Science advisory committee guidance on development and implementation of a habitat conservation plan / natural community conservation plan for Apple Valley, California

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Executive summary

As part of its development of a habitat conservation plan (HCP) and natural community conservation plan (NCCP), the town of Apple Valley, California convened an independent science advisory committee. As members of that committee, our primary aim was to provide realistic scientific guidance in the context of the town's constraints and opportunities, such as the extent to which reasonable conservation objectives can be achieved given existing levels of urbanization and fragmentation in the western Mojave Desert.

We encourage Apple Valley to increase the data available for drawing inference on the occurrence, environmental associations, and responses to environmental change of species that may be covered under the HCP / NCCP. We also encourage development of research, including monitoring, that will test assumptions and reduce uncertainties about species' ecology and responses to environmental change. Furthermore, we encourage Apple Valley to allocate funds for the duration of the permit period to employ one or more full-time staff members with extensive scientific training and practical experience in management of natural resources.

We suggest that the following may increase the probability of developing a successful HCP / NCCP.

> Over the duration of the permit period, collect data not only on conservation targets, but on known or hypothesized stressors to each of those targets. Allocate funds for long-term collection and rigorous analysis of these data.
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> Do not rely exclusively on projections of habitat or species occurrences from the Desert Renewable Energy Conservation Plan (DRECP) and California Department of Fish and Wildlife (CDFW) California Wildlife Habitat Relationships Program, but directly evaluate data on species occurrences and compare those data to projections derived from occurrence or occupancy models.
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> Develop and test continuous rather than binary models of habitat quality and occurrence probability.
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> Add data on geology and soils to the natural-community classifications and as covariates that may be associated with the distributions of species being considered for coverage.
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> Use theories of change to inform implementation of the HCP / NCCP and, to the extent that such a process is implemented, the adaptive management process. Theories of change are hypotheses about the mechanisms by which a given activity or set of activities might be expected to result in a given, measurable biological effect that is consistent with a specified conservation objective.
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> Base objectives related to human disturbance (e.g., assumptions about relations between a given land use and survival or reproduction of a given species) on robust field data and rigorous analyses in the peer-reviewed literature, not on hearsay. Similarly, use the peer-

reviewed literature and field data to test assumptions about responses of covered species to predation.

Concurrent with acquisition of conservation lands, test hypotheses about connectivity (e.g., that a given area supports movement of individuals between populations) rather than assuming that a given area supports movement.

Maintain soft rather than hard edges between development (e.g., housing) and areas in which development will be minimized.

if environmental education emphasizing the Mojave Desert is implemented as part of the HCP / NCCP, work closely with education professionals and social scientists to measure attitudes and behaviors over time.

Collaborate with wildlife epidemiologists to track diseases that may affect covered species, such as white-nose syndrome in bats, upper respiratory tract disease in desert tortoise, and pneumonia and bluetongue in bighorn sheep.

Compile additional information on the underlying assumptions, methods of development, and effectiveness of current conservation areas (e.g., areas of critical environmental concern [ACECs]) for plants and animals.

Allocate funds to employ a staff biologist with extensive scientific training and practical experience in management of natural resources to coordinate implementation of the HCP / NCCP and to develop or strengthen collaborations with agencies, academic institutions, and educators.

Introduction

The US Fish and Wildlife Service (FWS) encourages applicants for incidental take permits under section 10(a) of the US Endangered Species Act to engage independent scientists in development of a habitat conservation plan (HCP). For example, the current fact sheet for HCPs (www.fws.gov/midwest/endangered/permits/hcp/hcp_wofactsheet.html) states,

> "The views of independent scientists are important in the development of mitigation and minimization measures in nearly all HCPs. In many cases, these individuals are contacted by the applicant and are directly involved in discussions on the adequacy of possible mitigation and minimization measures. In other cases, the views of independent scientists are incorporated indirectly through their participation in other documents, such as listing documents, recovery plans, and conservation agreements, that are referenced by applicants as they develop their HCP."

California's Natural Community Conservation Planning (NCCP) Act aims to protect the state's biological diversity while reducing conflicts between protection of natural resources and economic development. The act requires that independent scientists be engaged in development of an NCCP. Independent scientific input is intended to guide conservation strategies for species and natural communities proposed to be covered by the plan; design of reserves that will conserve species, landscapes, ecosystems, and ecological processes in the planning area; development of management principles and conservation goals for monitoring and other aspects of adaptive management; and reduction of data gaps and uncertainties.

Therefore, as part of its development of an HCP / NCCP, the town of Apple Valley, California convened a science advisory committee (SAC). The town, SAC members, and consultants to the town agreed on four goals for engagement of the SAC in the planning process. First, understand the town's biological and social goals and objectives for the HCP / NCCP and the process that the town is following in developing the plans. Second, provide realistic scientific guidance in the context of the town's constraints and opportunities, such as the extent to which reasonable conservation objectives can be achieved given existing levels of urbanization and fragmentation in the western Mojave Desert. The latter goal includes assessing the extent to which science can inform decision-making given contemporary and past land use. Third, address not only covered species and natural communities but maintenance of ecological processes via open space, both within the planning area and regionally. Fourth, emphasize incorporation of science not only into development of the HCP / NCCP but into decision-making during the implementation of the HCP / NCCP.

