Report of Science Advisors

For the

Eastern Merced County
Natural Community Conservation Plan
Habitat Conservation Plan

Part I: General Review of Approach, Methods, and Planning Principles, and Responses to Initial Questions

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INTRODUCTION

Our group of advisors was assembled to offer independent review of the scientific foundations for the Eastern Merced County Natural Community Conservation Plan (NCCP)/Habitat Conservation Plan (HCP), a plan in progress. The objective of our review is to ensure the quality of the data, planning principles, analytic techniques, and interpretation of analytical results. We are charged to offer an independent evaluation of the science upon which planning decisions will be made in the proposed NCCP/HCP and to provide advice about how to improve the process with sound science. We generally will not comment on the goals or outcomes of planning. Moreover, for the purposes of this review we ignore the differences between NCCPs and HCPs and, instead, focus on scientific questions of concern to both processes. Although we avoid explicit comment on policies, it is difficult to divorce a discussion of scientific issues entirely from their policy implications.

We were selected by the County of Merced to conduct this review based on our knowledge of the geographical area and its ecology and/or for our expertise in conservation biology and planning (see Appendix A for brief biographies of the Advisors and Facilitator). Collectively, we offer expertise in locally occurring species and natural communities (for example, birds, mammals, reptiles, amphibians, vernal pool crustaceans, vernal pool plants, grasslands); important ecological processes and the physical environment (for example, water flow, soils, natural and anthropogenic disturbance regimes, landscape ecology); quantitative modeling; reserve design; biological monitoring; agricultural science; and resource management. In addition, we have called upon other experts to supplement our knowledge as needed.

Our first meeting was a workshop held June 19-20, 2002, at the University of California, Davis. On the morning of the 19th we were presented with information on the goals and structure of the planning process from the consultants for the County (EIP Associates and TAIC), along with a review of the methods, assumptions, and data applied to the process. Presentations were followed by question-and-answer sessions and discussion. Representatives from Merced County, U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game (CDFG), and other parties directly involved in the planning process also attended this first portion of the workshop.

The first afternoon and most of the second day were devoted to closed-door discussions among the science advisors and facilitator, Wayne Spencer. Discussion during the afternoon of the 19th centered on the existing data and methods of closing data gaps. On the 20th we addressed a list of initial questions compiled by the facilitator prior to the workshop. We arrived at tentative answers to many, but not all, of these questions.

This report constitutes Part I (the major portion) of our review. It includes a brief review of general principles for conservation planning that are relevant to this process, followed by our responses to the initial questions provided to us prior to our meeting. We include discussion of major issues and concerns that emerged during our closed sessions. It is important to note that although we were retained by Merced County as individual science advisors and reviewers, our comments in this report represent a consensus and the collective opinion of our team, except as noted. Appendices C through G include submittals by individual advisors, which do not necessarily represent a group consensus on all points.

The content of this report is inherently technical, although we've attempted to make the information accessible to a non-scientific audience. For simplicity, we have generally omitted latinized scientific names from the text for all species whose scientific names are provided in Appendix B. A glossary of technical terms is also included at the end of the report to assist the reader.

Our review of the planning process for the Eastern Merced County NCCP/HCP, at this stage in its development, is generally positive. We are impressed with the competence of the consultants and with their willingness to consider our critique in a professional manner. Our comments are meant to help the County and its consultants improve what is already a commendable planning process and make it more defensible in the face of public scrutiny. We have attempted to make our recommendations consistent with the conservation planning principles of the Natural Community Conservation Planning (NCCP) program and with the findings of recent research in conservation biology and other scientific disciplines.

PLANNING PRINCIPLES

In conservation planning, as in many other fields, principles are essentially empirical generalizations – things we have learned from experience. Although each case is to a large extent unique, when we look at enough cases, general patterns emerge. There are exceptions to all principles and generalizations, of course, and planners must constantly be on guard for those exceptions. Nevertheless, principles serve to guide planning and action in the absence of adequate case-specific data, or until such data can be gathered later in the planning process. Because HCPs and NCCPs are constrained by available time and money, there will rarely be enough data to assure that the decisions made are the best decisions possible. Nevertheless, if attention is paid to well-accepted planning principles, decisions can be defensible despite limited data.

Principles for Addressing Data Gaps and Uncertainty

Endless or unfocused data gathering is poor planning and poor science. At some point data must be analyzed and the results interpreted and applied to the decision-making process. In science, data are gathered, in part, to test competing hypotheses. Data are also gathered to learn enough about a place or a species that useful hypotheses can be formulated. In conservation planning, some of the most important data are those relating to the species, communities, and other features of interest in the planning area. Simple mapping of these data may show "hot spots" where features of interest are concentrated. More sophisticated analyses are necessary to determine how these features can be incorporated most efficiently into a reserve system, or to test hypotheses about the relative viability of species under alternative designs. Finally, data are gathered through monitoring programs to track the status of species or ecosystems over time and to test the effectiveness of alternative management techniques or programs. Because data are virtually always incomplete, decisions must be made in the face of uncertainty.

1. Ecosystems are not only more complex than we think, but more complex than we ***can*** think (Egler 1977).

Although the physical properties of ecosystems are based on invariant laws and are relatively predictable, biological responses are less predictable. As one moves from the physical to the biological realm, the basis of practical knowledge moves from universal laws to theories to empirical generalizations. Ecologists have a good general understanding of natural ecosystems, and the process of science is one of expanding knowledge and reducing uncertainty. Nevertheless, surprises are inevitable. For this reason, scientists generally recommend that caution and prudence be exercised when attempting to conserve or manage natural ecosystems. A frequently advocated approach is adaptive management (Holling 1978, Walters 1986), a process in which the ecosystem is monitored closely so that management can be systematically adjusted in response to new knowledge.

2. The fewer data or the more uncertainty, the more conservative a conservation plan should be.

Scientific certainty and an abundance of data are not necessarily equivalent. Nevertheless, with less information on the status of species, communities, and other elements of biodiversity, there is less certainty about how human activities may affect those elements. When information on species distributions, population sizes and trends, interactions among species, responses to disturbance, and other factors is scarce or questionable, a defensible strategy is one that minimizes development and other human disturbance until sufficient biological information becomes available to make reasonably accurate predictions about the effects. A key element of this "precautionary principle" is that it shifts the burden of proof to those entities proposing actions that might harm the environment. Under a strict application of the precautionary principle it would be up to a developer, for example, to show that his activities would not have a significant negative impact on the fauna and flora of a particular area. Spatial scale must be considered carefully in such cases, as an activity that has a strong impact locally may be of trivial consequence on a regional scale. This would not necessarily lead one to condone the activity, but rather to examine carefully whether the local or regional scale is more important. Conversely, the cumulative effect of many small projects that have minor local impacts is often significant when considered at a broader spatial or temporal scale.

In practice, application of the precautionary principle is not straightforward, because the principle does not specify what kind and level of precautions should be taken. Moreover, there are complicated issues of private property rights and regulatory taking, with sometimes contradictory legal precedents. In an NCCP/HCP planning process, the precautionary principle is typically applied case by case through negotiation, a process beyond the purview of science advisors. Nevertheless, the general idea, that cases with fewer data or more uncertainty demand a more conservative approach, is scientifically defensible. As scientists, we feel that the appropriate way to make strong recommendations in the face of uncertainty is to start the planning process conservatively, acting under the assumption that projects and processes that appear (based on common sense and existing data) to be detrimental to existing ecosystems probably *are* detrimental. This position reflects the fact that environmental damage, once done, is either impossible or extremely expensive to remediate. Thus, the most prudent and economically viable strategy is to construct plans that are initially sound, and therefore will not require expensive remediation in the future.

Principles for Landscape-scale Conservation and Reserve Design

Conservation biology, as we know it today, began in the 1970s with increasing awareness of the global extinction crisis. Its emergence was spurred, in large part, by interest in applying the equilibrium theory of island biogeography (MacArthur and Wilson 1967) to the problem of maintaining species within islands of natural habitat in human-altered landscapes. Principles of reserve design offered by conservation biologists in the 1970s (e.g., Diamond 1975) appealed to island biogeographic theory and were based on experience with extinction-prone animals, particularly rare birds and large carnivores.

Considerable research in conservation biology has been conducted since the 1970s, including in the emerging arena of ecosystem management. Inspired in part by research demonstrating the central importance of ecological processes in ecosystem sustainability, ecosystem management has provided many lessons about managing landscapes where the matrix is neither pristine nor entirely converted to intensive uses. The conservation planning principles developed by the Scientific Review Panel (SRP) for the NCCP program reflect the evolution of reserve design principles from the 1970s to the early 1990s. The California Department of Fish and Game and California Resources Agency directed that "subregional NCCPs will designate a system of interconnected reserves designed to: 1) promote biodiversity, 2) provide for high likelihoods of persistence of target species in the subregion, and 3) provide for no net loss of habitat value from the present, taking into account management and enhancement." The SRP recommended seven principles of reserve design as a way to accomplish these goals, to which an eighth was later added. In the last decade, more has been learned about what is required to maintain biodiversity in human-altered landscapes. This new knowledge can help us apply the SRP principles (below) to specific NCCPs/HCPs.

1. Conserve target species throughout the planning area.

Species that are well-distributed across their native ranges are less susceptible to extinction than are species confined to small portions of their ranges. This is because a widely distributed species will be unlikely to experience a catastrophe, disturbance, or other negative influence across its entire range at once. Variation in environmental conditions, such as precipitation and temperature, often influences population growth, but the broader a species' distribution, the less correlated that variation will be among sites. At any given time some populations of a species may be increasing while others are declining. The distributions of species should be considered at multiple spatial scales (for example, within the planning area, within the county, within the ecoregion, and across their entire range) in order to plan for their viability over the long term and to encompass genetic variation among populations. In addition, reserves should be distributed across all geological substrates and east to west as well as north to south. A broad distribution of reserves will help conserve genetic variation within and among species, reducing extinction risk as well as fostering greater overall diversity of habitats and species.

For most of the target species in the Eastern Merced County planning area (see Appendix A), we know relatively little about population differentiation and viability. For the few that we do understand, it appears that populations are somewhat interconnected, but also somewhat independent. This "semi-independence" of populations leads to the strong conclusion that keeping species well-distributed across the landscape, with ample opportunities for natural recolonization in the face of local extirpation, protects natural population processes and provides the best chance of retaining species across the management area.

2. Larger reserves are better.

That reserves should be large is probably the best-accepted principle of conservation biology (Soulé and Simberloff 1986). Larger areas typically have more habitats, individuals, and species than smaller areas, for a number of reasons (Noss and Cooperrider 1994). All else being equal, large populations are less vulnerable than small populations to extinction. The strongest support for large reserves comes from considerations of population viability for species with large home ranges and/or low population densities—for example, large mammals. Much recent research suggests that small areas, especially when isolated, tend to lose diversity of mammals over time (Newmark 1987, Gurd et al. 2001). In the Eastern Merced County study area, wide-ranging species such as kit foxes and badgers require large blocks of contiguous or connected habitat. Small reserves in a fragmented landscape will not likely maintain viable populations of these species. Brian Cypher and colleagues have observed this phenomenon in the southern San Joaquin Valley, where a number of small patches of seemingly high-quality habitat exist, but badgers and kit foxes rarely occur on these small areas.

On the other hand, there are cases in which a large number of small reserves will contain more species than a small number of larger reserves of equivalent total area, especially if one considers plants and invertebrates, which do not necessarily need large areas to survive, but have many species with localized distributions. Therefore, although reserves ideally should be large in order to benefit multiple species, small reserves should not automatically be written off as useless for conservation, especially where better alternatives no longer exist.

There may not be a simple relationship between reserve size and its relative importance. For some species, a 100-acre reserve may be nearly as effective as a 1,000-acre reserve, while for others a 1,000-acre reserve may be orders of magnitude more effective than a 100-acre reserve. The biology of individual species must be considered on a case-by-case basis. For example, recent data on reptile species persistence in coastal sage scrub patches in California (R. Fisher, unpublished data) suggests that snakes with broad foraging habits (e.g., coachwhip snake, *Masticophis flagellum*) are much more prone to extinction in small reserves than in large ones. However, more sedentary species (e.g., whiptail lizards, *Cnemidophorus hyperythrus*) may persist in very small habitat patches, even if they are bounded by roads and subdivisions.

3. Keep reserve areas close to one another.

Blocks of habitat that are close to one another (i.e., clustered) are better than blocks of habitat that are far apart. Suitable habitat for a species often does not occur in a single patch, but is distributed among a series of patches. The width and nature of the intervening habitat is an important consideration. Many organisms are capable of crossing narrow swaths of unsuitable habitat, such as a trail or a narrow road; far fewer are able to successfully traverse a six-lane highway or a major metropolitan area. In the absence of impenetrable barriers, habitat blocks that are close together will experience more interchange of individuals of a target species than will blocks far apart. If enough interchange occurs between habitat blocks, they are functionally united into a larger population that is less vulnerable to extinction for any number of reasons. For example, California tiger salamander breeding sites that are within about a kilometer of each other exchange a reasonable number of individuals, and are therefore able to "rescue" each other if a population falls to very low numbers (Trenham et al. 2001).

4. Keep habitat contiguous.

Habitat that occurs in less fragmented, contiguous blocks is preferable to habitat that is fragmented or isolated by urban or agricultural lands. Fragmentation involves a reduction in size of habitat patches and an increase in their isolation. Considering a single species, a small and isolated habitat patch is expected to have a smaller population and less opportunity to be "rescued" by individuals dispersing in from surrounding populations (Brown and Kodric-Brown 1977). Similarly, an unoccupied patch of suitable habitat isolated by fragmentation is less likely to be colonized or recolonized by the species in question. Ultimately, loss of local populations may lead to extinction of the regional population or the species as a whole.

Effects of fragmentation at community, ecosystem, and landscape levels are also well documented (Noss and Csuti 1997, Debinski and Holt 2000). Problems include edge effects that reduce the area of secure interior habitat in small habitat patches and often lead to proliferation of weedy and opportunistic species; increased human trespass and disturbance of sensitive habitats and species; and disruption of natural disturbance regimes (e.g., fire and flooding) and other natural processes. The end result of fragmentation is often a landscape that has lost sensitive native species and is dominated by exotics and other weeds (Noss 1983).

In most regions in which NCCPs and HCPs are being prepared, some high-value habitat is already heavily fragmented. Before "writing off" such areas as useless, a careful consideration of their potential value for particular species should be made. Many plants and invertebrates, and some vertebrates, are not particularly sensitive to fragmentation. Heavily fragmented landscapes may be the only areas where some of these species currently exist, and thus may have high conservation value. Nevertheless, small and fragmented parcels of habitat are generally less defensible against external threats and are missing many key ecological processes. If small fragments are included in a reserve system, intensive management will be required to sustain a semblance of ecological integrity in these areas.

Thus, all else being equal, larger reserves are better than smaller ones. If a landscape is already fragmented, restoration efforts to enlarge or combine small reserves into larger ones should be encouraged, particularly if sensitive species are "hanging on" in those small patches. Finally, even the smallest habitat patches should be censused before concluding that they are unimportant or of little conservation value. This is particularly true where narrow endemic species may persist in very small patches or unique habitat types.

5. Link reserves via corridors.

Connectivity is the antithesis of fragmentation. Interconnected blocks of habitat often serve conservation purposes better than do isolated blocks of habitat. Although arguments over the benefits versus costs of corridors persist, well-designed studies of corridors generally show that they provide beneficial connectivity for the species of interest (Beier and Noss 1998). Corridors or linkages can be expected to function better when habitat within them resembles that preferred by target species.

Some basic guidelines follow from the connectivity principle. They include (a) all else being equal, wide swaths of suitable habitat are better than narrow corridors; (b) corridors longer than normal dispersal distances for a target species should be sufficiently wide or have enough "stepping-stone" habitat patches to provide for resident home ranges; (c) animals usually follow a path of least resistance when moving through a landscape, such as along ridgelines, gentle contours, and riparian networks; (d) planners should base connectivity designs on the needs of species most sensitive to fragmentation (Noss and Cooperrider 1994).

For the kit fox and some other species in the San Joaquin Valley, mini-reserves were recommended to help individuals travel through landscape impasses such as urban areas. In addition, "stepping stones" through agricultural lands (produced through retirement of small parcels of farmland, living hedgerows, or other modest adjustments to agricultural land use practices) were proposed to aid kit foxes and other relatively mobile species (U.S. Fish and Wildlife Service 1998). Obviously, however, stepping-stone connections are inferior to continuous connections, and their use in conservation planning is generally restricted to cases where options for continuous connections have already been lost. A general design principle is to avoid worst-case designs, except where options for better designs are lost. We generally advocate stepping-stone connections only where continuous connections are no longer an option.

The connectivity requirements of vernal pool species are poorly known. Some hydraulic connectivity among vernal pools typically exists in all but drought years, because vernal pools typically fill and spill (i.e., one spills to the next one downstream and so on). These fixed routes of water movement allow for a one-way movement of water, but may provide for two-way connectivity for invertebrates and some vertebrates. A routine exception exists for large playa pools, which have much larger watersheds than typical vernal pools and which often do not overflow. Instead playa pools, which occupy large, flat basins, get larger with additional rainfall and runoff and therefore remain isolated in most years. Flooding can provide periods of linkage between playa pools as the entire landscape becomes inundated, and can also link the linear water routes that drain vernal pool landscapes, providing connectivity between pools. In general, the frequency of this type of connectivity, which depends on flood events, increases as the prevailing slope of the landscape decreases. In steeper vernal pool landscapes, adjacent pools separated by as little as, for example, 50 feet, may never be hydraulically connected if they are in different watersheds.

Presumably, flooding in years of high precipitation provides for movement of individuals among pools, and consequent genetic mixing for many species, but this has been poorly studied. Scheidlinger (1984) reported that the number of species within pools is often correlated with the area of the entire local "archipelago" of pools, suggesting that pools are periodically linked together to facilitate dispersal. She recommended that hydrologic connectivity of pool complexes be an important priority of conservation plans for vernal pools. It has also been noted repeatedly that several characteristics of the vernal pool habitat related to habitat connectivity, such as habitat subdivision and strong localized environmental gradients, provide ideal conditions for rapid speciation (McVaugh 1941, Mason 1952, Ornduff 1966, Spencer and Rieseberg 1998). This is especially true for vernal pool plants, which are typically annuals, have breeding systems that that often mix selfing with outcrossing, and have relatively low dispersal (Holland and Jain 1988).

One of the few species inhabiting eastern Merced County that has been reasonably well studied with respect to connectivity requirements is the California tiger salamand. In this species, there are no discernable terrestrial habitat corridors that are utilized in an uninterrupted landscape, and there is a clear relationship between the linear distance between breeding sites and the amount of genetic exchange between those sites (Trenham 1998, Trenham et al. 2001, Shaffer and Trenham in press). Thus, for this species, the rule of thumb is to retain sets of at least 4-6 breeding sites (i.e., large pools) within about a kilometer of each other, connected by grassland habitat, to maintain maximal connectivity.

6. Reserves should be diverse.

Blocks of habitat should contain a diverse representation of physical and environmental conditions. A trade-off may exist between capturing a diversity of environmental conditions within reserves versus among reserves. Maximal diversity within reserves corresponds to a relatively "fine-grained" habitat mosaic, with high beta diversity (i.e., turnover of species along an environmental gradient) but relatively small patch sizes of particular habitats. In contrast, maximal diversity among reserves can be attained by locating reserves in relatively large patches of particular habitats, but with different habitats featured in different reserves. This results in a more "coarse-grained" mosaic with lower beta diversity within reserves but larger patch sizes of particular habitats and potentially equivalent diversity across the network of reserves. We recommend trying to balance these two approaches, as different species are likely to be favored by each. One way to achieve such a balance is to simultaneously maximize diversity for both habitat specialists and wide-ranging generalists on the same landscape. In so doing, one may be able to de facto accomplish the best of both worlds in terms of local diversity protection.

Studies on the spatial distribution of vernal pool plant species have documented the importance of considering multiple spatial scales of diversity. Patterns of species diversity in the vernal pool flora exhibit regional scale responses to variation in soil type and geomorphology (Bauder and McMillan 1998), as well as pronounced variation in composition among and within pools (Lin 1970, Kopecko and Lathrop 1975, Holland and

Jain 1981, 1988). Similarly, complex patterns of community structure and local endemism have been described for many of the vernal pool crustacean assemblages (King et al. 1996, King 1998, Simovich 1998; Wilcox in review).

For example, Wilcox (in review) studied spatial and temporal structure in metapopulations of two fairy shrimp species in Merced County. He found that (1) the vernal pool fairy shrimp has an aggregated distribution, whereas the California linderiella is hyperdispersed; (2) differences in life history and dispersal mechanisms apparently influence these patterns; (3) in both species there is substantial turnover in which vernal pools are occupied over time. He concluded that vernal pool reserves must include a large number of populations and must accommodate both large clumps of pools in close proximity as well as scattered larger pools. Consequently, a reserve system for eastern Merced County should ideally maximize representation of all vernal pool types at multiple scales, both within and among different reserve areas, across the planning area.

7. Protect reserves from encroachment.

Blocks of habitat that are roadless or otherwise inaccessible to human disturbance serve to conserve target species better than accessible habitat blocks. Trombulak and Frissell (2000) listed seven general effects of roads that are documented in the literature: mortality from road construction, mortality from collision with vehicles, modification of animal behavior, alteration of the physical environment and drainage routes, alteration of the chemical environment, spread of exotics, and increased use of areas by humans. To these, we add the movement-barrier effect roads create for many animals, which is a direct form of fragmentation (Noss and Csuti 1997, Baker and Knight 2000).

To the extent that individual animals hesitate to cross roads, roads fragment populations into smaller demographic units that are more vulnerable to extinction. Studies have shown that many species of small mammals, beetles, amphibians, and other species rarely cross roads, especially wide ones (e.g., Mader 1984). For those animals that do attempt to cross roads, significant numbers are killed, which may lead to population declines and extinctions (Baker and Knight 2000, Fahrig et al. 1995).

Just as roads serve as barriers to the movement of some species, they serve as conduits for the invasion of others. For example, many exotic plants, insect pests, and fungal diseases of trees are known to disperse and invade natural habitats via roads and vehicles (e.g., Lonsdale and Lane 1994, Parendes and Jones 2000). Disturbed roadsides harbor many weeds, which disperse along the route of the road and often invade adjacent habitats. Vehicles using the road transport seeds and spores long distances, sometimes hundreds of miles.

Aside from roads, access to reserves by trails (whether planned or created by users) can be problematic for some species, especially those sensitive to harassment (whether intentional or accidental) by humans. Even the most innocuous-appearing human trespass may have catastrophic effects on species persistence. Residential housing adjacent to reserves are sources of trespassing humans, dogs and cats, other opportunistic mesopredators (e.g., raccoons, opossums), fire ignitions, chemicals, exotic plants and animals, unnatural light regimes, and other threats. Buffer zones of reduced human activity and development adjacent to reserves might help reduce these threats. Examples include placing recreational parks, roads, or parking lots between reserve areas and more intensively developed areas.

Because eastern Merced County may soon experience rapid human population growth, human encroachment on reserves could be a major issue. Buffer zones between sensitive reserve areas and areas of intensive human uses could be used to minimize such effects. In some areas, more aggressive protective measures may be necessary, including fencing and closure of some existing but non-essential roads.

8. Maintain natural processes.

An eighth principle was added to the Southern Orange County NCCP principles and also was emphasized by Noss et al. (1997). Reserves that are designed to maintain natural processes will sustain native biodiversity better than reserves in which such processes are disrupted. Flooding, fire, grazing, erosion, and sedimentation are among the processes that are likely critical to the perpetuation of species and natural communities of concern within eastern Merced County. For example, woody riparian species are generally dependent on freshly lain sediments for seed germination and, as previously noted, flooding is critical in providing periodic connectivity among vernal pools (see also Appendix C).

Vernal pools and their dependent species are probably the resources of greatest concern in Eastern Merced County. The draft vernal pool recovery plan identified the study area as critical to the recovery of some of these species, and the area was included in the recently proposed vernal pool Critical Habitat designation for vernal pool crustaceans and plants (USFWS 2002). The processes that maintain viable populations of these species must be identified and sustained within a natural range of variability to sustain and recover these listed species. Given that many of these processes are poorly understood at this time (see Appendix C), maintaining large, intact reserve areas is the prudent approach. All else being equal, natural processes tend to remain healthy and active in large reserves, but tend to stop functioning in small reserves or ones that are heavily used by humans.

