the social structures of society. Symbolism is the smallest unit of ritual which still retains the specific properties of ritual behavior. Symbols are, therefore, a special kind of way of conveying meaning. (Bloch 1980). Because ritual is never directed at the solution of trivial problems, but rather at those problems potentially productive of the greatest uncertainty (Laughlin and Stephens 1980), ritual, and the symbols employed, can be essential to the well-being of humans and the culture(s) in which they interact by providing a sense of meaning and purpose to their lives. .

The eagle has been a symbol of power and mystery throughout history, from the Sumerians (5000 BP) and Hittites (3500 BP) (Brentjes 2000) to the two-headed eagle of the Hapsburgs (Vermeir 2007). In the United States (U.S.), a Congress comprised of members with European ancestry chose the bald eagle to be depicted on the official seal of the United States, selecting it over the originally-proposed golden eagle because the golden eagle was also found in Europe (Lawrence, 1990), and more famously, selecting the bald eagle over the wild turkey. As the nation's symbol, the bald eagle represents U.S. citizens' sense of autonomy, courage, and power. Today, bald eagle imagery is ubiquitous in U.S. culture, attesting to the widespread symbolic importance the bald eagle holds in U.S. society.

In recent decades, the bald eagle has come to symbolize the U.S.'s growing environmental awareness of society's impact on the environment. The fluctuation of its population reflects the ecological footprint of people on this continent: being abundant prior to colonialism, declining during the expansion of the frontier and late 19th century industrialism; then nearly becoming extinct due to expansive use of chemical pesticides during the booming post World War II years; only to recover as the nation's growing ecological awareness led to increased regulation of pesticides and the passage of environmental laws such as the National Environmental Policy Act and the ESA. Because of this history, for many people, the bald eagle symbolizes the ecological consciousness of the U.S. and the health of our environment.

Evidence of the symbolic role of birds and their use in ritual can be found in analyzing burial practices, which included bird bone pendants as early as 8,000 years Before Present (BP)(Mannermaa 2008). The bones of a golden eagle wing tip were placed in a 12,000 year old burial of a shaman in Israel (Grossman et al. 2008). White-tailed sea eagles were included in late Neolithic (~4,000 BP) burial practices on the island of Orkney in Scotland (Jones 1998). Parts of the golden eagle, which was considered a spirit helper, were depicted in shamanic dress by some Siberian tribes (Siikala 2002). In North American pre-history, the symbolic importance of eagles is evident. The Fort Ancient people, a mound-

building culture in Ohio, included the beak of an immature golden eagle in the grave goods of the burial site (~1500AD) of a male, perhaps signifying status (Brady-Rawlins 2007). Parmalee (1958) cites the presence of wing bones for golden eagles and bald eagles in excavations of mounds in Illinois as an indication the eagles may have been killed for their plumage and used in ceremonial functions. Other research in Iowa revealed an assemblage of more than 260 broken and splintered lower legs of raptors, including eagles, which may have been evidence of trade in ceremonial birds (Fishel 1997). The use of eagles in Tribal ceremonies in Central California was ascertained by archaeological excavations revealing their bones as burial objects in three cultural horizons (Heizer and Hewes 1940). One notable find was an eagle skull with an abalone ornament over one eye.

Bald eagles and golden eagles remain sacred to many American Indian Tribes and tribal members, and are central to the religious practices of some tribal cultures in North America and other localities throughout the species' range. Some American Indian religious ceremonies call for the harvest of eagles from the wild. As discussed in Section 3.6 (Currently Authorized Take), permits are available for this purpose in certain circumstances. In addition, it is often the case that American Indian Tribes and individual tribal members have an interest in a particular eagle nest locality because of its aboriginal cultural, spiritual, religious, or traditional values, but the locality is outside currently-recognized Indian lands. American Indian interests are unique and unlike any other interests based on the status of Tribes as governmental sovereigns and the distinctive relationship between the United States and each Tribe.

While the cultural significance of both species of eagles is broad-based and not limited to ethnic origin, there is a separate Federal trust responsibility to Tribes, which among many other things, safeguards indigenous religious practices, cultural practices, places, sites, and objects. The NHPA, for example, emphasizes mandates of preservation for "areas of traditional religious and cultural importance to an Indian Tribe." If Congress had intended that all areas of religious and cultural importance for all Americans warranted the same levels of protection, it would never have been necessary to spell out this special provision for Native Americans in the NHPA. It would also have not been necessary for Congress, the President, the Secretary of Interior, and the Service to pass any of the additional legislation, or issue Executive Orders, and special policies that are reserved for Native Americans (AIRFA, E.O. 13007, 1992 amendments to NHPA, 36 CFR 800 citations on Tribes as automatic consulting parties to all federal undertakings, Service Native American Policy, Secretarial Order 3206, and the original Eagle Act provisions for religious take).

Largely because of the aforementioned cultural values, some eagle-use areas may be eligible as potential historic properties of religious and cultural importance under the NHPA. There may also be resources of similar importance in the vicinity for which review and consultation under Section 106 of NHPA are required.

Safety

The greatest human-caused risks to eagle safety appear to be electrocution by electrical distribution lines and collisions with various anthropogenic structures. While they pose some risk to individual eagles, aircraft collisions with eagles can represent a high human safety risk at airfields. Military aircraft engaging in training activities represent a collision risk to humans and golden eagles. Human safety can also be affected by proximity of failing nest trees or platforms to human residences or other facilities. In addition, while not a case of direct risk from an eagle or nest, the ability to conduct such actions as repair of natural gas pipelines in a timely fashion, regardless of season, can be critical to ensuring the ultimate safety of large numbers of humans. The degree to which safety of eagles or humans will be affected will depend in part on the permits available and the application of the permit process.

Socioeconomic

The potentially-affected socioeconomic environment includes the economy, cultural values and norms, recreation, and aesthetic values. The degree to which businesses and industry in the vicinity of bald eagle and golden eagle habitat will be affected is difficult to quantify. Industries most likely to be affected include residential developers, energy transmission companies, timber managers, resource development and recovery operations, utilities, transportation, shipping companies, commercial fishing operations, and businesses that depend on tourism and recreation. The economic value of private land where eagles occur may also be affected.

Numerous facets of the American lifestyle could be affected beyond straightforward economics. Among the many societal “norms” that could be affected are: transportation, urban planning, energy development and consumption, recreation, location of schools and hospitals, and waste management. The magnitude of the lifestyle impacts resulting from the proposed permits depends in part on the rate at which the new permits are approved. If project proponents do not incorporate eagle avoidance and minimization measures into early project planning, they will increase the likelihood their actions will be delayed by the need to revise plans.

3.9 Summary

Although both are protected under the Eagle Act, bald eagles and golden eagles are two distinct species that are not necessarily subject to the same habitat requirements or pressures. Information available for the bald eagle, including the Sonoran Desert population, points to an expanding population. On the other hand, while the information available for the golden eagle is uncertain, it appears populations may be declining in portions of the range. In addition, the Service does not have comparable resources for management of each species. A comparative summary of the resources and pressures for golden eagle versus the bald eagle populations is presented in Table 4.

Table 4. Bald Eagle v. Golden Eagle (GOEA), comparison of parameters.

Parameter	Bald Eagle	Golden Eagle	Source of GOEA data
North American Population Size	300,000	80,000	PIF
Population Trend	Increasing in most areas	Stable or Decreasing	Expert opinion and local data
Threat Trend	Mostly Decreasing	Increasing	Energy development
Falconry Demand	Low	High	Service Permits Database
Religious Demand	Low	High	Service Permits Database
Mineral resource Nest Take Under BGEPA	No`	Low	Service Permits Database
Depredation and Persecution Issues	Low	High	Regional data
Dedicated monitoring	Yes	Limited	WEST data

Table 5 Alternatives Comparison Matrix

Management of Bald Eagles and Golden Eagles Common to All Alternatives: Bald and Golden Eagle Protection Act (the Eagle Act), including the finalized definition of disturb under the Eagle Act. Would use existing eagle management documents as guidance.		
	Management Common to All Action Alternatives: Would Establish Thresholds for Permits, Management by Population Regions for Bald Eagle, Bird Conservation Regions for Golden Eagle	
Alternative 1: No Action - Provisions to Extend Eagle Act Take Authorization to Take Authorized under ESA sections 7 and 10	**Alternative 2– Disturbance Take Nest Take for the Public Health and Safety (such as airports) Programmatic Disturbance Permit**	**Alternative 3 – Alternative 2, Plus Other Forms of Take, Including Programmatic Permit to Reduce Ongoing Take Resulting in Mortality (TRM)**
Measures covering both species		
Provisions for future take of eagles limited to Habitat Conservation Plans with eagles	Authorizes disturbance take	Authorizes disturbance take
Provisions for future take of eagles limited to Habitat Conservation Plans with eagles, which may authorize mortality	Does not authorize take resulting in mortality, even in emergency circumstances	Authorizes take resulting in mortality in emergency circumstances or where take cannot practicably be avoided. Would also authorize a “Performance-Based” programmatic permit designed to reduce ongoing TRM
No issuance criteria	Includes issuance criteria to ensure certain prioritized needs are met by authorizing take according to an established order	Includes issuance criteria to ensure certain prioritized needs are met by authorizing take according to an established order
No provisions for population-based take thresholds	Includes provisions for population-based take thresholds	Includes provisions for population-based take thresholds

Alternative 1	Alternative 2	Alternative 3
“Grandfathers” existing eagle take authorizations into Eagle Act permits	“Grandfathers” existing eagle take authorizations into Eagle Act permits	“Grandfathers” existing eagle take authorizations into Eagle Act permits
Provisions for future take of eagles limited to Habitat Conservation Plans with eagles	Authorizes, on a case-by-case basis, unless populations affected, permits for disturbance at roost and congregation sites.	Authorizes, on a case-by-case basis, unless populations affected, permits for disturbance at roost and congregation sites.
Does not include provisions for enhanced coordination.	Same as Alternative 1	Includes provisions for enhanced coordination between the Service and State and Tribal wildlife jurisdictional entities to minimize the potential for adverse impacts to local areas populations.
Golden eagle-specific		
Only addresses take of either species if previously authorized under ESA	Authorizes new take only in the Western U.S., including Alaska	Authorizes new take only in the Western U.S., including Alaska
Causes of mortality to bald eagles and golden eagles associated with human activities		
Does not have specific measures to reduce ongoing take	Has limited measures to reduce ongoing take	Establishes permits designed to reduce ongoing take on a programmatic basis
Existing Eagle Act Permit Types		
Does not make changes to process for current take authorization	Does not make changes to process for current take authorization	Does not make changes to process for current take authorization