In November 2015, the SAC members, town staff, consultants, and personnel from the FWS, California Department of Fish and Wildlife, and Bureau of Land Management convened in Apple Valley. Following an introductory discussion of the history and context of the HCP / NCCP, the SAC members, town staff, and consultants briefly toured the planning area. On the following day, the SAC members, town staff, and consultants discussed the town's objectives in more detail. We also discussed the content and format of scientific advice that would be most relevant given those objectives and the associated constraints and opportunities. In March 2016, the SAC members, town staff, and consultants convened in Phoenix, Arizona to discuss interim progress by all parties; methods for refining goals, objectives, and reduction of uncertainties; concepts related to adaptive management; and Apple Valley's anticipated adaptive management process.

Conservation strategies

Conservation science and resource management are derived from myriad disciplines, including but not limited to ecology, genetics, statistics, sociology, and economics. Conservation biology, a subset of conservation science, has been recognized as an integrative discipline since the late 1970s. The fundamentals of conservation biology and conservation science are well established, and are detailed in numerous publications that are accessible and comprehensive. Accordingly, we do not summarize those fundamentals here. The following are some of the many reliable sources of information with considerable relevance to development of any HCP / NCCP, especially for individuals who have not received formal training in conservation biology or closely related disciplines.

Groom, M.J., G.K. Meffe, and C.R. Carroll, editors. 2006. Principles of conservation biology. Sinauer, Sunderland, Massachusetts.

Soulé, M. 1986. Conservation biology: the science of scarcity and diversity. Sinauer, Sunderland, Massachusetts.

Soulé, M. and B. Wilcox. 1980. Conservation biology: an evolutionary–ecological perspective. Sinauer, Sunderland, Massachusetts.

The following are resources on the foundations of conservation science and resource management, including the process of decision-making under uncertainty.

The Network of Conservation Educators & Practitioners' free modules on diverse topics related to conservation science. These modules are geared toward trainers and professionals. http://ncep.amnh.org/resources.php?globalnav=resources&sectionnav=modules&sectionsubnav=find_modules&action=default

Materials from a course on structured decision making that is offered by the National Conservation Training Center: http://nctc.fws.gov/courses/ALC/ALC3183/resources/index.html

The Open Standards for the Practice of Conservation, developed by the Conservation Measures Partnership: http://cmp-openstandards.org/

Furthermore, the following are reliable sources of information on climate science, regional climate, and climate change.

The website Real Climate: www.realclimate.org

G. Garfin, A. Jardine, R. Merideth, M. Black, and J. Overpeck, editors. Assessment of climate change in the Southwest United States: a technical report prepared for the U.S. National Climate Assessment. Southwest Climate Alliance, Tucson, Arizona. This free, peer-reviewed volume is available at http://www.swcarr.arizona.edu/

Provision of meaningful guidance on conservation strategies for a given element of biological diversity (e.g., species, community, or process) in a given location and time period requires substantial information on the element's biology, local and regional status and trend, stressors to the element, and the social and economic feasibility of alternative management actions. We define stressors as entities or processes that have negative effects on individuals or populations (e.g., reduce probabilities of survival, reproduction, or persistence) or any other biological element within a given time period and location. Stressors are defined relative to response variables. That is, a given anthropogenic or natural phenomenon may function as a stressor to some of the species or ecological processes in a specified area and time period, but not to others. With the Apple Valley planning area, a number of stressors to various species and ecological processes likely will affect the extent to which the town's biological and social goals and objectives are achieved. These include use of off-road vehicles, domestic dogs and cats that do not remain within their owners' homes, animal husbandry, agriculture, some types of landscaping (e.g., ornamentals, including lawns, that require considerable water), energy development, expansion of non-native invasive species, loss and fragmentation of native land cover, and ongoing changes in land use and climate. Efforts to minimize the effects of these stressors on conservation targets will require collection of data not only on response variables, but on the stressors.

Selection of proposed covered species

To determine which species should be proposed for coverage under the HCP / NCCP, and to inform the design of areas in which conservation will be a high priority, regulators suggested that Apple Valley rely on projections of habitat developed by the Desert Renewable Energy Conservation Plan (DRECP) and range maps from the California Department of Fish and Wildlife's California Wildlife Habitat Relationships Program. The uncertainties in these projections and maps sometimes are substantial. For example, we compared the DRECP's projections of habitat or occurrences of several species (e.g., *Chaetodipus fallax*, *Xerospermophilus mohavensis*, *Acanthoscyphus parishii* var. *goodmaniana*) with archived occurrence records (e.g., from VertNet and the California Native Plant Society's online inventory of rare, threatened, and endangered plants of California [www.rareplants.cnps.org]), and found considerable discrepancies. Despite the DRECP's projections, our ad hoc comparison led us to conclude that a number of the species tentatively proposed for coverage do not occur within the planning area (Table 1). We strongly suggest that Apple Valley not rely exclusively on the DRECP and CDFW projections, but directly evaluate actual occurrence data and compare those data to projections derived from occurrence or occupancy models.

