UNIVERSITY OF CALIFORNIA
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Adaptive Management for Southern California Grasslands

A Group Project submitted in partial satisfaction of the requirements for the degree of Master's of Environmental Science and Management for the Donald Bren School of Environmental Science and Management

Researched and written by:

Andrea Chadden
Edyta Dowksza
Laura Turner

Advisors:
Frank Davis
Peter Kareiva

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As authors of this Group Project report, we are proud to submit it for display in the Donald Bren School of Environmental Science and Management and on the web site such that the results of our research are available for all to read. Our signatures on this document signify our joint responsibility to fulfill the archiving standards set by the Donald Bren School of Environmental Science and Management.

____________________ Andrea Chadden	____________________ Laura Turner
____________________ Edyta Dowksza	

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The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) program. It is a four-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

____________________ Frank Davis	____________________ Dean Dennis Aigner
____________________ Peter Kareiva	____________________ Date

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Abstract

Southern California's remaining grassland communities are threatened by a multitude of influences, including degradation by invasive exotic species, urbanization, public use, habitat loss, changes in fire and grazing regimes, climate change, and pollution. The interactive nature of these influences creates uncertainty for managers of grassland areas seeking to maintain or restore habitat quality and native species composition and richness. In addition, the question of historic grassland distribution and composition in southern California complicates restoration. Adaptive ecosystem management is a technique that can help grassland managers reduce this uncertainty and improve management outcomes over time but which is rarely applied effectively due to lack of familiarity, financial and time constraints, and institutional barriers, among other factors. Adaptive management stresses learning as a central goal of management, and involves identifying management goals and targets, developing methods to establish a baseline of current conditions within a site, formulating hypotheses about system response to management, forming recommendations for management interventions and monitoring methods, and developing feedback mechanisms that inform the next iteration of management. Based on a literature survey and informational interviews with 35 southern California grassland managers and experts, we constructed conceptual models and an adaptive management framework for grassland managers in southern California. We demonstrate this framework for the Santa Rosa Plateau Ecological Reserve in Riverside County.

Executive Summary

It has been estimated that the majority of California's grassland communities have been destroyed or severely degraded (Keeley 1990). Remaining protected and non-protected grassland areas are threatened by a multitude of interacting influences: degradation by exotic species, urbanization and development, over-grazing, public use, habitat loss, changes in fire and grazing regimes, climate change, and pollution. This places increasing pressure on the managers of grasslands in public and private reserves, which tend to be small and increasingly isolated from one another, to maintain native plant and animal species. These difficulties are amplified in southern California where there has been a dearth of management-focused research on grassland.

Southern California grassland areas can be found at elevations ranging from sea level to 1,300 meters, and are characterized by open cover and dominance of grasses and forbs. Generally, they are divided into two types: Coastal Prairie and Valley Grassland. Most native grass species commonly found in California grasslands are perennials, while the majority of exotic species are annuals of Mediterranean origin.

Southern California grasslands in existing reserves are generally managed to maintain or restore native grassland vegetation, to decrease the dominance of exotic plant species, to promote the recovery of threatened or endangered species, and/or to promote other animal and plant species of special concern. Standard "best management practices" to promote and maintain native biodiversity do not exist for southern California grasslands. Common practices include prescribed burning, grazing, seeding, mowing, or no (i.e. passive) management. Reserve managers sometimes choose passive management because it demands the least resources, incurs the least risk, and sparks the least public resistance.

The purpose of this report is to provide The Nature Conservancy a guiding document for management of southern California grasslands. The report includes:

1. A review and synthesis of the literature relevant to southern California grassland and its management;
2. An assessment of current practices, beliefs and recommendations on grassland management collected during informational interviews of 35 grassland management experts and practitioners;
3. A Geographic Information Systems (GIS) analysis of the current state and location of grassland areas in southern California;
4. Guidelines for the adaptive management of a southern California grassland area;
5. An illustration of these guidelines for a southern California grassland reserve – the Santa Rosa Plateau Ecological Reserve.

We review the literature on grassland history, composition, ecological drivers, succession and management. We then report on interviews with experts and practitioners, documenting what they believe to be the key ecological drivers in southern California grassland, the main obstacles, constraints, and challenges in their management, the most critical uncertainties they face in management, and the tools they feel are most needed for reaching their goals. Recurrent themes from the interviews include the need for better understanding of the ecological role of fire, diverging opinions about the appropriateness of planned grazing and about the importance of a reference condition defined by historic grassland, and a recognition that even degraded grassland has conservation value.

Based on existing GIS data, remaining grasslands of Riverside and San Diego Counties are privately owned, highly fragmented and in poor ecological condition. Only 4.6% of this grassland is in formally designated reserves.