Biologists familiar with vernal pool ecosystems generally believe that maintaining their natural processes requires conserving not only groups of pools, but entire pool complexes and their encompassing watersheds (see Appendix C and Wilcox in review). One argument for this is that conserving entire watershed units will maintain natural hydrological processes that are essential to maintaining healthy vernal pool communities. However, hydrological studies are inconclusive regarding the specific effects of watershed size on pool dynamics. On the one hand, research by T. Hanes has shown that, once a relatively small watershed:pool area ratio exists, adding more watershed area does not significantly influence the inundation regime, at least on flatter terrain. Most vernal pools can fill with incident precipitation alone, and the importance of the surrounding upland is generally confined to a buffering influence, within about 25 feet of the pool margin, that tends to prevent early inundation and sustain it later in the season. However, other hydrologists believe these observations cannot be confidently extrapolated to all vernal pool landscapes, especially those on steeper slopes like those in Eastern Merced County (W. Wallender, R. Dahlgren, and T. Harter, personal communications). Thus, although we know of no published research indicating that reducing watershed area will *necessarily* induce a long-term adverse effect on pool hydrology, ecologists believe that essential ecological processes, which are not fully understood, function properly only within entire, interconnected vernal pool complexes and their watersheds (see Appendix C). The precautionary principle reinforces that this is therefore the prudent approach for conservation planning in this unique ecosystem. Reserve design should therefore consider natural hydrological and erosional regimes and attempt to encompass the area necessary to sustain them (including extreme events such as floods). Roads and other developments should be placed downslope from areas of intact vernal pools, to avoid changing natural flooding and depositional processes.

In addition, fire and grazing by hoofed mammals may both be important in controlling introduced grasses and herbs. These processes should be maintained and properly managed subject to results of biological monitoring under an adaptive management program.

Principles for Conserving Specific Target Species and Communities

The general principles reviewed above have relevance to the conservation of specific target species and communities in eastern Merced County. Generally, however, not enough is known about individual species to provide a detailed explanation of how various principles apply. We discuss what is known in our response to the initial questions (see below). Additional information is found in Appendices C through G.

Principles for Adaptive Management and Associated Monitoring

Principles for adaptive management and monitoring derive from the principles for data gaps and uncertainties, presented earlier, but must incorporate site-specific details. Here we offer some initial thoughts for consideration. Some of these issues are addressed in more detail in our responses to the initial questions, below. Others can only be expanded upon later in the planning process, as more site-specific and resource-specific information becomes available.

Adaptive management is an iterative process that evaluates management actions or program elements through carefully designed monitoring and proposes subsequent modifications (Muller et al. 2000). The modifications are in turn tested with an appropriate, perhaps redesigned, monitoring program. Even though adaptive management is logical, can deal with uncertainty and data gaps, and is similar to the scientific process of hypothesis testing, there are few examples of its successful implementation in the existing literature (but see Wisconsin DNR 1999 for a fully operating example). Although many reasons for its limited success can be cited, there appear to be two main reasons: (1) reluctance of resource managers to rely on monitoring data for decision-making, and (2) monitoring programs that are not specifically focused on management actions or that lack the statistical power to provide the necessary "comfort level" (level of certainty) that managers desire. Therefore, implementing an effective program for adaptive management and monitoring in eastern Merced County requires understanding the following principles:

1. Policy-makers, resource managers, and scientists must collaborate on the design of the adaptive management program from the very beginning of the planning process.

Initial "buy-in" as to how adaptive management works is absolutely essential so that policy makers and resource managers know how the monitoring program should be used and how it cannot be used. They must specify which management actions most urgently require evaluation, provide focus on specific issues to be included in the monitoring, and understand how the monitoring will provide the necessary data for modifying the existing action or proposing a new action. Similarly, the scientists must understand the policy and management needs, explain the design and limits of the proposed monitoring (e.g., error and power analyses), and provide useful distillations of the monitoring data for decision-making.

2. Different types of monitoring programs provide distinctively different services.

"Monitoring" is too vague a term to convey the variety of designs and information feedbacks that will be required for implementing an adaptive management program for all of eastern Merced County. Effective implementation of the NCCP/HCP will require these three types of monitoring:

Compliance Monitoring: This is a simple information feedback concerning fulfillment of permit conditions, mitigations, rates of land conversion, spatial patterns of development, preservation, or other forms of land use, and other non-biological measures. In essence, compliance monitoring should track whether the most basic objectives of the NCCP/HCP are being met. The County of Merced, through its planning department, could logically provide compliance monitoring for the eastern Merced County NCCP/HCP with oversight from the resources agencies.

Status and Trend Monitoring: Biological data on the population sizes, numbers of populations, areal extent, or quality of critical biological resources are subjected to trend analysis to determine how they are performing under the existing conditions imposed by the NCCP/HCP or under specific management regimes. Although agencies will probably require some kind of status assessment on all listed or CEQA species, the selection of indicator species or habitat types (see questions 3 and 4 of Species Addressed section, below) may provide a reasonable subsample of different organisms or community types for more detailed trend analysis. It should be noted the Status and Trend Monitoring does not establish cause and effect, but simply gives an evaluation of resource condition though time. Consequently, its statistical power must be appropriately evaluated to give managers clear indications of its limitations and levels of uncertainties. Sufficient monitoring to observe trends with statistical confidence is critical, since the inability to detect a trend will result in failure to alter management when such a change may actually be needed. Resource agencies (CDFG, USFWS) may have the appropriate expertise and databases for performing this kind of monitoring for the eastern Merced County NCCP/HCP, although they probably do not have the manpower to accomplish the task. The principles and techniques of trend analysis are given in Pavlik (1994), Willoughby et al. (1997), and Thompson et al. (1998).

Cause and Effect Monitoring: This is the most scientific of the three types of monitoring, because it tests management hypotheses with field experiments. It attempts to fill very specific data gaps by testing the effects of relevant variables (e.g., controlled burns, grazing regimes, reintroductions of rare species) on resources of concern (see Management and Monitoring section, question 2, below). A well-designed experiment with appropriate controls, replications and statistical power can provide the best management guidance, but is very specialized, time-consuming and relatively expensive. Consequently, this type of research-oriented monitoring would most likely be performed by qualified consultants or university scientists supplied with adequate levels of funding. The principles and techniques of cause and effect monitoring are given in Taylor and Gerrodette (1993), Pavlik (1994), Willoughby et al. (1997), Thompson et al. (1998) and Feinsinger (2001).

3. Oversight committees should facilitate communication among government, scientists, and the private sector.

Information flows between decision-making bodies and constituencies must be facilitated to promote the synergy necessary for successful adaptive management. Various structures have been proposed (Pavlik et al. 2002), but efficient and timely exchange of information between policy, research, and management must be of primary concern. A technical advisory group (TAG) should consist of policy, resource management, and scientific representatives that are responsible for the adaptive management program. Data from the various monitoring programs should flow back to the TAG, who recommend management alternatives or modifications to the NCCP/HCP. Recommendations of the latter sort should feed back from the TAG to a broader NCCP/HCP oversight group with broader representation (agencies, university officials, local government, development and agricultural interest) and the power to redirect or modify development or preservation activities.

RESPONSES TO INITIAL QUESTIONS

The following responses to questions submitted to the advisors by the facilitator, Wayne Spencer, emerged during our discussions at the June 19-20 workshop and in further thought and discussions thereafter. We present these responses as guidance to the planning process, albeit many are tentative and will change as new data become available.

Species Addressed

1. Is the current list of species to be addressed by the plan comprehensive enough to achieve the plan's biological goals? Should any species be added to assist in reserve design (e.g., species with no special protection status but that may serve as useful reserve design or monitoring indicators)? Should any species be removed as highly unlikely to be found in the plan area or be affected by the plan?

The list (see Appendix B) is a very good start, and is reasonably comprehensive, but we recommend several changes. First, we suggest that all CNPS List 1A species be considered High Priority, along with any other species that are endemic or near-endemic to the planning region (e.g., those with over 75% of their geographic range lying in the region). In particular, we recommend upgrading the following species to High Priority:

- Beaked clarkia
- Merced monardella
- Pincushion navarretia
- Shining navarretia
- Merced phacelia

We recommend that the following species be added to the target species list, for the reasons given parenthetically:

- Hogwallow starfish (*Hesperevax caulescens*; a good habitat indicator plant for clay flats)
- Red-legged frog (occurred historically in the planning area, and has potential for occurrence or reintroduction with appropriate management. Planners should confirm whether or not the planning area is within the designated critical habitat for the species. Incidentally, Brad Shaffer has written a manuscript that advocates elevating this endangered subspecies of red-legged frog to full species status, further emphasizing its unique biological status.)
- Badger (*Taxidea taxus*; an area-limited species that should prove useful for reserve design)

In addition, a new species of fairy shrimp (*Branchinecta*) may be described soon. If so, it should be added to the target species list, as it is presumably a narrow endemic. Fairy shrimp taxonomy is in need of a major update, and the list of target species should be revised over time to reflect changes in taxonomy (see Appendix C).

In general, we recommend that any species without recent documented occurrence in the planning region be deleted from the list of target species, unless the plan can demonstrate potential effects (positive or negative) on the species. We suggest the following species be deleted from the list, for the reasons given parenthetically (see Appendix D for additional detail), although we recognize that there may be precautionary reasons for retaining them:

- Aleutian Canada goose (recently delisted by USFWS; marginal or absent from Merced County east of Highway 99; D. Yee, J. Fulton, J. Gain, and H. Reeve, personal communications)
- Blunt-nosed leopard lizard (highly unlikely to occur in planning area; R. W. Hansen and S. Juarez, personal communications)
- Giant garter snake (highly unlikely to occur in planning area; R. W. Hansen, personal communication)
- San Joaquin antelope squirrel (highly unlikely to occur in planning area; USFWS 1998, S. Juarez personal communication)

Regarding the list of "Other Species for Consideration" (Appendix B) we tentatively recommend including all on the target species list *except* 4 birds and 1 mammal. The following birds have not been recently recorded in the study area and are considered unlikely to breed there or to be affected by the plan (R. Hansen, D. Yee, H. Reeve, J. Gain, D. Shuford, and K. Van Vuren, personal communications):

- Purple martin
- Barrow's goldeneye
- Black tern
- Western snowy plover

Likewise, the following mammal species is of relatively low sensitivity status and is considered unlikely to be affected by the plan, since it primarily occupies chaparral habitats in foothills outside of the study area (Laabs and Allaback 2002):

- California pocket mouse

In addition, the following species listed for consideration require more information on their status before being confirmed for the target species list:

- Silvery legless lizard (note, however, a historic locality is within the planning region, so potential habitat may exist)
- California horned lizard (again, a historic locality is within the planning region)
- Western least bittern
- All bat species on the list

2. Are there any new or pending taxonomic revisions or other issues that would affect the list of species addressed?

As noted above and in Appendix C, fairy shrimp (e.g., *Branchinecta*) are undergoing taxonomic revision. In general, these and other crustaceans are poorly known taxonomically. It is possible that genetically distinct temporal races (i.e., populations that emerge at different times) of some species exist. In fact, such variation is known to occur in some vernal pool plant species, and may occur in many others. In the few studies that have examined life history variation among populations in different pools and in sub-populations within pools, genetic differentiation has been detected (Linhart 1974, Keeler 1978, Linhart and Grant 1996).

We also note that, although there is not absolute consensus, most workers now use the generic name *Spea* instead of *Scaphiopus* for the spadefoot toad. The genus was split several years ago based on molecular evidence. Similarly, it has recently been suggested that the turtle genus *Clemmys* be reorganized, with the Calfornia species of pond turtle (previously *Clemmys marmorata*) shifted to the genus *Emys marmorata*. We recommend changing *Scaphiopus* to *Spea*, but retaining *Clemmys* for the moment. Several of the amphibian and reptile species listed are currently being examined at the DNA level in phylogeographic/taxonomic studies. Ongoing studies of the California tiger salamander (*Ambystoma californiense*), western spadefoot (*Spea hammondi*), foothill yellow-legged frog (*Rana boylii*), western pond turtle (*Emys marmorata*) and coachwhip (*Masticophis flagellum* complex) all may have bearing on the taxonomic distinctiveness of the Central Valley form. Emerging data indicate that this will almost certainly be the case for the coachwhip and the spadefoot, and that the tiger salamander is composed of more than one species. As noted above, Brad Shaffer advocates elevating the endangered subspecies of red-legged frog to full species status, *Rana draytonii*.

3. Are there effective ways of grouping species to assist in designing, managing, or monitoring a reserve (e.g., by species guilds or communities, landscape-level versus site-specific management requirements, narrow endemics versus wide-spread species)?

Grouping species into categories often is useful for recognizing shared characteristics and vulnerabilities of species, developing management strategies that may benefit multiple species simultaneously, and monitoring diverse communities by selecting subsets of species that are likely to respond to environmental changes in similar ways. However, we feel that the plan must individually analyze its likely effects on each species it proposes to cover, relative to all applicable state and federal standards.

One way to group species is by their scale of habitat use. For example, Poiani et al. (2000) recognized local-scale species (e.g., most plants and invertebrates, many small-bodied vertebrates), coarse-scale species (e.g., songbirds, medium-sized mammals), and regional-scale species (e.g., large carnivores and some ungulates). Because various development and management actions affect habitat configuration and quality on different spatial scales, such species groupings may be useful for predicting and monitoring responses of species and for implementing reserve designs and mitigation actions at the appropriate scale. For example, if the target species in a given case are all local-scale species, maintaining habitat quality in particular habitat patches (even quite small patches) might be the highest priority, whereas a reserve design for kit fox, badger, and other species that use habitat at coarse to regional scales must pay more attention to protecting large habitat patches and linkages among them.

Species differ tremendously in their vulnerability to human activities. Lambeck (1997) suggested that conservationists identify groups of species whose vulnerability can be attributed to a common cause, such as loss of area or fragmentation of a particular habitat type or alteration of a disturbance regime. Species in each group then can be ranked in terms of their vulnerability to those threats. Lambeck identified area-limited species, dispersal-limited species, resource-limited species, and process-limited species as vulnerability groups. For each group the focal species (the species we focus on in developing conservation plans) are the ones most demanding for the attribute that defines that group. They serve as the umbrella species for that group. Two or more species might be selected within a group, and a single species may occur in more than one group. Together, these species tell us what patterns and processes in the landscape must be sustained in order to sustain biodiversity. Their collective needs define the thresholds – patch size, isolation, fire frequency, etc. – that must be met if the native biota is to be maintained (Lambeck 1997).

To Lambeck's categories of important focal species we add keystone species, which have a profound influence on the ecosystems of which they are a part. The modern concept of keystone species separates them from dominant species and includes a number of examples besides top predators (which are perhaps the best known keystones). It is well accepted that the dominant species in a community exert a profound influence on energy flow, habitat structure, species composition and abundances, and other processes and patterns in the community (e.g., Newbould 1994). Keystone species, on the other hand, are less abundant, or even uncommon, species that exert a strong influence on the community, out of proportion to their numerical abundance (Power et al. 1996). For example, the burrowing actions of fossorial rodents, such as pocket gophers (*Thomomys* sp.) strongly affect soil, vegetation, and animal communities. Their burrows are used as shelters by numerous other vertebrate and invertebrate species, such as reptiles and amphibians that require them for aestivation. Furthermore, pocket gophers are probably responsible for creating and maintaining the unique mima mound and vernal pool microterrain of eastern Merced County and many other locales in the West (Cox 1981, and see Appendix E). Hence, many other species may ultimately depend on their activities.

Elimination of dominant or keystone species from an area is predicted to lead to cascades of direct and indirect changes on more than a single trophic level, ultimately leading to losses of habitats or functions crucial to the persistence of other species. Therefore, it may be appropriate to consider goals for maintaining these species, not in minimally viable populations, but in ecologically optimal populations, that is, within their natural range of variability in abundance. When they have declined, restoration (including reintroductions, where necessary) should be a high priority.

Table 1 summarizes several categories of potential focal or indicator species. Table 2 provides a conceptual overview of how various taxa may fit into indicator categories.

Table 1. Categories of species-level biodiversity indicators. Adapted from Noss (1990, 1991), Lambeck (1997), and Caro and O'Doherty (1999).

area-limited species	species with large home ranges or low densities, whose populations therefore require large habitat areas to persist
dispersal-limited species	species most limited in mobility or reluctant to travel through a developed landscape
resource-limited species	species most dependent on resources that are at least sometimes in critically short supply
process-limited species	species most sensitive to the frequency, intensity, timing, extent, spatial pattern, or other characteristics of fire, flooding, or other natural processes
keystone species	species whose impact on the ecosystem is disproportionately large for their abundance
flagship species	charismatic species that attract the attention and imagination of the general public
ecosystem health indicator	species sensitive to and indicative of anthropogenic disturbances to ecological functions

4. Are there any species that can serve as good indicators or umbrellas for other species, habitats, or communities?

As noted above (from Lambeck 1997) the most vulnerable species in each vulnerability group may be umbrellas for other species in that group. In addition to the ecosystem health indicators suggested in Table 2, local tarantula species and specialized pollinators (especially burrowing bees) may serve as indicators of habitat integrity. Despite their hypothetical inclusion in Table 2, not enough is known about the vernal pool crustaceans to recommend particular species as indicators or umbrellas. Vernal pool amphibians could certainly be used as an umbrella, since they require intact pools and surrounding terrestrial habitat. Tiger salamanders fill this role, although they only occupy large pools that hold water for a minimum of 2 months—so their use would not cover small pools needed by many other species.

Table 2. Species groups (rows) potentially useful as indicators of biodiversity in eastern Merced County, and the indicator groups (columns) in which they potentially fall. Note that species in different groups may function best as indicators at different spatial scales, for instance vascular plants and crustaceans at a local scale, songbirds and raptors at a landscape (coarse) scale, and carnivores at a regional scale.

	Area-limited	**Dispersal-limited**	**Resource-limited**	**Process-limited**	**Keystone**	**Flagship**	**Ecosystem health indicator**
endemic or sensitive vascular plants		Y	✔	✔			✔
endemic vernal pool crustaceans		✔	✔	✔			✔
songbirds	✔		✔			✔	
raptors	✔	✔	✔		✔	✔	
amphibians		✔		✔	some		✔
pocket gophers		✔			✔		✔
carnivores (kit fox, badger)	✔	✔			✔	✔	✔

Amphibians as a group might be useful as bioindicators in this ecosystem. Bioindication is the assessment of population changes in one or a few select species to infer effects of various practices and pollutants on larger organismal complexes or communities. Bioindicator species are much better understood for freshwater aquatic than for terrestrial systems. The use of arthropod bioindicators in agricultural systems has gotten little attention, although ants have been suggested as likely bioindicators (Peck et al. 1998). Amphibians have been suggested as especially sensitive to environmental perturbation, and several Californian amphibians are believed to be declining in part because of agricultural chemicals, especially organophosphorus insecticides (Davidson et al. 2001, 2002; Sparling et al. 2001). Perhaps such species could serve as bioindicators of agrochemical over-use. However, causes of declines of California's red-legged frog and foothill yellow-legged frog are still poorly understood, and may be complex (Ashton et al., no date). These declines have been related not only to pesticide use but also to introduced predators and changes in hydrology (e.g., dams and their management change stream flow and sedimentation patterns and thus affect breeding).

Davidson et al. (2002) examine 8 species of amphibians in California and evaluate hypotheses of decline that have a spatial component that can be tested using a GIS framework. They found that western spadefoot and California tiger salamander both are primarily sensitive to urban/agricultural habitat destruction as the primary cause of their declines in California. The other species examined, including the foothill yellow-legged frog and the red-legged frog, seem to be primarily declining due to agrochemicals. Hence, a finer-resolution classification of vulnerability guilds might be derived from studies of this sort.

Certain species may be useful as indicators of ecosystem degradation or "disintegrity." Invasive exotics stand out in this regard. In particular, vernal pool exotics (e.g., *Triops* spp.) may be good indicators of habitat degradation. Occurrences of fire ants (*Solenopsis invicta*; detrimental exotic, recently found in Merced County) should also be tracked and considered in reserve design and management.

In general, goals related to representing a broad diversity of physical habitat types in the planning region – the coarse filter approach – may do more for overall biodiversity than managing presumed umbrella species. We recommend that the recently completed classification of vernal pools by Bainbridge (2002), supplemented by a classification of soils in the planning region (see Appendix E) be used for this purpose. Nevertheless, the indicator species and groups suggested above may serve to guide reserve design and management, and be appropriate targets for monitoring.

Existing Data

1. Do the biological data reports prepared to date appropriately compile and interpret existing information, and do they present a firm scientific foundation for conservation planning? Are there additional data sources or literature pertaining to the resources of Eastern Merced County that should be incorporated into the database and considered during planning and analysis?

Although the data reports prepared to date do a good job of interpreting existing information, they do not present a firm foundation for conservation planning. Existing data on species distributions, particularly for plants and invertebrates, are insufficient for reserve selection and design based on species occurrences or a biological "hotspot" approach to reserve design. For most species, existing biological information and presence-absence (or abundance) data are insufficient to prepare species-specific distribution maps or habitat value maps. Almost nothing is known of demography, genetics, dispersal, or habitat relations for many or most of the target species (especially the narrow endemic plants and vernal pool crustaceans). Such information is essential for predicting species occurrence in space or time, and for recommending management actions. Many of these species are cryptic (hard to detect with single surveys) with long dormancy periods.

Moreover, many of the target species (especially vernal pool species) are tremendously variable in time as well as space, and surveys done in a single year (particularly a dry year) are insufficient for characterizing distribution or abundance. Holland and Jain (1984) found that vernal pool plant species that were widespread and relatively common during years of average or above-average precipitation were rare or completely absent during a dry year. The survey results compiled by the consultants are indicators of presence only (not confirming absence) for most species. In addition, surveys were performed using different sampling techniques (e.g., stratified random sampling versus other), making it difficult to compile into a unified database for producing or testing distribution models.

Swainson's hawk is an example of a bird that may have been under-detected in species surveys due in part to secretive behaviors of the species during the nesting season, concerns about the timing of surveys, and observations that the species is increasing and expanding its breeding range during recent years. Based on a personal observation of a juvenile Swainson's hawk along La Paloma Road during June 2002, as well as interviews with other birders knowledgeable about the region (W. Holt, K. Van Vuren, J. Fulton, J. Gain, S. Juarez, H. Reeve, and D. Shuford, personal communications) Robert Hansen believes that Swainson's hawks may be more common in the Merced area than indicated in the consultant reports. He recommends that the study area be surveyed using the more intensive survey protocols developed by the Swainson's Hawk Technical Advisory Committee, which requires 5 survey visits between late March and June.

Cryptic, sensitive reptiles (e.g., coachwhip snakes, legless lizard, horned lizard) may also be underrepresented in survey results. These species have all have been shown to be present in other areas (e.g., San Diego, Orange, and Los Angeles counties) when appropriate trapping designs were used, even though standard survey techniques failed to detect them.

Because "fine filter" data on species distributions are so limited for Eastern Merced County, planners will have to make more use of the "coarse filter" of protecting a full spectrum of habitat types along environmental gradients. As suggested above, setting representation targets for the geomorphic classes of vernal pools recognized by Bainbridge (2002) and soils classes from the Soil Survey of Merced County (see Appendix E) would help correct existing limitations.

2. What gaps in existing information create the greatest uncertainties for planning, analyzing, managing, and monitoring an ecosystem reserve in this setting? What are the most effective methods for addressing these data gaps?

See above. Unfortunately, time and funding limitations likely preclude obtaining more complete survey data for most target species in the planning area during the course of NCCP/HCP plan development. Nevertheless, there are several classes of information for which we believe data can be gathered in a cost-effective way, and which will aid the planning process. Among these kinds of information are the following:

- Additional soils data (see Appendix E). USDA soil series maps are considered the most precise and accurate of the available geological maps for predicting species occurrences or defining physical planning units. We recommend digitizing the soils series maps. However, it should be recognized that there are inaccuracies in these maps. The USDA/NRCS web page should be consulted for information on physical and chemical properties of local soils (the data behind the soil series maps). These data should at least be referred to and made available.

- More information is needed on temporal variability in vernal pool ecosystems, and this issue should be researched in the literature. For example, we recommend reviewing a copy of Chris Wilcox's dissertation (UC Santa Cruz; community and population dynamics and genetics in vernal pool crustaceans; see also Wilcox in review).

- We recommend obtaining additional data on vernal pool species via Robert Holland. A recently completed study (Hogle 2002) on Colusa grass, a playa pool "specialist," has indicated that the distribution of this grass among pools may be limited by dispersal rather than by habitat suitability. Within pools, microtopography and some aspects of soil chemistry were correlated with survival and reproduction of Colusa grass.

- We recommend seeking additional information on bat biology. However, according to Dan Williams (CSU-Stanislaus) none of the bat species likely to occur in the planning region need to be addressed in the target species list. In general, the grassland and vernal pool habitats are not critical for the bats of this region, although these habitats are sometimes used for foraging. Riparian and foothill habitats with trees and rock outcrops are more valuable to bats. Specific features in the landscape that might benefit bats include rocky outcrops, cliffs, old-growth riparian forests or stringers, water sources (including vernal pools, streams, stock ponds, and stock tanks), and anthropogenic features such as bridges and buildings including old barns, outbuildings, and abandoned homes.

- We recommend obtaining and using CDF fire history maps for the planning area to better establish relationships between fire history and resource distributions.

- We are concerned that much "gray literature" (unpublished) data may be missing from the consultant reports. Although this gray literature may not be as reliable as published literature, it is still a valuable source of information.