Not only projections of habitat but occurrence data require screening. The majority of presence records reflected in museum records and in compilations such as eBird, VegBank, CalFlora, and the California Natural Diversity Database were not collected with a formal sampling design. As a result, some locations within the range of a species may have been sampled heavily whereas others (especially on private land or far from roads) have not been sampled, or have not been sampled at the appropriate time of year or day given the biology of the species. Databases or checklists such as eBird may place some filters on submitted records, but the data still may reflect incorrect identifications (e.g., Gzrybowski 2015). Many small-mammal species within genera such as *Chaeotodipus* and *Perognathus* (pocket mice) are quite difficult to identify without use of molecular genetic methods, and therefore often are misidentified in museum collections. Additionally, although dates are associated with the presence records, users of such records sometimes pool data from fairly long periods of time; records for the Apple Valley area extend back to the late 1800s, when the Bureau of Biological Survey actively collected specimens throughout the western United States and deposited them in the National Museum of Natural History. Therefore, the composite records may represent whether the species ever has been detected in a given area—sometimes prior to extensive changes in land use or land cover—as opposed to whether the species is present currently. As noted below, standardized surveys are a potential means to fill data gaps.

Additionally, projections of habitat are not synonymous with projections of occurrence. It can be misleading to associate land-cover types or vegetation types with binary habitat classifications (i.e., habitat or non-habitat), and then to assume that a target species may occur in any area projected to be habitat. Habitat is defined as the physical area occupied by a given species and the abiotic and biotic resources for that species that are present within the occupied space. Thus, habitat is defined from the perspective of a given species, and is different for virtually all species. Habitat is not synonymous with land-cover type, vegetation type, land-use type, or climate; desert and agriculture, for example, are not so-called habitat types. Habitat is suitable by definition—suitable habitat is redundant, and unsuitable habitat is an oxymoron—and its quality varies in space and time. Furthermore, species typically occur in or use a more circumscribed area than that projected to be habitat. Reliance on coarse-grained estimates of habitat presence is likely to overestimate considerably the area in which a given species may occur. Doing so is not precautionary, but constitutes weak inference. Use of continuous models of habitat quality or occurrence probability is preferable to use of binary models.

Descriptions of some of the DRECP models that were available in DataBasin reference use of expert knowledge. We support use of expert elicitation as one of the ways to minimize the error inherent in developing models that must be based on few data (e.g., O'Hagan et al. 2006, Martin et al. 2012). However, we caution that asking experts for their opinion does not constitute formal expert elicitation. Expert elicitation encompasses a rigorous set of methods for synthesizing knowledge to inform decision-making, and has proven reliable and practical when field data are limited (e.g., Donlan et al. 2010). It is useful for identifying plausible alternative hypotheses, estimating model parameters, and prioritizing collection of data that may have considerable bearing on policy or management decisions (Martin et al. 2012). The information may be elicited as point estimates or as distributions of parameters (Runge et al. 2011). Although expert elicitation can be valuable, it is not necessarily fast, cheap, or easy. Even formal expert elicitation cannot substitute for collection of robust empirical data.

We recommend adding geology and soils to the natural-community classifications and to testable projections of where species being considered for coverage occur. For example, knowledge of where carbonate substrates are located may help to project occurrences of plant genera including *Acanthoscyphus*, *Boechera*, and *Sclerocactus*. Free data on soils at 10–100 m resolution are available from the USDA Natural Resources Conservation Service's Soil Survey Geographic Database (SSURGO). If the accuracy of soil data for the planning area is uncertain or low, it may be worthwhile to invest in a soil survey in the planning area.

Design of reserves that will conserve species, landscapes, ecosystems, and ecological processes in the planning area

The fundamental principles of reserve design have been well-established for more than 40 years (Diamond 1975). All else being equal, the probability of achieving conservation objectives at any level of biological organization increases as the size of reserves increases, as the spatial continuity of reserves increases, as the isolation of reserves (at least those with similar ecological attributes) decreases, as the evenness of distance among reserves increases (i.e., reserves that are equidistant generally are more effective than reserves that are distributed linearly), as the land cover between reserves becomes more similar to that within the reserves, and as dispersal distances within reserves decrease (i.e., reserves that are approximately circular generally are more effective than reserves that are long and narrow) (Diamond 1975). Nevertheless, all else virtually never is equal. For example, species that inhabit riparian areas in a desert may have a higher probability of persistence in a long, relatively narrow reserve along a free-flowing stream or river than in a circular reserve centered around the stream.