Adaptive management, conceived in the late 1970's, is "a process in which management activities are implemented in spite of uncertainty about their effects, the effects of management are measured and evaluated, and the results are applied to future decisions." (Elzinga et al. 2001). Adaptive management aims to reduce uncertainty regarding ecological processes and management outcomes by treating management activities as experiments, with learning as a central goal. The pace of learning under adaptive management can be faster than traditional ecosystem management. In the most rigorous form of adaptive management, active adaptive management, one tests multiple management techniques with a management design that includes replication and control.

An adaptive management plan can be seen as having two main parts: the management plan and the monitoring plan. The general steps involved with following an adaptive management approach include:

1. Defining the project by clarifying the mission of the group and finding common ground with project partners.
2. Modeling the site to establish a baseline and understand threats by reviewing and compiling existing information about the project site, developing an initial conceptual model of the project site, assessing local site conditions to refine and improve the model, and identifying and ranking threats at the project site.
3. Formulating a management, or work, plan by developing goals, identifying areas of key uncertainty, formulating hypotheses about the system and its functioning, stating specific objectives, and identifying activities for the project.
4. Creating a monitoring plan through determining audiences, information needs, monitoring strategies and indicators, selecting methods and tasks necessary to collect data, and determining when, by whom, and where data will be collected.
5. Implementing the management and monitoring plans.

6. Analyzing data and sharing results with stakeholders.
7. Using results to adapt the management strategy, if necessary. In this step assumptions and hypotheses are put to the test. Based on the monitoring results, the project should be adapted as needed.

Conceptual models are created to represent hypothesized interactions between targets, key ecological processes, important threats, and possible management interventions. They serve to highlight areas of uncertainty, which can be investigated through adaptive management. We created three types of conceptual models: general system models for grassland, vernal pools, prescribed burning, and planned grazing; plant species phenograms that display the calendar of important life history events (seed set, flowering, seed fall, germination, growth period(s), and senescence); and, envirograms for selected animal species that encapsulate factors affecting distribution and abundance, such as predators, breeding sites, and resources. Accompanying the phenograms and envirograms are fact sheets for each species, which include information on the species' distribution, management issues and threats, ecology, reproduction, and habitat requirements. Also included in the adaptive management section are excerpts from existing grassland management plans, and suggestions for further reading for specific topics.

Finally, we created an adaptive management framework for the Santa Rosa Plateau Ecological Reserve, located at the southern end of the Santa Ana Mountains in southern California, to demonstrate the application of the information, guidelines and tools included in this document to the management of an actual grassland area in the region. The case study section includes a description of the site and current management, as well as suggestions for modifying site management and monitoring.

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Part One. Adaptive management for southern California grasslands

1.1 Introduction

It has been estimated that the majority of California's grassland communities have been destroyed or severely degraded. Of the remaining grasslands in southern California, only a few are currently protected as natural reserves (Keeley 1990). Remaining protected and non-protected grassland areas are threatened by a multitude of interacting influences: degradation by exotic species, urbanization and development, public use, habitat loss, changes in fire regimes, changes in grazing regimes, climate change, and pollution. This places increasing pressure on the managers of grasslands in public and private reserves to maintain native plant and animal species on generally small and increasingly isolated reserves.

Southern California grasslands in existing reserves are generally managed to maintain current grassland vegetation, to promote the recovery of threatened or endangered species, to decrease the dominance of exotic plant species, and/or to promote animal species of special concern. On non-reserved grasslands, these management objectives may or may not conflict with other management objectives such as livestock production, fuel and wildfire management, and public recreation.

At this time it is unclear what "best management practices" to promote and maintain native biodiversity are for southern California grasslands. There are several management options for use alone or in concert over large areas (as opposed to spot treatments such as hand weeding or irrigation). The most commonly used options are: prescribed fire, prescribed grazing, seeding, mowing, or no management. Reserve managers often select the latter over active management because on the surface it appears to demand the least resources, incur the least risk, and spark the least public resistance.

California’s grassland reserve managers work at a unique interface of scientific, economic, and political challenges that demand new approaches to management. Adaptive management is an approach to management that allows managers to deal with uncertainty while taking immediate management action. Adaptive management is not easy to implement, however, and southern California grassland managers are often short on the time and resources needed to create an effective adaptive management plan. A framework is needed specifically for management of southern California grassland reserves that will aid grassland managers in the process of creating an effective adaptive management plan. This project is aimed at providing that framework.

1.2 Grasslands in southern California

Grassland areas can be found at elevations ranging from sea level to 1,300 meters, and are characterized by open cover and dominance of grasses and forbs, although some trees and shrubs are not uncommon (Sawyer 1995). Grassland areas in California are generally divided into two types: Coastal Prairie and Valley Grassland (Heady 1977; Brown 1998). Valley Grassland is dominated by non-native annual grass species, and is sometimes referred to as the California annual grassland (Mayer 1988). Coastal Prairies have also been invaded by exotic species, but the invasion is usually not as severe as in Valley Grassland areas, with more native perennials remaining (Heady 1991).