Alternative 1	Alternative 2	Alternative 3
Does not change availability of numbers of existing permit types.	Would authorize permitting limits on existing permit types	Would authorize permitting limits on number of existing permit types
Mitigation		
	For most individual disturbance permits, no additional compensatory mitigation required, except for disturbance associated with the permanent loss of a breeding territory or important traditional communal roost site	For most individual disturbance permits, no additional compensatory mitigation required, except for disturbance associated with the permanent loss of a breeding territory or important traditional communal roost site
Compensatory mitigation may be included in HCPs, but not specifically required	Compensatory mitigation required programmatic disturbance permit	Compensatory mitigation required programmatic permit for TRM
Will meet the Service's requirements for government-to-government consultation, but no enhanced coordination and consultation measures to mitigate impacts from the proposal.	Will meet the Service's requirements for government-to-government consultation, but no enhanced coordination and consultation measures to mitigate impacts from the proposal	Includes enhanced coordination and consultation measures to mitigate impacts to eagle populations and ensure improved and consistent compliance with requirements for government-to-government consultation.
Religious and Cultural		
Does not change language relative to compliance with Tribal statutes	Would notify applicant of need to comply with Tribal statutes	Would notify applicant of need to comply with Tribal statutes

Alternative 1	**Alternative 2**	**Alternative 3**
Does not change current authorization practices regarding Native American Religious take	Would prioritize Native American Religious take	Would prioritize Native American Religious take
No enhanced consultation measures, but will consult on a permit-by-permit basis, as necessary.	No enhanced consultation measures, but will consult on a permit-by-permit basis, as necessary.	Includes consultation measures to ensure improved and consistent compliance with requirements for government-to-government consultation. Consultation will take place on a permit-by-permit basis, as necessary, and on the eagle program as a whole.
Safety & Security		
No specific measures to prevent hazards	Take of nests would be authorized for reasons of public health and safety and safety related to eagles	Take of nests would be authorized for reasons of public health and safety and safety related to eagles
No measures to prioritize safety and security activities	Would prioritize take necessary to protect public health and safety	Would prioritize take necessary to protect public health and safety
Socioeconomic Factors		
No specific measures related to socio-economic factors, may result in significant socio-economic impacts to some sectors	Allocation prioritization, after Native American Religious take, will be for activities necessary to ensure public health and safety, and (for golden eagle nests only) resource development or recovery operations	Allocation prioritization, after Native American Religious take, will be for activities necessary to ensure public health and safety, and (for golden eagle nests only) resource development or recovery operations

Alternative 1	Alternative 2	Alternative 3
Provisions for Eagle Act permits for future Habitat Conservation Plans with measures for eagles. This minimizes economic and legal burden on HCP holders.	Same as “No Action”	Same as “No Action”
No enhanced coordination measures	No enhanced coordination measures	Includes provisions for enhanced coordination between the Service and State and Tribal wildlife jurisdictional. This enhanced coordination will lead to better data regarding demographics and populations, and may therefore facilitate increased thresholds for allowable disturbance, as warranted.

CHAPTER 4: ENVIRONMENTAL CONSEQUENCES OF THE ALTERNATIVES

4.1 Introduction

In this chapter the FEA applies the elements described in Chapter 2 to the reference or existing conditions to produce projected environmental consequences of the alternatives. In each discussion the potential environmental consequences first, followed by the projected results for each resource and for each alternative. As with development of the alternatives, we have integrated issues and concerns raised in comment letters on the proposed regulation and internal agency scoping into the analysis.

4.1.2 Analysis of Direct and Indirect Impacts

In determining the significance of direct, indirect, and cumulative impacts of the alternatives, the Service evaluated whether each alternative or its components: 1) will be compatible with the preservation of eagles (maintaining increasing or stable regional populations, and not to exclude preservation of locally-important smaller populations within a region) on a national or regional scale; 2) will substantially burden a Tribe's free exercise of its religion; 3) may increase the probability of circumstances placing human or eagle safety or health at risk; or 4) will result in impacts deleterious to a broad regional area or sector of the national economy.

Portions of the alternatives may be additive to preceding alternatives. Our analysis of direct and indirect impacts emphasizes those subsequent components that are new or altered. The Service assumes that some components that are the same between alternatives will have similar impacts, and will identify them without redundant analysis. The FEA will analyze potential cumulative effects in a separate section.

4.2 Management Common to All Alternatives

This portion of the proposal does not contain any management prescriptions, but does provide definitions intended to make implementation of the proposal more consistent and more readily understood. Because permits issued for take of eagles under the Eagle Act may not have been evaluated cumulatively relative to population, and because there are uncertainties regarding population levels and demographics for golden eagles that we discuss in this FEA, there may be localized negative impacts to golden eagles from this management scenario. However, there will be no significant direct impacts on a national scale from any provisions in this portion of the proposal without subsequent authorization of take.

4.3 Alternative 1– No Action: Permit Existing and Future Take Authorized Under the ESA

The potential impacts from creating a permit for previously-authorized take and future take authorized under the ESA are not easy to measure. However, the Service expects the number of past and future take authorizations under HCPs to be minimal. In addition, measures that will be provided for under the ESA may include extensive habitat measures designed to avoid or minimize the ongoing, future risk of disturbance to eagles.

4.3.1 Bald Eagle

The potential impacts to bald eagles from this alternative are difficult to quantify. However, because the conservation measures required under the ESA are adequate to ensure compatibility with the preservation of the eagle, and since the take authorized to date under ESA has had no significant impact on the population, the Service expects conditions to remain the same. The extension of ESA take authorization to take under the Eagle Act provides members of the public with continuing authorization to proceed under the conditions of a pre-existing authorization. However, without provisions to effectively permit additional legal take except as associated with a future HCP, there may be greater risk of unauthorized take. In addition, without provisions for take for safety reasons, this alternative may impact a few individual bald eagles or have minor impacts to local area populations.

4.3.2 Golden Eagle

There will be minor changes through increased take relative to golden eagle management under this alternative by extending Eagle Act take authorization to HCPs that include golden eagles covered as a nonlisted species. Provisions to effectively permit take under HCPs comparable to those for bald eagles may reduce the risk of unauthorized take. However, without provisions for take of nests for reasons related to the safety of eagles, and without a permit type designed to reduce ongoing mortality, this alternative would impact individual golden eagles or have impacts to local area populations. In addition, because there are uncertainties regarding potentially declining population levels and regarding demographics for golden eagles, there may be significant negative impacts at all scales to golden eagles from the “No Action” alternative.

4.3.3 Biological and Physical Environment

There will be some direct impacts to eagle habitat from this alternative, but there may be beneficial impacts from HCP measures intended to improve habitat conditions. The Service expects few adverse, indirect impacts, primarily in cases where habitat requirements are poorly applied, or where HCPs fail to adequately address effects to other species.

4.3.4 Eagle Mortality Associated with Human Activities

This alternative is expected to have few direct impacts on the current level of eagle mortality associated with human activities. Indirectly, the lack of incentives to reduce mortality through a permit process will tend to result in increasing mortality for both species and would have negative impacts to both species. Given the apparent downward population trend for golden eagles, the long-term effects of mortality associated with human activities from Alternative 1 may be significant.

4.3.5 Currently-Authorized Take

Under the "No Action" alternative, there will be no changes and no impacts to any of the currently-authorized take. Because eagle populations have sustained existing levels of take, the Service expects conditions to remain the same (see discussions of the existing permits in Chapter 3, Affected Environment, Section 3.7, pages 57-60 for comparison to reference conditions).

4.3.6 Societal

Religious and Cultural

Because there will be no change from the current state of management, the Service anticipates no change in direct impacts to religious and cultural resources. However, without a permit type designed to reduce ongoing mortality, and if golden eagle populations continue to decline, there may be negative impacts to take of golden eagles for tribal religious practices. Because we will conduct consultation, as necessary, on a case-by-case basis, there is minimal potential for adverse affects to cultural or religious resources from inadequate consultation under Section 106 of NHPA or government-to-government consultation on actions related to eagles.

Safety

Alternative 1 will have no specific provisions for take of nests in the case of hazard or health risk to eagles or humans. It will not make provisions for a comprehensive approach to managing eagles at airfields, which will result in unnecessary delays that pose safety risks to humans and eagles. Nor will it provide for the removal or relocation of nests away from hazardous sites. Therefore, this alternative will pose significant risks to human and eagle safety at such locations.

Socioeconomic

Project proponents with existing ESA take authorizations, who will receive permits for their actions under the Eagle Act, and future developers of HCPs that include bald eagles or golden eagles as covered, non-listed species will likely be able to proceed without confusion and economic uncertainty. With a permit that clearly sets out conditions for operating within the law, those project proponents and lenders will be able to take actions that might be viewed as disturbing

eagles. While there may be small delays as the permit process is learned, there will likely be no cancellation of residential and commercial development projects, timber operations, natural resource extraction, and other activities that occur in habitat used by eagles, for take previously authorized. However, the lack of additional types of take permits for future activities, except as associated with a future HCP, will mean that projects must be re-located, re-scheduled, or dropped. The socioeconomic impacts from not providing for future take of bald eagles will result in impacts deleterious to a broad regional area or sectors of the national economy. Conversely, for golden eagles, the Service has relied on enforcement discretion and voluntary measures to this point to regulate and limit take, which has resulted in unauthorized take that is not prosecuted. Under the "No Action" alternative, the current status will continue. As in the past, many activities that incidentally take golden eagles will not be stopped, altered, or rescheduled because there will be no available permit system for non-purposeful take. Project proponents that decide to go ahead anyway without a permit may not see much effect if they are not prosecuted; but other proponents that fear prosecution may incur economic effects. Therefore, there are competing socioeconomic impacts from not providing for future take of golden eagles, and they may be deleterious to some sectors of the national economy.