- Kevin Rice has been researching the status of recent vernal pool grazing studies. Observational studies on long term grazing exclosures have indicated that the margins of ungrazed vernal pools become dominated by exotic annuals, and the hydrology of the pool complex may become altered by the build-up of exotic plant litter (Barry 1998). Recently completed cattle grazing studies by The Nature Conservancy indicate that with no grazing there is a decrease in native plant species richness in both pools and pool margins. This decrease may be related to the increase of exotic species cover in ungrazed pools and pool margins (J. Marty, unpublished data).

- We strongly recommend compiling a GIS data layer summarizing what is known about current and historic grazing practices in the study area. Grazing records should be adequate for some ranches. The most readily available and useful data would be records of stocking rates and seasonal on/off dates. This information could be compared against data on the distribution or abundance of various species, either now or with future, more systematically collected, species data.

- It would be useful to have a GIS layer displaying the history of pesticide applications over several decades, if such data are available. At least for amphibians, pesticide contamination is a major issue. Carlos Davidson, CSU Sacramento (cdavidson@csus.edu), is working on statewide agrochemical applications, and may be able to provide such a layer.

- We recommend that up-to-date species distribution maps be prepared for all species on the target list (not just those sampled in consultant surveys). If possible, maps should clearly distinguish (1) unsampled areas, (2) areas sampled and species absent, and (3) areas sampled and species present. Criteria used for determining absence must be clearly laid out for each species.

- We recommend compiling a GIS data layer for certain invasive exotics. Among these are several weedy plants that follow roads, including goat grass, star thistle, and medusahead.

- We recommend obtaining accurate maps of existing and planned roads in the planning region, ideally categorized by road type or traffic volume.

- We recommend that range-wide genetics work be completed and incorporated into the planning process to identify "distinct population segments" for important target species. This has already been completed for the California tiger salamander and submitted to the USFWS (Shaffer et al., unpublished report). Such data for other vernal pool species would be invaluable in the planning process.

3. Are habitat suitability models or other models recommended for predicting species ranges where distribution data are sparse? If so, what standards for formatting, parameterizing, or testing such models are recommended? Are the existing data for input variables sufficiently accurate and precise to model species' distributions?

For most target species, data are too limited and biased by preferential sampling (i.e., sampling where the species is suspected to occur or be most abundant) to develop habitat suitability models. Hence, the ability to extrapolate beyond known occurrences and predict occurrences—much less population sizes or densities—elsewhere is extremely limited. In addition, some species may be dispersal-limited and thus their distribution may be poorly predicted by habitat variables. For example, in a recent study of the distribution of an endangered vernal pool species (Colusa grass), no environmental variables measured predicted the distribution of this grass among pools (Hogle 2002).

A few, better-studied species may lend themselves to creating useful habitat evaluation or suitability models, including:

- Badger
- Burrowing owl
- Swainson's hawk
- Tiger salamander
- Kangaroo rats

Conservation Guidelines and Reserve Design Process

1. What basic tenets of reserve design are pertinent to planning a reserve system in this area, and how should these tenets be translated into measurable standards and guidelines for reserve design? What theoretical or empirical support is available for designing necessary and sufficient biological core areas, linkages, wildlife movement corridors, buffers, or other aspects of reserve design?

We reviewed some basic tenets of reserve design in the earlier section on "Principles for Landscape Scale Conservation and Reserve Design," which included discussion of some of the theoretical and empirical support for designing core areas, linkages, corridors, and other components of reserve design.

An additional consideration, also referred to above is the relative emphasis that should be placed on "coarse filter" versus "fine filter" approaches to the inventory and protection of species and natural communities. The fine filter focuses primarily on species and populations. Individual occurrences of imperiled species (which may or may not correspond to populations) are located, mapped, and targeted for protection. This approach, as traditionally pursued, works well for plants and small-bodied animals, but performs poorly for large-bodied, wide-ranging animals. The fine filter is dependent on comprehensive, or at least well distributed, biological surveys to be most useful.

The coarse filter, on the other hand, seeks to protect samples of the entire range of environmental variation in a region, for example by locating and protecting high-quality examples of all natural communities or ecosystems. If applied to small, localized occurrences of imperiled community types, as it often has been in practice, the coarse filter is really not much different from the fine filter. If applied on a landscape scale, however, with the notion of representing all ecosystems in a region across their natural range of variation, the coarse filter is complementary to rare-species conservation. The coarse filter is an example of the representation approach to biological conservation, the history of which extends back to the early 20th century in North America (Noss and Cooperrider 1994).

Based on problems noted earlier with species distribution data and models, and the unlikelihood of sufficiently filling gaps quickly, we suggest that the overall approach to reserve design in the Eastern Merced County planning area should emphasize coarse-filter considerations, based primarily on physical factors. This coarse-filter approach should be supplemented as possible with a "fine-filter" approach based on known concentrations of rare species or other special features.

2. What objective methods are recommended for designing a necessary and sufficient reserve system to meet plan goals? Are explicit reserve selection algorithms (e.g., the SITES or MARXAN computer programs) recommended, and are existing data sufficient for their application? How can scientifically justifiable goals be set for such methods?

We recommend the use of an explicit site-selection algorithm in the planning region, e.g., a simulated annealing algorithm such as SITES or MARXAN. These algorithms are computer models used to find near-optimal solutions to the problem of attaining a given set of quantitative conservation goals most efficiently (typically, in the least overall area). This approach to conservation planning originated largely in Australia, and is now used by conservation researchers around the world, including The Nature Conservancy and other organizations in the United Sates.

Site-selection algorithms have many advantages over earlier approaches to reserve selection, which depended on manual mapping to delineate sites and on simple scoring procedures to compare and prioritize sites. The large number of conservation targets (i.e., species, communities, and other features) and the large size and diverse types of data sets describing the targets in large study regions require the use of systematic and efficient site-selection procedures.

We caution, however, that these algorithms do not provide what most researchers or stakeholders would consider an ideal reserve design. There remain many considerations (e.g., disturbance and hydrology regimes, connectivity for particular species) that cannot be incorporated adequately in a selection algorithm. Rather, what an algorithm does is give a set of sites to work with in developing a final design, e.g., a set of potential core areas to which transitional or buffer areas and linkages may be added. It can also identify the specific contributions each defined site makes to conservation goals. Hence, it makes explicit many of the tradeoffs involved in selecting or not selecting particular sites. For recent summaries of the use and limitations of site-selection algorithms, see Andelman et al. (1999), Margules and Pressey (2000), Possingham et al. (2000), Pressey and Cowling (2001), Noss et al. (2002), and Leslie et al. (in press).

3. *What aspects of the Eastern Merced County ecosystem (e.g., vegetation communities, geological substrates, climate regimes) should be used for setting reserve design representation goals? Which ecosystem gradients are most important to consider?*

We noted earlier that a coarse filter approach based on the physical environment is probably the most useful approach in this planning region. The general approach we tentatively recommended is:

1. Determine environmental gradients most relevant to species of concern (considering soil types and geological formations?). We recommend using the

Bainbridge (2002) classification system for vernal pools, as well as a soils classification (see Appendix E). We note that since some species require small, ephemeral vernal pools and others require much larger, longer lasting ones, there should be distinct planning goals to optimize each of these habitats. Also, for amphibians (which mostly breed in large pools), terrestrial habitat is also essential, often hundreds of meters away from pools.

2. Partition the study area into planning units based on geology, soils, and other relevant physical factors. (Note that watershed units may be helpful, but see discussion below regarding some cautions).

3. Use a site-selection algorithm (e.g., the SITES model) to identify large, intact landscape units that achieve representation goals for these physical gradients.

4. Run the model, guided by interaction from the science advisors.

5. Fit in known occurrences of species or other rare features (the "fine filter").

6. Supplement reserve design as needed for linkages, movement corridors, and hydrology based on pre-determined criteria. (Consider using badger, kit fox, and California tiger salamander to help define criteria for movement corridors.)

Watershed units may be helpful in partitioning the study area into planning units (number 2 above), although they may be too fine-scaled to be relevant for reserve design in this ecosystem, especially at elevations below the terrace landscape, where incised channels begin to form. An exception might exist for headwater pools, because fragmentation of headwater watersheds could affect large numbers of downstream pools. Hanes and Stromberg (1998) studied vernal pool hydrology by instrumenting vernal pool watersheds, conducting a paired watershed experiment to assess the effect of pool construction on the hydrology of an existing pool, evaluating overland flow and subsurface flow contributions, developing a model to predict watershed contributions, and performing other related investigations. Using a simple water balance model, which assumed no watershed contributions, they found that during years of normal precipitation the pools could fill from precipitation alone, and that during wet years the pools could fill to 4-5 times their maximum volume exclusively from incident precipitation. In contrast, during dry years, they observed no net inflow from the watershed. Since watershed contributions are nil during dry years and far exceed a pool's storage capacity during wet years, the importance of watershed runoff in influencing a pool's regime is limited to those years receiving near-normal precipitation. Overland flow into vernal pools happens so rapidly, and occurs during times when the pools are full, or nearly so, such that it has little influence on the inundation regime, and the residence time in most vernal pools is a matter of minutes. Hanes and Stromberg found that there are important pool-upland hydrologic interactions, but that these are typically limited to a narrow band around the pool perimeter. Vernal pools that are not in headwater positions generally have such large watersheds that the through-flow of water far exceeds the storage volume. However, for some playa pools, which may not routinely overflow each year, including the entire watershed in a reserve is especially important. While maintaining the entire watershed area of pools with large watershed:pool area ratios may not be needed to maintain their hydrologic integrity, it may nonetheless be important for many other natural processes. In Santa Barbara County, for example, science advisors strongly recommended against any activity, even walking trails, that could disturb the local watershed of individual playa pools (H.B. Shaffer, personal communication).

Given that there will be finite resources available for the purchase of lands or easements, we recommend that the plan provide a prioritization system to help guide county planners in protecting lands as acquisition opportunities become available. For example, lands supporting very rare or irreplaceable resources would be a high priority for protection, particularly if they are otherwise at risk of loss or degradation. The most biologically valuable sites should be selected by the site-selection algorithm, but they may need to be further prioritized for protection based on their inherent biological value (i.e., irreplaceability; Margules and Pressey 2000) and on such factors such as whether they adjoin or are close to existing reserves, establish connectivity between existing reserves, buffer existing reserves, or help maintain natural processes (e.g., protect intact watersheds). Lands that are more isolated or replaceable should receive lower priority for protection. We suggest that a defensible site-prioritization system will benefit county planners and also may help reduce some of the subjectivity and politics of acquisition.

It should be recognized that the age of geological substrates (soil age) is a relevant ecological gradient (see Appendix D). Soil type rarity should be recognized in setting representation goals (e.g., China Hat Ridge, the last example of a unique geological formation type in California). Furthermore, many of the best remaining vernal pools are in the southern portion of the planning area (e.g., highest occurrence of sensitive amphibians, lowest occurrence of exotic frogs?). Therefore, representation goals (or "penalties" for not meeting goals in the reserve selection algorithm) should perhaps be set higher for resources that are rarer or have declined the most since European settlement, and for subregions with documented higher habitat quality.

An additional possible consideration is using bird-nesting substrate for classifying habitat in representation analysis (e.g., short-grass versus long-grass nesters).

4. Does existing information reveal specific geographic locations that are critical to reserve design (e.g., biodiversity "hotspots," crucial linkages, rare microhabitats, genetically unique population areas)?

The entire planning area is a recognized hotspot of biodiversity. Nevertheless, we recommend against relying heavily on identified or presumed hotspots (based on species occurrences) for conservation planning within the planning area, as survey data for most species are so limited (see earlier discussion). However, well-documented hotspots should be included in site selection—for example, they could be "locked in" to the site-selection solution, in addition to existing protected areas. We suggest the following as potential "hotspots" of diversity to incorporate into the design:

- Smith Trust lands around Yosemite Lake
- Top of China Hat Ridge
- Pool complexes in southern portion of study area
- Playa pools containing sensitive species

Regarding corridors or linkages, planners should consider using kangaroo rats, kit foxes, and badgers as focal species for identifying critical areas. Information (anecdotal, if nothing better) on the movement patterns of these species should be sought. Otherwise, experts familiar with the species may be able to offer informed opinion on the location of likely linkages. It is likely that north-south (along contour) and east-west (across contour) movements and linkages are both important in the planning area.

Tiger salamanders may also be an appropriate focal species for considering connectivity as well as buffers in reserve design. These salamanders appear to disperse out in random directions from breeding ponds, but return from the direction of greatest habitat security. Thus, broad buffers around salamander breeding areas should be included in the design, even if they extend outside the pond's watershed. Additional research is needed to determine the necessary width of buffers in different settings, but current data indicate that buffers on the order of 1 km or more are needed, based on studies of this and other amphibian species (Trenham and Marsh 2001). For example, P. Trenham has documented natural migrations of California newts >3 km between ponds and upland habitats (Trenham 1998). For California tiger salamanders, Trenham et al. (2001) have recaptured marked salamanders moving between ponds separated by up to 670 m. In addition, during the 4 months after breeding, Trenham radio-tracked the movements of 11 adult California tiger salamanders, one of which moved to a burrow 248 m from the pond. The remaining documented movements were shorter distances, but several salamanders that were lost in the study may represent long-distance movements (Trenham 2001). Because this radio tracking only encompassed adults and a maximum of 4 months, the science team has been using the 670 m figure (0.4 miles) to guide recovery planning in Santa Barbara County. Other researchers have captured adult California tiger salamanders on the move >1 km from any known breeding pond, but the movements recorded by Trenham et al. (2001) are the only ones where the origin of the animals was unambiguously known. At this point this is the best available data for this species, and is considered as among the most extensive studies of its kind for any amphibian.

5. What ecological processes are most critical to maintaining ecosystem and species viability, and how can they be effectively accommodated in designing an ecosystem reserve for this region?

Hydrological processes are of obvious importance in the planning area. Nevertheless, the influences of hydrological variables such as watershed size and water quality on species composition are not well understood, and specialists sometimes disagree about the significance of certain variables. For example, although some researchers believe that watershed size is a critical variable affecting species composition, in 14 years of field experience T. Hanes has not observed a marked change in plant species composition as a function of watershed area relative to pool area. Hanes believes that this lack of a "hydrologic gradient" may be explained by the fact that vernal pool plants and many invertebrates reproduce as the pools are drying or have already dried, at which point the pools are no longer hydraulically connected. Water quality during the runoff season must then also not play a strong role, and, indeed, little variation in water quality is observed during runoff events within individual pool complexes (with the possible exception of pools in more alkaline settings). Even if a strong gradient in water quality existed across pool complexes, it is unlikely that species would become so specialized on such a fragile environmental trigger, since most runoff events rarely last longer than several days in these ephemeral drainage systems.

Rainfall patterns obviously play a part in the inundation regime of individual pools, and may influence which species germinate in which depth-inundation duration zones. The largest source of variation in inundation regime for non-headwater pools is the year-to-year variation in rainfall. As stated previously, vernal pools can fill entirely from incident precipitation in most areas, and even pools in headwater positions can fill and spill up to 10 times or more over their storage capacity during normal and wet years from a combination of incident precipitation and watershed runoff. Because the topographically determined inundation area is what provides for sustained inundation, it can be argued that as long as sufficient watershed area exists to allow the pool to fill, there will be no adverse long-term effect of additional variability in hydrology. The unique evolutionary pathway of vernal pool species is their ability to sustain populations over extreme variation in yearly inundation regimes, not their fragility with respect to the same. Nevertheless, significant changes in the hydrology of vernal pools induced by watershed disturbance or truncation, landscape irrigation runoff, or road construction that alters existing flow paths, should be avoided. Maintaining the natural inundation regime of the larger and more isolated vernal pools, especially playa pools, may be crucial for maintaining the more specialized plant and invertebrate populations these pools support, and also in providing for genetic mixing.

Another important ecological process is the influence of animals on habitat structure. As noted earlier, a leading hypothesis for creation and maintenance of the vernal pool/mima mound topography is the earth-moving action of burrowing rodents, chiefly pocket gophers. We are concerned that rodent poisoning or other land-management actions that reduce rodent populations may interfere with the long-term maintenance of these features by interrupting a natural ecosystem process. This issue should be carefully investigated, and in the absence of adequate data, a precautionary approach that maintains populations of burrowing rodents within natural size limits should be applied. Under such an approach, rodent control in or near reserve areas should only be implemented once it can be demonstrated that such control does no significant harm to essential ecosystem processes or components. Moreover, it is well known that rodent burrows are the most important source of summer retreats for amphibians and reptiles, including California tiger salamander and western spadefoot toad, and maintaining healthy rodent populations is a key element of their persistence.

Other symbiotic interactions among species should also be considered. Specialized pollinators are critical to many plant species, but understudied and therefore often neglected. Robbin Thorp at UC-Davis is a world expert on this topic, and should be consulted. Burrowing bees depend on uplands adjacent to vernal pools may be essential to the long-term sustainability of some vernal pool plant species. Likewise, dispersal vectors may be important to many species (e.g., dispersal of vernal pool crustaceans by cattle feet), but are largely unstudied.

Fire and grazing regimes are probably important to the maintenance of natural communities in the planning region, but require more study. Existing and ongoing studies and perspectives on these topics should be thoroughly researched. Most vernal pools in the planning region exist on privately-owned cattle ranches, which vary in how they manage the lands and likely vary in how they affect the integrity of biological communities. Ranchers interviewed by Billy Weir feel that it is fairly well accepted that proper cattle grazing is not harmful to vernal pools, but that seasonal grazing is preferable to continual grazing. Most of the ranch owners have cow-calf operations and pasture their animals only during October to May.

On the other hand, the conclusion of science advisors in Santa Barbara County was that grazing by livestock is detrimental to the long-term health of at least large playa pools, due to the potential for increased erosion and sedimentation in pools. Pools in a natural landscape can last for literally hundreds of thousands of years, because very little sedimentation, and hence no significant ecological succession, occurs naturally. The Santa Barbara advisors concluded that erosion caused by cows might change this sedimentation regime dramatically, hastening the decline of large playa pools.

In contrast, T. Hanes, found erosion potential to be nearly nonexistent in flatter vernal pool landscapes, even with cattle grazing. Erosion is a function of slope, slope length, rainfall energy, and surface roughness. Vernal pool landscapes are nearly level, and the steeper individual local slopes (e.g., mima mound slopes) are also very short. This limits the accumulation of overland flows and hence erosion potential. In California, where thunderstorms are rare in areas of vernal pools, there is also insufficient rainfall energy to induce erosion. T. Hanes also notes that cattle hoof prints, along with rocks and vegetation, add to soil surface roughness, thereby decreasing turbid flows into pools even more. T. Hanes' personal observations of grazed vernal pool landscapes during storms have shown very few occurrences of turbid runoff and no instances of rill erosion. The few instances where he has observed turbid runoff was in playa pool landscapes with clayey surface soils. There, T. Hanes suspects that introduction of fine sediments into pools is probably offset by wind erosion from the pool bottom during dry periods. Although cattle may disturb pool bottoms during inundation, and thereby directly create temporary turbidity within pools, T. Hanes' believes there is no significant net sedimentation in pools by sediment transport from outside the pools. Lastly, it would seem that fire, with its effect of removing all groundcover, would have a higher potential for causing erosion than cattle grazing, and yet vernal pool landscapes have experienced fire for thousands of years with no apparent ill effects.

Eviner and Chapin (2001) and Eviner and Chapin (in press), indicate that pocket gophers (*Thomomys bottae*) are important in reducing the establishment of the invasive exotic, barbed goat grass (*Aegilops triuncialis*) in grasslands of Mendocino Co., California. The authors cite other papers indicating that pocket gopher activity was reduced in grazed pastures (Hobbs and Mooney 1991, Hunter 1991, Stromberg and Griffin 1996). Since grazing has some value in controlling exotic species and maintaining biodiversity in grasslands, there may be trade-offs between livestock and pocket gophers.

Regarding fire effects on community composition, Pollak and Kan (1998) documented the beneficial aspects of controlled burns on the composition of both vernal pools and upland grasslands at the Jepson Prairie Preserve. They found that late spring burns increased the cover of both native grasses and forbs in pools and reduced the cover of most exotic species. Ongoing studies by The Nature Conservancy on the effects of controlled burns on vernal pool composition indicate that the increase of native species cover by controlled burning is more pronounced in upland sites. Although native species cover within pools is not very responsive to fire, species richness of native plants within pools is significantly increased by controlled burning (J. Marty, unpublished data).

Agricultural water management, via California's vast and intricate system of dams, reservoirs, canals, catchments, ditches, and irrigation systems, has greatly affected temporal and spatial patterns of water availability to natural communities in the study region (Bugg et al. 1998). Water districts alter flow patterns in all the major rivers flowing into the Great Central Valley except the Cosumnes River. The presence and management of dams affect not only flow but also sediment size and texture, and impact stream dynamics both upstream and downstream. Recharge of groundwater in flood plains can also be impaired. All this can affect the viability of native plants and animals.

Reduced groundwater recharge as a result of stream channel incision and reduced flooding has been invoked as a partial explanation for the decline of valley oak (*Quercus lobata*). Also, dam releases cause unnaturally high flows in late sping and early summer, washing away eggs and larvae of foothill yellow-legged frog, a species that breeds in channels with low flow.

In some cases, artificial wetlands and catchments that result from agricultural water use may seem to mimic natural features of the Great Central Valley, yet there are important differences. For example, due to patterns of impoundment, re-channeling, and release, the seasonal abundance of water in many areas may differ profoundly from natural patterns: many artificial wetlands contain water during seasons when water may not be available in nearby, more natural, systems. This can enable survival of invasive exotic species such as bullfrog (*Rana catesbeiana*), which interferes in various ways with red-legged frog, foothill yellow-legged frog, and Pacific treefrog (*Hyla regilla*) (Lawler et al. 1999, Chivers et al. 2001). This issue may affect siting of reserves, because bullfrog may colonize reserve areas that are located close to permanent catchments of agricultural waters. Introduced sport fish and mosquito fish also interfere with native fish and amphibians (Goodsell and Kats 1999, Lawler et al. 1999.), and are present in many permanent water bodies in the Central Valley, such as agricultural ponds. These fishes demonstrate a strong negative correlation with native amphibians, and have been proposed as a major threat to several species (Fisher and Shaffer, 1996). Permanent water bodies also enable overwintering by larvae of various dragonflies, especially *Aeshna* spp. and *Anax* spp. (Odonata: Aeschnidae), which in the succeeding spring are important predators of native amphibian larvae (see Petranka and Hayes 1998). Perhaps seasonal draining of such ponds would lessen these problems, as has been shown in other parts of the United States (Adams 2000).

Finally, nitrogen enrichment must be considered in our discussion of ecological processes, although the Science Advisors have not reached a consensus on its potential importance in this study area. Nitrogen enrichment of soils is known to pose a general threat to native Californian floristic diversity by favoring exotic annual grasses and weeds over native species, and thus creating physical conditions that promote increased fire frequency, which further favors exotics over natives (Minnich and Dezzani 1998, LeJeune and Seastedt 2001). In coastal Southern California, this occurs through atmospheric pollution and deposition of N, favoring invasive introduced Mediterranean annual grasses at the expense of native scrub vegetation (Allen et al. 1996, Minnich and Dezzani 1998, Padgett et al. 1999). In the San Francisco Bay area, analogous enrichment favors invasive introduced annual grasses at the expense of native forbs and associated butterflies (Weiss 1999). However, this effect is mitigated by cattle grazing that selectively removes the grasses. Grazing may enhance botanic diversity in other settings as well (Germano et al. 2001, Safford and Harrison 2001), but does not do so universally (Leiva et al. 1997, Hatch et al. 1999). In the face of increased development in Merced County, some advisors believe that atmospheric pollution and N deposition may be expected to increase, potentially changing the competitive posture of various plants. Others, however, believe that increased human development won't necessarily elevate N deposition relative to existing conditions, and point out that agricultural practices may have a greater effect on N levels than other sources. We therefore recommend that these issues be more thoroughly researched during plan development, and that management and monitoring plans address potential effects as appropriate.

Nitrogen enrichment of freshwater aquatic systems can occur as the result of land-use patterns and farming systems (Honisch et al. 2002). Data from Marco et al. (1999) suggest that larval Amphibia may be especially sensitive to such perturbations, and that adverse effects occur below the thresholds recommended by the U.S. Environmental Protection Agency. This should be considered in the management of reserve lands, and in recommending best management practices for agriculture in the region. Appendix F provides further review of farm-wildlife issues relevant to the study region. Appendix G includes abstracts of articles related to farmland management and nitrogen enrichment.

6. How can long-term processes or cycles (e.g., population dynamics, disturbance cycles, ecological migration) be effectively addressed? What effects might local or global climate changes have on this ecosystem and the target species, and how can these effects be effectively addressed?

We addressed processes above (albeit incompletely, due to insufficient information). Little is known about how the species and processes in this ecosystem respond to climate change. The ecosystem appears to be driven by cyclic processes of climatic variation at annual, decadal, and longer temporal scales. In the absence of more information, maintaining heterogeneity and connectivity within and among the natural communities of the planning region, as well as connections to other adjoining regions, is a safe strategy (e.g., see Noss 2001). Obviously, the potential for upslope migration of biological communities with climate change (see Field et al. 1999 for an overview) suggests that broad connections be maintained with the Sierra Nevada ecosystem.