Presence of a species (i.e., detection of individuals) and presence of a population are not synonymous. Presence of a population generally implies that individuals are reproducing or that there is a regular flow of immigrants into the area. Furthermore, absence at a given point in time (e.g., during a particular survey) does not necessarily mean that the species is not using the area. The population structure of many species is dynamic; local populations are connected by limited dispersal, and regularly become extirpated or recolonize patches of habitat. Similarly, the quality of patches of habitat varies in space and time.

Assessing whether objectives related to connectivity of populations—as distinct from connectivity of a given land-cover type—have been met requires documentation not only of presence of the species but of movement through a given area. One cannot assume that an area of putative habitat functions as a movement corridor. Similarly, assessing whether an area functions as habitat, whether seasonally (e.g., breeding habitat), for a given behavior (e.g., foraging), or more comprehensively, requires evidence that the species is not only present but using the area for that purpose. For example, validation that an area functions as breeding habitat requires evidence of reproduction and of survival of offspring.

Potential ecological responses to climate change

Beyond first principles (e.g., conserve areas with varied topography and elevation; Anderson et al. 2014), it is not possible for us to comment with confidence on how individual species are likely to respond to climate change or whether particular strategies or actions are likely to allow the species to persist within the planning area as climate changes. One can develop models to make testable projections of such responses, but it is essential to evaluate these projections rigorously over time.

Many research groups are downscaling global climate models (GCMs; about 100 to 300 km native resolution) that were included in the Coupled Model Intercomparison Project Phase 5 (CMIP5) and the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPPC). However, the focus of most downscaling efforts is on temporal means rather than extremes, and the two often are not tightly correlated. For example, across much of the southwestern United States, mean daily maximum temperature in the warmest month (July) is not highly correlated with the maximum temperature on the warmest day of the same month. Climate extremes can cause mortality or asynchrony with food sources and can affect energy budgets, developmental processes, and reproductive behavior of species (Parmesan et al. 2000, Lovich et al. 2014). Temperature and precipitation extremes often are strongly associated with species' range boundaries (Easterling 2000). Effects of climate extremes vary according to their magnitude, timing, and abruptness relative to species' life cycles (Jentsch et al. 2007). Extreme weather or climate events especially may affect species at the edges of their ranges, where they are near their physical limits (Hoffman and Parsons 1997), and when the species' capacity to acclimate is substantially exceeded, resulting in atypical physiological or developmental responses (Gutschick and BassiriRad 2003).

In some cases, deviations in temperature, precipitation, or other climate variables relative to local means may be more relevant than actual temperatures for projecting effects of climate extremes because the former accounts for local acclimation. For example, animals and plants in coastal California become heat stressed at lower temperatures than inland residents (Knowlton et al. 2009, Gershunov et al. 2011, Guirguis et al. 2013).

Droughts of annual to multidecadal (e.g., 50 years) duration were frequent in the Southwest over the last 2000 years (Woodhouse and Overpeck 1998, Cook et al. 2010, Routson et al. 2011) and likely will become more extreme and possibly more frequent (e.g., Cayan et al. 2010). Heavy precipitation in the Southwest is projected to increase. Even CMIP5 simulations that do not yield substantial changes in mean annual precipitation project changes in the frequency and intensity of daily precipitation events. The ensemble-mean frequency of wet days and the precipitation amounts on those wet days are projected to decrease and increase, respectively, over the Southwest (Dettinger 2011, Gershunov et al. 2013, Kunkel et al. 2013, Polade et al. 2014). As a result, within-year and among-year variability are projected to increase.

Numerous efforts have been made to classify species according to their potential susceptibility to future changes in climate (e.g., Barrows 2011, Gardali et al. 2012). These so-called vulnerability indices often are based on the extent of the species' current distribution and the climate within that area as compared with the extent and location of areas projected to have similar climate in the future; biological traits, from genetic diversity to environmental associations to dispersal ability; and whether observed changes in the species' distributions were associated with historical changes in climate. For some taxonomic groups (e.g., birds), such classifications have been conducted at levels from global (Foden et al. 2013) to continental or national (National Audubon Society 2014) to state (e.g., Nevada's Natural Heritage Program applied NatureServe's Climate Change Vulnerability Index [Young et al. 2011] to more than 100 species of birds). Proponents of vulnerability indices commonly suggest that the classifications can be used to inform or prioritize management actions. Rarely if ever have the indexes been evaluated empirically, especially at scales relevant to management actions. Lack of evaluation hinders identification of tractable management actions for species and their habitats that go beyond those based on first principles.

Most analyses that have been applied to project species' responses to climate change, including those based on presence-only data (e.g., MAXENT, Phillips et al. 2006) or presence-absence data (e.g., occupancy models) (MacKenzie et al. 2006), implicitly and erroneously assume that relations between attributes of a given species and climate variables do not vary in space or time (e.g., MacDonald 2010). There is ample evidence of such variation (Lovich et al. 2012). Adaptive responses of species to climate change, which may reflect either phenotypic plasticity or adaptive evolution (Reed et al. 2011), may occur over years or decades (MacDonald et al. 2008, Willis and MacDonald 2011). Some long-term demographic data (e.g., Reed et al. 2013) and theoretical models of population genetics allow one to explore rates of climate change that may allow populations to persist (Reed et al. 2011) or lead to extirpation (Moore and Pavlik 2015). Incorporating estimates of phenotypic plasticity and local adaptation in models of species' responses to climate change typically yields estimates of survival and area occupied that are higher than if evolutionary processes were not modeled (Garzón et al. 2011).