Native grass species commonly found in southern California grasslands include purple needlegrass (*Nassella pulchra*), foothill needlegrass (*N. lepida*), nodding needlegrass (*N. cernua*), small-flowered melic (*Melica imperfecta*), blue wildrye (*Elymus glaucus*), deergrass (*Muhlenbergia rigens*), and slender fescue (*Vulpia octoflora*). Representative members of a diverse forb flora include annual lupine (*Lupinus bicolor*), goldfields (*Lasthenia californica*), California poppy, Menzies’ fiddleneck (*Amsinckia menziesii*), purple clarkia (*Clarkia purpurea*) and popcorn flower (*Plagiobothrys nothofulva*). Common sub-shrubs include coast goldenbush (*Hazzardia squarrosa*), common California-aster (*Lessingia filaginifolia*) and coyote brush (Baccharis pilularis). Common exotic species include wild oats (*Avena fatua*), slender wild oats *(A. barbata*), bromes (*Bromus spp.*), wild barley (*Hordeum spp.*), foxtail fescue (*Festuca megalura*), non-native filaree (*Erodium spp.*), and non-native clovers (*Medicago spp.*) (Kie 1988). Of the native grass species commonly found in California grasslands, most are perennial species, while the majority of exotic species are annuals.

Perennial plant species live for many years, and therefore allocate more energy to biomass production than to seed production. Having larger above and below ground biomass allows a perennial plant to compete with neighboring individuals for resources more effectively, which in turn extends its lifespan and allows it to produce more seed over an extended period of time. Since perennial plants produce seeds over many years, seeds do not need, and often so not have, a long lifespan in the soil. In contrast, annual plants live for only one year and have only one chance to reproduce, and so allocate a much larger proportion of resources to seed production (Heady 1977). *Nassella pulchra* recruitment in California is often strongly seed-limited (Hamilton 1999).

Common mammals found in southern California grassland areas include deer, jackrabbits, ground squirrels, pocket gophers and kangaroo rats (Heady 1977). Common birds include hawks, finches, and sparrows. Many of the organisms that are most dependent on grasslands are now species of concern, such as the orange-throated whiptail lizard, burrowing owl, and black-shouldered kite (McNab 1996). In addition, several species of fairy shrimp are found in vernal pools within grassland areas.

History of California grasslands

There is debate concerning the historical range and composition of grassland in California. The writings of Fray Juan Crespi, a Franciscan who arrived in Baja California in 1767, are often taken as evidence of the existence of large areas of grassland in historical Southern California. Crespi joined the Portola Expedition in 1769 and traveled up the coast to San Diego and finally Monterey, where he established the Mission San Carlos Borromeo. Crespi described large expanses of grassland and “green pasture” all along the expedition’s route (Bolton 1927). Dodge argues that since the route followed by the Portola expedition is now dominated by chaparral, chaparral must have invaded vast areas of grassland which previously had been maintained by frequent fire(Dodge 1975). However, Keeley points out that highways now occupy most of the route followed by Crespi, and that grassland has been replaced by asphalt if anything (Keeley 1990). Keeley also states that many of the “green pastures” must have been riparian and wetland areas, given that the expedition traveled in July and August, when California grasslands are anything but green. Oberbauer concludes that Crespi’s is not an unbiased account of conditions in the New World (Oberbauer 1978). Some of Crespi’s writings may have exaggerated the quality of the vegetation for grazing to increase the Church’s interest in establishing more missions. Travel on foot or horseback could also have given Crespi an inaccurate impression of the scale of the landscape.

In contrast, Cooper believed that in some areas grassland had replaced chaparral (Cooper 1922). When an influx of settlers to California in the early 19^{th} century resulted in increased demand for rangeland, brush-dominated sites were type-converted to annual grasslands through burning to satisfy that demand. Pollen-core evidence from northern California shows that shrubs decreased and grasses increased after the arrival of Europeans (Russell 1983). Frequent burning by the Chumash, with the purpose of increasing native annual species presence as a food source, has been documented in southern California as well (Timbrook 1982). This evidence supports the idea that shrub land has been replaced by grassland to some extent, as does the fact that grassland will be invaded by shrubs in the absence of disturbance (Oberbauer 1978).

These two points of view are not necessarily mutually exclusive. There is no doubt that in some areas grasslands have been paved over by homes and highways, as have many other communities. At the same time, the evidence that grassland area has been created through type-conversion of shrubland (and removal of oaks for range improvement in some oak woodlands) is also convincing. It is most likely that in some areas grassland has replaced shrubland, while in other areas grassland has been replaced by chaparral, resulting in an extent of grassland today that is similar to what was originally present (Heady 1992).