Conservation Analyses

1. What types of data can best be quantified (acres, population sizes, distributions, etc.) to analyze plan effects on target species and ecosystem processes? What other issues must be addressed to confidently assess plan effects on species or ecosystem viability (e.g., effects on symbionts, competitors, mutualists, predators, population genetics, etc.)?

Many variables in the planning region can be quantified better than they have been so far, and this would aid conservation planning and effects analysis. For example, such ecological processes as fire, grazing, and flooding can be quantified in terms of frequency, intensity, seasonality, areal extent, and so on. It would be useful to quantify the extent of flooding and the interconnectedness of vernal pools, particularly the larger pools in the southern portion of the planning area, during El Niño (wet) years and to analyze the effects of existing and planned roads on flood events affecting pool connectedness. However, hydrological models that would allow such an analysis are only now being developed by a vernal pool research team at UC-Davis. Hanes and Stromberg (1998) developed a vernal pool hydrologic model in 1992, which has been used to evaluate the sensitivity of watershed area on vernal pool inundation regimes and can also be used to evaluate periodicity of pool filling.

Acreages of soil types, vernal pool density classes, and other habitat features can also be better quantified and used in representation analyses. It should be recognized, however, that one cannot necessarily predict vernal pool size, depth, and duration of inundation based on soil types.

Measures of fragmentation and connectivity, such as edge:area ratios, also may be valuable in reserve design and analysis. Population genetic data on indicator species could be collected to gain further information on natural connectivity of populations in those species, and to analyze likely plan effects on genetic diversity. If several species of vertebrates and invertebrates were studied that have different biological attributes, it might be relatively quick to assess how species use the landscape. This information, in turn, would inform decisions about the appropriate size and configuration of reserves. Candidate species for such analyses include the California tiger salamander and spadefoot toad, and perhaps some fairy shrimp. Such analyses could be added to ongoing research on the amphibians in the region for a modest cost, or possibly at no cost at all if specimens were made available.

2. How should uncertainties about plan effects be addressed in the conservation analysis?

As discussed earlier, the precautionary principle provides general guidance, but not specific advice. Nevertheless, from the standpoint of maintaining biodiversity (including viable populations of the target species), it is always better to put more land than necessary into the reserve system, rather than too little. In the long term, the best approach is to keep land management flexible and responsive to new information, which is the key attribute of adaptive management.

Management and Monitoring

1. What management actions are necessary and sufficient to meet the plan's biological goals? How are current or future land uses likely to directly or indirectly affect biological resources on adjacent reserve areas, and vice-versa? How might adverse effects be minimized via the adaptive management program?

A general lesson is that we cannot rely on management to compensate for habitat loss and fragmentation, especially given the level of ignorance about this ecosystem. Probably the most urgent concern about current or future land use is that development will sever inter-pool connectivity and lead to an irreversible degeneration of the ecosystem. Adaptive management only works when options are left open, and this is possible only if a significant portion of the planning region is left undeveloped and unirrigated. Then, adaptive management can be applied to grazing, fire, water management, and other practices in an experimental manner to determine what practices contribute most positively to biological goals.

The topic of vernal pool creation and restoration is controversial, with most of our team highly skeptical of previous efforts. There is strong consensus among our group that vernal pool creation and restoration should not be allowed to substitute for preservation (e.g., see Appendix C) , and is therefore not a mitigation for lost pool habitat. The state-of-the-art of vernal pool creation has progressed to the point where some projects are successful from a jurisdictional perspective, in that new vernal pools meet the jurisdictional definition of wetlands and mimic the hydrology and floristics of nearby natural pools. However, most apparently successful projects are less than 10 years old and the long-term trends and sustainability of vernal pool flora, invertebrates, and amphibians have not been verified. For this reason, preservation must be the fundamental strategy in maintaining vernal pool ecosystems within the planning area, and this preservation must be on a landscape scale that protects both large complexes of vernal pools and isolated large pools with sensitive species. Vernal pool creation—consisting of constructing new vernal pools within existing vernal pool complexes or constructing new pools on substrates that do not normally support vernal pools—is not at this time a scientifically supportable method to mitigate for loss of pools or reduction in the size of vernal pool habitat areas. Nevertheless, vernal pool restoration—consisting of restoring former vernal pool landscapes that were previously leveled for agriculture or other reasons—may serve as acceptable mitigation on a very limited basis, as long as rigorous design and construction standards are developed to ensure that only projects of the highest quality are performed, and provided that such efforts are treated as experiments within a broader adaptive management program.

Another issue is how design and management of reserves relates to management of other lands in the study region and beyond—e.g., is management of reserves and farmlands conflicting or complementary in terms of meeting conservation goals? Reserve design and management should relate meaningfully to other regional land uses, and synergies may be obtained through cooperation and collaboration with other private and public land managers, scientists, and regulators, as well as with advocacy organizations and educational institutions. Such collaborations, for example, could lead to subtle changes in farm management that profoundly affect wildlife survival, breeding success, and dispersal patterns (see Appendix F). Thus, to attain maximal results, reserve design and management require a comprehensive view and an interactive approach.

Milk, chicken, cattle, and turkey production as practiced in Merced County all present potential contamination issues that require address in order to protect ground and surface waters and associated native organisms. These issues include nitrate, phosphate, coliform bacteria, protozoan parasites, antibiotic feed additives (e.g. antimicrobials and anthelminthics), and growth hormones (both natural and synthetic) that can act as endocrine disruptors. Regional authorities on these issues include Steve Goodbred <goodbred@usgs.gov>, US Geological Survey, Sacramento and D. Michael Fry <dmfry@ucdavis.edu>, Dept. of Avian Science, UC Davis.

The confinement feeding operations for poultry and cattle raise the possibility of using vegetative filter strips to reduce run-off of contaminants and increase their tenure time and their likelihood of breaking down. Such filter strips have been suggested and implemented with the aim of reducing impacts on streams. We include several key articles in Appendices F and G. In general, vegetative filter strips have shown good potential value in reducing sediment transport, but have not fared so well in reducing phosphate, nitrate, or pathogen transport.

There has been only one critical study of vegetative filter strips done in California, and this was on rangeland (by Tate et al. 2000). This study involved only one (non-native) vegetational complex (mainly rose clover, *Trifolium hirtum*, an annual forb, and barnyard grass, *Dactylis glomerata*, a perennial bunch grass). The Mediterranean climate in Merced probably does not lend itself very well to vegetative filter strips, unless these are irrigated. We have no information on how seasonal dormancy of many California native flora affect their potential value in these strips, but we suspect that such dormancy will prove to be a negative factor. If native plants can be included in effective vegetative filters, this could serve some conservation needs.

A variant of the vegetative filter strip is to make use of myco-remediation, which means the use of fungi to mitigate environmental damage, and to kill pathogens. The main person advocating this is Dr. Paul Stamets of Fungi Perfect, near Olympia, WA (see: http://www.fungi.com/mycotech/farmwaste.html). There are few data to support this concept. It may be a more useful approach in the humid Northwest than in arid Merced County.

A final potential management action that deserves serious attention, coupled with monitoring, is periodic draining of unnatural perennial water bodies (e.g., man-made ponds, reservoirs) to control exotic species (e.g., bullfrogs and exotic fishes). Such efforts have proven at least partially successful in other parts of California in reducing pests that are detrimental to native species (R. Fisher, personal communications). Obviously, the optimal strategy would be to return ponds to a seasonal filling-and-drying regime to keep exotics from recolonizing after they are drained.

2. What specific management principles or hypotheses are most important to test via the adaptive management program?

Several key hypotheses that emerged during our discussions are stated below as research questions:

- What specific grazing regimes will contribute the most to perpetuation of target species in the planning region and other conservation goals? Do the different types of vernal pools or species respond differently to a given grazing regime?

- What is the role of pocket gophers (and other rodents, particularly ground squirrels) in the creation and maintenance of mima mound/vernal pool microtopography? Is there a threshold population density of gophers, below which this microtopography cannot be maintained?

- What role do pocket gophers or other native animals have in controlling exotic plants and maintaining plant diversity in this ecosystem? How do rodent populations and their effects on vegetation vary under different livestock grazing regimes?

- What is the role of specialized pollinators, such as burrowing bees, in the study region? (This is more a question for research than for monitoring.)

- How effective, in the biological sense, are various approaches to vernal pool creation and restoration? (A critical review is needed on this topic quickly, as current approaches to vernal pool creation are not completely successful.)

- What is the role of fire in the maintenance of vernal pool communities? What seasons, frequencies, and intensities of fire are most effective in maintaining favorable ecological conditions?

- How will deposition of nitrogen or other pollutants change with changing land uses in the area, and what effects might this have on native communities?

- How does flooding effect the dispersal, and ultimately the viability, of vernal pool species? How might a more natural hydrologic regime be restored?

- What is the variability in time and space of vernal pool species and communities? How is it affected by changes in the landscape and land uses?

- How much geographic variation exists in the genetics of vernal pool species? Are there genetically distinct populations or temporal races within pools or pool complexes in the planning region? Elam (1998) reviewed what little data are available on the genetics of vernal pool plants and found that previous studies on vernal pool plants in other locations in California indicate that significant genetic differentiation occurs both within and among pools. (Genetic research, including but not limited to monitoring, is needed to address these questions.) Shaffer (unpublished data) has found that six distinct population segments occur within the California Tiger salamander, and that considerable genetic diversity exists among pools within these DPSs.

- Can extirpated species, such as the red-legged frog, be reintroduced successfully to the planning region? What management actions favor the persistence of reintroduced species?

- How can the harmful effects of roads (e.g., barriers to movement, avenues for invasion of exotics) be mitigated?

- How are wide-ranging species such as kit foxes and badgers occupying and using the planning area? Can key core areas and linkages be identified for these species?

- Can the periodic draining of man-made ponds be used to control exotic species such as bullfrogs? (We recommend this action as a test of the hypothesis.)

- What are the population trends of invasive exotics in the planning area, and what are the most effective control methods?

- Does the coarse-filter approach of representing proportions of all habitat types (e.g., vernal pool geomorphic types, soil types) capture and maintain viable populations of target species and biodiversity generally? (Answering this question will require more intensive biological surveys than those conducted so far.)

- For vernal pool species that also rely on terrestrial habitat, how large a buffer around pools is sufficient to ensure long-term survival? This is a question that can be answered relatively quickly, and is key for managing amphibians. Our current data are for the tiger salamander only.

- Do upland target species such as coachwhip snakes, legless lizards, and horned lizards use habitat in the same general region as vernal pools, or do they require more xeric conditions away from the pools?

3. Is existing information sufficient to suggest measurable ranges, endpoints, or indicators for monitoring species or ecosystem processes? What specific monitoring protocols are necessary and sufficient to detect changes in species populations or processes?

The selection of specific indicators or monitoring protocols is a topic beyond the scope of this report. Generally, not enough is known about this ecosystem to predict with high confidence which indicators will prove most useful. Importantly, however, indicators should be selected to correspond to the particular questions one seeks to answer (i.e., those stated above) and the particular trends (degenerative or regenerative) one seeks to track. Ideally, indicators should have validated relationships to the phenomena of interest. Among other useful criteria for the selection of indicators are (1) convenience and cost-effectiveness of the indicator for repeated measurement, (2) ability of the indicator to provide an early warning of change or trouble ahead, and (3) ability of the indicator to distinguish changes caused by management or other human activity from natural changes (Noss 1990).

We emphasize that, in addition to monitoring, basic research on the biology of vernal pool species and other issues is needed, along with manipulative experiments to test management hypotheses rigorously. We recommend that wildlife agencies promote such experiments (e.g., rotational grazing and controlled burns) on UC Reserve sites to inform management.

Even with these caveats, we emphasize that long-term monitoring is an essential element of management, particularly adaptive management. Long-term monitoring is often the element that is excluded from reserve design and management for financial and logistic reasons. However, it is absolutely essential both to document the success, or failure, of the reserves, and to adaptively manage reserves that are established.

4. What aspects of this environment might most effectively be used to monitor ecosystem integrity? Are there good indicator or umbrella species that can be monitored as proxies for other species or aspects of ecosystem health?

These questions were addressed above and earlier.

CONCLUSIONS

The vernal pools, grasslands, and other natural communities of the eastern Merced County planning area constitute one of the most biologically distinct ecosystems in California. The region as a whole is a documented biodiversity hotspot. Yet, as this report indicates, many key questions about the ecology of this region, the distributions of target species, and responses to management, are unanswered. Given these uncertainties, we recommend a cautious approach, applying the coarse filter of habitat representation liberally, in order to maintain options for adaptive management.

GLOSSARY

Adaptive management: the process of implementing policy decisions or management actions as scientifically driven experiments designed to test predictions or hypotheses about the responses of species or ecosystems to alternative policies or actions; the resulting information is used to improve policy or management.

Beta diversity: the change in species composition and diversity along environmental gradients or among different habitats, as opposed to the diversity occurring within a particular site or habitat (alpha diversity).

Biodiversity: the variety of life and its processes, including the diversity of genes, species, communities, and ecosystems.

Biogeography: the study of how organisms are distributed on the planet and the processes that explain these distributional patterns.

Bioindication: the assessment of population changes in one or a few select species to infer effects of various practices and pollutants on ecosystems or communities.

Community: in ecology, the association of interacting populations of the various species that co-occur in an area.

Core: large areas of habitat capable of supporting populations of target species over the long term.

Corridor: a relatively linear strip of habitat along which organisms may move between two or more core habitat areas.

Crustacean: any chiefly aquatic arthropod of the class Crustacea, typically having the body covered with a hard shell or crust.

Dispersal: movement of organisms away from the place of birth or from centers of population density.

Dominant species: the most abundant or prevalent species, often in terms of total biomass, within an ecological community or guild.

Ecological integrity: the ideal state of an ecosystem that is whole, undiminished, unimpaired, healthy, and unconstrained by human activities.

Ecoregion: areas within which ecosystems are generally similar based on patterns and the composition of biotic and abiotic phenomena, including geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology.

Ecosystem sustainability: the state of an ecosystem that maintains its basic structure, function, and composition over time, either with or without human uses and extraction of resources.

Ecosystem: a dynamic complex of organisms that interact with one another and their non-living environment as a unit.

Edge effects: habitat degradation concentrated near the interface between natural and disturbed areas, such as increases in weedy species, pollutants, and predation by house pets.

Endemic species (endemism): species restricted in distribution, occurring nowhere outside a defined geographic area, such as a particular county or ecoregion.

Enhancement: management actions having the goal of enhancing ecological integrity within a degraded habitat area.

Exotic: non-native; species that have invaded or have been introduced from other lands, often with deleterious results to native species.

Fauna: the animal species (or species list) of a defined geographic area.

Flagship species: charismatic species, such as pandas or eagles, that attract the attention and imagination of the general public and are therefore sometimes used to garner support for conservation programs.

Flora: the plant species (or species list) of a defined geographic area.

Fossorial: burrowing; living entirely or chiefly within the soil.

Fragmentation: the process by which a relatively continuous habitat area is subdivided into smaller and more isolated pieces, usually resulting in the loss of species and ecosystem integrity.

Geomorphology: the form and structure of geological formations.

Guild: a group of species using environmental resources in a similar way (e.g., nectar-feeding insects).

HCP: a habitat conservation plan prepared pursuant to section 10(a) of the U.S. Endangered Species Act.

Hotspots: areas of concentrated biodiversity (e.g., high species diversity or endemism); the term often, but not always, connotes a high level of threat from human activity.

Hydrology: the science that deals with the occurrence, circulation, distribution, and properties of water of the Earth and its atmosphere; the water regime of an area, e.g., the cycle of flood and drought, with corresponding changes in water table, runoff, and stream flows.

Indicator species: species that indicate something about the condition of an ecosystem and can therefore serve as surrogates for other species or processes of interest.

Keystone species: species that have an effect on the ecosystem that is disproportionately large for their abundance (e.g., rodents whose burrowing activities strongly influence properties of soil, flora, and fauna).

Matrix: the most abundant habitat type in a landscape, in which other habitats are embedded (e.g., extensive grasslands within which various forms of wetlands may occur).

Mesopredators: medium-sized mammalian predators (e.g., raccoon, opossum, house cat) that often increase in human-dominated landscapes due to reduction or elimination of larger predators (e.g., wolves, mountain lions), and which in turn can adversely affect populations of sensitive species (e.g., songbirds or reptiles).

Metapopulation: an assemblage of local populations inhabiting distinct spatial patches, but with at least occasional dispersal of individuals among patches, such that the populations are not totally isolated from one another demographically or genetically.

Mima mounds: small hillocks of relatively well drained soils, up to 1 m high and 30 m in diameter, atop soils having an impermeable layer; often associated with vernal pools.

NCCP: natural community conservation plan prepared pursuant to the NCCP planning Act of the State of California.

Outcrossing: breeding between individuals from different and distinct populations of a species; or breeding between different individuals of a plant species (compare with selfing).

Playa pool: a large, shallow vernal pool (generally greater than 60 m across), which tends to remain inundated longer than most vernal pools and therefore supports a somewhat different suite of species, specifically adapted to these conditions; sometimes called a vernal lake.

Population: all individuals of a given species living within a defined area, usually considered at least partially isolated from other individuals of that species.

Precautionary principle: a principle that states that, in the face of uncertainty, it is best to take the action that minimizes possible harm (i.e., to err on the side of caution in the face of uncertainty).

Raptor: a bird of prey, such as a hawk, eagle, owl, or falcon.

Reintroduction: the act of returning animals or plants to an area that their species once inhabited, but from which it was extirpated.

Representation: the act of including examples of species, habitats, or ecosystems in a set of nature reserves or other managed areas.

Reserve: a protected or managed area where conservation of biodiversity is a high priority.

Selfing: mating with oneself, as in the case of plants where individuals have both male and female sexual organs; i.e., cloning.

SITES: one of several computer programs designed to select a near-optimal set of reserve sites that maximizes representation of biological goals while minimizing cost constraints, such as the total reserve acreage or length of edge.

Speciation: the evolutionary process whereby new species arise from other species.

Stepping stone: a patch of suitable habitat that may be used by an animal dispersing across a landscape; or a patch of habitat large enough to support one or a small population of individuals in the short term, and that thus may serve to connect larger core habitat areas over the longer term (inter-generational stepping stone).

Trend analysis: a statistical analysis of samples collected over time intended to demonstrate temporal changes in a species population level or another measure of concern.

Trophic level: a particular level in the food chain, e.g., herbivore or carnivore.

Umbrella species: a species that, if protected, results in the effective protection of other species with similar but less demanding needs.

Vernal pool: a low-lying area that is regularly filled with water after winter/spring rains but dries out thereafter, and that therefore supports an ecological community specifically adapted to these patterns of flooding and desiccation.

Viability: for populations, the quality of being able to persist for a long time as a self-sustaining population.

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Appendix A

Expertise of the Eastern Merced Science Advisors

Ronald Amundson, Ph.D., Professor, Division of Ecosystem Sciences, University of California, Berkeley. Dr. Amundson studies the role of soils in geochemical cycles, and the manner in which soils record environmental conditions. His research also focuses on using soils to understand natural processes and how humans modify nitrogen and carbon cycles in California soils. He is an expert on paleosols, including the fossil soils underlying the Merced vernal pool region.

Michael Barbour, Ph.D., Professor, Department of Environmental Horticulture, University of California, Davis. Dr. Barbour is a plant ecologist with broad expertise in the ecology of California native plant communities, including those of vernal pools in the Central Valley. He has been instrumental in developing standards for vegetation sampling and classification, and has co-authored textbooks for the study of introductory plant biology, plant ecology, vegetation of California, and vegetation of North America. He has served on many scientific advisory and review panels.

Robert Bugg, Ph.D., Senior Analyst, UC Sustainable Agriculture Research and Education Program (UC SAREP), University of California, Davis. Dr. Bugg studies methods for enhancing biological pest control, cover cropping, restoration ecology, earthworm biology, nitrogen dynamics, and pollination biology. He has conducted studies with field crops, vegetables, vineyards, and orchards, as well as in agricultural field borders. Dr. Bugg also co-founded the prize-winning and internationally acclaimed Biologically Integrated Orchard Systems (BIOS) Program, which takes an integrated, whole farming system approach to voluntary agrichemical reduction. He has served with BIOS Management Teams in Merced, San Joaquin, Solano, Stanislaus, and Yolo counties.

Brian Cypher, Ph.D., Research Ecologist, California State University-Stanislaus, Endangered Species Recovery Program, Fresno, CA. Dr. Cypher specializes in mammal-habitat relationships of the San Joaquin Valley, with a focus on rare and endangered species. He is an expert on the ecology and demography of endangered San Joaquin kit foxes in urban environments, and he has investigated the abundance, distribution, ecology of and conservation strategies for kit foxes, endangered giant kangaroo rats, endangered blunt-nosed leopard lizards, and several listed and candidate plant species.

Richard Grosberg, Ph.D., Professor, Section of Evolution and Ecology, and Chair, Center for Population Biology, University of California, Davis. Dr. Grosberg is an evolutionary biologist focusing on the ecology and behavior of invertebrates, including vernal pool crustaceans. He is an expert on invertebrate population genetic structure in natural communities and is interested in advancing an understanding of the origins and maintenance of biological diversity. Dr. Grosberg heads the UCD Center for Population

Biology, which has as one of its goals the improvement of environmental, public health, and agricultural programs and policies.

Toby Hanes, Owner and Senior Hydrologist, HydroScience, Vacaville, CA. Mr. Hanes has an MS in hydrology from the University of Arizona and is a certified professional hydrologist and soil erosion and sediment control specialist. His studies have focused on the hydrology of wetlands, including in California's vernal pool ecosystems, ecological restoration, wetlands creation, watershed management, channel and riparian area dynamics, nonpoint pollution control, water quality, and water resource assessment. He is experienced with hydrologic and watershed modeling methods, and has published on the hydrology and water relationships of vernal pools in Central California.

Robert Hansen, Biology Department, College of the Sequoias; Owner and Principal Biologist, Hansen's Biological Consulting, Visalia, CA; Vice President, Sierra Los Tulares Land Trust. Mr. Hansen is a leading local expert on San Joaquin Valley native species, particularly birds and their habitats. He has conducted over 100 wildlife surveys in seven San Joaquin Valley counties and has led hundreds of tours and field trips in the area. He has experience as a land manager of valley oak woodland, vernal pools, grassland, freshwater marsh, riparian forest, and desert scrub habitats in Tulare and Kern Counties, and has participated in a number of HCPs.

Reed Noss, Ph.D., Professor, Department of Biology, University of Central Florida, Orlando, Florida. Dr. Noss, an internationally known conservation biologist, has special expertise in landscape ecology, land use planning, ecosystem management, and reserve design. He is leading a new conservation biology graduate program at the University of Central Florida. He has a particular interest in translating the principles of conservation biology to policy and management, and was first author of an influential book entitled *The Science of Conservation Planning*. Dr. Noss has served as a member and as lead scientist on numerous scientific advisory committees, including those for several other NCCPs/HCPs. Dr. Noss served as the lead scientist for the Merced science advisors.

Bruce Pavlik, Ph.D., Professor, Mills College, Oakland. Dr. Pavlik is an expert on the ecology, physiology, and conservation of rare and endangered plants, including those native to vernal pool communities in California. His research focuses on developing scientific approaches to restoring plant populations and ecosystems. He has written extensively on ecological characteristics of rare plants, and on approaches, techniques, and measures of success for plant population restoration and recovery. Among his many publications, Dr. Pavlik authored the fifth edition of the Inventory of Rare and Endangered Vascular Plants of California.

Kevin Rice, Ph.D., Professor, Department of Agronomy and Range Science and Center for Population Biology; Chair, Ecology Graduate Group, University of California, Davis. Dr. Rice is an expert on native California grasslands and foothill woodland ecosystems, and factors promoting the invasion of exotic species. His research spans multiple spatial scales and addresses restoration and management strategies in rangeland environments. He has contributed to symposia on sustaining rangeland ecosystems and to publications such as *Agriculture, Ecosystems, and Environment*.

Bradley Shaffer, Ph.D., Professor, Section of Evolution and Ecology, University of California, Davis. Dr. Shaffer is an expert on the ecology, evolution, genetics, and management of amphibians and reptiles, most particularly tiger salamanders and freshwater turtles. He has written extensively about possible causes of declining amphibian populations in California and elsewhere, and he currently serves on two species recovery teams. He has prior experience providing information for habitat conservation planning at the county level.

[1]**Wayne Spencer, Ph.D., Senior Conservation Biologist, Conservation Biology Institute, San Diego.** Dr. Spencer is a conservation biologist and wildlife ecologist with expertise in conservation planning and endangered species recovery. He has worked on various regional NCCPs and HCPs in California as a consulting biologist, science advisor, and science facilitator. His research focuses primarily on rare and endangered mammal species, including the endangered Stephens' kangaroo rat and Pacific pocket mouse. He previously studied the ecology and evolution of mammalian space-use patterns, spatial cognition, and the brain. Dr. Spencer facilitated the science advisory process for the Eastern Merced County NCCP/HCP.