Identification of goals and objectives for adaptive management

Many definitions of adaptive management exist. We define adaptive management as an iterative process of experimentally testing alternative hypotheses and changing actions in response to new information. Because the public generally expects social and economic systems to be predictable, organizations that implement adaptive management must reconcile that process with the fact that predictability in management actions can seem more fair and transparent than flexibility, and with the public's desire for stability and certainty. For example, Apple Valley's residents may wish for certainty in zoning, outdoor recreational opportunities, regulatory constraints to land use, and the status of protected species. The regulatory certainty that would be created by a fully executed HCP / NCCP may conflict with the flexibility inherent in a true adaptive management program. Adaptive management generally must be flexible not only to biological uncertainty, but to social uncertainty. This reality is reflected in the US National Research Council's (2004) definition of adaptive management as "[a] strategy that aims to create flexible resource management policies that can be adjusted as project outcomes are better understood and as stakeholder preferences change."

A number of enabling conditions must exist for adaptive management to be implemented and succeed. Information must have a high value in decision-making, and there must be a real choice among management alternatives. Moreover, that choice must affect target resources. Adaptive management requires a commitment from the implementing organization to measure the outcomes of management, and to take action, despite uncertainty, in response to those measurements. It must be possible to express uncertainty as a set of testable, quantitative models. It must be possible to take different actions in the future and to set a priori triggers for changes in adaptive management. Also, the temporal extents of learning and decision-making must be similar.

The objectives of adaptive management must be explicit and measurable. Concepts such as health, integrity, functioning, and sustainability, which are common in statutes and in documents such as records of decision, are not easily translated into measurable targets. Conservation and protection also are difficult to quantify. Furthermore, the targets cannot be set strictly on the basis of science. The basis for quantitatively defining concepts such as healthy, adverse impact, recovery, or endangered usually is an acceptable level of risk (i.e., a probability), also referenced as a risk characterization. Society may consider some level of change in abundance, survival, or reproduction to be tolerable. For example, member states of the European Union suggested that an average annual decrease in population size of > 1% over 12 years would lead to unfavorable conservation status, a potential violation of the European Union's habitats directive (92/43/EEC). The latter implies that an annual decrease in population size of ≤ 1% over 12 years is tolerable. Although science can inform selection of the acceptable level of risk, the acceptable level fundamentally is a societal value that is predicated on ethical judgments or personal policy preferences (Wilhere 2012). The Glen Canyon Dam Adaptive Management Program, one of the oldest and best-funded adaptive management programs, is a rare example of effective implementation of this form of management (Gloss et al. 2005, Lovich and Melis 2007). At a smaller extent, an adaptive management program for a rare plant in the Lake Tahoe Basin is considered successful because it obviated the need to list the plant under the US Endangered Species Act and produced practical guidance for implementation of similar management programs (Pavlik and Stanton 2014).

Despite statutes that prevent take of individuals, only those takings and the environmental changes that affect survival or reproduction in the wild are relevant to assessment of population persistence (NRC 2013). Habitat-based goals may be acceptable to regulators, but do not allow inference to the status of the species. That an area serves as habitat is a hypothesis that only can be validated by survival and reproduction of the species. Similarly, presence of a species in the planning area may not indicate presence of a sustainable population, whether in the planning area or regionally. If there is an expectation that the HCP / NCCP will contribute to recovery, then goals should be related to survival and reproduction. Although theory suggests that occupancy reflects abundance, and abundance is associated with viability, these relations rarely have been evaluated empirically.

We suggest that the adaptive management process be informed by theories of change—hypotheses about the mechanisms by which a given activity or set of activities might be expected to result in a given, measurable biological effect that is consistent with a specified conservation objective (e.g., Stem et al. 2005, Pavlik and Stanton 2014). Use of theories of change is well-established in the field of program evaluation (the systematic assessment of the implementation or results of a program) (e.g., Bonner 2003, Auspos and Kubisch 2004, Blamey and Mackenzie 2007).

Theories of change can be communicated in many ways, including the use of conceptual models and results chains (Margoluis et al. 2013). A conceptual model presents mechanistic hypotheses about the relations between a response variable and the anthropogenic or natural covariates that directly and indirectly affect the response variable. A results chain presents hypotheses about the mechanisms by which a given intervention (i.e., an action intended to improve a particular situation) will ameliorate the undesirable effects of a human activity and thereby improve the status of the response variable (Margoluis et al. 2013). Even if no intervention is planned, and thus development of a results chain is not warranted, theories of change are applicable to the design of monitoring to assess biological responses to management and other types of environmental change.