4.3.7 Summary

Neither species will receive the protection offered by a permit that will allow take of a nest to protect the eagles from a hazard. Nor will there be measures to reduce ongoing TRM. There is also a potential for adverse affects to local area populations. In addition, without further guidance, this alternative may not adequately meet all our statutory requirements for consultations related to cultural resources. Therefore, this alternative is not compatible with the preservation of the eagle and will not fulfill the purpose and need for the proposal.

4.4 Management Common to Both Action Alternatives

This section discusses the impacts from the proposal to revise some regulations by establishing permit thresholds and to establish a management framework. The Service anticipates requests for take authorizations for numerous types of activities including the following: housing and commercial development; development proposed by governments at all levels (local, State, tribal and federal); energy exploration and development; transportation and energy corridors; timber harvest; and recreation (see Appendix J for Regional perspective). The Service also anticipates increases in take requests for the following reasons:

- A single section 7 exemption sometimes provided authorization to a large number of grantees or permittees; individual authorizations will be required under the Eagle Act.
- Bald eagle and human populations are increasing in most areas.

- The Eagle Act applies to Alaskan eagles, where ESA permits were not applicable, since Alaskan bald eagles were never listed under the ESA.
- Permits will be available for golden eagle take (previously only a few HCPs have covered golden eagles).
- Knowledge regarding the proposed permit will raise awareness that past practices might have resulted in take of golden eagles about which project proponents or agencies were unaware, and for which they will now seek permits.

4.4.1 Bald Eagle and Golden Eagle

The potential impacts to bald eagles and golden eagles of creating a permit for authorized take are difficult to quantify. However, since bald eagle populations flourished despite the take authorized under the ESA, and because the Service is setting permit thresholds for both species based upon half the take the populations are able to support (as predicted by models), we expect no significant adverse impacts on bald eagles or golden eagles. In addition, because the Service intends to regularly reassess the take relative to populations, the Service will be able to modify thresholds before take approaches levels that are not "compatible with the preservation of eagles." Without a provision allowing the take of nests to protect human or eagle safety, Management Common to Both Action Alternatives will result in some adverse effects to individual eagles. In addition, without provisions for managing programmatic disturbance, there will be some instances of piecemeal, iterative loss of important eagle-use areas. The proposed management, without additional measures, may result in localized, temporary loss in productivity that may be significant to a local population, but this is not expected to be significant to regional or national populations.

The Service does not expect bald eagle or golden eagle population declines at the national level as the result of the authorizations granted under Management Common to Both Action Alternatives. Instead, the Service anticipates the improved management will increase protection of eagle populations making declines less likely. However, it is possible that local area populations may be adversely affected by take authorized in a fashion disproportionate to population. It is also possible that external factors could arise that negatively affect eagle populations. In addition, take occurring at winter roost sites or important foraging areas may have the potential to take greater numbers of birds than we anticipate. Whatever the cause, if data suggest population declines **are approaching a level where additional take will be incompatible with the preservation of the eagle** (emphasis added) (as interpreted above), the Service will refrain from issuing permits until we can re-evaluate the premises upon which our estimation of take is based, and until such time that the take will be compatible with the preservation of the bald eagle and golden eagle.

4.4.2 Biological and Physical Environment

There will be no direct impacts to the biological and physical environment from the creation of a permit for authorized take of eagles. If we create this permit, issuance of take authorization will indirectly result in impacts to eagle habitat from loss, fragmentation, and reduced habitat suitability. On the other hand, especially for golden eagles, creation of this permit system may reduce impacts in many situations. Ongoing or new activities that were implemented in the past without compliance with the Eagle Act because no permit was available for non-purposeful take (e.g., wind power farms and oil or gas well pads) will be more likely to obtain a permit and apply the required mitigation and avoidance techniques. Because our permit thresholds are based upon Service Region and BCR population segments, the Service believes the impacts to habitat will be widely dispersed and not incompatible with the protection of the biological and physical environment.

4.4.3 Eagle mortality associated with human activities

The Management Common to Both Action Alternatives is expected to have few direct impacts on the current level of eagle mortality associated with human activities. However, without incentives to reduce mortality through a programmatic permit process for ongoing TRM, current rates and levels of mortality will tend to increase. Negative impacts to local populations both species may be significant.

4.4.4 Currently-Authorized Take

4.4.4 .1 Take Authorized Under the Bald and Golden Eagle Protection Act

Permits are issued for scientific, educational, and Indian religious purposes, depredation, and falconry (golden eagles) (Tables 6 and 7). The provisions under Management Common to Both Action Alternatives will not eliminate any of the existing permits. However, in some instances, existing permits may authorize activities that will take eagles under the Eagle Act. If so, then those permits will be subject to the cumulative thresholds for the permits under this proposal.

The historical levels of previously-authorized take are incorporated into the baseline conditions affecting eagle populations. Thresholds for permits involving take that affects productivity will be based upon levels above baseline that the breeding populations can support. Future take above the baseline levels authorized under existing permit types will be subject to annual thresholds under both action alternatives. Therefore, the impacts analyses on “Currently-Authorized Take” will largely consider the potential impact of the proposal on future above baseline level of existing permit types. However, if data indicate a continued decline in golden eagle populations that requires active remedial measures, then the Service may reduce the level of take currently considered baseline.

§22.21 Scientific Collecting and Eagle Exhibition

As noted previously (Section 3.7.1, p. 45), the Service has not authorized any take from the wild for eagle exhibition. Scientific-collecting permits that authorize take from the wild for bald eagles have only been authorized in Alaska, where they are numerous and have not been listed under the ESA. Within the last six years, 20 bald eagle eggs have been held under this permit, and 23 bald eagles have been sampled and released (Table 6). Within the last six years, seven golden eagles have been trapped and released under this permit, and three have been relocated (Table 7).

Because of the limited use of this type of permit, while it may temporarily impact individual eagles, it has generally not affected productivity. However, if the Service determines the permitted activity will affect eagle productivity, the permit will be subject to the annual permit thresholds. In some instances, permits for scientific collecting and eagle exhibition may not be available. For example, in those areas in Service Region 2 where the bald eagle is not listed and requests for permits exceed the number compatible with the preservation of eagles (see Tables 6 and 7), then no permits for scientific collecting would be issued.

§22.22 Eagle Parts for Native American Religious Purposes/Certification of Enrollment in a Federally-Recognized Tribe

The currently-authorized average annual take of golden eagles under this permit has been confined to Service Region 2, the Southwest Region, and birds taken have averaged approximately 24 per year over the last six years, although the permits have authorized take of up to 40 birds to the Hopi Nation and an average of one golden eagle per year to other tribes. The take by the Hopi Nation, which has occurred over centuries without adverse affect to golden eagle populations, is considered part of the baseline, and will not be subject to or factored into the allocation. In addition, the permits authorized have been limited to golden eagles (Table 7). Because the historical levels of previously-authorized take are incorporated into the baseline conditions affecting eagle populations, the implementation of permit thresholds under Management Common to Both Action Alternatives will not affect the level of take that has actually occurred, as averaged over the past six years. Therefore the Service does not believe conditions under Management Common to Both Action Alternatives will substantially burden a Tribe's free exercise of its religion. However, if data indicate a continued decline in golden eagle populations that requires active remedial measures, then the Service may reduce the level of take currently considered baseline.

§22.23 Take of Depredating Eagles

Over a six-year period, the national average annual total for this permit type was 14 for bald eagles (Table 6) and 25 for golden eagles (Table 7). However, many of the permits were for hazing or trap and removal activities (Table I.2 and Table I.6) and were generally applied to limited locales. While the permitted activity may temporarily impact individual eagles, it does not result in population

impacts at the regional or national scale. Under Management Common to All Alternatives, future take above the baseline levels authorized under this existing permit type will be subject to annual thresholds. Where requests for permits may exceed the number compatible with the preservation of eagles, permits above baseline for depredating eagles may not be available. And, if data indicate a continued decline in golden eagle populations that requires active remedial measures, then the Service may reduce the level of take currently considered baseline.

§22.24 Eagle Falconry

Only golden eagles from a specified depredation area may be trapped for falconry purposes. There is currently only one such specified depredation area, in Service Region 6, where the Service has permitted an average annual falconry take of four eagles from 2002 to 2007 (Table 7). Because of the limited use of this type of permit, while it may impact individual eagles, it does not result in national population-level impacts. Under Management Common to All Alternatives, this permit will be subject to the proposed thresholds. In some instances, where requests for permits may exceed the number compatible with the preservation of eagles, permits for eagle falconry may not be available.

§22.25 Take of Golden Eagle Nests for Resource Development and Recovery

This permit for take of inactive golden eagle nests is rarely issued during a resource development or recovery operation (Table 7). In addition, it must be determined that the taking is compatible with the preservation of the area's nesting population of golden eagles. However, there may be instances when take of an inactive nest may lead to the abandonment of a territory. In such cases, under Management Common to All Alternatives, this will be subject to the proposed thresholds. The Service expects that, with increasing development of energy-related projects, there will be instances where requests for permits may exceed the number compatible with the preservation of eagles; therefore permits for take of golden eagle nests for resource development and recovery may not be available.

4.4.4.2 Take Authorized Under the Endangered Species Act

There will be no changes to take authorized under the Endangered Species Act from any of the action alternatives; therefore, the Service will eliminate it from further detailed analysis.

4.4.5 Societal

Religious and Cultural

The degree to which religious and cultural resources may be affected under Management Common to Both Action Alternatives will depend to some degree on the number of permits available for religious take under the proposed rule and the locations in which any permits are authorized. Because we will conduct

consultation, as necessary, on a case-by-case basis, there is minimal potential for adverse affects to cultural or religious resources from inadequate consultation under Section 106 of NHPA or government-to-government consultation on actions related to eagles.

Under this alternative, the creation of this new permit does not affect the continuation of existing permits for Native American Religious Use. However, by establishing thresholds for permits that populations can sustain, it may result in the occasional unavailability of permits, especially towards the end of the year, and in areas where there are numerous requests for the new take permit. However, the Service will mitigate that impact by implementing a structured-allocation process in each Service Region if there is evidence that demand for take will exceed take thresholds for either species of eagle, to ensure that take of birds necessary to meet the religious need of a Native American Tribe will not be denied due to other take being authorized for another purpose.