[2]**Peter Trenham, Ph.D., Postdoctoral Researcher, Section of Evolution and Ecology, University of California, Davis.** Dr. Trenham is an expert on the ecology and management of amphibians. He is a member of the recovery team for the endangered Santa Barbara California tiger salamander, and his extensive studies of this species have been instrumental in the creation of reserve design strategies in this region. He has published peer-reviewed papers on the life history, metapopulation ecology, and upland movements of California tiger salamanders and on amphibian conservation strategies generally.

Billy Weir, Ph.D., University of California Cooperative Extension (UCCE), University of California Division of Agriculture and Natural Resources. Dr. Weir recently retired after 36 years in Merced County as UCCE field crops farm advisor. In addition to local agricultural outreach and education, he has conducted extensive experimental research on field and vegetable crop production, pest management, and soils irrigation at the Field Research Laboratory in Merced County. Dr. Weir has received numerous awards for excellence in research in agronomy and crop science. His studies have resulted in innovative changes in agricultural practices worldwide.

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[1] Wayne Spencer facilitated the science advisory process. Although not officially one of the advisors, he assisted with editing and producing this report.

[2] Peter Trenham is not one of the officially appointed advisors; however, he participated in the science workshop as a proxy for Dr. Brad Shaffer, and contributed substantially to the content of this report.

Appendix B

List of Species Considered in the Eastern Merced County NCCP/HCP

EASTERN MERCED COUNTY NCCP/HCP PROPOSED SPECIES LIST

Common Name	Scientific Name	Status (State/Fed/Other) Priority: High/Mod./Low	Habitat Type(s)
PLANTS			
Henderson's bent grass	*Agrostis hendersonii*	--/--/List 3	Vernal pools
Alkali milkvetch	*Astragalus tener* var. *tener*	--/--/List 1B	Valley and foothill grasslands, playas, and vernal pools on alkaline soils
Heartscale	*Atriplex cordulata*	--/--/List 1B	Chenopod scrub, valley and foothill grasslands, and meadows on alkaline soils
Brittlescale	*Atriplex depressa*	--/--/List 1B	Chenopod scrub, valley and foothill grasslands, and meadows on alkaline soils
Lesser saltscale	*Atriplex minuscula*	--/--/List 1B	Chenopod scrub, valley and foothill grasslands, and meadows on alkaline soils
Vernal pool smallscale	*Atriplex persistens*	--/--/List 1B	Alkaline vernal pools
Subtle orobranche	*Atriplex subtilis*	--/--/List 1B	Valley and foothill grasslands
Hoover's calycadenia	*Calycadenia hooveri*	--/--/List 1B	Cismontane woodland or valley and foothill grasslands on exposed rocky, barren soils
Succulent owl's clover	*Castilleja campestris* ssp. *succulenta*	E/T/List 1B	Vernal pools with appropriate soils
Hoover's spurge	*Chamaesyce hooveri*	--/T/List 1B	Late-season vernal pools
Beaked clarkia	*Clarkia rostrata*	--/--/List 1B	Protected slopes in valley and foothill grasslands
Dwarf downingia	*Downingia pusilla*	--/--/List 2	Clay soils, mesic valley and foothill grasslands, and vernal pools
Four-angled spikerush	*Eleocharis quadrangulata*	--/--/List 2	Marshes, lakes, and pond margins
Spiny-sepaled button celery	*Eryngium spinosepalum*	--/--/List 1B	Vernal pools
Boggs Lake hedge hyssop	*Gratiola heterosepala*	E/--/List 1B	Lake margins and vernal pools
Ahart's dwarf rush	*Juncus ahartii*	--/--/List 1B	Vernal pools
Legenere	*Legenere limosa*	--/--/List 1B	Vernal pools
Merced monardella	*Monardella leucocephala*	--/--/List 1A	Valley and foothill grasslands on sandy soils

EASTERN MERCED COUNTY NCCP/HCP PROPOSED SPECIES LIST

Common Name	**Scientific Name**	**Status (State/Fed/Other) Priority: High/Mod./Low**	**Habitat Type(s)**
Pincushion navarretia	*Navarretia myersii* ssp. *myersii*	--/--/List 1B	Vernal pools
Shining navarretia	*Navarretia nigelliformis* ssp. *radians*	--/--/List 1B	Alkali flats and valley and foothill grasslands
Colusa grass	*Neostapfia colusana*	E/T/List 1B	Late-season vernal pools
San Joaquin Valley orcutt grass	*Orcuttia inaequalis*	E/T/List 1B	Late-season vernal pools
Hairy orcutt grass	*Orcuttia pilosa*	E/E/List 1B	Late-season vernal pools
Merced phacelia	*Phacelia ciliata* var. *opaca*	--/--/List 1B	Clay valley and foothill grasslands
Slender-leaved pondweed	*Potamogeton filiformis*	--/--/List 2	Freshwater marshes and other shallow water habitats (e.g., low-flow drainage canals)
Hartweg's golden sunburst	*Pseudobahia bahiifolia*	E/E/List 1B	Mima mound formations in valley and foothill grasslands
Sanford's arrowhead	*Sagittaria sanfordii*	--/--/List 1B	Freshwater marshes and other shallow water habitats (e.g., low-flow drainage canals)
Greene's tuctoria	*Tuctoria greenei*	R/E/List 1B	Late-season vernal pools
INVERTEBRATES			
Conservancy fairy shrimp	*Branchinecta conservatio*	--/E/--	Large playa pools underlain with specific clay soils (Pescadero, Anita, Peters, Raynor)
Vernal pool fairy shrimp	*Branchinecta lynchi*	--/T/--	Vernal pools
Midvalley fairy shrimp	*Branchinecta mesovallensis*	--/--/--	Vernal pools
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	--/T/--	Elderberry shrubs within riparian habitat
Vernal pool tadpole shrimp	*Lepidurus packardi*	--/E/--	Vernal pools
California linderiella	*Linderiella occidentalis*	--/--/--	Vernal pools
Molestan blister beetle	*Lytta molesta*	--/--/--	Grasslands and open scrub communities
FISH			
Kern brook lamprey	*Lampetra hubbsi*	--/--/CSC	San Joaquin River and associated drainages
Central Valley, California Steelhead ESU	*Oncorhynchus mykiss*	--/T/--	Major drainages

EASTERN MERCED COUNTY NCCP/HCP PROPOSED SPECIES LIST			
Common Name	**Scientific Name**	**Status (State/Fed/Other)** **Priority: High/Mod./Low**	**Habitat Type(s)**
AMPHIBIANS			
California tiger salamander	*Ambystoma californiense*	--/C/CSC	Large vernal pools and stockponds associated with extensive grasslands
Foothill yellow-legged frog	*Rana boylii*	--/--/CSC	Shallow, flowing, small to moderate-sized drainages with at least some cobble-sized substrate
Western spadefoot	*Scaphiopus hammondi*	--/--/CSC	Vernal pools or seasonal wetlands in grassland or oak savannah
REPTILES			
Western pond turtle	*Clemmys marmorata marmorata*	--/--/CSC	Ponds, streams, marshes, rivers, and irrigation ditches adjacent to suitable upland (open vegetation communities)
Blunt nosed leopard lizard	*Gambelia silus*	E/E/--	Alkali sink/grassland
Giant garter snake	*Thamnophis gigas*	T/T/--	Canals, irrigation ditches, low gradient streams, marshes, and rice fields
BIRDS			
Tricolored blackbird	*Agelaius tricolor*	--/--/CSC	Freshwater marsh or blackberry/wild rose stands near open water (nesting) and grassland/agricultural fields (foraging)
Great blue heron – *rookery*	*Ardea herodias*	--/--/--	Riparian or other large stands of trees with open crown structure
Burrowing owl	*Athene cunicularia*	--/--/CSC	Grasslands, open scrub communities, and agricultural lands (particularly uncultivated fringes)
Aleutian Canada goose	*Branta canadensis leucopareia*	--/Delisted/--	Open water and grain fields
Swainson's hawk	*Buteo swainsoni*	T/--/--	Grasslands and agricultural fields ± within 10 miles of riparian
Great egret – *rookery*	*Casmerodius albus*	--/--/--	Riparian or other large stands of trees with open crown structure
Mountain plover	*Charadrius montanus*	--/--/CSC	Sparse grasslands and agricultural fields
Northern harrier	*Circus cyaneus*	--/--/CSC	Grasslands, marshes, and agricultural fields
Little willow flycatcher	*Empidonax traillii brewsteri*	--/--/--	Riparian habitats
Greater sandhill crane	*Grus canadensis*	T/--/--	Grasslands and agricultural grain fields
Bald eagle	*Haliaeetus leucocephalus*	E/T/--	Various wetland habitats and surrounding upland habitats (typically with abundant populations of fish or waterfowl)

EASTERN MERCED COUNTY NCCP/HCP PROPOSED SPECIES LIST

Common Name	**Scientific Name**	**Status (State/Fed/Other) <u>Priority</u>: High/Mod./Low**	**Habitat Type(s)**
Black-crowned night heron – *rookery*	*Nycticorax nycticorax*	--/--/--	Dense riparian or marsh habitat near wetland feeding sites
Double-crested cormorant – *rookery*	*Phalacrocorax auritus*	--/--/CSC	Riparian or other large stands of trees with open crown structure
Bank swallow	*Riparia riparia*	T/--/--	Vertical banks, bluffs, and cliffs (generally with sandy or loamy soils and near water)
MAMMALS			
Merced kangaroo rat	*Dipodomys heermanni dixoni*	--/--/--	Sparse grasslands and open scrub communities
Fresno kangaroo rat	*Dipodomys nitratoides nitratoides*	E/E/--	Alkali sink/grassland
Riparian woodrat	*Neotoma fuscipes riparia*	--/E/CSC	Dense riparian habitat
San Joaquin pocket mouse	*Perognathus inornatus*	--/--/--	Sparse grasslands and open scrub communities
Riparian brush rabbit	*Sylvilagus bachmani riparius*	E/E/--	Dense riparian habitat
San Joaquin kit fox	*Vulpes macrotis*	T/E/--	Grasslands, open scrub communities, and agricultural lands

EASTERN MERCED COUNTY NCCP/HCP OTHER SPECIES FOR CONSIDERATION		
Common Name	Scientific Name	Status (State/Fed/Other)
Silvery legless lizard	*Aniella pulchra*	-/-/CSC
San Joaquin coachwhip	*Masticophis flagellum ruddocki*	-/-/CSC
California horned lizard	*Phrynosoma coronatum frontale*	-/-/CSC
Purple martin	*Progne subis*	-/-/CSC
Delta button celery	*Eryngium racemosum*	E/-/-
Common yellowthroat	*Geothlypis trichas*	-/-/CSC
Barrow's goldereye	*Bucephala islandica*	-/-/CSC
Black tern	*Chlidonias niger*	-/-/CSC
Cooper's hawk	*Accipiter cooperi*	-/-/CSC
Ferruginous hawk	*Buteo regalis*	-/-/CSC, BLM Sensitive
Golden eagle	*Aquila chrysaetos*	-/-/CSC, Fully protected, CDF Sens, BLM Sensitive
Western least bittern	*Ixobrychus exilis hesperis*	-/-/CSC
Long-eared owl	*Asio otus*	-/-/CSC
Merlin	*Falco columbarius*	-/-/CSC
Osprey	*Pandion haliaetus*	-/-/CSC, CDF Sens.
Prairie falcon	*Falco mexicanus*	-/-/CSC
Short-eared owl	*Asio flammeus*	-/-/CSC
Western snowy plover	*Charadrius SP*	-/-/CSC
White-faced ibis	*Plegadis chihi*	-/-/CSC
White-tailed kite	*Elanus leucurus*	Fully Protected
Yellow warbler	*Dendroica petechia brewsteri*	-/-/CSC
Yellow-breasted chat	*Icteria virens*	-/-/CSC
California horned lark	*Eremophila alpestris actia*	-/-/CSC
Yuma myotis (San Joaquin myotis)	*Myotis yumanensis*	-/-/BLM Sensitive
Pallid bat	*Antrozous pallidus*	-/-/CSC; USFS Sens., BLM Sensitive
Townsend's big-eared bat	*Corynorhinus townsendii townsendii*	-/-/CSC; USFS Sens., BLM Sensitive
Western mastiff bat	*Eumops perotis*	-/-/CSC, BLM Sensitive
Spotted bat	*Euderma maculata*	-/-/CSC, BLM Sensitive
Fringed myotis	*Myotis thysanodes*	-/-/BLM Sensitive
Long-eared myotis	*Myotis evotis*	-/-/BLM Sensitive
Long-legged myotis	*Myotis volans*	-/-/BLM Sensitive
Western red bat	*Lasiurus blossevillii*	-/-/USFS Sens
California pocket mouse	*Chaetodipus californicus femoralis*	-/-/CSC
Ringtail	*Bassariscus astutus*	Fully Protected

Appendix C

Conservation Planning
for the Vernal Pool Crustaceans
of Eastern Merced County

Prepared by Richard Grosberg

BACKGROUND

The vernal pool complexes of eastern Merced County represent one of the last remaining ecosystems that harbors a full array of endemic, vernal pool crustaceans. These include roughly ten species of large branchiopods, all adapted to live in seasonal, ephemeral wetlands, six of which have their centers of distribution in the Central Valley, and all but one limited to California. Three of these species are federally listed as endangered or threatened, a fourth is currently under petition for federal listing, and – in terms of their ecological roles – the remaining two species are of equal importance to the integrity of the Eastern Merced County Vernal Pool Ecosystem.

As discussed in the body of this report, many of the unique plants and animals that inhabit this ecosystem originated and evolved in a spatially extensive, temporally dynamic mosaic of seasonal aquatic habitats. For example, some playa pools in complexes are large and deep, with impermeable underlying soils. They fill almost every year, and provide a long hydroperiod (*i.e.*, duration of a wet pool). Other pools are shallower and smaller, perhaps with more permeable underlying soils. They may fill less often, and have shorter hydroperiods. Between these extremes lies a complex spectrum of pools, each with distinctive chemical, hydrological, and biological characteristics, each enmeshed to a greater or lesser extent in local and regional systems of pools.

In large part, it is this diversity of pool types that makes the crustacean biota of eastern Merced County so regionally rich and distinctive. Although we do not fully understand the detailed habitat requirements of all of the crustacean species that live in these vernal pools, we do know that most are restricted to specific types of pools.

Just as importantly, there is growing evidence that a critical feature of populations of many of these species, one that governed their evolution and ecology and explains much of their unique biology, is that due to drought, flooding, and other climatic and geomorphological variables, they periodically become locally extinct on annual, decadal, or even longer periods. To some extent, their persistence relies on their ability to produce dormant stages that survive summer heat and desiccation. In addition, their local and regional survival hinges on re-colonization by dispersal from other local populations, which themselves may become extinct in different years. Therefore, the number of pools that exist in a region, their proximity to each other, and their hydrologic integrity (as a result of runoff and flooding) are additional critical factors that determine whether most species of vernal pool crustacean will survive or become extinct.

In the case of Eastern Merced County, the lack of significant development and alteration of soils, hydrology, and other aspects of the landscape has allowed many of the natural physical and biological interconnections and boundaries among pools and pool complexes to remain intact over hundreds of kilometers. In short, eastern Merced County may be the only place left in the United States where these organisms live in a basically unfragmented landscape that approximates that ecological regime in which they evolved. The same could be said for many of the unique plants that live here, making this region even more valuable.

BIOLOGICAL FEATURES RELEVANT TO CONSERVATION PLANNING & RESERVE DESIGN

Taxonomy & Diversity: On a regional basis, there are at least 60-70 species of crustacean that live in the seasonally ephemeral vernal pools of eastern Merced County. The majority of these species have fairly widespread distributions, some living in both permanent and temporary bodies of water throughout the west. This section focuses on six remarkable species of large branchiopod crustaceans of the region, many of which are endemic to California. It emphasizes the ecological and life-history traits that are critical to conservation planning in the region.

The vernal pools and playas of eastern Merced County host at least four species of anostracan branchiopods, including the Conservancy fairy shrimp (*Branchinecta conservatio*), the vernal pool fairy shrimp (*Branchinecta lynchi*), the midvalley fairy shrimp (*Branchinecta mesovallensis*), and the California fairy shrimp (*Linderiella ocidentalis*). One endemic, federally listed notostracan, the tadpole shrimp *Lepidurus packardi*, occurs in several pools and playas, although numerous potentially suitable areas have not been surveyed. Finally, the California clam shrimp, *Cyzicus californicus*, a conchostracan, occurs sporadically throughout the planning area. Of these species, *B. conservatio* and and *L. packardi*, both federally listed as endangered, have the most limited distribution, in terms of number of pools occupied, diversity of pool types, and range of distribution (*i.e.*, very scattered or restricted).

Almost certainly, this list is a woefully incomplete accounting of the real species diversity of branchiopods in vernal pools of the region. Many of these species are highly endemic, and many nominal species remain to be described. New species are being described annually. There is a high potential for sibling/cryptic species to exist in this system, undistinguishable based on morphology, but nevertheless genetically and ecologically distinct.

The high degree of endemism of many of these branchiopods also suggests that many species will be locally and regionalized adapted to particular kinds of pools and pool complexes. In the absence of systematic analysis of genetic structure and ecological specialization in any of these species, science has virtually no understanding of the extent to which any of the described species exhibit local adaptation to local and regional variation in habitats. As studies of native grasses in California have already shown, conservation of this sort of intraspecific ecological and genetic diversity may be as important as habitat preservation in ensuring the viability of these endemic branchiopods. Moreover, in such a variable environment, the full spectrum of ecological and genetic diversity may only be represented across years and on regional scales.

Distribution, Dispersal, & Landscape: Each of these species occupies a range in California that extends over hundreds of kilometers, and some species may even be locally abundant, at least in some years and in particular places (see "Data Gaps"). The overall geographic ranges of these branchiopods, however, present a misleading picture of their vulnerability to decline and extinction. Within their geographic range, each species inhabits a relatively small number of pools, their populations dynamics may oscillate widely, and their distributions are often highly disjunct, with large tracts of seemingly habitable pools and playas devoid of one or more species. As Bainbridge (2002) put it, "Their [vernal pool crustaceans] distribution is characterized by high endemism, high diversity, and lack of predictability on a regional scale."

This disjunct and unpredictable distributional pattern likely reflects interactions among the capacity of these crustaceans for dispersal, the fragmented nature of the landscape they inhabit – greatly accelerated over the last 100-150 years by human activities – and the habitat requirements of each species. All of these species have very limited intrinsic dispersal capability, relying on transport by water, animal vectors (*e.g.*, waterfowl, cattle), and perhaps wind to move on scales more extensive than a few meters. In addition, none of the species is truly a habitat generalist, found in all types of pools and playas. Although several attempts have been made to correlate the occurrence of these species with specific types of seasonal wetland and other landscape features, each species occasionally occurs where it is unexpected, and is often absent where the physical characteristics of a pool suggest it should be (Helm and Vollmar 2002). At best, the existing physical data provide very modest predictive power about the presence or absence of particular species. Similarly, most of what we know about the interactions of these branchiopods with other species comes from univariate correlative analyses, rather than multivariate analyses or experiments that would reveal mechanism of co-existence or exclusion. Whether these absences are due to incomplete knowledge of a species' or population's habitat requirements, their interactions with other members of the community, or dispersal failure is generally unknown.

Life Cycles & Population Dynamics: The life cycles of all six of these species exhibit the same basic seasonal organization that reflects their evolutionary history in unpredictable seasonal wetlands with torrid summers. Although all are intrinsically weak dispersers in space, all have prodigious power to "disperse" in time. In years where fall and winter rains drop enough precipitation to fill pools, dormant or diapausing cysts (either fertilized eggs or embryos) that have over-summered in the dry sediment, begin to hatch into juvenile stages. Juvenile pass through a series of pre-adult instars that eventually molt into a reproductively mature adult. Depending on the species and prevailing conditions, completion of the life cycle may takes as few as 18 days (*B. lynchi*) or as long as 40-55 days (*B. conservatio*, *L. packardi*). Obviously, slowly maturing species can only survive in pools with fairly long hydroperiods; less obviously, some rapidly maturing species may not persist in pools with longer hydroperiods, because these pools may harbor a more diverse array of predators and competitors.

In some species, adult females may either produce subitaneous eggs that hatch immediately into juveniles (*e.g.*, *Lepidurus packardi*), diapausing or dormant eggs/embryos that will not hatch until after at least one summer of desiccation, or perhaps some combination of the two types of egg. Even in species that produce only dormant offspring (*i.e.*, univoltine), not all eggs/embryos will hatch in a given year. Some resting stages may hatch the season after they are produced. Others may take years, decades, or even longer, producing the animal equivalent of a seed bank in the sediments of vernal pools and playas.

Our knowledge about what combination of stimuli induces hatching in these spaces, and why there is so much variation among species, habitats, seasons, and perhaps even individual females in the proportion of resting eggs/embryos that hatch is particular year, is virtually nil. In any case, the production of dormant stages, and the variation in their responsiveness to hatching stimuli, buffers a members of a population against complete reproductive failure in the event that the hydroperiod in a given year is too short to support complete development. The existence of an egg/embryo bank also makes it difficult to predict population dynamics based on simple demographic models (Philippi and Simovich 2002). A particular species may be rare or absent for many years, then suddenly become abundant with many eggs hatching, only to decline again as the egg bank becomes depleted.

Unfortunately, virtually of the studies of the branchiopod crustaceans of eastern Merced County focus on the presence or absence of particular species, with samples taken over a limited time period (usually a single year). To our knowledge, there are no studies in the region that attempt to quantify changes in population sizes over time frames that include the short- and long-term climatic variation that influenced the evolution of these species, and their present-day population dynamics. In addition, virtually all information concerning dispersal within and among pool complexes is indirect, based either on inferred connections following flooding events, or geomorphology.

There is limited indirect genetic information from other regions in California, some of which suggests that local populations of at least some species of branchiopods may remain sufficiently isolated for enough time to accumulate detectable genetic differences. This, and the fact that many of these species have evolved *in situ* in a relatively short geological time frame, suggest that there is the potential for local adaptation to evolve in this environment. Moreover, pools vary enormously in their biological and physical parameters across pool, pool complex, landscape, and regional scales. At this point, we have no idea how common local adaptation is, and over what spatial scales it occurs.

DATA GAPS RELEVANT TO CONSERVATION PLANNING

Here I summarize some of the most important data gaps in our understanding of the population biology, taxonomy, population genetics, evolutionary history, and community ecology of the branchiopod fauna of eastern Merced County:

1. Life Cycles and Population Biology

- Life Cycle Variation: Previous studies have identified the basic developmental sequences and timing for most of the target branchiopod species. Nevertheless, our knowledge of the basic life cycles of virtually all of the branchiopods is seriously incomplete. For example, we do not understand why there is so much spatial and temporal variation in the expression of life cycles within these species, and what the environmental and genetic contributions are to this variation. Without this information, it is virtually impossible to predict natural patterns of population variation, and to circumscribe the critical units that control population dynamics and persistence.

- Egg/Embryo Bank: As with seed banks, the size of the egg/embryo bank and the stimuli that induce hatching determine the extent to which pools will be repopulated each year, and potentially buffer local populations against extinction. In addition, the genetic composition of the egg/embryo banks reflects the accumulation of generations of environmental variation and selection. The banks may hold far more ecologically important genetic variation than appears in the hatched population in any given year (*i.e.*, a genetic storage effect). Presently, little is known about the size, genetic composition, hatching fraction, and hatching stimuli for any of the six target branchiopod species.

- Population Dynamics: Given the enormous temporal and spatial variation intrinsic to the vernal pool ecosystem of eastern Merced County, the population dynamics of the inhabitants of the vernal pools should also fluctuate. The available data on the large branchiopods of eastern Merced County primarily document the presence and absence of particular species, and not numbers. As a result, we have no short- or long-term data that would allow assessment of what constitutes natural fluctuations, and what fluctuations should be cause for serious concern. Local and regional data on population sizes and dynamics would also help to clarify spatial and temporal correlations within and among pools and pool complexes, and therefore whether regional dynamics can be understood on the basis of local dynamics.

- Population Ecology: The species presence/absence data, combined with a relatively complete knowledge of the chemistry, turbidity, soils, hydroperiod (including pool depth and area), temperature, and geomorphology of the vernal pools in eastern Merced County, have given scientists some understanding of basic habitat associations of several species of branchiopods in the region. Nevertheless, species are often absent where they are expected, based on the physical characteristics of a site. The data are available to perform far more sophisticated multivariate analyses (*e.g.*, principal components analysis, discriminant function analysis, or multiway likelihood tests) of the habitat requirements of these species. Such analyses would allow a far more complete assessment of what we do and do not know about the habitat requirements of the large branchiopods.

- <u>Sampling</u>: The sampling regime to date likely does not reflect the full range of species and genetic diversity present in the vernal pools of eastern Merced County. Most pools were sampled a single time, and there are many areas in the planning region that have high densities of vernal pools, and that were not sampled at all.