Conceptual models and results chains are included in a set of open-source, standardized methods for project design, management, and monitoring that were developed by the Conservation Measures Partnership (conservationmeasures.org), a group of more than 20 international conservation organizations. Results chains often are more explicit than conceptual models (Margoluis et al. 2013). For example, results chains specify not only the hypothesized indirect and direct effects of a disturbance and which effects are linked, but the hypothesized direction of each intermediate effect (e.g., an increase or decrease), and ideally, the hypothesized magnitude and timing of the effect. In some cases, one can use simulation modeling to identify variables or relations in the theory of change that will reduce uncertainty to the greatest extent. One also can apply value-of-information analyses to identify which uncertainties are most relevant to decision-making (Runge et al. 2011, Moore and Runge 2012).

It may be quite difficult to measure whether objectives related to contributions of Apple Valley to range-wide conservation of covered species have been achieved. Status or management outside the planning area will affect status within the planning area. Objectives related to native or, especially, endemic species, should reference the area of endemism (e.g., Mojave Desert, southwestern United States).

We suggest that objectives related to human disturbance (e.g., assumptions about relations between a given land use and survival or reproduction of a given species) be based on robust empirical data and rigorous analyses in the peer-reviewed literature, and that such objectives not be based on hearsay. Similarly, we suggest that assumptions about responses of covered species to predation be scrutinized. There are few data on whether predators are constraining survival and reproduction of covered species at the population level (but see Lovich et al. 2014), or whether any measures intended to minimize predation or predator populations are effective. In general, predator control is not highly effective. For some species, control of domestic animals, let alone decisions about allocation of land use, may be equally or more effective than trying to control native predators.

Adaptive management in the context of HCP / NCCPs is constrained by the lack of a established and reliable source of funds. Apple Valley is not unique in its need for development fees to acquire reserve lands and to begin implementing management, whether adaptive or otherwise. We suggest that concurrent with acquisition, a process be implemented for testing hypotheses about connectivity (e.g., that a given area supports movement of individuals between populations).

We suggest that Apple Valley consider maintaining soft rather than hard edges between development (e.g., housing) and areas in which development will be minimized. For example, it may be more feasible to maintain ecosystem function if riparian areas are not channelized or armored, but some overflow is possible during high-water periods. In non-riparian areas, occupancy, reproduction, and movement of native species may be more feasible if domestic animals are not allowed to roam freely. Continuation of Apple Valley's current incentives for xeriscaping and use of native plants in landscaping, especially along wildland edges and near riparian corridors, also may increase the probability of occupancy, reproduction, and movement of native species, and decrease human demands for limited water. We suggest minimizing fencing that may impede movements of native species (Harrington and Conover 2006, Stevens et al. 2012, Woodroffe et al. 2014).

Apple Valley assumes that societal acceptance of the goals and methods of the HCP / NCCP is necessary for the success of these plans. We think this assumption is quite reasonable. Apple Valley also assumes that favorable attitudes about the goals and methods of the HCP / NCCP will lead to behaviors consistent with achieving those goals. Moreover, the town assumes that community participation in local, practical, and scientifically informed restoration and management projects will lead to acceptance of and support for the HCP / NCCP and to effective management. In our professional judgment, the latter two assumptions warrant testing (Heberlein 2012). For example, if environmental education emphasizing the Mojave Desert is implemented in primary and secondary schools as part of the HCP / NCCP, we suggest that Apple Valley work closely with education professionals and social scientists to measure attitudes and behaviors over time. Apple Valley expressed interest in establishing continuing education programs. We suggest that the town explore the potential for partnerships with master naturalist or similar programs and development of a volunteer docent program. Groups in the Santa Monica Mountains may be effective partners or mentors for a docent program. If Apple Valley chooses to conduct outreach with user groups, especially recreational-use groups, then we again suggest that the town work with social scientists to increase participation in restoration and management efforts and to measure attitudes and behaviors over time.

Opportunities to fill data gaps

Standardized surveys are a potential means to fill data gaps in existing occurrence records. It may be helpful to prioritize species for which records are sparse (but the species is believed to be more widespread or abundance) or old, or that are believed to occupy areas in which land use or land cover has changed considerably in recent decades. Given the extent to which precipitation, and variation in weather more generally, can drive ecological responses in the Mojave Desert, it is essential to conduct surveys across years with different weather patterns.

Delineation of populations on the basis of geography typically is a hypothesis that can be tested with demographic and genetic data. It would be quite helpful to collect and analyze genetic data to characterize effective population sizes (Ne) and perhaps the effective number of breeders in one reproductive cycle (Nb). Genetic data also can provide information on movements among populations (i.e., connectivity), historical trends in population size, and genetic distinctiveness. These data can be compared to estimates of census population size (Nc) to prioritize management actions.

We suggest that Apple Valley collaborate with wildlife epidemiologists to track diseases that may affect covered species, such as white-nose syndrome in bats, upper respiratory tract disease in desert tortoise, and pneumonia and bluetongue in bighorn sheep.