Many scientists believe that grasslands prior to European settlement consisted of native perennial bunchgrasses with some perennial forbs and native annual grasses growing in between (Burcham 1957; Munz and Keck 1959; Bartolome 1981). It is believed that *Nassella pulchra* was the dominant species (Burcham 1957; Heady 1977), but not all researchers concur on this point (Hamilton 1997).

Today, the majority of California grasslands are dominated by exotic annual species of Mediterranean origin (Heady 1977). Most exotic grassland species were introduced from Europe during the gold rush era, though some had been introduced during, and possibly before, the European exploration of California in the late 1600s (Hendry 1931). The major period of invasion was in the 18th century, and many of these species were well established by the following century (Keeley 1990).

During the second half of the 19th century, California's immigrant population increased rapidly in response to the Gold Rush and promoted the expansion of cattle and sheep populations and associated demand for rangelands. By 1860 cattle reached an estimated 1 to 3 million animals compared to roughly 250,000 in 1850 (Burcham 1957; Dasmann 1966). Grazing at this intensity is thought to have increased the sensitivity of native species to drought due to decreased root growth. Severe droughts occurred in California in 1828, 1862, and 1864, and some grasses were only able to survive in the seed bank (Keeley 1990). This sequence of events is thought to have led to the transition from native to non-native dominated grasslands in California. Tillage of large areas probably contributed to the conversion of pristine grasslands as well (Heady 1977).

The loss of grassland area combined with the degradation of remaining grasslands has resulted in a strong need for active management to control exotics and encourage the growth of native plants, both for the preservation of native plant species and to meet the habitat needs of grassland-dependent fauna.

Regional context of grassland areas in southern California

Using digital vegetation maps obtained from local government agencies in Riverside County and San Diego County, we characterized grasslands within the NCCP area. Unfortunately, we were unable to obtain vegetation data for Orange County. The vegetation data for Riverside and San Diego Counties was created using different vegetation classification and mapping systems, so the two counties have been analyzed separately.

In San Diego County, the grassland types we examined were non-native grassland, valley needlegrass grassland, wildflower fields, valley sacaton grassland, and a miscellaneous grassland type, which encompasses grassland areas that were difficult to categorize. In Riverside County, the categories we encountered were non-native grassland, valley and foothill grassland, vernal pool areas, and southern interior basalt vernal pool.

We assessed the extent of grasslands and management status in Riverside and San Diego counties. We also analyzed the average ecological condition of each grassland type. The ecological condition analysis was performed using a grid developed by Davis et al. (2003) as part of the California Legacy Project. The grid maps the ecological condition of each cell within the grid based on four factors: land conversion (C), road effects (R), residential housing impact (H), and forest structure (F).

Land uses and land cover types such as urban and agricultural were mapped as converted and given a C value of zero, while all other areas were given a C value of one. The road effects, forest structure, and residential housing variables were calculated in a more complex way. Residential housing impact was mapped using the California Department of Forestry and Fire Prevention Fire and Resource Assessment Program (CDF-FRAP) housing density projections for 2000 and 2040 based on 1990 census data. The impact of housing was assumed to be distributed evenly within each grid cell. Road effects were calculated using traffic volume and road class, which are more accurate predictors of road effects than road density alone. The road impacts were modeled using year 2000 Topologically Integrated Geographic Encoding and Referencing (TIGER) system data obtained from the United States Census Bureau. Forest structure was mapped only for areas where it was a relevant variable.

Davis et al. (2003) combined all of these indices using Boolean logic. Using this method, an area in good ecological condition is not converted, is not affected by roads, and is not impacted by housing. An area that meets all of these criteria is assigned an ecological condition value of one. An area that meets none of these conditions is assigned a value of zero. Intermediate values range between zero and one. Further information regarding the ecological condition index used in this analysis can be found at the following website: http://www.nceas.ucsb.edu/nceas-web/projects/4040/TerrBiod_framework-report.pdf.

In our area analysis, we examined the total area of grassland in San Diego and Riverside Counties, as well as the total area consisting of each grassland type and the fractional area occupied by each type. We also looked at the average patch size for grasslands of each type. The results for San Diego County are summarized in Table 1.1.

Table 1.1. San Diego County grassland areas

Type	Mean area (ha)	Mean area (acres)	Total area (ha)	Total area (acres)
Non-native	9.07	22.42	26,982.40	66,674.96
Valley needlegrass	32.13	79.39	12,593.80	31,119.96
Miscellaneous	9.41	23.26	75.31	186.11
Wildflower field	12.75	31.50	624.72	1,543.72
Valley sacaton	18.68	46.17	149.46	369.33
All grassland	11.78	29.11	40,425.70	99,894.09

The contrast between the mean sizes of native versus non-native grasslands suggests that although native valley needlegrass grassland and other native grasslands have been significantly reduced in area, some relatively large contiguous areas remain. Given the larger mean patch size, we would expect the overall condition of native grasslands to be better than that of non-native grasslands.