2. Taxonomy, Phylogeny, Population Genetics, & Evolutionary History

- <u>Taxonomy & Phylogeny</u>: Virtually all of the taxonomic studies to date rely on morphological characters to distinguish species of branchiopods in these vernal pools. If the biology of these species is any clue to their true diversity, we expect there to be numerous cryptic species of branchiopod “hidden” within these morphospecies. These species are likely to have different life cycles, mating behaviors, and ecological relationships and requirements. They may be critical, but unrecognized, members of this ecosystem. A genetically based taxonomic analysis, with extensive geographic sampling would help to resolve this question.

- <u>Evolutionary History</u>: Many of the branchiopods living in this vernal pool system have highly specialized life histories. How often do such life histories evolve, and do vernal pool specialists primarily evolve from other specialists, or from non-specialists? Genetic information would clarify the evolutionary relationships among this suite of species, and – for the first time – reveal the time frames over which these species diversified, who they evolved from, and the ecological circumstances that promoted speciation in these lineages. *In so doing, the value of this ecosystem as a generator of diversity could be assessed for the first time.*

- <u>Population Genetics</u>: The spatial scales over which populations of a given species are genetically subdivided can provide critical demographic information about patterns and scales of migration/dispersal. If neutral genetic markers indicate that populations can be genetically distinguished, then it is virtually certain that they have not recently exchanged immigrants. (The converse is generally not true: genetically indistinguishable populations may, for the purposes of demographic connection, also be isolated, because it takes relatively few migrants per generation to homogenize genetic composition.) Information about genetic structure can also reveal the spatial scale over which populations can evolve independently in response to locally varying selection pressures. Information about genetic structure of any of these species is limited, at best, particularly in the region.

3. Community Ecology

- Species Associations & Interactions: Several attempts have been made to describe biotic associations of the large branchiopod fauna, primarily in terms of the presence or absence of other large branchiopods. These studies need to be extended in several crucial ways. First, with the exception of pools at the UC Merced site, most of the pools have only been sampled a single time. Even at the UC Merced site, samples only include several years of data. Almost certainly, this approach underestimates branchiopod diversity. Second, as with studies of the population ecology of these branchiopods, other species, including predators, prey, pathogens, and competitors need to be considered, and analyses should be done using multivariate approaches. An important first step toward understanding the importance of specific biotic interactions to the maintenance of diversity in this ecosystem would be identification of these associations, and analysis of interaction strengths. Third, in establishing these associations, care should be taken to avoid pseudoreplication of sampling, so that pools and pool complexes that are ecological interconnected are not multiply sampled.

CRITICAL PLANNING PRIORITIES

Rationale: All of the large, endemic branchiopod crustaceans are restricted to habitats that are extraordinarily dynamic across nearly every imaginable spatial and temporal scale. Over seasonal time frames, their habitats usually fill, and always dry, exposing each generation to extreme conditions of heat and desiccation. Over decadal time frames, some pools more dependably fill than others, and flooding due to El Niño events episodically connects some pools that in dry years are demographically and genetically isolated. Longer period climatic oscillations may also be important drivers of the connections among pools and pool complexes. All of these processes are certain to influence the population dynamics and evolution of these species, in large part because all of these species produce resting stages that may remain dormant for years, decades, or perhaps far longer.

In demographic terms, pool destruction and alteration of landforms and drainage patterns in eastern Merced County will, in general, reduce connections among pools and pool complexes, decrease the likelihood of recolonization following local extinction events, and increase at a regional scale the likelihood of extinction of all of the branchiopods.

In ecological terms, disruption of the vernal pool landscape will likely render formerly habitable pools uninhabitable, and alter the ecological interactions the are likely the linchpins of this ecosystem. In particular, significant alterations of the landscape will affect the species pool, facilitate the establishment of generalist, non-endemic species (some of which are noxious invaders), and likely reduce the diversity of the vernal pool ecosystem at both local and regional scales. As with the genetic and evolutionary consequences of habitat destruction (see below), it appears that much of the extraordinary regional branchiopod biodiversity accrues as a result of the diversity of pool types ***and*** their interconnections.

In genetic and evolutionary terms, such habitat alterations, along with the construction of new pools as mitigation, will change patterns of genetic exchange at an historically unprecedented rate. In some cases, these alterations will connect previously disconnected subpopulations, and in other cases, interrupt genetic exchange between formerly linked populations. The outcome will be a disruption in patterns of local adaptation, and perhaps in local and regional genetic diversity. This would likely facilitate extinction, as well.

Goals:

1. Maintain the diversity and integrity of the current landscape. This includes...

- preserving individual pools, complexes of pools, and larger scale groups of complexes;
- keeping local and regional drainages in their current configuration;
- avoiding alterations to the water table and soils.

This acknowledges that the ecological and evolutionary processes that affect these species of branchiopod simultaneously operate at local, landscape, and regional scales, and will ...

- maintain the diversity of habitats/pool types that currently exist in as close to an historical status as possible;
- preserve current demographic and genetic connections;
- stabilize current patterns of species and genetic diversity;
- reduce the risk that locally adapted populations will lose their genetic and ecological integrity (and thereby reduce the risk of extinction)

2. **Avoid the need to mitigate either in the region or outside the region.** This acknowledges that...

    - We still lack convincing evidence in the scientific literature that reconstructed vernal pools fully recreate the population dynamics, species diversity, community structure, and ecological functions of intact, natural pools, and that the pools retain natural characteristics over the decadal periods in which egg, embryo and seed banks are replenished. We simply do not know enough about the role of sediments, the egg/embryo banks they contain, species tolerances and interactions, and pool connections to rely on re-creation of new habitat. Several projects have shown that some vernal pool crustaceans colonize reconstructed pools, and may persist there. However, until it is shown through ***experimental manipulations and comparisons to control pools*** that reconstructed pools have the population and community characteristics of natural pools, the use of reconstruction as a mitigation tool is premature.

    - Offsite mitigation runs counter to the principles of regional conservation planning, especially when there is strong evidence for many of the branchiopods of eastern Merced County that the region represents their center of distribution, and that they may be locally differentiated from populations living in other parts of the state.

3. **Recognize that there are especially large data gaps in our understanding of the physical and biological factors that govern the existence of these species, and that these species live in complex and dynamic habitats**. In most situations, it remains difficult to predict with any measure of confidence whether a species will be present or absent. Consequently, planning priorities should include...

    - protection of the full range of pool types found in the region;

    - maintenance of the full range of pool types at the local ***and*** regional scales.

4. **Integrate the concept of uncertainty into the development of a plan.** Because of the data gaps identified previously, and because large-scale variation in population dynamics is an intrinsic feature of the biology of these branchiopods, we simply do not know what constitutes a viable population at local or regional scales.

    - It is imperative to view the long-term viability of populations of all of these species in terms of regional-scale processes.

Appendix D

Information on the Distribution and Status of Selected Vertebrate Species in Eastern Merced County

Prepared by Robert Hansen

Editor's note: References to report page numbers in this appendix refer to a previous draft of the Science Advisors' Report, and may no longer be accurate.

Aleutian Canada goose - John Fulton (pers. comm.) stated, "This formerly endangered race of Canada goose, after being downlisted to Threatened, has been officially delisted. With its current population in excess of 35,000 individuals, there is already discussion of limited hunting in coming years. 98% of the population of these Aleutian breeders spend their winter between Interstate-5 and Highway 99 in the vicinity of Faith Ranch, Mapes Ranch and Dos Rios Ranch in central Merced County." David Yee (pers. comm.) added, "I have never seen Aleutian Canada goose east of Highway 99 in Merced County." All of David's records for this species during winter months in Merced County come from land between Highway 99 and Interstate-5. Harold Reeve, one of the two most active birders in neighboring (to the north) Stanislaus County, birded eastern Merced County "a moderate amount" in the 1980s" (pers. comm.). Jim Gain, who also has extensive field experience as a birder in Stanislaus County, has birded in eastern Merced County "south to the Merced River from spring into July" (pers. comm.). Gain and Reeve (pers. comm.), concur with David Yee, and note that, "Although there are sporadic records for Aleutian Canada goose at Turlock Lake in Stanislaus County, we have never seen this species east of Highway 99 in Merced County".

Blunt-nosed leopard lizard - Robert W. Hansen, the most well-respected and most frequently cited San Joaquin Valley herpetologist, stated "Blunt-nosed leopard lizard does not occur on any of the lands within the Eastern Merced County Conservation Plan area" (pers. comm.). For over 20 years, Steve Juarez has conducted extensive blunt-nosed leopard lizard and San Joaquin antelope squirrel field surveys throughout the San Joaquin Valley for California Department of Fish and Game, California Department of Water Resources, and as a private consultant. Steve noted that, "While there may be a few old blunt-nosed leopard lizard records from the Eastern Merced County Conservation Plan area, that they are almost certainly extirpated there now; I don't know of any recent records" (pers. comm.).

Giant garter snake - Robert W. Hansen (pers. comm.) also noted that "Giant garter snake does not occur on any of the lands within the Eastern Merced County Conservation Plan area."

San Joaquin antelope squirrel - Steve Juarez (pers. comm.) said "There are no Merced County records of San Joaquin antelope squirrel on any of the lands east of Highway 99."

Note: Page 12 of the original draft report proposed (probably because of my suggestion) that mountain plover be considered for deletion from the list of target species. I retract that suggestion based on the record in Vollmar (2002) and because Gain (pers. comm.) mentioned that "the eastside grasslands are where most of the mountain plover records come from in eastern Stanislaus County (in the vicinity of Turlock Reservoir) just north of the Merced County study area."

To shed light on the 5 bird species that are among the 6 "Other Species for Consideration" noted near the bottom of page 12, I interviewed Jim Gain, Harold Reeve, Dave Shuford, Kent Van Vuren, and David Yee, five active birders who have all spent field time in eastern Merced County. Dave Shuford is an authority on the status of California birds. Kent Van Vuren, spends much of his field time birding in the central San Joaquin Valley. Van Vuren (pers. comm.) birded eastern Merced County "5-6 times between 1995 and 2000, mostly between September and May."

Purple martin - None of these five birders consider eastern Merced County to be within the normal breeding range of this species. Of the 5 birders, only Reeve (pers. comm.) commented, "purple martin might occur in Merced County's higher elevation mixed conifer habitats in the vicinity of Snelling, although I have never seen this species in the area during the breeding season."

Barrow's goldeneye - None of these five birders consider eastern Merced County to be within the normal breeding range of this species. Of the 5 birders, Reeve (pers. comm.) stated, "Barrrow's goldeneye can be found on the [Merced?] River in winter." Gain (pers. comm.) said that Barrow' goldeneye is seen "annually in small numbers during winter months on nearby (Stanislaus County) Turlock Reservoir" (pers. comm.).

Black tern - Although none of these five birders consider eastern Merced County to be within the normal breeding range of this species, it is a transient (migrates are noted in many years) in the area and there are reports of black tern breeding at Turlock Lake in Stanislaus County. While Gain (pers. comm.) and Van Vuren (pers. comm.) referenced a single breeding record at Turlock Lake in 1999, Reeve (pers. comm.) felt that the record was questionable; "adult terns seen on the ground in a Forster's Tern colony at Turlock Lake but no eggs or young seen to confirm the record."

Western snowy plover - None of these five birders consider eastern Merced County to be within the normal breeding range of this species. While Gain (pers. comm.) indicated that he knew of, "no records east of Highway 99 in Merced County", Reeve (pers. comm.) stated that "transient snowy plovers could occur in the area."

White-faced ibis - While Gain (pers. comm.) observed that "no white-faced ibis breeding colonies have been located in eastern Merced County." all five observers mentioned that flocks of foraging ibis, which were formerly restricted to the western, marshy portions of the San Joaquin Valley, have been seen with increasing frequency along the eastern edge of the valley, including the Eastern Merced County Conservation Plan area. Shuford (pers. comm.) even saw a winter flock of ibis near the Merced River during December. Reeve (pers. comm.) observed that, "The surveys conducted by Sloat and Whisler (2002) concluded in early June, too early to determine whether this species might be breeding in the area." Based on these findings, I would recommend that white-faced ibis remain on the target species list.

At the bottom of page 12 and the top of page 13 there are 3 species (two reptiles and one bird) which are listed for consideration but which require more status information before being confirmed for the target species list. To shed more light on the status of those three species, I interviewed Juarez, R.W. Hansen, and the 5 birders noted above.

Silvery legless lizard - R.W. Hansen (pers. comm.) is only aware of one published record for silvery legless lizard in eastern Merced County, "near Delhi in the vicinity of Highway 99, presumably the same record referenced in Vollmar (2002)." Hansen felt that this species was "probably more widespread historically" but agreed that more information is needed on this difficult to observe species to determine its true local status.

California horned lizard - Based on observations (in nearby counties) of horned lizard in habits similar to those in eastern Merced County, Juarez felt that "there are probably still a few horned lizards in the study area." Similarly, R.W. Hansen, who is familiar with horned lizard records near Bryceburg in neighboring (to the east) Mariposa County, thinks that "additional field work would probably turn up other horned lizard records in the low foothills and grasslands of eastern Merced County."

Western least bittern - Although none of the five birders I interviewed consider eastern Merced County to be within the normal breeding range of this species (none of them had ever seen or heard least bittern in the area), American bittern was seen on several occasions in the very limited freshwater marsh habitat in the study area (Vollmar 2002). Since this elusive marsh species is a late (summer) breeder like white-faced ibis, I would recommend that Western least bittern remain on the target species list and that a focused survey protocol be established to search for this species in late May through July to better ascertain its local status.

Page 13: In the second full paragraph there is a reference to the taxonomic status of the coachwhip complex (coachwhip was also mentioned in the earlier draft on page 12). Juarez (pers. comm.) is not aware of any coachwhip records "that far north along the east side of the San Joaquin Valley. R.W. Hansen (pers. comm.), said that in his computer files, "all coachwhip records north of Madera County come from west of the San Joaquin River. Like Juarez, Hansen is unaware of any historical coachwhip records in the Eastern Merced County Conservation Plan area.

Page 18: In Paragraph 3 on this page I would add the following suggestion Re Swainson's hawk status:

Holt (pers. comm.) mentioned that there are two Swainson's hawk survey protocols being used by agency biologists in Central California. Biologists conducting Swainson's hawk surveys for California Department of Fish and Game, Region 2 (north of the Merced/Stanislaus County line), use a survey protocol that entails multiple visits. Holt (pers. comm.) noted that CDF&G Region 2 (which includes the eastern Merced County Conservation Plan area), has not had the same emphasis on Swainson's hawk status and impact analysis that has been applied in CDF&G Region 4. Holt also stated that the Swainson's hawk protocol developed by the Swainson's hawk Technical Advisory Committee (which calls for 5 visits between late March and June) is used by biologists from United States Army Corps of Engineers, United States Fish and Wildlife Service, and California Department of Water Resources. On page 280 of the Vollmar (2002) report, it was noted that "Several Swainson's hawks were observed foraging in the oak savanna at the Kelsey Ranch in early April, a time of their migration, but were not observed during surveys in May or June." As Holt (pers. comm.) mentioned, Swainson's hawks in this part of California are most quiet and least detectable during May when they are on nests. Hence the absence of May sightings during the Vollmar survey may represent a false negative. If adult birds were sitting on nests and went unobserved in May, then the last surveys conducted by birders in the Vollmar report (6 June 2001) could have ended too early in the year to detect hatching year birds out of nests. In fact, during my only day spent in the field in the study area (19 June 2002), I saw a juvenile Swainson's hawk along La Paloma Road between China Hat and Haystack Mountain. Van Vuren (pers. comm.) thinks that there are more Swainson's hawks breeding in blue oak savanna (away from alfalfa fields on the valley floor) than current data indicates and all of the birders I interviewed said that this species has increased in numbers in recent years and has been extending its range east and uphill into the oak savanna. While neither one of the above mentioned Swainson's hawk survey protocols has been officially adopted (Holt, pers. comm.), I would recommend that a thorough survey of the eastern Merced County Conservation Plan area be conducted using the more intensive protocol developed by the Swainson's hawk Technical Advisory Committee.

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Appendix E

Soil and Geological Issues
Relevant to Eastern Merced NCCP/HCP

Prepared by Ronald Amundson

INTRODUCTION

The eastern half of the San Joaquin Valley consists of a series of river and stream deposits derived from the Sierra Nevada to the east. Cyclic episodes of glaciation of the Sierra Nevada during the Pleistocene, combined with tectonic uplift of the mountain range, resulted in rapid deposition events followed by stream entrenchment and subsequent periods of low sedimentation (Marchand and Allwardt, 1981). Old alluvial fans that opened to the west have been incised over time by the cyclic erosional/depositional events and now contain a suite of inset river terraces. Soils and ecosystems found on the complete set of these terraces comprise a chronosequence varying from Holocene (~10^3 yrs) to Plio-Pleistocene (~3000 Ky) in age. Soil and, to a more subtle extent, ecological properties change profoundly as the age of the landform increases, creating a mosaic of habitats and ecosystems within the Great Valley annual grassland biome.

The eastern Merced County area is unique and special within this regional geological and ecological context:

- First, the Merced River drainage in the northern part of the county contains, to our knowledge, the only remaining remnant of the oldest member (3 to 4 million years) of the western Sierra river terrace sequence: the China Hat member of the Laguna formation (Marchand and Allwardt, 1981). In addition, many (possibly all) intermediate age landforms are present, making the region an "ecological staircase" through millions of years of time. The time spanned by this series of landforms is comparable to the chronosequence of ecosystems on the Hawaiian Island chain, an area of intensive ecological and geological investigation stimulated by its designation as a "model ecosystem" (Vitousek et al., 1997). The Merced River chronosequence comprises an analogous continental setting of equal scientific interest.

- Second, the region is largest remaining undisturbed ecosystem in the eastern San Jaoquin Valley, and large tracts of all landforms are still present in a rangeland state.

- Third, because of the combination of unique habitats and the dwindling areas of undisturbed rangeland in the Valley, the area is a key part of the California Floristic Province, an area identified as one of the top 25 biodiversity hotspots on Earth (Cincotta et al., 2000; Myers et al., 2000).

It is in this context that the planning process for the Eastern Merced County NCCP/HCP begins. In this report, I address issues surrounding soil and geological resources that are relevant to the planning process.

DATA NEEDS

The ecological "habitats" of the county are, as indicated above, dictated by the geological and pedological (soil) resources. These, and their availability in the planning process, are discussed below. First, I briefly discuss why these data layers are scientifically important.

Soil properties (the type and degree of development of soil horizons, soil fertility, hydrological characteristics) are related to 5 factors of soil formation: time, climate, topography, biological factors, and bedrock/sediment type (Jenny, 1941). The key variables in Merced County are time and bedrock type. Most of the region is part of a chronosequence, and the soil properties vary predictably with time. Of great importance to conservation planning are the development of vernal pools and mima mounds on the various landforms. The prevailing theory for the formation of these habits hinges on the combination of soil development (through landform age) or bedrock type and gopher activity (Arkley and Brown, 1954; Cox, 1984). Briefly, old soils with clay-rich subsurface (B) horizons, or silica-cemented hardpans, promote seasonal perched water tables within a few centimeters of the land surface. Burrowing animals, especially pockets gophers, respond to this by locating their nests on better drained parts of the landscape. Over periods of hundreds of years (and longer), these animals redistribute soil surface material preferentially toward these better drained areas, leading eventually to a marked hummocky surface topography, with exposed seasonal pools (the top of the perched water table) in the inter-mound areas. Therefore, an identification of vernal pool habitats can be accomplished through geological and soil data bases – and the published knowledge of correspondence of pools with soil (Arkley, 1962) and geological units (Marchand and Allwardt, 1981).

Eastern Merced County is fortunate to have been the subject of (then) novel and innovative geological mapping in the 1970s and 1980s. Dennis Marchand (and colleagues) of the US Geological Survey undertook a detailed study and mapping of the Quaternary deposits (deposits less than 2 million years in age) at a scale of 1:24,000. These maps (published as USGS Open File Reports) have been digitized (EIP consultants?) and are a key data layer in the planning process for identifying critical habitat types.

Presently, the only soils data layer available is the STATSGO (State Soil Geographical Data Base) soil database/map for the area. STATSGO is a highly generalized soil data base, derived by compiling information from the most detailed (1:24,000 scale) soil surveys that are produced by the US NRCS (Natural Resource Conservation Service). For the eastern Merced area, the 1:24,000 scale *Soil Survey of Merced Area, California* (Arkley, 1962), is the relevant resource. I note here that the production of this survey was based on pioneering recognition of landform age to soil types, and that the subsequent geological mapping in the area depended heavily (at least initially) on this survey

(Marchand and Allwardt, 1981). For solid science and identification of habitat types, the Science Advisors strongly recommend that this soil survey be digitized and fully utilized in the planning process.

The soil maps in the *Soil Survey of Merced Area, California* represent only a portion of the data potentially derivable from USDA data bases. Most of the soils mapped in Merced County have a wealth of chemical, physical, and management information developed for them which is available via the world wide web (National Soil Survey Center home page: http://www.statlab.iastate.edu/soils/nssc/). In particular, http://www.statlab.iastate.edu/soils/ssl/natch_data.html is the portal into the variety of data for each soil series in the area. Relevant information for each soil includes (but more might be useful): soil profile description, soil characterization data (chemical, physical and mineralogical properties of all horizons for each soil seres), and ratings/classifications/interpretations for each soil. These data will provide chemical and hydrological information that should be relevant to reserve and management planning.

CONSERVATION PLANNING APPROACH

If the "coarse filter" approach to planning is applied, the geological and soils data bases will (when combined with topographic data) identify key habitat areas: i.e. soils with near surface impermeable layers on gentle slopes are key sites for vernal pool formation of various types.

In the planning process, soils and geological units themselves deserve consideration from a rarity and diversity perspective. In addition to providing habitat conditions for flora and fauna, soils themselves provide ecological, scientific, and educational services (Amundson, 1998; 2000; Amundson et al., 2002). Many of the soil types in the Merced area are naturally of small areal extent or, because of the pervasiveness of agriculture and urbanization in the Great Valley, have experienced large reductions in the area of their undisturbed landscapes (including the official state soil of California, the *San Joaquin series*, found in sections of the study area). Additionally, the China Hat member of the Laguna formation and its soils (the crest of the "China Hat ridge in the Vollmar report), is the only area of its type in the state.

Given the natural and human-induced rarity of many of the natural soil types in the planning area, and the impending growth of educational needs in the area through the development and growth of the UC campus, explicit attention to the preservation of geological, as well as biological, resources is deemed important to the citizens of the state.

ECOSYSTEM PROCESSES

In many sections of the Eastern Merced planning area, mima mounds and vernal pools form a landscape mosaic that is the backbone supporting the rare and endangered plant and animal species. Surprising little is known about the formation and maintenance of these micro-topographic features. Any long-term management plan for the area must consider the physical maintenance of the topography. Specifically, because pocket gophers are suspected of creating and maintaining this habitat, land management actions must maintain healthy gopher populations. The background behind this recommendation is given below.

Limited field observations support the hypothesis that directed burrowing of gophers moves gravel-free soil preferentially to well-drained areas, resulting relatively gravel-free mounds which overly water-restrictive subsurface horizons and gravel layers (which are exposed at the surface in the vernal pool areas) (Figure 1).

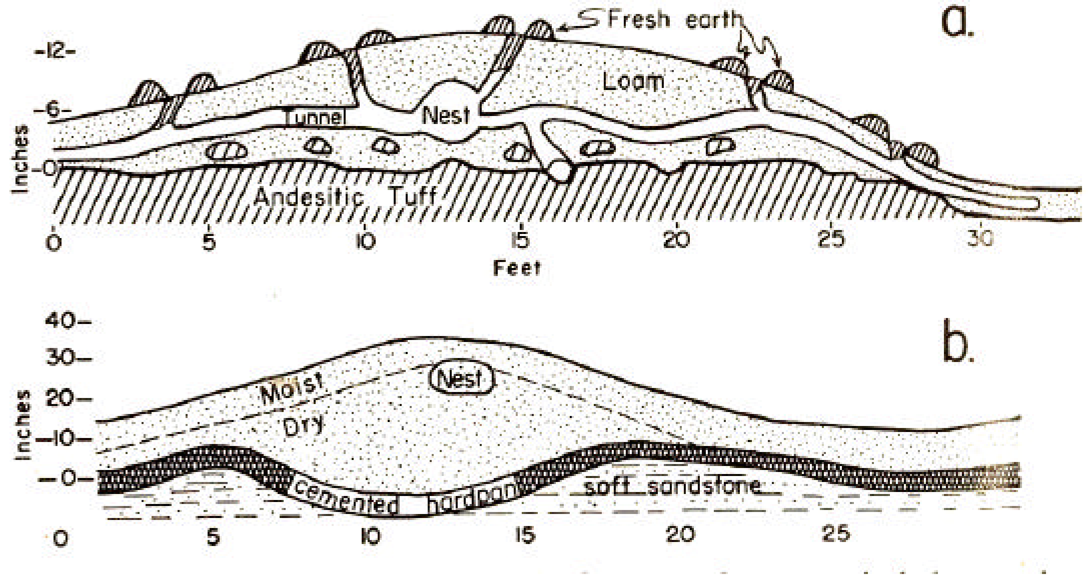

Figure 1. Diagram illustrating summary of observation of gopher burrows and mounds in a mima mound/vernal pool landscape (from Arkley and Brown, 1954).