Safety

The provisions under Management Common to Both Action Alternatives will have no specific provisions for take of nests in the case of hazard or health risk to eagles or humans. It will not make provisions for a programmatic approach to managing eagles at airfields, which will result in risks to humans and eagles. Nor will it provide for the removal or relocation of nests away from hazardous sites. Therefore, without additional, measures, this management scenario may pose local, but significant risks to human and eagle safety.

Socioeconomic

Energy production and distribution, manufacturing, transportation, real estate development, recreation, and other human activities can continue with more predictability because a permit will be available to disturb eagles, and the conditions for the permit will be set out in a binding rule that provides a discernible threshold that the public can comply with. However, because the Service will limit take, especially for golden eagles, in some areas of the country, the uncertainties regarding permit availability and permit limits may lead to postponement or delays in planning for some projects.

In all Service Regions, except Arizona and New Mexico, we will substantially increase the proposed permit allocations for bald eagles over the combined average annual totals for past ESA authorizations and Eagle Act permit authorizations (Table 6). However, the proposed permit allocations available for golden eagles (except in Region 6) will limit development if project proponents are unable or unwilling to include avoidance and minimization measures in project designs (Table 7). The Service anticipates minimal impacts to socioeconomic resources from the proposed thresholds for bald eagles. Initially, until data indicates the population can support take, projects seeking individual permits for take of golden eagles above baseline would not receive them, and would experience locally adverse impacts. However, permits for programmatic disturbance, or programmatic permits to reduce take resulting in mortality would be available, if the standard practices adopted as permit conditions will result in a

net reduction in take or a net take of zero, and no net loss to the breeding population. Therefore, while there would be locally adverse impacts, the provisions would not result in impacts deleterious to a broad regional area or sector of the national economy

4.4.6 Summary

The Management Common to Both Action Alternatives meets most of the purposes of the action. It is consistent with the text of the Eagle Act, feasible to implement, predictable for compliance purposes, and enforceable. In addition, while there will be some localized, socioeconomic impacts, there are provisions to ensure this alternative will not result in impacts deleterious to a broad regional area or sector of the national economy. However, neither species will receive the protection offered by a permit that will allow take of a nest to protect the eagles from a hazard. Nor will there be measures to reduce ongoing TRM. There is a potential for significant adverse affects to local area eagle populations as well as socioeconomic resources. Therefore, without additional measures, this management scenario is not compatible with the preservation of the eagle and will not, in itself, fulfill the purpose and need for the proposal.

Table 6. Previously Authorized and Estimated Annual Take and Annual Technical Assistance provided for Bald Eagles, and Proposed Annual Maximum Cumulative Take Allowable[a].

Region	Technical Assistance Actions[b] (2006-2007)	Past ESA-authorized Take/Reference (2002-2007)		Reported Bald Eagle Actions Under the Eagle Act (January 2002-July 2007)		Proposed Service Regional[c] Maximum Cumulative Take Allowable / Predicted Population[d]
		Estimated Average Annual Individuals Authorized	Total Nests or Roosts Authorized	22.21 Permit (Scientific & Exhibition) Avg. Annual Reported	22.23 Permit (Depredation/Hazing) Avg. Annual Reported	
R1	30	18	15	0	2	58 / 7,104
R2	126	7	0	0	0	5 / 797
R3	147	1[e]	0[e]	0	8	224 / 27,617
R4	85	0[e]	0[e]	0	0	106 / 13,111
R5	174	118	2	0	0	104 / 14,020
R6	52	22	6	4	2	44 / 5,385
R7	400	0	0	3	2	555 / 86,550
R8	4	17	1	0	0	7 / 888
Total	1018	148	24	7	14	1,103 / 155,473

[a] Although the majority of permits issued will authorize disturbance, the maximum cumulative take allowable includes all types of take under the new permit and other existing permits. This includes take of individual eagles; disturbance at nests, communal roosts, and important foraging areas; and nest removal. The Sonoran Desert eagles will be managed under the ESA.
[b] Technical assistance reported for Region 7 is under the Eagle Act because the bald eagle was not listed in Alaska.
[c] Regional presentation for comparison purposes only. Eagles will be managed by BCRs, but permits authorized by Region. See Table C.3. in Appendix C for detailed allocation by BCR.
[d] The predicted population estimates are based on the modeling effort explained in the text, Section 2.4.3.
[e] Notwithstanding the large populations of bald eagles in Service Regions 3 and 4, differences in the take authorized relative to other Service Regions can be partly explained by potential permittees being able to comply with the eagle guidelines so that take was avoided.

Table 7. Reported Golden Eagle Actions under the Eagle Act (January 2002-July 2007) and Proposed Annual Maximum Cumulative Take Allowable[a].

Region	Estimated Annual Technical Assistance Requests for Golden Eagle	22.21 Permit (Scientific & Exhibition) Avg. Annual Reported	22.22 Permit (Religious Take[b]) Avg. Annual Reported	22.23 Permit (Depredation/Hazing) Avg. Annual Reported	22.23 Avg. Annual Reported Transfer for Falconry	22.25 Total Permit (Nest Take for Resource Recovery) Authorized[c]	Proposed Service Regional[d] Maximum Cumulative Take Allowable / Predicted Population
R1	1	0	0	5	0	1 (in 5 years)	3 / 1896
R2	12	1	24	0	0	3/year[e]	5 / 2,453
R3	0	0	0	0	0	0	0
R4	1	0	0	0	0	0	0
R5	0	0	0	0	0	0	0
R6	338	2	0	8	4	3/year	38 / 20,430
R7	0	0	0	12	0	0	4 / 2400
R8	13	0	0	0	0	0	10 / 5,414
		Average Annual Totals					
Estimated National Totals	365	3	24	25	4	16	60 / 32, 593

[a] Although the majority of permits issued will authorize disturbance, the maximum cumulative take allowable includes all types of take under the new permit and other existing permits. This includes take of individual eagles; disturbance at nests, communal roosts, and important foraging areas; and nest removal.
[b] Since 2003, all 22.22 Permits have been authorized by Service Region 9, but take has occurred in Service Region 2.
[c] Only 1 nest reported destroyed, all others either relocated or access blocked.
[d] Regional presentation for comparison purposes only. Eagles will be managed by BCRs, but permits authorized by Region. For example, the take for BCR 16, from which the Hopi permit is allocated, will be 27 individuals (see Table C.4, in Appendix C for detailed allocation by BCR).
[e] Where permit has no limit specified, reported take used in estimation.

4.5 Alternative 2– Eagle Take Permits, Structured Allocation Authorized, Nest Take for Public Health and Safety, and Programmatic Disturbance

In Alternative 2, the Service described provisions for authorizing: disturbance take of eagles; nest take to protect public health and safety and eagles; and a proposed programmatic disturbance authorization. In Chapter 4, the FEA specifically analyzes those provisions in Alternative 2 that are additive to Management Common to Both Action Alternatives.

4.5.1 Bald Eagle and Golden Eagle

The potential impacts to both species of eagles from Alternative 2 will be similar to those under the Management Common to Both Action Alternatives. However, the provision in Alternative 2 allowing the take of nests to protect human or eagle safety will result in some benefits to individual eagles. In addition, the provisions for programmatic disturbance will reduce the risk of a piecemeal, iterative loss of important eagle-use areas. Furthermore, setting thresholds and establishing an allocation process based upon modeling and population information, and regular review of golden eagle populations will indirectly improve conditions for the species. These procedures will allow the Service to respond more quickly to declines and develop conservation measures, including the ability to adjust permit levels.

Because the Service will review take thresholds on a regular basis (at least once every five years) relative to bald eagle and golden eagle population and demographic parameters, the Service will be able to modify or adjust permitting accordingly. In addition, the Service used conservative assumptions (estimating take by survival rather than productivity) and application (initially placing a cap on permitted take at 5% estimated annual productivity for bald eagles and 0% estimated annual productivity for golden eagles) of the model used to estimate take thresholds to account for inherent uncertainties and limitations of surveys and monitoring efforts.

The Service does not expect population declines to result from the authorizations granted under Alternative 2. However, it is also possible external factors could arise that negatively affect eagle populations, and there is an increased possibility that local area populations may be adversely affected by take authorized that has disproportionate effects on a specific population. Whatever the cause, if data suggest population declines are approaching a level where additional take will be incompatible with the preservation of the eagle (as interpreted above), the Service will refrain from issuing permits until such time that the take will be compatible with the preservation of the bald eagle and golden eagle.

4.5.2 Biological and Physical Environment

There will be some short-term, direct impacts to the biological and physical environment from this alternative through the provisions for the programmatic disturbance permit. However, the permits will incorporate measures for long-

term mitigation or standard practices designed to avoid or minimize the ongoing and future risk of disturbance to eagles. If the Service creates this permit, issuance of take authorization may indirectly result in impacts to habitat from loss, fragmentation, and reduction of suitability for eagles and other wildlife. On the other hand, development may continue without a permit system, as it has to this point, without mitigation measures and standard practices in place and only the voluntary management guidelines and Service enforcement discretion available to limit or discourage take. Therefore, a permit program requiring mitigation measures and standard practices may also result in benefits to the biological and physical environment. Because we will base our permit thresholds upon Service Region and BCR population segments, the Service believes the impacts to habitat will be widely dispersed and will not be significant at the scale of permitting.

4.5.3 Eagle Mortality Associated with Human Activities

This alternative is expected to have few direct impacts on the current level of eagle mortality associated with human activities, except for the benefits from the few permits authorized for take of nests that pose a hazard to eagles. Indirectly, without incentives to reduce mortality through a programmatic permit process to reduce ongoing TRM, current rates and levels of mortality will tend to increase. Negative impacts to local populations both species may be significant.

4.5.4 Currently-Authorized Take of Eagles

4.5.4.1 Take Authorized Under the Bald and Golden Eagle Protection Act

§22.21 Scientific Collecting and Eagle Exhibition, §22.23 Take of Depredating Eagles, and §22.25 Take of Golden Eagle Nests for Resource Development and Recovery

The impacts to these permits under Alternative 2 are greater than to those under Management Common to All Alternatives. On the occasion when the Service determines the permitted activity will take eagles with an effect on the population, the permit will be subject to the annual permit thresholds. Because the prioritization hierarchy set forth in Alternative 2 does not prioritize this permit, there will be years when requests permits for scientific collecting that would affect productivity cannot be met.