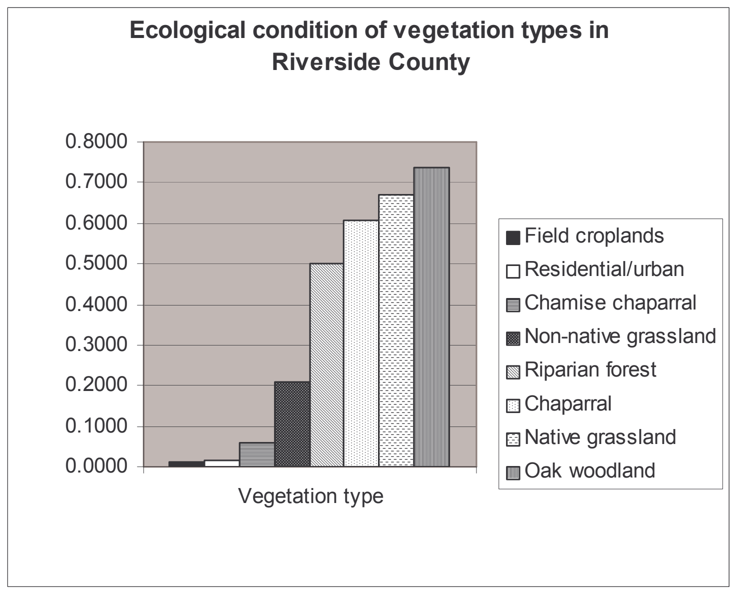
The results of the area analysis for Riverside County are summarized in Table 1.2.

Table 1.2. Riverside County grassland areas.

Type	Mean area (ha)	Mean area (acres)	Total area (ha)	Total area (acres)
Non-native	210.31	519.69	668,560.11	1,652,048.13
Valley and foothill	2,383.53	5,889.83	11,917.65	29,449.16
Vernal pool	10.23	23.26	81.88	202.33
Southern interior basalt vernal pool	33.92	83.82	237.47	586.80
All grassland	212.82	525.88	680,797.11	1,682,286.42

As in San Diego County, although the total area of native grasslands in Riverside County is small, mean patch size is relatively large compared to non-native grassland. Again, this indicates that the mean ecological condition of native grasslands in Riverside County is probably higher than the condition of non-native grasslands. The mean area size for non-native grasslands is 210.3 hectares, which is also larger than the mean area size of non-native grasslands in San Diego County.

The results of the ecological condition analysis are summarized in Figure 1.1. In Riverside County, vernal pool areas have an average condition of zero, which is probably due to close proximity to roads. The ecological condition analysis shows that, in both Riverside and San Diego Counties, non-native grassland areas have the lowest condition values, as predicted by the area analyses. In both counties, the average condition of non-native grassland areas is roughly 0.2. This low value is due to high housing densities as well as high road traffic volume near non-native grassland areas. This value seems particularly low when compared to the condition values associated with native grassland types. The high condition values associated with native grassland types in general are due to the relative



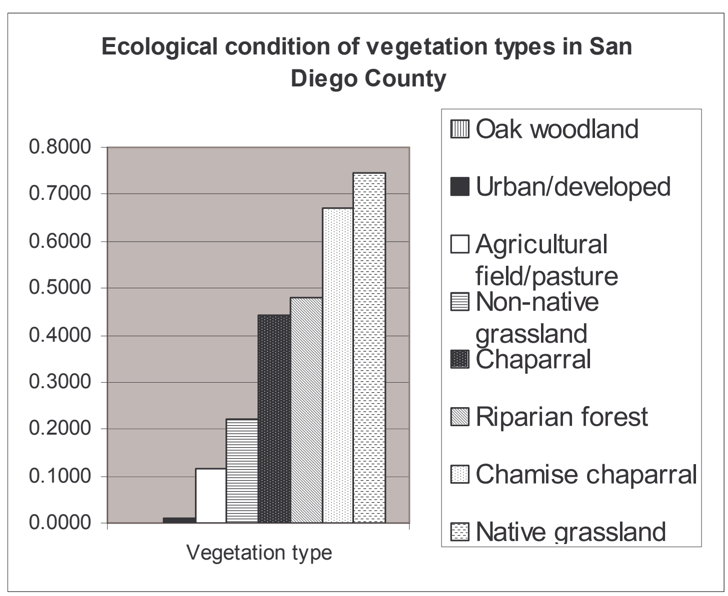


Figure 1.1. Average ecological condition of several vegetative community types in San Diego and riverside Counties.

isolation of native grassland areas from urban and residential areas.