The hypothesis of mound formation by burrowing organisms is still deserving of further work, but geomorphological analyses of these landscapes indicates that there must be some on-going soil movement at work because the slope of the mounds, combined with reasonable rates of downslope soil creep, should level the landscape within several hundred years (Hallet, 1994).

Therefore, the Science Panel suggests that past (Storer, 1947), and on-going, efforts to eradicate burrowing rodents be evaluated and reconsidered with respect to its effect on pocket gophers, and the possible central role pocket gophers play on maintaining the conditions critical to the entire vernal pool ecosystem.

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Appendix F

Mini-review of Farm-Wildlife Issues

Prepared by Robert Bugg

Introduction

The expansion of agriculture has often been at the expense of native plants, and wildlife (Gall & Orians 1992, Gall & Staton 1992, Merenlender 2000), yet some of the damage may be mitigated by changing farming, forestry, and rangeland practices. California agricultural lands make up about 24 million acres, contrasted with about 15 million acres contained in national and state lands (parks, forests). This points up the potential value of any improvements in harboring native plants and wildlife. As emphasized by Scott et al. (2001), strategic planning will increase the likelihood of success over piecemeal efforts at conservation and restoration.

Background

For many years, the Natural Resource Conservation Service (formerly known as the Soil Conservation Service) has promoted windbreaks, grassed waterways, tailwater ponds, and other on-farm features that support wildlife (consult *Journal of Soil and Water Conservation*). Conover (1998) polled 2000 U.S. farmers nationwide on their experience and opinions concerning on-farm wildlife. 24% of the 1,347 respondents were reluctant to establish wildlife habitat because of potential damage to crops. 38% of respondents said that they would oppose creation of wildlife refuges near their farms. Farmers noted that damage was especially severe from mammals such as deer, raccoons, and coyotes. Despite these perceived problems, 51% of respondents reported that they modified their management to accommodate wildlife, including providing cover for wildlife near fields (39%), providing a water source (38%), leaving crop residue in the field (36%), leaving some crop unharvested (17%), and providing salt licks (12%). Given the willingness of many farmers to alter their practices, there appears to be continuing opportunity to implement on-farm restoration ecology and conservation biology.

The experience of The Nature Conservancy in their Sacramento River Project points up the major role that farmers can play in restoring native vegetation to riparian corridors that adjoin farms, and the importance of in-field management changes to conserve and enhance native bird species (Dawit Zeleke, Pers. Comm.). A challenge lies in providing economic incentives and infrastructural support to allow landowners to accommodate, maintain, and enhance or restore ecological parameters on the landscape.

There has been little published on how farming in eastern Merced County affects wildlife. Several recent studies from elsewhere have concerned how farming systems influence birds, including several papers from Great Britain and Canada. Here I summarize selected papers and, where possible, attempt to draw inferences or make recommendations relevant to Merced County agriculture.

Farming Affects Birds

Fluetsch & Sparling (1994) conducted a replicated study of insecticide use, songbird diversity, and nesting success of Mourning dove (*Zenaida macroura*) and American robin (*Turdus migratorius*) in organic vs. conventional apple orchards of Pennsylvania. Their data reflect heavy use of organophosphorus insecticides and document insecticide deposition in bird nests. Further, daily survival rate (DSR) of immature birds and bird diversity were significantly greater in organic orchards. Intermediate forms of orchard management that are not organic have also eliminated organophosphorus insecticides (Santer 1995) in Merced County almond production, and might be expected to be more hospitable to birds.

In the Prairie Pothole region of southeastern North Dakota, Lokemoen & Beiser (1997) evaluated bird densities, bird nest densities, and daily survival rates on conventional, minimum-tillage, and organic farms (sunflower and wheat production; organic farms used yellow sweetclover as a green manure or fallow). Mean number of nesting species and mean nest densities were higher on minimum-tillage and organic than on conventional farms. Significantly greater densities of birds were observed on reduced-tillage than on conventional farms. Daily survival rate for shore birds was greater in minimum-tillage than in organic fields. No other differences among farm type were observed. For organic fields, there was a negative correlation between tillage treatments (numbers of diskings) and bird nest densities. In light of the low nesting success rate, the authors suggested use of late-maturing legumes to allow delay plowing down of organic fallow fields until late June, which would in turn enable bird nesting. The authors also recommended further reduction of tillage. Reduced tillage farming systems are being developed for field and vegetable crops in the San Joaquin Valley, through work by Jeff Mitchell of the University of California Kearney Agricultural Experiment Station, Parlier, and others. These systems may involve summer forage crops such as sorghum/sudangrass and winter cover crops of oat, vetch, pea, and bell bean, as well. These reduced tillage systems should be evaluated for impacts on birds, relative to conventional tillage-based systems. Vineyard and orchard cover crops, mainly non-native grasses and forbs, are often used in Merced County almond orchards and winegrape vineyards. Clearly, cover crops can be an attractive sink for birds, since, depending on management, they may induce but not necessarily fully support nesting. I suggest that cover-crop selection and the timing - - and spacing - - of mowing and tillage should be investigated, in orchards, vineyards, and field crops, to maximize nesting success and winter foraging by desirable bird species.

In England and Wales, Chamberlain et al. (1999) compared replicated pairs of organic and nearby conventional farms. The same observer assessed each pair of farms, to avoid systematic bias. Farms were not matched by crop rotation, because rotation is an intrinsic difference between the organic and conventional approaches, as are pesticide and fertilizer regimes and management of non-crop areas (e.g. hedgerows). In the spring and summer (the breeding season), the number of territorially active birds were estimated. During fall and winter, numbers of birds in boundaries (edges) of fields were assessed. On-farm habitat was characterized, including area, crop types, and boundary conditions. The study included fall and winter data for 1992/93 - 1993/94 (two years) as well as breeding-season data for 1992-1994 (three years). There was no overall pattern in the Shannon-Weiner species diversity index. Pair densities for 17 species over three breeding seasons showed 43 of 51 differences in favor of the organic farms, and data from 1992 (15 of 17 comparisons) and 1994 (16 of 17) were significant individually, whereas data from 1993 (12 of 17) were not, by themselves, significant. During fall and winter, bird density was greater on organic than conventional in 56 of 64 cases. Nine of these individual cases showed statistical significance, and sign tests showed significantly greater overall densities for organic in three of the four years of sampling. Outside the breeding season, bird densities in fields were greater for organic in 50 of 68 cases, but only in the winter of 1992 was a difference detected for a given time period. The researchers infer that territorial exclusion may lead to smaller differences between organic and conventional during the breeding season, but that in fall and winter territorial behavior is relaxed for most species, so densities will better reflect resource availability. I suggest that, in Merced County, sampling outside the nesting season of may at times provide a sensitive indicator of differences among farming systems, and may, for a given sampling effort, provide greater statistical power in detecting systematic differences in bird densities and diversity.

Shutler et al. (2000) evaluated bird diversity and density over an approximately one-year period on Saskatchewan, Canada wild sites and on organic, reduced-tillage, and conventional fields. Geographic area was used as a blocking variable to provide local clusters of fields representing all four treatments. A fixed-radius, point-count method was used, and several ecological covariates were measured within the quartersections containing the fields where bird density was assessed. Values for these variables were based on whether wetlands or woodlands were located within a 200-meter radius of the center of each sampling area, and on the area of wetlands and woodlands and an estimate of habitat complexity within the quartersection containing each sampling site. Several species of birds showed significantly higher densities on organic farms or the adjoining wetlands. For example, black-billed magpie, American robin, Le Conte's sparrow, and Vesper sparrow, all had significantly greater densities on organic than on one or more of the other three treatments. Relative abundance of birds on organic farms was significantly greater than on conventional or reduced tillage farms, and was not significantly less than for wild sites. Wetlands and their margins adjoining organic fields had significantly greater relative abundance of birds than did those adjoining reduced tillage or conventional fields. I suggest that, in Merced County, regulations be developed to enhance bird life in wetlands by favoring the use on adjoining lands of organic and related farming systems that are both reduced-risk and ecologically based.

In Ontario, Canada, Freemark & Kirk (2001) studied bird diversity on 10 pairs of organic and conventional farms. Mean bird diversity and species richness were significantly higher and eight species were more abundant on organic farms. Two species were significantly more abundant on conventional farms. Statistical trends ($0.05 < P < 0.10$)

suggested four additional species were more abundant on organic and 3 on conventional farms. Further statistical analyses revealed the importance of non-crop habitats, permanent crop cover, and the negative effect of intensive, conventional management practices on bird species diversity. I suggest that, in Merced County, the use of perennial hedgerows, including medicinal and culinary plants that can be harvested, be explored as means of enhancing bird diversity and densities on farms.

In a review article, Vickery et al. (2001) highlighted probable reasons for decline of bird diversity and density on lowland neutral grasslands in England, apparently correlated with intensification of forage-production practices. The followng points were emphasized:

1) Transition from cattle to sheep has led to simplification of the sward floristic composition.
2) Transition from grazing to silage production has led to monocultures of high-statured plants subject to frequent close mowing for harvest.
3) Addition of fertilizer nitrogen leads to simplified stand composition, uniform, high stature, and reduced densities of several key arthropod prey of birds.
4) Use of the anthelminthic (de-worming) medicines called avermectins makes animal dung less hospitable to various arthropods that are a food base to birds.

The authors note that low-input grazing operations have long been recognized as a major reservoir for native biodiversity, but that most on-farm studies of bird ecology have focussed on arable (=tillage-based) agriculture rather than extensive grasslands. The authors advocate the conservation and restoration of extensive, low-input grazing operations, the protection of field edges from grazing, and the exploration of alternative antihelminthic medicines to the avermectins now used to treat stock animals. Range management practices in eastern Merced County should be evaluated to determine whether there are problems similar to those reported by Vickery et al. (2001), and whether floristic and faunistic diversities could be better supported by modifying those practices.

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Appendix G

Abstracts Related to Farmland Management and Nitrogen Enrichment

Prepared by Robert Bugg

Adams, M.J. 2000. Pond permanence and the effects of exotic vertebrates on anurans. ECOLOGICAL APPLICATIONS 10(2):559-568.

Abstract
In many permanent ponds throughout western North America, the introduction of a variety of exotic fish and bullfrogs (*Rana catesbeiana*) correlates with declines in native amphibians. Direct effects of exotics are suspected to be responsible for the rarity of some native amphibians and are one hypothesis to explain the prevalence of amphibian declines in western North America. However, the prediction that the permanent ponds occupied by exotics would be suitable for native amphibians if exotics were absent has not been tested. I used a series of enclosure experiments to test whether survival of northern red-legged frog (*Rana aurora aurora*) and Pacific treefrog (*Hyla regilla*) larvae is equal in permanent and temporary ponds in the Puget Lowlands, Washington State, USA. I also examined the direct effects of bullfrog larvae and sunfish. Survival of both species of native anuran larvae was generally lower in permanent ponds. Only one permanent pond out of six was an exception to this pattern and exhibited increased larval survival rates in the absence of direct effects by exotics. The presence of fish in enclosures reduced survival to near zero for both native species. An effect of bullfrog larvae on Pacific treefrog larval survival was not detected, but effects on red-legged frog larvae were mixed. A hypothesis that food limitation is responsible for the low survival of native larvae in some permanent ponds was not supported. My results confirm that direct negative effects of exotic Vertebrates on native anurans occur but suggest that they may not be important to broad distribution patterns. Instead, habitat gradients or indirect effects of exotics appear to play major roles. I found support for the role of permanence as a structuring agent for pond communities in the Puget Lowlands, but neither permanence nor exotic vertebrates fully explained the observed variability in larval anuran survival.

Belden, L.K. and A.R. Blaustein. 2002. Exposure of red-legged frog embryos to ambient UV-B radiation in the field negatively affects larval growth and development. OECOLOGIA 130 (4): 551-554.

Abstract
Exposure to ultraviolet-B radiation (UV-B; 280-320 nm) has a wide array of effects on aquatic organisms, including amphibians, and has been implicated as a possible factor contributing to global declines and range reductions in amphibian populations. Both lethal and sublethal effects of UV-B exposure have been documented for many

amphibian species at various life-history stages. Some species, such as red legged frogs, *Rana aurora*, appear to be resistant to current ambient levels of UV-B, at least at the embryonic and larval stages, despite the fact that they have experienced range reductions in the Willamette Valley of Oregon, USA. However, UV-B is lethal to embryonic and larval *R. aurora* at levels slightly above those currently experienced during development. Therefore, we predicted that exposure of embryos to ambient UV-B radiation would result in sublethal effects on larval growth and development. We tested this by exposing *R. aurora* embryos to ambient UV-B in the field and then raising individuals in the laboratory for I month after hatching. Larvae that were exposed to UV-B as embryos were smaller and less developed than the non-exposed individuals I month post-hatching. These types of sublethal effects of UV-B exposure indicate that current levels of UV-B could already be influencing amphibian development.

Chivers, D.P., E.L. Wildy, J.M. Kiesecker, A.R. Blaustein. 2001. Avoidance response of juvenile pacific treefrogs to chemical cues of introduced predatory bullfrogs. JOURNAL OF CHEMICAL ECOLOGY 27(8):1667-1676.

Abstract

Bullfrogs (*Rana catesbeiana*), native to eastern North America, were introduced into Oregon in the 1930's. Bullfrogs are highly efficient predators that are known to eat a variety of prey including other amphibians. In laboratory experiments, we investigated whether juvenile Pacific treefrogs (*Hyla regilla*) recognize adult bullfrogs as a predatory threat. The ability of prey animals to acquire recognition of an introduced predator has important implications for survival of the prey. We found that treefrogs from a population that co-occurred with bullfrogs showed a strong avoidance of chemical cues of bullfrogs. In contrast, treefrogs from a population that did not co-occur with bullfrogs, did not respond to the bullfrog cues. Additional experiments showed that both populations of treefrogs use chemical cues to mediate predation risk. Treefrogs from both populations avoided chemical alarm cues from injured conspecifics.

Dyer, A.R. 2002. Burning and grazing management in a California grassland: Effect on bunchgrass seed viability. RESTORATION ECOLOGY.10(1):107-111.

Abstract

Prescribed fire is an important management tool for reducing the dominance of non-native species in annual grasslands; both annual and perennial native species show strong vegetative responses in the subsequent growing season. However, although the postfire contribution of native species to the seed bank is assumed to be larger than in pretreatment years, the effects on seed quality, particularly viability and longevity, are not well understood. In this study, I germinated *Nassella pulchra* (purple needlegrass) seed that had been stored for 10 years after collection from target plants receiving treatment combinations of summer burning and grazing by sheep. Seeds from burned plants were larger and had higher germinability than seed from unburned plants. Seeds from plants that were both burned and grazed had the highest germination. The strong relationship between long-term viability and seed size suggests greater maternal provisioning and increased seed quality subsequent to burning and grazing. I conclude

that managing for seed quality may be a useful approach for conservation of native species in California's critically endangered grassland habitats.

Germano, D.J., G.B. Rathbun and L.R. Saslaw. 2001. Managing exotic grasses and conserving declining species. WILDLIFE SOCIETY BULLETIN 29 (2): 551-559.

Abstract

California's southern San Joaquin Valley, as with much of western North America, has been invaded by exotic plant species during the past 100-200 years. The herbaceous cover of these introduced grasses and forbs often creates an impenetrable thicket for small ground-dwelling vertebrates. Contrary to some earlier descriptions of upland habitat of the southern and western San Joaquin Valley as perennial grasslands, recent evidence suggests that most of this area was a desert vegetated by saltbush scrub with sparse cover of native annual grasses and forbs. Many of the small vertebrates that evolved in these habitats, some of which are listed as threatened or endangered, are desert-adapted. These species evolved in sparsely vegetated habitats and rely on open ground to forage and avoid predation. Preliminary research indicates that populations of giant kangaroo rats (*Dipodomys ingens*), San Joaquin kangaroo rats (*D. nitratoides*), San Joaquin antelope squirrels (*Ammospermophilus nelsoni*), and blunt-nosed leopard lizards (*Gambelia sila*), all listed as threatened or endangered, are affected negatively by thick herbaceous cover. This cover also may adversely affect several listed plant species. Removing anthropogenic disturbances does not reduce or eliminate these exotic plants. Fire is effective in reducing herbaceous cover but kills native saltbush and often is costly to implement or control. Although livestock may have contributed originally to habitat destruction and introduction of exotic plants, we believe that in some years, moderate to heavy grazing by livestock is the best way to decrease the dense cover created by these exotics. Recent decisions to decrease or eliminate livestock grazing on conservation lands without definitive studies of grazing in these habitats may lead to further declines of native species and possible local extinction of some listed plants and animals.

Goodsell, J.A. and L.B. Kats 1999 Effect of introduced mosquitofish on pacific treefrogs and the role of alternative prey. CONSERVATION BIOLOGY 13(4):921-924.

Abstract

Mosquitofish (*Gambusia affinis*) are distributed by, many mosquito control programs because of their. broad habitat tolerance and because they are considered by some to be effective mosquito predators. As a result, mosquitofish have become established as an exotic species in numerous perennial streams in the Santa Monica Mountains within the last 10-15 years Previous studies have found that mosquitofish prey heavily on California newt (*Taricha torosa*) larvae that inhabit mountain streams. We found Pacific treefrog (*Hyla regilla*) tadpoles in the stomachs of 65% of stream-caught mosquitofish. In both laboratory, and field experiments, we found that mosquitofish preyed heavily on treefrog tadpoles even when high densities of mosquito larvae were presented as alternative prey. Thus, despite apparent high densities of Pacific treefrog populations, our experiments suggest that introduced mosquitofish may negatively affect stream-breeding *H. regilla* in the Santa Monica Mountains

Harrison, S. 1999. Native and alien species diversity at the local and regional scales in a grazed California grassland. OECOLOGIA 121(1):99-106.

Abstract

Serpentine meadows in Northern California supported higher species richness at the 1-m(2) scale than adjacent nonserpentine meadows, and had a considerably higher proportion of native species. Within each soil type, total species richness (natives plus aliens) was unrelated to biomass, cover, soil depth, or soil characteristics (N, P, Ca++, Mg++, water-holding capacity). However, the proportion of native species on serpentine was higher in meadows with lower levels of phosphorus and a lower calcium/magnesium ratio; the proportion of native species in nonserpentine meadows was higher on cool (north to northeast facing) slopes. At a regional scale, some of these effects were partly reversed; the rate at which new species accumulated with the addition of new sites, or beta diversity, was highest for native plant species in nonserpentine meadows. All of the above effects were independent of whether grazing by cattle was absent (removed 13 years ago) or present. The status of low-productivity serpentine soils as a refuge for native grassland species appears to be the result of their abiotic resistance to alien species, but not of a negative relationship between productivity and total species richness.

Hatch, D.A., J.W. Bartolome, J.S. Fehmi, and D.S. Hillyard. 1999. Effects of burning and grazing on a coastal California grassland. RESTORATION ECOLOGY 7 (4):376-381.

Abstract

We tested the effects of fall burning and protection from livestock grazing as management to enhance native grasses on a coastal grassland in central California. Plants from the Mediterranean, introduced beginning in the late 1700s, have invaded and now dominate most of California's grasslands. Coastal grasslands are generally less degraded than those inland and have higher potential for restoration and conservation. Productivity of the experimental plots varied annually and declined over the course of the study because of rainfall patterns. Foliar cover of the native *Danthonia californica* (California oatgrass) increased more under grazing than grazing exclusion and did not respond to burning. Two other natives, *Nassella pulchra* (purple needlegrass) and *Nassella lepida* (foothill needlegrass), responded variably to treatments. The response of *N. pulchra* differed from that reported on more inland sites in California. Restoring these grasslands is complicated by differing responses of target species to protection from grazing and burning. The current practice of managing to enhance single species of native plants (e.g, *N. pulchra*) may be detrimental to other equally important native species.

Hays, J.B., A.R. Blaustein, J.M. Kiesecker, P.D. Hoffman, I. Pandelova, D. Coyle, T. Richardson. 1996. Developmental responses of amphibians to solar and artificial UVB sources: A comparative study. PHOTOCHEMISTRY AND PHOTOBIOLOGY 64(3):449-456.

Abstract

Many amphibian species, in widely scattered locations, currently show population declines and/or reductions in range, but other amphibian species show no such declines. There is no known single cause for these declines. Differential sensitivity to UVB radiation among species might be one contributing factor. We have focused on amphibian eggs, potentially the most UVB-sensitive stage, and compared their resistance to UVB components of sunlight with their levels of photolyase, typically the most important enzyme for repair of the major UV photoproducts in DNA, cyclobutane pyrimidine dimers. Photolyase varied 100-fold among eggs/oocytes of 10 species. Among three species-*Hyla regilla*, *Rana cascadae*, and *Bufo boreas* - for which resistance of eggs to solar UVB irradiance in their natural locations was measured, hatching success correlated strongly with photolyase. Two additional species, *Rana aurora* and *Ambystoma gracile*, now show similar correlations. Among the low-egg-photolyase species, *R. cascadae* and *B. boreas* are showing declines, and the status of *A. gracile* is not known. Of the two high-photolyase species, populations of *H. regilla* remain robust, but populations of *R. aurora* are showing declines. To determine,whether levels of photolyase or other repair activities are affected by solar exposures during amphibian development, we have initiated an extended study of *H. regilla* and *R. cascadae*, and of *Xenopus laevis*, laboratory-reared specimens of which previously showed very low photolyase levels. *Hyla regilla* and *R. cascadae* tadpoles are being reared to maturity in laboratories supplemented with modest levels of UV light or light filtered to remove UVB wavelengths.

Young *X. laevis* females are being reared indoors and outdoors. Initial observations reveal severe effects of both UVA and UVB light on *H. regilla* and *R. cascadae* tadpoles and metamorphs, including developmental abnormalities and high mortalities, Assays of photolyase levels in the skins of young animals roughly parallel previous egg/oocyte photolyase measurements for all three species.

Honisch, M., C. Hellmeier, and K. Weiss. 2002. Response of surface and subsurface water quality to land use changes. GEODERMA 105(3-4):277-298.

Abstract

Modern agricultural production systems need to reduce their environmental contamination potential. Within the test site of the FAM Research Network on Agroecosystems, the existing agricultural system was modified from intensive to sustainable land use practices. The aim of this study was to quantify the long-term effects of these new practices on the surface and subsurface water quality at the Research Station Scheyern in Bavaria, Germany. Nutrient concentrations in soil water and ground water were monitored by soil hydrological stations and in multilevel wells. Water and material fluxes were observed in a brook and in the tile drain system over a 4-year period. Nitrate

concentrations in soil water were affected by soil types, relief position and fertilization (farming system). Highest concentrations were found in soils under potatoes and integrated crop production (ICP), lowest under organic farming (OF). Since monitoring began in 1994, nitrate concentrations below the root zone decreased continuously from 25-50 to 5-30 mg NO3- l(-1). Temporal variable concentrations within the root zone were stabilized by plant uptake and lateral subsurface flow in deeper soil horizons. Lower material inputs to soils were confirmed by decreasing nitrate and chloride concentrations in drain water and diffuse lateral input to the Brook West. Nitrogen loading into the brook decreased up to 50% whereas in the upper regional ground water, values greater than 50 mg NO3- l(-1) still reflect former nutrient loads. Surface water phosphorous load was also strongly affected by agricultural practice. The lateral inputs area into the brook from the farm showed that phosphate loading decreased up to 25% (from 0.37 to 0.09 kg P ha(-1) a(-1)). However, concentrations of dissolved reactive ortho-phosphate (DRP) remained high, due to remobilization from the brook's sediment. Our results have shown that adapted land use practice can reduce groundwater and surface water loads effectively. The anti-erosion program (mulching, minimum tillage, fallow strips and others) minimized lateral loads to the surface water and optimized fertilization and intercropping, whereas ecofarming mainly reduced the leakage potential of soils. The slow response in the groundwater is strongly affected by the mean transit time, whereas lateral subsurface flow and buffering effects of soils and sediments determine the dynamics within brooks and ponds.

Johnson, P.T.J., K.B. Lunde, E.M. Thurman, E.G. Ritchie, S.N. Wray, D.R. Sutherland, J.M. Kapfer, T.J. Frest, J. Bowerman, and A.R. Blaustein. 2002. Parasite (*Ribeiroia ondatrae*) infection linked to amphibian malformations in the western United States. ECOLOGICAL MONOGRAPHS 72(2):151-168.