§22.22 Eagle Parts for Native American Religious Purposes/Certification of Enrollment in a Federally-Recognized Tribe

The impacts to these permits under Alternative 2 are expected to be less than those under Management Common to All Alternatives or alternative 1. Under this alternative, permits for Native American Religious Purposes will receive the highest allocation priority; therefore, we expect there will be fewer cases where a request for a permit could not be met than under the previous alternatives.

4.5.5 Societal

Religious and Cultural

The degree to which religious and cultural resources may be affected will depend largely on the availability of permits under the proposed rule. However, implementation of the rule could indirectly affect religious and cultural resources if holders of take permits do not consider them in their planning. There may be some adverse effects to cultural or religious resources such as sacred places from inadequate consultation under Section 106 of NHPA or government-to-government consultation on actions related to eagles.

Safety

The provisions under Alternative 2 will have specific provisions for take of nests in the case of hazard or health risk to eagles or humans. We expect that the provisions for a programmatic approach to managing eagles at airfields will reduce permit delays, thus lowering risks to humans and eagles. The provisions for the removal or relocation of nests away from hazardous sites will also be beneficial for humans and eagles. The benefits from this alternative will be localized and for individual eagles. In addition, the Service estimates the numbers of permits authorized under this proposal will be concentrated in areas with larger eagle populations and will not exceed approximately 30 for bald eagles and one for golden eagles nationally. Therefore, we do not expect that these programmatic permits will have significant population impacts at the regional or national scale.

Socioeconomic

Energy production and distribution, manufacturing, transportation, real estate development, recreation, and other human activities could continue with more predictability because a permit will be available to disturb eagles in the course of conducting such activities. In addition, the provision for programmatic disturbance take under this alternative would potentially minimize economic impacts by allowing more actions to take place without reaching the take thresholds. On the other hand, there is no provision for programmatic permits to reduce TRM, and simplify long-term management issues for industries that currently contribute to TRM.

4.5.6 Summary

Alternative 2 meets most of the purposes of the action. It is consistent with the text of the Eagle Act, feasible to implement, predictable for compliance purposes, and enforceable. It will ensure that prioritized interests are met by authorizing take according to an established order. However, neither species will benefit from measures to reduce ongoing TRM. In addition, the lack of programmatic TRM does not meet the purpose of simplifying long-term management issues and could result in unacceptable socioeconomic impacts to local interests. For example, railway corridors that have reduced bald eagle

mortality to the extent possible, and for which incidental take may have been available under ESA, will be unable to acquire a take authorization under the Eagle Act. There is also a potential for adverse affects to local area populations. Therefore, without additional measures, this management scenario is not compatible with the preservation of the eagle and will not, in itself, fulfill the purpose and need for the proposal.

4.6 Alternative 3– Alternative 2 Plus Take Resulting in Mortality (TRM) Individual and Programmatic Option (Preferred Alternative and Environmentally-Preferred Alternative):

The only differences between Alternative 3 and Alternative 2 are the provisions for non-purposeful TRM. The primary purpose for Alternative 3 is to ensure that any authorized programmatic TRM also include measures to reduce long-term risk of take. This alternative will also authorize programmatic permits that could include TRM. We will subject authorized individual permits for TRM to the same allocation process used for individual disturbance permits.

4.6.1 Bald Eagle and Golden Eagle

Because the Service is setting thresholds for take based upon the predicted ability of the populations to support that level of take, the impacts of individually-permitted TRM should have a negligible impact on populations. The Service expects the impacts of a Programmatic Permit to Reduce or Minimize TRM Take, as proposed, will result in reductions to ongoing take of bald eagles and golden eagles, and may have population benefits at a local or regional scale. Such reductions will be compatible with the preservation of eagles (maintaining increasing or stable bald eagle and golden eagle populations) on a national or regional scale.

Because the Service will review take thresholds on a regular basis (at least once every five years) relative to bald eagle and golden eagle population and demographic parameters, the Service will be able to modify or adjust permitting accordingly. In addition, the Service used conservative assumptions (estimating take by survival rather than productivity) and application (initially placing a cap on permitted take at 5% estimated annual productivity for bald eagles and 0% estimated annual productivity for golden eagles) of the model used to estimate take thresholds to account for inherent uncertainties and limitations of surveys and monitoring efforts.

The Service does not expect population declines as the result of the authorizations granted under Alternative 3. However, it is also possible external factors could arise that negatively affect bald eagle populations. Whatever the cause, if data suggest population declines are approaching a level where additional take will be incompatible with the preservation of the eagle (as interpreted above), the Service will re-evaluate the conditions of existing permits and will refrain from issuing additional programmatic permits until such time that the take will be compatible with the preservation of the bald eagle and golden eagle.

4.6.2 Biological and Physical Environment

There will be no significant, direct impacts to the biological and physical environment from this alternative. If the permit is created, issuance of take authorization will indirectly result in impacts to habitat from loss, fragmentation, and reduced suitability for eagles and other wildlife due to implementation of projects or portions of projects that may not have proceeded without the permit because they are located in areas that are currently considered too high-risk for eagle mortality. On the other hand, a permit system with advanced conservation practices for programmatic reductions in TRM may provide indirect benefits to other wildlife and habitat if compensatory mitigation measures include habitat improvements. Because we will base our permit thresholds on Service Region and BCR population segments, the Service believes the impacts to habitat will be widely dispersed and will not be significant at the scale of permitting. In addition, if the permit is widely applied, it will provide indirect benefits to other wildlife by reducing mortality incurred from the same industries currently taking eagles, because conservation measures are likely to benefit other wildlife.

4.6.3 Eagle Mortality Associated with Human Activities

Alternative 3, via the option for programmatic permits to manage TRM, is the only alternative that will provide a mechanism to reduce eagle mortality, as opposed to disturbance, associated with human activities. While the initial benefits to populations will not be significant on a national or regional basis, they may provide substantial benefits to local area populations. If such permits become widespread, there could be a substantial positive effect on regional and even national populations. Current, ongoing take that is factored into the baseline would be reduced as well as future take. Implementation of permits for new infrastructure would have a goal of no net loss to the population, so we expect they would not lead to increased levels of take overall. At a minimum, wide-scale adoption and implementation of measures under the programmatic lethal permit may buffer the direct and indirect impacts of increased development.

4.6.4 Currently-Authorized Take of Eagles

The Service anticipates no changes to currently-authorized take of bald eagles and golden eagles under the Eagle Act, beyond those already addressed in Alternative 2. However, if the adoption and implementation of the "Performance-Based" Programmatic TRM permit is effective at a broad scale, there may be increases in regional populations. If increases in populations are documented and confirmed, an increase of available take permits may be warranted.

4.6.5 Societal

Religious and Cultural

The Service anticipates impacts to religious and cultural resources from this alternative to be similar to those under Alternative 2. If the adoption and

implementation of the “Performance-Based” Programmatic TRM permit is effective, there may be increases in Service Regional populations, thus indirectly benefitting religious and cultural resources. However, implementation of the rule could indirectly affect religious and cultural resources if holders of take permits do not consider the affects of their actions on religious and cultural resources. The commitments in this alternative to improved consultation will minimize the potential for adverse effects.

Safety

The impacts to safety under Alternative 3 will be similar to those under Alternative 2.

Socioeconomic

In addition to the same socioeconomic impacts as Alternative 2, Alternative 3 will provide a mechanism by which industries and agencies could implement practices to reduce ongoing eagle mortality, thus demonstrating their commitment to improving conditions for eagles. This will create additional costs, but those costs will be balanced by regulatory certainty that comes with knowing they are not subject to enforcement proceedings, and may not be significant. Therefore, the Service expects no impacts deleterious to any sectors of the national economy from this alternative. In addition, TRM may be necessary to protect public health and safety.

4.6.6 Measures to Minimize Uncertainty

The measures added to minimize uncertainty will tend to reduce the impacts to cultural resources by providing local information regarding the cultural significance to tribes and local communities of specific eagle nests and nest areas that would not be available to us otherwise. That kind of site-specific information will also ensure that we do not authorize take that has disproportionate effects on a specific population. In addition, implementation of goals to improve eagle management will tend to reduce impacts to local area populations by providing the service with better data and specific management goals for each species.

4.6.6.1 Structured-Coordination Process with State and Tribal Wildlife Jurisdictional Entities and Improved Implementation of Service Trust Responsibilities to Tribes

The structured-coordination measures in Alternative 3 will minimize the effects of our permit actions on local area populations, increase the ability for effective implementation, improve the ability to share monitoring reports and data, help develop standard practices for programmatic permits, and improve the ability to develop the required components for more localized thresholds and management. The measures for comprehensive standard operating procedures on government-to-government consultation, not only on each permit as necessary, but also regularly on the eagle program as w hole, will better ensure

consistent, appropriate consultation, and improve our compliance with NHPA, AIRFA, and RFRA.

4.6.6.2 Goals for Improved Ability to Manage Eagle Populations and the Permit Program

As we acquire funding and incrementally meet the goals in *2.6.5 Identified Goals for Improved Ability to Manage Eagle Populations and Permit Program,* which we set forth in this alternative to mitigate uncertainty, we expect improvements in the ability of the program to respond more quickly to effects on bald and golden eagle populations from the program and environmental and human-related factors.

4.6.8 Summary

This alternative meets the purposes of the action in all respects. It is consistent with Congress's intent to protect bald eagles and golden eagles, consistent with the text of the Eagle Act, feasible to implement, predictable for compliance purposes, and enforceable. In addition, except for safety-related permits, it will ensure that authorized take of birds necessary to meet the religious need of a Native American Tribe will not be denied due to other take being authorized for another purpose, thereby supporting our trust responsibilities to tribes. Measures for take for public health and safety and the programmatic TRM provisions will decrease the probability of circumstances placing human or eagle safety or health at risk. Most importantly, the provisions in this alternative for programmatic permits to reduce TRM also provide an important mechanism to reduce lethal take for both species of eagles, and to improve conditions for golden eagle populations. Without measures for programmatic reduction in TRM as contained in Alternative 3, our actions may not be compatible with the preservation of the golden eagle.