A further comparison of native versus non-native grassland condition values is shown in figure 1.2. In this figure, native grassland types have been grouped together and a mean condition for all native types has been taken that is weighted by area. This was done because some grassland types, such as vernal pool areas and valley sacaton grassland, occupy very small areas. These condition values are shown in figure 1.2, along with the fraction of the total grassland area occupied by native and non-native types. The results show that in both counties, non-native grassland occupies a much larger fraction of the total grassland area than native grassland types, but that native grassland types have relatively much higher condition values. This is a function of the fact that urbanization is one of the drivers resulting in the conversion of native grasslands to non-native grasslands. This causes remnant native grassland areas to be located in more isolated areas since those areas by definition are not as intensively developed and have lower housing densities and traffic volumes.

Since the mean area size for native grasslands in Riverside County is higher than the mean area size for native grasslands in San Diego County, we might expect that the

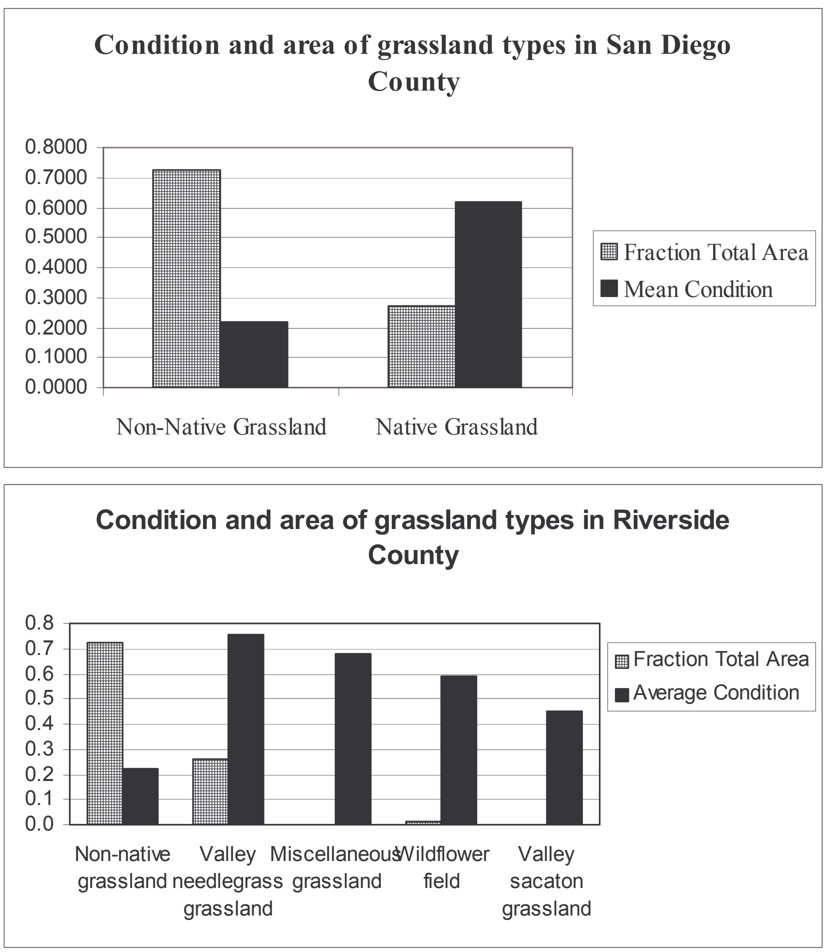


Figure 1.2. The average ecological condition and total fractional areas of grassland types in San Diego and Riverside Counties.

mean condition of native grasslands will also be higher in Riverside County, but this does not appear to be the case. The mean condition of native grasslands in Riverside County is actually lower than the mean condition of native grassland types in San Diego County. This effect could be a function of development patterns. It is also possible that the presence of a few large areas of native grassland types, such as the Santa Rosa Plateau Ecological Reserve, increased the mean area size for native grasslands in Riverside County out of proportion to the total area of native grasslands. However, since the mean condition values are based on the total fractional area of native grassland types, the condition value would be unchanged by this effect.

We also examined the management status of grasslands in Riverside and San Diego Counties using the Management Landscape grid published by the California Department of Forestry and Fire Protection in 2002. Each cell of the management landscape is described using three factors, which are divided into subclassifications. The three factors are:

1. Predominant land use:
    a) Urban: housing density is greater than one unit per acre or classified as industrial/commercial/transportation. Presumed to have little or no value as habitat to most native species.
    b) Agricultural: lands for which the primary use is agriculture. Presumed to have some value as habitat for some native species.
    c) Rangeland: land managed for some commodity output. Presumed to retain a significant value as habitat for some native species.
    d) Reserve: land permanently protected and having a mandated management plan (equivalent to GAP status classes 1 and 2).
2. Housing density (if predominant land use is urban, development density is high and housing density classifications do not apply):
    a) Rural residential: housing density greater than one unit per 20 acres.
    b) Sparse residential: housing density less than one unit per 20 acres.