Abstract

Parasites and pathogens can influence the survivorship, behavior, and very structure of their host species. For example, experimental studies have shown that trematode parasites can cause high frequencies of severe limb malformations in amphibians. In a broad-scale field survey covering parts of California, Oregon, Washington, Idaho, and Montana, we examined relationships between the frequency and types of morphological abnormalities in amphibians and the abundance of trematode parasite infection, pH, concentrations of 61 pesticides, and levels of orthophosphate and total nitrate. We recorded severe malformations at frequencies ranging from 1% to 90% in nine amphibian species from 53 aquatic systems. Infection of larvae by the trematode *Ribeiroia ondatrae* was associated with. and functionally related to, higher frequencies of amphibian limb malformations than found in uninfected populations (less than or equal to 5%). Parasites were concentrated around the basal tissue of hind limbs in infected anurans, and malformations associated with infection included skin webbings, supernumerary limbs and digits, and missing or malformed hind limbs. In the absence of *Ribeiroia*, amphibian populations exhibited low (0-5%) frequencies of abnormalities involving missing digits or distal portions of a hind limb. Species were affected differentially by the parasite, and *Ambystoma macrodactylum, Hyla regilla, Rana aurora. R. luteiventris* and *Taricha torosa* typically exhibited the highest frequencies of abnormalities. None of the water-quality variables measured was associated with malformed amphibians. but aquatic snail hosts (*Planorbella* spp.) were significant predictors of the presence and abundance of *Ribeiroia* infection. Morphological comparisons of adult specimens of *Ribeiroia* collected from different sites and raised in experimental definitive hosts suggested that all samples represented the same species- *R. ondatrae*. These field results, coupled with experimental research on the effects of Ribeiroia on amphibians, demonstrate that *Ribeiroia* infection is an important and widespread cause of amphibian limb malformations in the western United States. The relevance of trematode infection to declines of amphibian populations and the influence of habitat modification on the pathology and life cycle of *Ribeiroia* are emphasized as areas requiring further research.

Kiesecker, J.M., A.R. Blaustein. 1999. Pathogen reverses competition between larval amphibians. ECOLOGY 80(7): 2442-2448.

Abstract

Ecologists have often suggested that the presence of pathogens that differentially affect interacting species may affect the outcome of interactions, yet few experimental studies have documented pathogen-mediated interactions using a natural host-parasite system. We studied the effects of a pathogenic water mold, *Saprolegnia ferax*, on competitive interactions between the Cascades frog *Rana cascadae* and the Pacific treefrog *Hyla regilla*. Previous studies have shown that outbreaks of *Saprolegnia* infection in the Cascade mountains of Oregon, USA, result in high embryonic mortality for *Rana* but not for *Hyla*. Thus, we examined how infections of *Saprolegnia* during amphibian embryonic development could influence larval recruitment and competitive interactions between larval *Rana* and *Hyla*. We manipulated the presence of *Saprolegnia* and embryonic *Hyla* and *Rana* in replicated artificial ponds and determined mean survivorship to hatching per pool from daily observations during embryonic development. Pools were then followed throughout larval development, and we recorded mean mass of tadpoles at metamorphosis and time to metamorphosis per pool. The presence of *Saprolegnia* differentially affected larval recruitment of the two species; larval recruitment of *Rana* was reduced by 46.2% in the presence of *Saprolegnia*, whereas *Hyla* survival was not affected. However, larval *Rana* that survived *Saprolegnia* infection developed faster and were larger at metamorphosis compared to individuals not exposed to *Saprolegnia*. In the absence of *Saprolegnia*, *Rana* had strong negative effects on the growth, development, and survival of *Hyla*. However, in the presence of *Saprolegnia*, the outcome of competitive interactions between the two species was reversed. *Saprolegnia* may have positive indirect effects on both *Hyla* and *Rana* by regulating both intra- and interspecific competition. These results suggest that pathogens can have strong effects on species interactions and may ultimately influence community structure.

Kupferberg, S.J. 1997. Bullfrog (*Rana catesbeiana*) invasion of a California river: The role of larval competition. ECOLOGY 78(6):1736-1751.

Abstract

I studied the invasion of *Rana catesbeiana* (the bullfrog) into a northern California river system where bullfrogs are not native. Native yellow-legged frogs, *Rana boylii*, a species

of special concern, were almost an order of magnitude less abundant in reaches where bullfrogs were well established. I assessed the potential role of larval competition in contributing to this displacement in a series of field manipulations of tadpole density and species composition. The impact of *R. catesbeiana* on native tadpoles in the natural community agreed with the outcome of more artificial experiments testing pairwise and three-way interactions. In 2-m(2) enclosures with ambient

densities of tadpoles and natural river biota, bullfrog tadpoles caused a 48% reduction in survivorship of *R. boylii*, and a 24% decline in mass at metamorphosis. Bullfrog larvae had smaller impacts on Pacific treefrogs, *Hyla regilla*, causing 16% reduction in metamorph size, and no significant effect on survivorship. Bullfrog tadpoles significantly affected benthic algae, although effects varied across sites. Responses to bullfrogs in field settings were similar qualitatively to results seen in smaller-scale experiments designed to study size-structured competition among disparate age/size classes of species pairs and trios. Competition from large overwintering bullfrog larvae significantly decreased survivorship and growth of native tadpoles. Competition from recently hatched bullfrog larvae also decreased survivorship of *R. boylii* and *H. regilla*. Native species competed weakly, both interspecifically and intraspecifically. The only suggestion of a negative impact of a native species on bullfrogs was a weak effect of *H. regilla* on recent hatchlings. Competition appeared to be mediated by algal resources, and there was no evidence for behavioral or chemical interference. These results indicate that, through larval interactions, bullfrogs can exert differential effects on native frogs and perturb aquatic community structure.

Lawler, S.P., Dritz D., T. Strange, M. Holyoak. 1999. Effects of introduced mosquitofish and bullfrogs on the threatened California red-legged frog. CONSERVATION BIOLOGY 13(3):613-622.

Abstract

Exotic species have frequently caused declines of native fauna and may contribute to some cases of amphibian decline. Introductions of mosquitofish (*Gambusia affinis*) and bullfrogs (*Rana catesbeiana*) are suspected to have caused the decline of California red-legged frogs (*Rana aurora draytonii*). We tested the effects of mosquitofish and bullfrog tadpoles on red-legged frog tadpoles in spatially complex, speciose communities. We added 720 hatchling red-legged frog tadpoles to each of 12 earthen ponds. Three ponds were controls, 3 were stocked with 50 bullfrog tadpoles 3 with 8 adult mosquitofish, and 3 with 50 bullfrogs plus 8 mosquitofish. We performed tests in aquaria to determine whether red-legged frog tadpoles are preferred prey of mosquitofish. Mosquitofish fed on a mixture of equal numbers of tadpoles and either mosquitoes, Daphnia, or corixids until <50% of prey were eaten; then we calculated whether there was disproportionate predation on tadpoles. We also recorded the activity of tadpoles in the presence and absence of mosquitofish to test whether mosquito fish interfere with tadpole foraging. Survival of red-legged frogs in the presence of bullfrog tadpoles was less than 5%; survival was 34% in control ponds.

Mosquitofish did not affect red-legged frog survival, even though fish became abundant (approximately 1011 pet pond). Two mechanisms may have blocked the effects of

mosquitofish on tadpole survival: (1) fish ponds contained fewer predatory invertebrates, and (2) mosquitofish preferred other prey to red-legged frogs in laboratory trials Red-legged frog tadpoles suffered more injuries in ponds with fish, however, and weighed 34% less at metamorphosis. The growth decrease could have been caused by injuries or by lower foraging levels in the presence of fish. Laboratory results showed that young tadpoles were less active in the presence of mosquitofish. Although both mosquitofish and bullfrogs affected red-legged frogs, the impact of bullfrogs on the survival of red-legged frogs may contribute more strongly to their decline.

Leiva, M.J., F.S. Chapin, and R.F Ales. 1997. Differences in species composition and diversity among Mediterranean grasslands with different history - The case of California and Spain. ECOGRAPHY 20(2):97-106.

Abstract

Species composition and diversity were compared among twenty Mediterranean annual grasslands in northern and central California and central and southern Spain, encompassing climatic gradients and local site variation in topography and soils. Geographic proximity was more important than environmental factors such as climate, topography and parent material in predicting the species composition of these grasslands, with Californian and Spanish grasslands sharing only 9% of the species and geographically separated regions within each country sharing only 20-32% of the species. This importance of geographic separation in predicting species composition suggests a strong role of dispersal limitation in determining current community composition. Mean species diversity was lower in Californian than in Spanish grasslands and was negatively correlated with cover of annual grasses that tended to be greater in California than in Spain. However, there were few differences in species diversity among sites within either country and patterns of species diversity were unrelated to soil fertility or productivity. We suggest that current grazing regimes contribute to the greater abundance of grasses and lower species diversity of Californian than of Spanish grasslands. The apparent importance of dispersal limitation and grazing in explaining differences in species composition and diversity between Californian and Spanish grasslands and within each country suggest that the structure of these grasslands has been and will continue to be sensitive to human influence.

LeJeune, K.D. and T.R. Seastedt. 2001. Centaurea species: the forb that won the west. CONSERVATION BIOLOGY. 15(6):1568-1574.

Abstract

Grasslands of the western United States and Canada are being converted to ecosystems that resemble "old fields," dominated in terms of percent cover or biomass by forb species, In particular, five species of the genus Centaurea (star thistle, diffuse, spotted, squarrose, and Russian knapweed) have invaded millions of hectares of western United States and Canadian grasslands. Centaurea species are fundamentally different from the preexisting dominant species and may exploit changes in resource availability to become established. We suspect that they then maintain dominance by preventing resources from returning to levels that favor the native species. Increased atmospheric nitrogen deposition, reduced fire frequency, and, possibly, direct and indirect fertilization resulting from cattle grazing appear to have reduced the historically strong nitrogen limitation to which native species of western grasslands are adapted, We suggest that the success of Centaurea species in dominating grasslands is explained by their ability to compete successfully for the neu, limiting resource or resources. Our preliminary evidence suggests that phosphorus limitation or a colimitation of phosphorus and water best explains the current dominance patterns.

Marco, A., C. Quilchano, and A.R. Blaustein. 1999. Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific northwest. ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY 18(12):2836-2839.

Abstract

In static experiments, we studied the effects of nitrate and nitrite solutions on newly hatched larvae of five species of amphibians, namely *Rana pretiosa*, *Rana aurora*, *Bufo boreas*, *Hyla regilla*, and *Ambystoma gracile*. When nitrate or nitrite ions were added to the water, some larvae of some species reduced feeding activity, swam less vigorously, showed disequilibrium and paralysis, suffered abnormalities and edemas, and eventually died. The observed effects increased with both concentration and time, and there were significant differences in sensitivity among species. *Ambrystoma gracile* displayed the highest acute effect in water with nitrate and nitrite. The three ranid species had acute effects in water with nitrite. In chronic exposures, *R. pretiosa* was the most sensitive species to nitrates and nitrites. All species showed 15-d LC50s lower than 2 mg N-NO2-/L. For both N ions, *B. boreas* was the least sensitive amphibian. All species showed a high mortality at the U.S. Environmental Protection Agency-recommended limits of nitrite for warm-water fishes (5 mg N-NO2-/L) and a significant larval mortality at the recommended limits of nitrite concentration for drinking water (1 mg N-NO2-/L). The recommended levels of nitrate for warm-water fishes (90 mg N-NO3-/L) were highly toxic for *R. pretiosa* and *A. gracile* larvae.

Maron , J.L. and R.L. Jefferies. 1999. Bush lupine mortality, altered resource availability, and alternative vegetation states. ECOLOGY 80 (2):443-454.

Abstract

Nitrogen-fixing plants, by altering the availability of soil N, potentially facilitate plant invasion. Here we describe how herbivore-driven mortality of a native N-fixing shrub, bush lupine (*Lupinus arboreus*), increases soil N and light availability, which promotes Invasion by introduced grasses to the detriment of a native plant community.

Soils under live and dead lupine stands contained large amounts of total N, averaging 3.14 mg N/g dry mass of soil (398 g/m(2)) and 3.45 mg N/g dry mass of soil (438 g/m(2)), respectively, over four years. In contrast, similar lupine-free soil was low in N and averaged only 1.66 mg N/g dry mass of soil (211 g/m(2)) over three years. The addition of N fertilizer to lupine-free soil produced an 81% increase in aboveground plant biomass compared to plots unamended with N. Mean rates of net N mineralization were higher under live lupine and where mass die-off of lupine had occurred compared to soils free of bush lupine. At all sites, only 2.5-4.2% of the total soil N pool was mineralized annually.

Soil enriched by lupine is not available to colonists while lupines are alive. The dense canopy of lupine shades soil under shrubs, reducing average photon-flux density in late spring from 1725 mu mol . m(-2) . s(-1) (full sunlight) to 13 mu mol . m(-2) . s(-1) (underneath shrubs). Stand die-off due to insect herbivory exposed this bare, enriched soil. In January, when annual plants are establishing, average photon-flux density under dead lupines killed by insect herbivores was 370 mu mol m(-2) . s(-1), compared to the photon-flux density under live lupines of the same age, which averaged 83 mu mol . m(-2) . s(-1). The availability of bare, N-rich patches of soil enabled nonnative annuals (primarily *Lolium multiflorum* and *Bromus diandrus*) to colonize sites, grow rapidly, and dominate the plant assemblage until lupines reestablished after several years. The N content of these grasses was significantly greater than the N content of the mostly native plants that occupied adjacent coastal prairie devoid of bush lupine. Between 57 and 70% of the net amount of N mineralized annually was taken up by introduced grasses and subsequently returned to the soil upon the death of these annuals. Even in the absence of further N inputs, we estimate that it would take at least 25 yr to reduce the soil N pool by 50%, indicating that the reestablishment of the native prairie flora is likely to be long term.

McDonald, P.M. and G.O. Fiddler. 2002. Relationship of native and introduced grasses with and without cattle in a young ponderosa pine plantation. WESTERN JOURNAL OF APPLIED FORESTRY 17(1):31-36.

Abstract

On an above-average site in northern California, an early shrub-forb-grass plant community was treated by artificially seeding two forage grass species at plantation age 3, cattle grazing with and without seeded grasses, and applying a soil-active chemical (Velpar). Planted ponderosa pines (*Pinus ponderosa* var. *ponderosa*) were part of this community. Results for a 10 yr period (1988-1997) are presented for a native, naturally invading needlegrass (*Achnatherum nelsonnii*), introduced orchard grass (*Dactylis glomerata*) and introduced pubescent wheatgrass (*Agropyron trichophorum*). In general, all three grasses became established, grew well, and spread throughout the study area. Density of needlegrass was highest in the Velpar, fenced control, and grazed control treatments (more than 72,000 plants/ac). Orchard grass density was highest in the seeded and grazed and seeded and fenced treatments (more than 14, 000 plants/ac) and relatively high in the Velpar treatment (8,400 plants/ac). Pubescent wheatgrass established well in both seeded treatments (more than 24,000 plants/ac) and spread best to the grazed control (6,950 plants/ac). Ecologically, the introduced grasses had no major effect on the native plant community, and, economically, their effect was positive, although minor.

Padgett, P.E., E.B. Allen, A. Bytnerowicz, and R.A. Minich. 1999. Changes in soil inorganic nitrogen as related to atmospheric nitrogenous pollutants in southern California. ATMOSPHERIC ENVIRONMENT 33(5):769-781.

Abstract

The deposition of nitrogenous pollutants has serious implications for ecosystem function and stability. Research in temperate ecosystems has indicated a wide range of ecological responses, yet very little is known about arid ecosystems. In this study, measurements of atmospheric and soil concentrations of the plant-available NO3- and NH4+ were evaluated to identify a potential gradient in nitrogen (N) deposition. The evaluations were conducted in coastal sage scrub, a semi-arid vegetation type native to the lower elevations of southern California. The summer atmospheric concentrations of nitrate (NO3-) and ammonium (NH4+) were determined at five locations on the Perris Plain of southern California. The atmospheric influences varied from direct interception of pollution generated in the Los Angeles Basin at the northern end of the gradient to a site 70 km south lacking any direct Los Angeles influence. The summer atmospheric concentrations of NO3- varied more than three-fold along the gradient. Ammonium concentrations followed a similar pattern, but the gradient was less steep. Winter concentrations were very low for both compounds.

The summer soil surface NO3- concentrations were near the detection limits at low pollution sites but in the range of 50-60 mu g N g(-1) soil under highly polluted conditions. Wet deposition was found to be a minor contributor of plant-available N, suggesting that dry deposition may be a consequential source of plant-available N.

The detection of significant changes in inorganic, plant-available N in the upper layer of soils is enhanced by the unique environmental conditions and vegetation of southern California. This study suggests that the coastal sage scrub ecosystem is experiencing significant changes in N fertility that may contribute to changes in plant species composition. The data also show that this semi-arid ecosystem provides a unique opportunity to assess many physical, chemical and biological responses to dry deposition alone.

Safford, H.D. and S.P. Harrison 2001. Grazing and substrate interact to affect native vs. exotic diversity in roadside grasslands. ECOLOGICAL APPLICATIONS 11(4):1112-1122

Abstract

We compared the native and exotic species composition of ungrazed roadside verges with that of adjacent grazed interiors in the grasslands of California's inner northern coast range (Napa and Lake Counties). We sampled 72 pairs of verge and interior quadrats at five sites representative of the region's grasslands, on both fertile (loan]) and infertile (serpentine) soils, avoiding all obvious forms of roadside physical disturbance. We found that, on serpentine soils, ungrazed verges had a higher proportion of exotic species than grazed interiors; on nonserpentine soils, the reverse was true. Within serpentine soils, native species were more prevalent in quadrats with lower biomass within nonserpentine,

natives were more prevalent in quadrats receiving less radiation. Overall, the total species diversity was higher in grazed interiors than on ungrazed verges, regardless of the fertility of the substrate. Our results indicate that the ecological role of roadside verges depends oil the interactive effects of community composition and history, environmental gradients, and land use practices that characterize a region.

Samuel, M.J. and R.H. Hart. 1998. Nitrogen fertilization, botanical composition and biomass production on mixed-grass rangeland. JOURNAL OF RANGE MANAGEMENT 51(4): 408-416

Abstract

Many studies have reported nitrogen (N) fertilization of rangeland, but few have reported changes in botanical composition, which may be as important as changes in forage production, or were continued for as long as 14 years. We determined frequency of occurrence of over 90 plant species in 1976-1988 under rates of 0, 22, or 34 kg N ha(-1) applied in spring or fall to mixed-grass rangeland in southeast Wyoming; frequency of 23 species will be reported. We also determined total biomass production and production of major species and species groups in 1982-1988, Blue grama *Bouteloua gracilis* (H,B,K;,) Griffiths] frequency decreased during years 5 through 7 because of the interaction of N and drought. The effects of long-term application of N decreased blue grama in year 12 and beyond. Nitrogen fertilization increased frequency of western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Level in all years except the driest year of the study. Needleleaf sedge [*Carex eleocharis* Bailey] decreased because grazing had been removed from the study area; this occurred sooner and to a greater extent on fertilized than on unfertilized plots. Fourteen other perennial species were quite variable in response to the 3 rates and the 2 seasons of application. Frequency of 6 annual species fluctuated greatly among years and treatments, Nitrogen fertilization did not increase average forage production enough to be profitable for cattle production.

Sher, A.A., D.L. Marshall, S.A. Gilbert. 2000 Competition between native *Populus deltoides* and invasive *Tamarix ramosissima* and the implications for reestablishing flooding disturbance. CONSERVATION BIOLOGY 14(6):1744-1754

Abstract

Changes in historical disturbance regimes have been shown to facilitate non-native invasions, but reinstatement of disturbance can be successful only if native colonizers are able to outcompete colonizing invasives. Reintroduction of flooding in the southwestern United States is being promoted as a means of reestablishing *Populus deltoides* subsp. *wislizenii*, but flooding can also promote establishment of an introduced, invasive species, *Tamarix ramosissima*. We investigated competition between Populus and Tamarix at the seedling stage to aid in characterizing the process by which Tamarix may invade and to determine the potential ability of Populus to establish itself with competitive pressure from Tamarix. We planted seedlings of Tamarix and Populus in five ratios at three densities for a total of 15 treatments. The growth response of each species was measured in terms of height, above-ground biomass, and tissue concentrations of nitrogen and phosphorous. These measurements across treatments were modeled as threedimensional response surfaces. For both species, Populus density was more important than Tamarix density for determining growth response. Both species were negatively affected by increasing numbers of Populus seedlings. Due to the large size of the native Populus, we predict that its superior competitive ability can lead to its dominance when conditions allow native establishment. Our results suggest that even in the presence of an invader that positively responds to disturbance, reestablishment of historical flooding regimes and post-flood hydrology can restore this ecosystem by promoting its dominant plant species.

Robertson, W.D. 1995. development of steady-state phosphate concentrations in septic system plumes. JOURNAL OF CONTAMINANT HYDROLOGY 19(4):289-305.

Abstract

Long-term monitoring of PO43- behaviour in a well-defined septic system plume on calcareous sand (Cambridge site) shows that, after 17 yr of system operation, a distinct PO43- plume (PO43--P > 1 mg L(-1)) is present extending 20 m downgradient from the infiltration bed. The PO43- plume migration velocity is similar to 1 m yr(-1), reflecting retardation by a factor of 20 compared to the groundwater velocity. During monitoring between years 10 to 17, an expanding steady-state zone was noted below the infiltration bed where PO43--P levels remained consistently near 4 mg L(-1), a value similar to 25% lower than the average effluent value (6.3 mg L(-1)). The pattern of attenuation - a 25% mass loss in the 2-m-thick vadose zone, then little further attenuation along the flowpath - is suggestive of a condition of equilibrium with a controlling phosphate mineral phase. Chemical equilibrium modelling shows supersaturation with respect to hydroxylapatite and variscite. Four other field sites are identified from the literature and from our work where similar steady-state PO43- zones are present in septic system plumes. In these, steady-state levels range from 15% to 68% of effluent values, with lower concentrations observed in the more acidic plumes, again indicative of a mineral solubility control, possibly variscite. PO43- behaviour in these plumes suggests that, although P migration velocity is controlled by the processes of sorption, the magnitude of P-4(3-) that is present is governed by the constraints of phosphate mineral solubility. When septic systems on sands are located relatively close to sensitive surface water bodies and when long-term downgradient impact is the primary concern, more attention should be focused an the geochemical conditions that control PO43- mineral solubility rather than only on the sorption characteristics of the sediment.

Stromberg, M.R. and J.R. Griffin. 1996. Long-term patterns in coastal California grasslands in relation to cultivation, gophers, and grazing. ECOLOGICAL APPLICATIONS 6(4):1189-1211.

Abstract

Grasslands at the Hastings Natural History Reservation (HNHR) and in adjacent Santa Lucia coastal range of Monterey County, California were sampled from 1971 to 1991. Grasslands on HNHR showed two distinct and stable associations: stands with and without historical cultivation (approximate to 1865-1937). Relict stands dominated by native, perennial grasses (e.g., *Nassella pulchra*, *Poa secund*a) are limited to uncultivated, steeper stands, often where soils have more clay. Abandoned agricultural fields have stable compositions dominated by *Avena fatua*, *Bromus mollis, B. diandrus*, *Erodium* spp., *Hypochaeris glabra*, *Vulpia* spp., *Eremocarpus setigerus,* and *Amsinckia* spp. Patterns in species composition were associated with gradients in soil texture, gopher abundance, and slope. Gophers provide a significant and continuous source of soil disturbance and may slow successional processes in old fields. Where gophers are excluded, aboveground biomass accumulates. Germination and establishment of native perennial grasses (compared to introduced, annual grasses) are reduced on gopher tailings in old fields.

Species composition patterns reflecting past cultivation on both grazed and ungrazed stands are apparent. Relict (uncultivated) stands of native grasses persist under many historical levels of grazing. Effects of grazing are often only seen on old fields, and not on relict grasslands. Compared to stands where grazing was removed in 1937, stands currently or recently grazed by cattle show higher soil nitrogen, but reductions in cover of gopher tailings, species diversity, soil phosphate, and sulfate.

Weiss, S.B. 1999. Cars, cows, and checkerspot butterflies: Nitrogen deposition and management of nutrient-poor grasslands for a threatened species. CONSERVATION BIOLOGY 13(6):1476-1486.

Abstract

Nutrient-poor, serpentinitic soils in the San Francisco Bay area sustain a native grassland that supports many rare species, including the Bay checkerspot butterfly (*Euphydryas editha bayensis*). Nitrogen (N) deposition from air pollution threatens biodiversity in these grasslands because N is the primary limiting nutrient for plant growth on serpentinitic soils. I investigated the role of N deposition through surveys of butterfly and plant populations across different grazing regimes, by literature revives, and with estimates of N deposition in the region. Several populations of the butterfly in south San Jose crashed following the cessation of cattle grazing. Nearby populations under continued grazing did not suffer similar declines. The immediate cause of the population crashes was rapid invasion by introduced annual grasses that crowded out the larval host plants of the butterfly. Ungrazed serpentinitic grasslands on the San Francisco Peninsula have largely resisted grass invasions for nearly four decades. Several lines of evidence indicate that dry N deposition from smog is responsible for the observed grass invasion. Fertilization experiments have shown that soil N limits grass invasion in serpentinitic soils. Estimated N deposition rates in south San Jose grasslands are 10-15 kg N/ha/year; Peninsula sites have lower deposition, 4-6 kg N/ha/year. Grazing cattle select grasses over fobs, and grazing leads to a net export of N as cattle are removed for slaughter. Although poorly managed cattle grazing can significantly disrupt native ecosystems, in this case moderate, well-managed grazing is essential for maintaining native biodiversity in the face of invasive species and exogenous inputs of N from nearby urban areas.