Setting national and Service Regional thresholds based upon the sustainability of such take of bald eagle and golden eagle populations, through provisions for programmatic approaches and through measures to reduce ongoing TRM of both species, will: (1) be compatible with the preservation of eagles; (2) develop a management system that will simplify complex, long-term eagle management issues by allowing programmatic approaches; (3) provide a consistent approach to permitting between our Service Regional offices; and (4) make take authorization available to meet socioeconomic needs.

4.7 Cumulative Effects

Cumulative effects are the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably-foreseeable future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions (40 CFR 1508.7). We have focused the cumulative-effects evaluation primarily on the potential for impacts that will require modification of permit thresholds or conditions. Those impacts could either be to eagle populations or societal resources.

4.7.1 Bald Eagle and Golden Eagle

When considering the impacts of the permit, past activities, current pressures, other foreseeable activities such as development, and effects of climate change, the Service expects that bald eagle populations will continue to grow and expand overall, although there may be some localized adverse cumulative effects. The Service expects there may be localized adverse cumulative effects on golden eagles from the proposed permit, considering past, present, and reasonably-foreseeable future activities, in particular, energy development, including wind, invasive weeds, and the effects of climate change. The negative cumulative effects to both species from Alternative 1, which will not create a new permit, will be greater than the proposed alternative because it does not contain provisions for reducing ongoing take. In addition, because, under "Management Common to Both Action Alternatives", we are setting thresholds for take based upon the predicted ability of the populations to support that level of take, because cumulative impacts are considered and addressed on a case-by-case basis during the permit process, and because the Service will adjust permit thresholds to incorporate changes in existing conditions, most of the cumulative effects to eagle populations from this proposal added to other actions will be addressed through the permitting system. In addition, Alternative 3, which provides for programmatic efforts to reduce and minimize take resulting in mortality, may have cumulatively-less-negative population effects than Alternative 2.

4.7.2 Biological and Physical Environment

Bald Eagle Habitat

The United States Census Bureau (2005) interim population projections for numerical change in population between 2000 and 2030 estimate that Florida, California and Texas will account for 46% of the United States population growth (Appendix G). Habitat loss for bald eagles is likely to occur in the foreseeable future through incremental land clearing for development. For example, it is projected that between 1978 and 2020, the developed area of the Chesapeake Bay watershed will increase by 74% in Maryland and 80% in Virginia (Gray et al. 1998). North Carolina is projected to gain 4.2 million people. Most of the States that currently have the larger bald eagle populations are projected to have human population increases above 2000 levels ranging from nearly 30% to as high as 79.5% in Florida. In addition, as one commenter pointed out, there may be considerable expansion of human development into areas not now considered major growth areas. They noted that, in Montana, the fastest growing counties are where the eagles are. The cumulative effects from all alternatives, including the proposal, and human population growth may lead to localized losses and fragmentation of bald eagle habitat. However, we will be developing and implementing a structured coordination process to minimize the potential for negative local effects. Therefore, the Service does not anticipate significant negative cumulative impacts from this proposal nationally on bald eagle habitat in the foreseeable future. The Service also believes measures in Alternative 3 to improve coordination at the regional and local level as well as development of a

national golden eagle conservation and management plan will minimize the potential for negative effects to regional and local populations.

Oil and gas development within the Intermountain West is expected to continue for the foreseeable future, particularly in Montana, Wyoming, Colorado, New Mexico, and Utah, where bald eagles typically occur along narrow river corridors and reservoirs (Figure 8) (USGS 2007a). In addition, there are undiscovered, technically-recoverable oil and gas resources in other areas supporting bald eagles (Figure 8). For example, the undiscovered, technically-recoverable resources of Michigan Basin include a mean of 990 million barrels of oil and a mean of 311.5 billion cubic meters (11 trillion cubic feet) of natural gas (USGS 2005). In the foreseeable future, the cumulative effects to bald eagles from the proposal and energy development may lead to negative effects to bald eagles in areas such as the Intermountain West. However, these impacts will be localized, and the Service does not anticipate significant negative impacts from the proposal and energy development on a national scale. Re-evaluation and potential adjustments of the permit thresholds and conditions, as well as comprehensive evaluation of cumulative effects at the permit issuance stage will minimize the cumulative effects of energy development on bald eagle habitat.

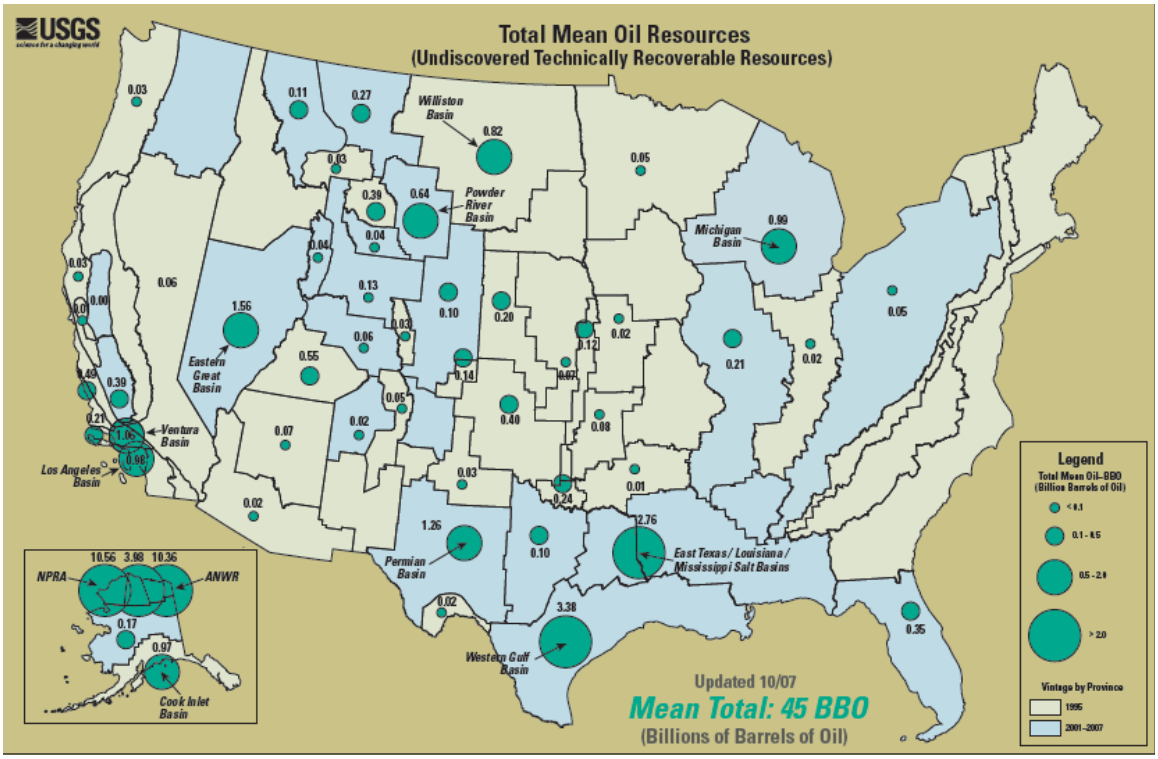

Figure 8 Total Mean United States Oil Resources

Climate Change

Global climate change could raise sea level, perhaps by as much as one meter (Titus 1990) by the end of this century by expanding ocean water, melting

mountain glaciers, and causing ice sheets to melt or slide into the oceans (Senior et al. 2002). Such a rise would inundate coastal lowlands, and impact bald eagle nest locations associated with them.

At our request, Dr. J. Weiss at the Department of Geosciences, Environmental Studies Laboratory at the University of Arizona conducted GIS analysis for FEA of predicted sea-level rise relative to coarsely identified bald eagle nest areas[7]. According to Weiss's analysis, using USGS Digital Elevation Models (DEMs) with a 30-meter resolution, a one-meter sea-level rise will impact approximately seven percent of currently-identified bald eagle nest areas (Figure 9). At the time of the analysis, the Service had no data available for nests in Alaska, so they are not shown. However, because most of the surveyed nests in Alaska are in coastal areas, there will be impacts to those nests as well.