3. Ownership:
    a) Public: lands owned by a public agency.
    b) Private: lands privately owned, including private conservancy lands.

Each cell is assigned one subclassification for each factor and assigned a numeric code. The code assigned to each cell within the Management Landscape grid represents the combination of classifications present within that cell. The results of our analysis are summarized in Figure 1.3. In Riverside County, the majority of grassland area is located in areas classified as sparse residential. The largest area of grassland is classified as being privately owned rangeland in a sparse residential area. The second largest area of grassland in Riverside County is classified as privately owned agricultural land in a sparse residential area. The third largest area is classified as privately owned rangeland in a rural residential area. In San Diego County, by far the largest proportion of grassland consists of area that is publicly owned rangeland in a sparse residential area. The significance of these facts is that the value of most of the remaining grassland area in these two counties has been compromised.

San Diego	Reserve	Urban	Agriculture	Rangeland	Total
Area (ha)	559	1,765	9,341	28,679	40,344
Percentage	1.4	4.4	23.2	71	100

Riverside	Reserve	Urban	Agriculture	Rangeland	Total
Area (ha)	4,226	3,769	22,550	32,733	63,278
Percentage	6.7	6	35.6	51.7	100

Figure 1.3. Grassland area in San Diego and Riverside Counties by management type.

In summary, our GIS analysis of Riverside and San Diego Counties shows that most of the grasslands that remain in these areas have been highly fragmented, are in poor ecological condition, and are not in formally designated conservation areas.

Ecological drivers in grassland areas

Grasslands are affected by a variety of ecological drivers, often operating in concert. This makes it extremely difficult to determine the exact effects of any one factor. The major physical, biological and disturbance-related drivers operating in southern California grasslands are described below.

Physical factors

Climate and microclimate

Climate is a strong driving factor determining the composition of grasslands in California. Many grassland species are annuals, and strong interannual variability in precipitation can lead to interannual changes in community composition (Hobbs 1995). This variation may obscure management effects in the short run.

The growing period for most California native grass species is during the months of January-May. Research suggests that native perennial grasses are often recruitment-limited, and that water is the most important limiting factor (Hamilton 1999). Coastal grasslands in California are less heavily invaded than inland grasslands overall, which has been attributed to higher moisture levels at the coast during the growing season (Heady 1992). Many of the dominant exotic species found in coastal grasslands are perennial species, which suggests that coastal grasslands may be more suitable for perennial species in general (Seabloom 2003).

Ongoing climate change may be driving some current trends in grasslands, as well as in other communities in California. Research shows that global climate change will likely result in warmer and wetter winters, warmer summers, and a heightened El Nino Southern Oscillation (ENSO) within the next century (Field et al. 1999, Gutowski et al. 2000). There have been many studies predicting the effects of these factors individually, but relatively few addressing their effects when occurring in concert. Shaw et al. (2002) showed that interacting mechanisms of climate change, such as increased precipitation, elevated CO_2 concentration, warming, and increased deposition of nitrogen-containing compounds, can cause a reduction in net primary productivity in California annual grasslands. Loss of habitat due to climate change may also be a threat to grassland-dependent species. Thomas et al. (2003) expect almost 16 percent of grassland species to eventually go extinct due to climate-related habitat loss.

Soils

Soils also exert strong effects on grassland distribution and composition. California native grasslands are typically found on clay soils (Stromberg 1996). Serpentine soils, which are nutrient-poor, have been shown to be a refuge for native grass species which have been out-competed by exotic annual grasses in areas with more nutrient-rich soils (Harrison 2003). Serpentine soils are relatively rare, however, and most coastal California annual grasslands are located on non-serpentine soils (McNaughton 1968).

Air pollution

The deposition of nitrogen-containing compounds from the air is a result of fossil fuel combustion and is expected to increase over time (International Panel on Climate Change 2001). Research has suggested that grassland areas that are nutrient-poor serve as refuges for native perennial grass species (Harrison 2003). The addition of nutrients such as nitrogen through deposition could reduce diversity in these grasslands substantially, since nitrogen is the main limiting nutrient on nutrient-poor soils (Weiss 1999). Weiss (1999) found that in a Bay Area serpentine grassland, deposition of dry nitrogen at rates of 10-15 kilograms nitrogen/hectare/year eliminated nitrogen limitation, an effect that is known as nitrogen saturation (Fenn 2003). This facilitated the invasion of exotic annual grasses, which significantly reduced the presence of certain native species. In southern California, exotic grasses have shown increased productivity in the presence of increased nitrogen deposition, but since plant growth in southern California is generally moisture-limited, not nitrogen-limited, this effect is only significant during wet years (Allen 1998; Padgett 1999; Rapport 1999). Nitrogen deposition has also been shown to result in decreased mycorrhizal diversity in coastal sage scrub communities in southern California (Fenn 2003).