White-nose syndrome, which is caused by the fungus *Geomyces destructans*, has substantially reduced the abundance of hibernating bats in the northeastern United States (Foley et al. 2011). Although the mechanism of mortality is not fully understood, severity of infection in hibernating bats is positively correlated with the frequency of arousals from torpor. Arousals increase body temperatures and reduce energy stores, ultimately leading to starvation and death (Reeder et al. 2012). It has been hypothesized that *G. destructans* increases arousal frequency by dehydrating membrane surfaces (Willis et al. 2011).

G. destructans occurs in environments with high humidity and can survive at temperatures above 3˚ C. Depending on the strain of the fungus, growth is optimal from 12.5–15.8˚ C, with an upper limit of 19–20˚ C (Verant et al. 2012). Growth rates of the fungus are sensitive to small changes in temperature, translating into differences in severity of infection on the basis of small changes in microclimate within a hibernaculum (Verant et al. 2012). Bats in relatively cold regions may be more susceptible to mortality than bats in relatively warm regions given the higher energetic costs associated with disruption of torpor (Boyles and Willis 2009) and that longer durations of hibernation increase the likelihood of exhausting energy stores (Flory et al. 2012, Hallam and Federico 2012).

White-nose syndrome was detected in the northeastern United States in 2006. It spread steadily and by early 2013 had been detected as far west as Missouri (Butchkoski 2013). Although the fungus can be dispersed via animals, wind, or water (Hayes 2012), transmission is thought to occur primarily through contact between bats (Lorch et al. 2011). The fungus can persist in cave substrates in the absence of bats (Lorch et al. 2013), and transmission through contact with cave environments in which the fungus is present also is possible (Lindner et al. 2011, Puechmaille et al. 2011). Density-dependent declines in abundance of solitary bats have been observed. By contrast, species that cluster in a hibernaculum are linked to high transmission rates regardless of population size (Langwig et al. 2012). Migration also is thought to drive the spread of white-nose syndrome (Frick et al. 2010), and the presence of migratory bats within a hibernaculum may increase probability of infection (Sullivan et al. 2012).

Hibernating species may have the highest probabilities of infection with white-nose syndrome (Cryan 2012). Two of the species that occur in the Mojave Desert, big brown bat (*Eptesicus fuscus*) and especially little brown myotis (*Myotis lucifugus*), were affected by white-nose syndrome in the eastern United States (Foley et al. 2011). A case of the fungus in *M. lucifugus* in the state of Washington was confirmed in March 2016, suggesting the potential for long-distance transmission by migrating bats or perhaps by humans who come in contact with the fungus. Climate data from caves and mines in national parks in the Mojave Desert and across the western United States indicate that conditions could support *G. destructans* growth. However, it is unclear how *G. destructans* will respond to the lower humidity typical of the arid and semi-arid western United States.

A frequently lethal bacterial infection that causes pneumonia frequently occurs in bighorn sheep populations throughout the western United States. In 2013, populations in the eastern Mojave Desert became infected. Although maintenance of connectivity between populations generally is considered to be consistent with achieving conservation objectives, isolation of local populations of bighorn sheep may help to prevent transmission of disease during outbreaks.

We think it would be helpful to compile additional information on the underlying assumptions, methods of development, and effectiveness of current conservation areas (e.g., ACECs) for plants and animals.

We suggest that four elements be included in designing and implementing a monitoring program to evaluate whether human activities, including management, are affecting the survival and reproduction of covered species (Fleishman et al. 2016). The first is development of a theory of change: a set of mechanistic hypotheses that outline why a given activity might be expected to have one or more measurable effects on individuals and populations, and ideally the magnitude, timing, and duration of the effects. The second element, definition of biologically meaningful effect sizes, ultimately facilitates the development of a monitoring program that can detect those magnitudes of effect with the desired levels of precision. The third element, selection of response variables for monitoring, allows inference to whether observed changes in the status of individuals or populations are attributable to management. The fourth element is specification of the temporal sequence of monitoring.

Although common, it is not best practice to measure change and then decide whether the level of change is acceptable. Collection of data on responses to management or other environmental changes will yield more insight if biologically meaningful effects are defined before monitoring begins (Murphy and Weiland 2011). Models of population growth, which are parameterized with estimates of demographic rates, allow one to gauge how variation in survival and reproduction affect a population's probability of persistence over a given period of time. Once an allowable level of take has been specified, outputs from a population model also can inform the design of a monitoring program with the capacity to detect the associated effect size (the defined magnitude of the biological effect) with desired levels of precision (Noon 2002). For example, one could apply a population model to assess the extent to which a 2% annual decrease—or a positive or negative change of any other magnitude—in a population's size is likely to affect the population's probability of extirpation over 20, 50, or 100 years.