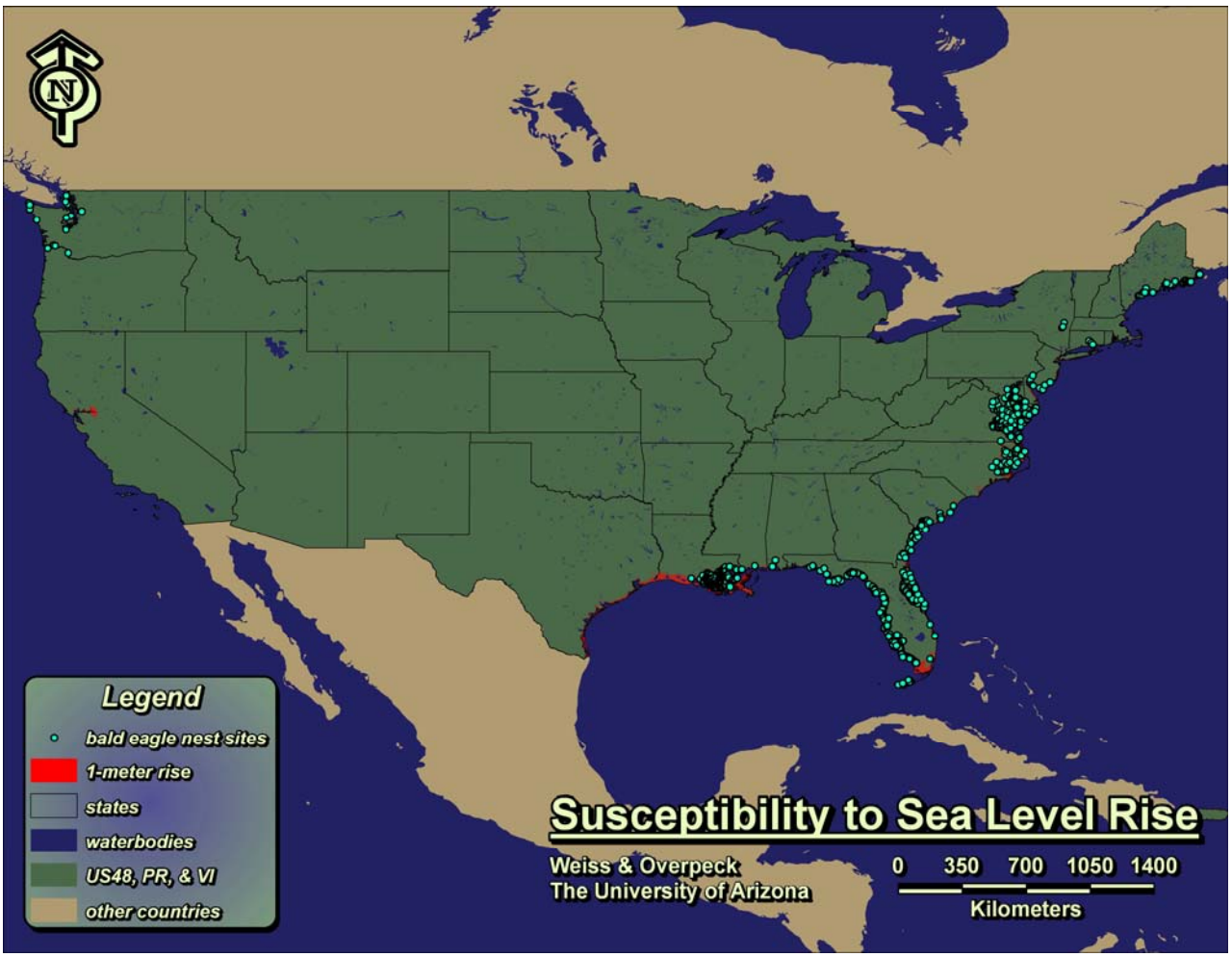

Figure 9 Bald Eagle Nest Areas Susceptible to a One-meter Sea Level Rise

[7] Details regarding this analysis can be found at: http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise_technical.htm.

Because the sea-level rise is expected to take place gradually, over a span of years, bald eagles will have time to relocate. Further, in the years ensuing between now and the full extent of a one-meter sea-level rise, the Service expects bald eagle populations to continue to increase. However, because impacts will be occurring to human property in the same areas, the Service may see an increase in the requests and need for permits related to human and eagle safety in these areas.

Cumulatively, if permits thresholds are not adapted to changing conditions, the impacts of permits may exacerbate the climate-change impacts upon the bald eagle's habitat, and may have some localized, negative impacts to bald eagle populations and socio-economic factors. Alternative 1, which will not create a new permit, may therefore reduce developmental pressures on habitat, and may have fewer impacts than either Alternative 2 or 3. On the other hand, without permits setting standards and conditions, and a program setting population-based thresholds, negative cumulative effects from Alternative 1 may be significant. Re-evaluation and potential adjustments of the permit thresholds and permit conditions will minimize the cumulative effects of the permit and climate change in coastal areas.

Golden Eagle Habitat

Good et al. (2007b) state that if human activities, including development, continue to increase in the West, the Service can expect an increase in pressures on golden eagle populations. The sagebrush-shrub habitat, identified as one of the most altered and at-risk habitats in the West (Knick et al. 2003), is also the focus of widespread restoration initiatives. We expect that efforts throughout the western United States to combat cheatgrass invasions and restore sagebrush-shrub habitats will have short-term negative impacts on the availability of habitat supporting golden eagle prey species. The permits proposed, if issued for restoration projects, may contribute to short-term negative cumulative effects on golden eagle habitat. However, if the restoration projects include habitat provisions addressing the needs of golden eagles, indirect, long-term cumulative benefits should accrue from issuance of the permits.

We also expect continued energy development within the golden eagle's range to a substantial degree for the foreseeable future. For example, the combined total mean, undiscovered, technically-recoverable natural gas resources of the Powder River Basin, SW Wyoming Basin, Uintah Piceance Basin, and San Juan Basin amount to approximately 4.9 trillion cubic meters (173 trillion cubic feet) of gas (Figure 10) (USGS 2007b). In areas where the natural gas reservoirs are limited to few formations, the life of the development will be shorter than that in oil fields, particularly those in complex basins with multiple formations. In addition, reclamation and restoration of fields in arid areas may be prolonged.

We expect the trend towards greater wind-energy development to continue. Although wind development is currently unregulated, and the Service does not have authority to stop development for lack of a Service-issued permit, some developers may be reluctant to proceed without one for fear of violating the Eagle

Act. If permits are developed that adequately address eagle mortality from wind turbines, there may be even greater increases in siting of wind development in areas where eagles occur. In that case, issuance of permits for wind development will indirectly lead to increasing loss and fragmentation of golden eagle habitat. In areas where restoration projects and energy development coincide, issuance of permits under the proposal may cumulatively lead to local degradation of golden eagle habitat. The impacts of the no action alternative, Alternative 1, (assuming that projects will continue to go forward anyway) will significantly outweigh the impacts of the action alternatives, which require minimization and mitigation.

However, these impacts will be localized, although there may be some regional impacts. The Service does not anticipate significant negative impacts to golden eagle habitat from the proposal and energy development on a national scale, although there will be significant impacts to habitat on a regional scale, and to individual golden eagles from direct mortality. Re-evaluation and potential adjustments of the permit thresholds and conditions, as well as comprehensive evaluation of cumulative effects at the permit-issuance stage will minimize the cumulative effects of the permit and factors affecting habitat.

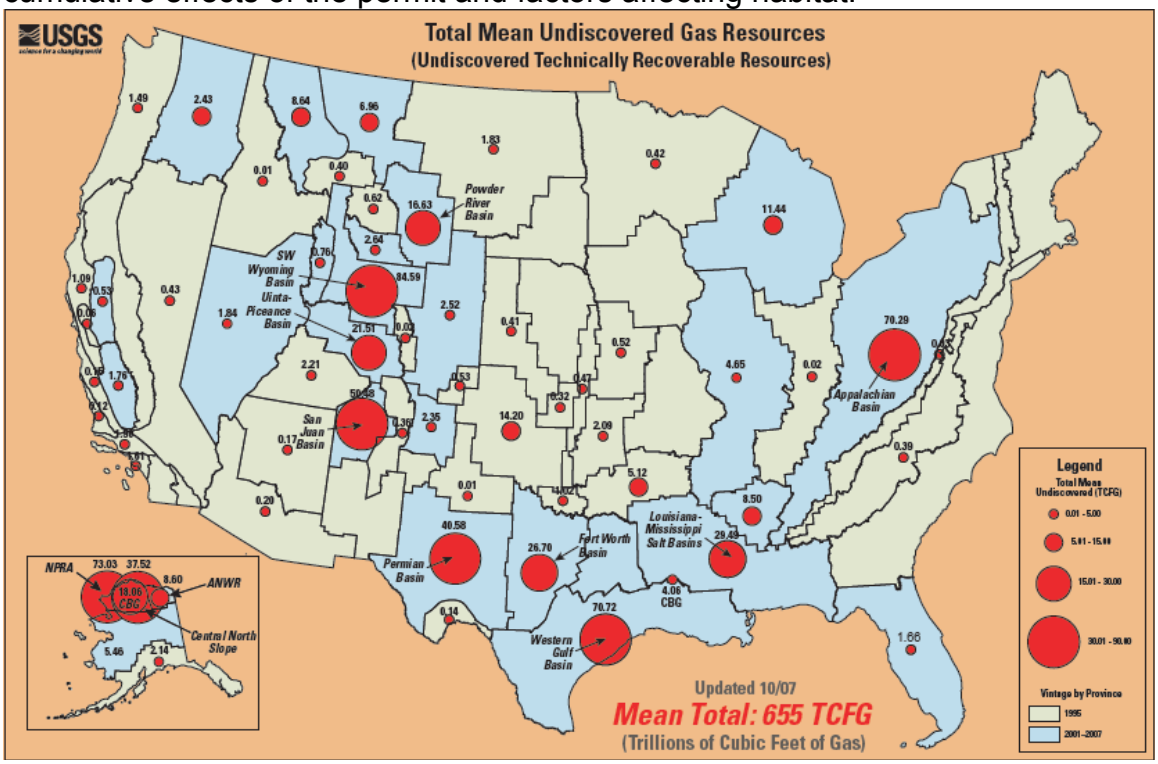

Figure 10 Total Mean Undiscovered Gas Resources

Climate Change

It is difficult to predict the cumulative effects of the permit and global climate change. Climate-change effects will locally lead to increased or lower average annual or seasonal temperatures, or increased or lowered precipitation. Predicting impacts to eagles from the permit and the local effects of climate change is subject to changes or fluctuations in such variables as land use,

vegetation, predation dynamics, parasites, prey abundance or cycles of prey abundance, and changes in human behavior that leads to increased disturbance (Mustin et al. 2007). For example, effects from climate change in the Great Basin are predicted to exacerbate to some degree the existing golden eagle habitat impacts from altered fire regimes and invasive annual grasses (Wagner 1998). Climate change-related increases in nitrogen deposition and atmospheric CO_2 concentration favor groups of species that share certain physiological or life-history traits that are common among invasive species, allowing them to benefit from global change (Dukes and Mooney 1999). Raptors in general may be able, through behavioral adaptations such as dispersal to areas with better conditions, to mitigate some of the predicted impacts from climate change (Wichmann et al. 2005). However, particularly in areas with expanding human development or habitat degradation, we expect to see increasingly-limited areas with better conditions to which eagles may disperse.

Cumulatively, the Service does not anticipate significant impacts from the proposal when coupled with climate change impacts. However, if permit thresholds were not modified to reflect the altered habitat, the proposal may exacerbate the impacts from climate change and other activities affecting golden eagles and their habitat. The proposal may have some localized cumulative effects that will require adjustments to permit conditions or thresholds.