Financial and technical support for implementation

Apple Valley is in the process of translating its biological goals and objectives for its HCP / NCCP into explicit, measurable objectives that account for regional land cover and land use, land tenure, stakeholder expectations, and partnership opportunities. We strongly suggest that Apple Valley's budget include funds to employ a staff biologist with extensive scientific training (e.g., a graduate degree in ecology) and practical experience in management of natural resources to coordinate implementation of the HCP / NCCP and to develop or strengthen collaborations with agencies, academic institutions, and educators. We are encouraged by the potential for conservation of open space in the western Mojave that would be associated with scientifically informed implementation of the Apple Valley HCP / NCCP, and grateful that we have been able to contribute to the process.

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Table 1. Results of a search of nine quadrangles, centered around Apple Valley, California, of the California Native Plant Society's online inventory of rare, threatened, and endangered plants of California (www.rareplants.cnps.org). *Acanthoscyphus parishii* var. *goodmaniana* is listed as endangered under the US Endangered Species Act. None of the species are listed under the California Endangered Species Act. Highlighted species have a relatively high probability of occurrence in the planning area or are of relatively high conservation or legal concern. CNPS, California Native Plant Society. CA, California.

Hemizonia (*Dienandra*) *mohavensis*, *Mentzelia tridentata*, *Eriogonum ovalifolium* var. *vineum*, and *Boechera shockleyi* also were included on Apple Valley's preliminary species decisions list (*H. mohavensis* as likely to be covered, and the other three species as requiring further input or research), but did not appear in the nine-quadrangle search. Of these four species, *Mentzelia tridentata* is likely to occur in the planning area.

							Elevational range (m)			Initially considered for coverage		
Scientific name	Common name	Family	Lifeform	CNPS rank	State rank	Global rank	high	low	CA endemic	likely to cover	more input needed	not likely to cover
Acanthoscyphus parishii var. *goodmaniana*	Cushenbury oxytheca	Polygonaceae	annual herb	1B.1	S1	G4?T1	2377	1219	yes			X
Androsace elongata ssp. *acuta*	California androsace	Primulaceae	annual herb	4.2	S3S4	G5?T3T4	1200	150	no			
Boechera dispar	pinyon rockcress	Brassicaceae	perennial herb	2B.3	S3	G3	2540	1200	no		X	
Calochortus plummerae	Plummer's mariposa lily	Liliaceae	perennial bulbiferous herb	4.2	S4	G4	1700	100	yes			
Canbya candida	white pygmy-poppy	Papaveraceae	annual herb	4.2	S3S4	G3G4	1460	600	yes		X	
Castilleja plagiotoma	Mojave paintbrush	Orobanchaceae	perennial herb (hemiparasitic)	4.3	S4	G4	2500	300	yes			
Chorizanthe spinosa	Mojave spineflower	Polygonaceae	annual herb	4.2	S4	G4	1300	6	yes			
Cryptantha costata	ribbed cryptantha	Boraginaceae	annual herb	4.3	S4	G4G5	500	-60	no			
Cymopterus deserticola	desert cymopterus	Apiaceae	perennial herb	1B.2	S2	G2	1500	630	yes	X		
Cymopterus multinervatus	purple-nerve cymopterus	Apiaceae	perennial herb	2B.2	S2	G4G5	1800	790	no			

Dudleya abramsii ssp. *affinis*	San Bernardino Mountains dudleya	Crassulaceae	perennial herb	1B.2	S2	G4T2	2600	1250	yes		X
Eremothera boothii ssp. *boothii*	Booth's evening-primrose	Onagraceae	annual herb	2B.3	S2	G5T4	2400	815	no		X
Eriophyllum mohavense	Barstow woolly sunflower	Asteraceae	annual herb	1B.2	S2	G2	960	500	yes	X	
Lycium torreyi	Torrey's box-thorn	Solanaceae	perennial shrub	4.2	S3	G4G5	1220	-50	no		
Mimulus mohavensis	Mojave monkeyflower	Phrymaceae	annual herb	1B.2	S2	G2	1200	600	yes	X	
Muilla coronata	crowned muilla	Themidaceae	perennial bulbiferous herb	4.2	S3	G3	1960	670	no		
Opuntia basilaris var. *brachyclada*	short-joint beavertail	Cactaceae	perennial stem succulent	1B.2	S3	G5T3	1800	425	yes		
Pediomelum castoreum	Beaver Dam breadroot	Fabaceae	perennial herb	1B.2	S2	G3	1525	610	no		
Saltugilia latimeri	Latimer's woodland-gilia	Polemoniaceae	annual herb	1B.2	S2	G2	1900	400	yes		X
Sclerocactus polyancistrus	Mojave fish-hook cactus	Cactaceae	perennial stem succulent	4.2	S3	G3	2320	640	no		
Scutellaria bolanderi ssp. *austromontana*	southern mountains skullcap	Lamiaceae	perennial rhizomatous herb	1B.2	S3	G4T3	2000	425	yes		
Symphyotrichum defoliatum	San Bernardino aster	Asteraceae	perennial rhizomatous herb	1B.2	S2	G2	2040	2	yes		X