4.7.3 Eagle Mortality Associated with Human Activities

The Service does not anticipate significant negative cumulative effects from the permit proposal to eagle mortality associated with human activities, although achievement of mortality-reduction goals in the programmatic lethal permit could mitigate some of the cumulative effects. In addition, (Alternative 3, which provides for programmatic efforts to reduce and minimize take resulting in mortality, may have cumulatively-less-negative population effects than Alternative 2. Activities currently leading to eagle mortalities will likely increase in scale and there may be additional sources of mortality the FEA has not considered or anticipated. If bald eagle populations continue to increase, the numbers of deaths, but not necessarily the proportion of the population affected, will increase regardless of changes in risks or availability of permits. If current estimates regarding the potential decline of golden eagle population trends are accurate and continue, an increase in the number of deaths will result in an increase in the proportion of the population affected. For both species, if factors leading to habitat alteration remain the same, the numbers of deaths will be expected to rise. If the Service does not modify permit thresholds to reflect the altered mortality, there may be some additional, localized effects on eagles. Notwithstanding predictions, because the Service will review take thresholds on a regular basis relative to eagle population and demographic parameters, we will be able to modify or adjust permitting. In addition, wide-scale adoption and implementation of measures under the programmatic lethal take permit will tend to buffer the direct and indirect lethal impacts of increased development.

4.7.4 Currently-Authorized Take of Eagles

Cumulatively, the Service does not expect changes or appreciable impacts to the continuation or magnitude of currently-authorized take of eagles from this permit proposal. Nor do we expect the cumulative effect on eagles from the permit proposal and currently-authorized take to alter in the foreseeable future. Notwithstanding predictions, because the Service will review take thresholds on a regular basis relative to eagle populations and demographic parameters, we will be able to modify or adjust permitting. Alternative 1, which will not create a new permit, will have cumulatively fewer impacts on other forms of currently-authorized take of eagles than Alternative 2. Alternative 3, which provides for programmatic efforts to reduce and minimize take resulting in mortality, may minimize the cumulative effects to currently-authorized permits by resulting in increased populations and higher take thresholds.

4.7.5 Societal

Religious and Cultural

In some regions of the country, particularly in the Southwest, cumulative effects from the proposed permit to eagles and habitat from all types of development and climate change may result in local population declines. Because the Service will review take thresholds on a regular basis relative to eagle population and demographic parameters, the Service will modify or adjust permitting accordingly. This will have some negative impacts on local religious and cultural resources. However, we do not expect significant cumulative effects to religious and cultural resources from the proposal.

Safety

Cumulatively, the Service does not anticipate appreciable changes or impacts to human or eagle safety from the proposal. There may be some localized impacts to safety if eagle populations increase to the point of becoming over-abundant, or in areas experiencing habitat changes from energy development, invasive species, or climate change effects, or TRM from energy development. Because the Service will review take thresholds on a regular basis relative to eagle population and demographic parameters, the Service will be able to modify or adjust permitting to ameliorate most impacts.

Socioeconomic

The Service does not expect significant cumulative effects to socioeconomic resources in the foreseeable future. If the bald eagle populations continue to grow in the same Service Regions as the greatest human population growth, there will also likely be an increase in the permit thresholds. That will minimize the potential impacts to development. If bald eagle populations decline while human populations increase, there may also be a decline in available permits, leading to a localized impact on economic development. In some local areas,

because of annual permit thresholds and impacts to population from other factors, there may be limitations to the rate of development.

Permit thresholds may have some negative impacts on energy development if it takes place near areas subject to other development pressures.

However, this will be localized and likely not significant on a regional or national scale. Because the Service will review take thresholds on a regular basis relative to eagle population and demographic parameters, the Service will be able to modify or adjust permitting accordingly. Therefore, the Service expects no impacts deleterious to a broad regional sector of the national economy.

4.7.6 Summary

There are few differences between alternatives relative to the cumulative effects from factors presented in this FEA. Alternative 3, with provisions for permitting TRM once mortality-reducing performance standards are met, may serve to buffer some negative impacts to eagle populations. Overall, the cumulative effects to eagle populations from other resources will tend to overshadow the impacts of the proposed permits and render them more difficult to detect. Because the Service will review take thresholds on a regular basis (at least once every five years) relative to eagle population and demographic parameters, the Service will be able to modify or adjust permitting accordingly. In addition, the Service will adopt conservative assumptions (estimating take by survival rather than productivity) and application (setting a limit consistent with Millsap and Allen (2006)) of the model used to estimate take thresholds to account for inherent uncertainties and limitations of surveys and monitoring efforts. The periodic review and conservative approach to thresholds will mitigate the cumulative effects to eagle populations from the proposal and other reasonably-foreseeable activities conducted by other entities.

4.8 Trans-boundary Effects of the Alternatives

The Service foresees no impacts of Alternative 1 on bald eagles or golden eagles in Canada or in Mexico. Alternatives 2 and 3 may have some impacts to individual eagles of either species from Canada or Mexico by permitting disturbance of birds at winter roosts or other concentration areas during migration. However, because the majority of the permits are for disturbance and for take during the breeding season, there will be no significant population impacts. The preferred alternative (proposed action), because of measures designed to reduce ongoing mortality, is expected to protect the current populations of both species in the United States and is likely to provide a greater level of protection for bald eagles or golden eagles breeding in Canada or Mexico but migrating or wintering in the United States.

Preparers

The assessment was prepared by Diana M. Whittington and George T. Allen, Ph. D., both from the Division of Migratory Bird Management, in Service Region 9. Preparers from Service Region 2 were Brian A. Millsap, Ecological Services, and David Siegel, Cultural Resources Manager.

Ms. Whittington has a number of years experience in land use and energy-related wildlife management issues, with an emphasis on raptor conservation.

Dr. Allen has approximately 20 years experience in wildlife research and management, with an emphasis on raptors. He is a Certified Wildlife Biologist.

Mr. Millsap has 29 years of experience in wildlife research and management, with an emphasis on raptor conservation.

Mr. Siegel has had 40 years experience in cultural resources management with D.O.I., and state and private museums in the western US.

Agencies, Organizations, and Persons Consulted for Purposes of this EA

Name	Purpose and/or Authorities for Consultation or Coordination	Summary
U.S. Fish & Wildlife Service (USFWS)	Information on Intra-Service Consultation, under Section 7 of the Endangered Species Act (16 USC 1531)	We have determined, through Intra-Service coordination, that consultation pursuant to section 7(a)(2) of the Endangered Species Act is not required for these regulations. The regulations do not directly or indirectly authorize any activities that would result in adverse effects to listed species, so they will not affect any listed species or critical habitat. We will conduct section 7 consultations on the issuance of any future permits where the authorized activities may affect listed species or critical habitat.
Advisory Council on Historic Preservation John Eddins, PhD., Historic Preservation Specialist	Consultation for undertakings, as required by the National Historic Preservation Act (NHPA) (16 USC 470)	Advised that as long as the EA and the actual regulations indicate that FWS will do Section 106 process on a case by case basis as appropriate, ACHP will not suggest that FWS needs to do Section 106 for the development of the regulations.
Navajo Natural Heritage Program David Mikesic, Zoologist	Consult with as an agency or individual with expertise on impacts on eagles.	Coordination regarding conservation measures for and status of bald eagles and golden eagles as maintained by the Navajo Nation.
USGS, Forest and Rangeland Ecosystem Science Center, Snake River Field Station, and Boise State University - Raptor Research Center Mark Fuller	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of golden eagles. Topics discussed included survey and monitoring tools, management applications, demographic information, habitat modeling, and impact analysis of annual grass invasion and fire regime effects upon golden eagle prey base.
USGS, Forest and Rangeland Ecosystem Science Center Michael N. Kochert, Research Wildlife Biologist	Consult with as an agency or individual with expertise on golden eagles.	Coordination regarding conservation recommendations for and status of golden eagles. Topics discussed included survey and monitoring tools, long term management issues, and impact analysis of annual grass invasion and fire regime effects upon golden eagle prey base.

Name	Purpose and/or Authorities for Consultation or Coordination	Summary
NPS, Denali National Park and Preserve, Carol McIntyre, Wildlife Biologist	Consult with as an agency or individual with expertise on golden eagles.	Coordination regarding conservation recommendations for and status of golden eagles, with emphasis on demographics and migration biology.
FS, Rocky Mountain Research Station Teryl Grubb, Wildlife Research Scientist	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of bald eagles and golden eagles, with emphasis on disturbance research and eagle biology.
University of Nevada, Reno Michael W. Collopy Executive Director Academy for the Environment	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of bald eagles and golden eagles, with emphasis on disturbance research and eagle biology.
Texas Tech University Clint Boal, Research Associate Professor	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of golden eagles in the Texas panhandle. Topics discussed included long term management issues, impact analysis of annual grass invasion and fire regime effects upon golden eagle prey base.
Nevada Division of Wildlife Larry Neel, Non-game Biologist	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of bald eagles and golden eagles in Nevada, in particular impact analysis of annual grass invasion and fire regime effects upon golden eagle prey base.
Maine Department of inland Fisheries Charles Todd, Wildlife Biologist	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of bald eagles and golden eagles in Maine
Oregon Department of Fish and Wildlife Charles Bruce, Threatened and Endangered Species Coordinator	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of bald eagles and golden eagles in Oregon.
Idaho Department of Fish and Game Bruce Haak	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of golden eagles in Idaho

Name	Purpose and/or Authorities for Consultation or Coordination	Summary
Utah Division of Wildlife Resources Jimmie R. Parrish, Avian Program Coordinator,	Consult with as an agency or individual with expertise on eagles.	Coordination regarding conservation recommendations for and status of golden eagles in Utah
Texas Parks and Wildlife, Danny Swepston and Dave Holderman	Consult with as an agency or individual with expertise on golden eagles.	Coordination regarding conservation recommendations for and status of golden eagles in Texas, including ecological conditions affecting populations.
USDA APHIS, Wildlife Hazard Office, Tom Seamans and Richard Dolbeer	Consult with as an agency or individual with expertise on impacts related to eagles.	Coordination regarding airport safety risks presented by bald eagles and golden eagles and management tools
U.S. Air Force Bird Air Strike Hazard (BASH) Team Eugene LeBoeuf, Chief	Consult with as an agency or individual with expertise on impacts related to eagles	Coordination regarding flight safety risks presented by bald eagles and golden eagles
U.S. Air Force, Air Combat Command Alton Chavis, Deputy Chief, Environmental Division	Consult with as an agency or individual with expertise on impacts related to eagles	Coordination regarding general applicability of programmatic permit concept to flight operations

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