Disturbance

Disturbances associated with grazing, tillage, burning, and fossorial mammals are considered among the most influential ecological drivers in California grassland areas. The shift to exotic species dominance in California was partially driven by disturbance in the form of grazing, and gopher activity and fire have also been shown to have significant effects on community composition and species richness in grasslands (Tilman 1983; Keeley 1990; Harrison 2003). Each of these disturbance mechanisms is discussed in more detail below.

Fire

Fire plays an important role in California grasslands. Many native grasses, particularly *Nassella pulchra,* appear to be highly adapted to frequent fire return intervals (Sampson 1944, Jones and Love 1945, Bartolome and Gemmill 1981). These species demonstrate a positive response to fire by re-sprouting and flowering very quickly, sometimes only days after fire events (Ahmed 1983, Menke 1989, Dyer and Menke 1996, Bartolome 1979, Wills 2001, Keeley 1981, Axelrod 1985, Young and Miller, 1985, Glenn-Lewis et al. 1990, Fehmi and Bartolome 2003). Seedling establishment has also been observed to increase after fire events (Bartolome 1981). Dyer (2002) found that *Nassella pulchra* seeds that came from plants that had been exposed to fire were larger and had higher germinability than seeds from plants that had not been exposed to fire. This suggests a general benefit to burning for communities composed primarily of perennial grasses. Menke (1992) recommends burning every 3-4 years to produce this benefit.

In highly invaded grasslands, the use of fire as a management tool can promote the growth of exotic species (Heady 1977). It is possible, however, to control some exotic species through the use of fire as a management tool. One such species, *Centaurea solistitialis*, has been shown to be present at significantly lower levels of abundance in burned plots when compared to unburned plots, although several years of regular burning were required to achieve this effect (DiTomaso et al. 1999). In addition, regular fire may reduce growth rates of exotic grasses by reducing soil nitrogen through volatilization (Bauder 2000).

Fire can have positive effects on the presence of native forbs in California grasslands (Meyer and Schiffman 1999). Parsons and Stohlgren (1999) demonstrated an increase in biomass of *Trifolium microcephalum* after three consecutive spring burns. They also showed increased biomass of *Orthocarpus attenuatus* after three consecutive fall burns. Biomass of *Lotus subpinnatus* was shown to increase after spring or fall fire events. York (1997) found that *Brodiaea terrestris*, *Blennosperma nanum*, *Lasthenia californica*, *Navarreta tagetina* and *Triphysaria eriantha* all responded positively to burns during the growing season.

Although burning has the potential to reduce the proportion of annual grasses in a community and boost the diversity or cover of native species, as well as reduce the presence of weed species in grassland areas and increase the presence of broad-leaved plants, it must occur at the right time (Hervey 1949; Menke 1989; Meyer 1999). Hopkinson et al. (1999) showed that the timing of burn events had a significant effect on the response of non-native grasses to fire. Poorly timed burning can result in an increase in the abundance of annual exotic species (Seabloom 2003). Meyer and Schiffman (1999) found that winter burns did not have a significant effect on native plant diversity or cover in grasslands, while spring and fall burns significantly increased native plant species diversity and cover.

Environmental variability can contribute to uncertainty regarding the effects of fire. Major (1963) stated that plant growth in southern California grasslands is primarily limited by moisture availability, and research has shown that lack of precipitation can lead to a decrease in perennial grass productivity during the first season after a burn event (Blaisdell 1953, Daubenmire 1968, Robberecht and Defosse 1995). This effect could be caused by a change in fire intensity due to the absence of moisture, although Defosse and Robberecht (1996) found that *Festuca idahoensis* growth rates increased after fire across a variety of fire intensities, with no significant mortality.

The effects of fire can be difficult to predict, especially when used as a management tool in conjunction with other techniques, such as grazing. Over-grazing reduces fire frequency by maintaining fuel levels too low to support burning (Keeley 1990). Kan (Kan 1998) found that grasslands that are burned and grazed at low intensities support native plants in greater abundances that grasslands that are not, and other research suggests that grasslands that are perturbed in multiple ways may have greater biodiversity (Collins 1985). However, burning can have negative impacts when used in conjunction with grazing when done either too frequently or with too much intensity. Fire has been shown to reduce species richness on grazed sites (Harrison 2003).

Grazing

Grazing has played an important role in the recent history of California's grasslands and continues to be a dominant force in most grasslands today. Grazing changes the amount of bare soil present in a grassland, as well as the productivity, community composition, soil bulk density and associated hydrological and chemical properties. These effects are dictated by the species of grazer, the timing and intensity of grazing as well as characteristics of the grassland being grazed (Harrison 2003).

The historic influence of grazing on California's grasslands extends back to the Pleistocene (Edwards 1992). Fossils from the late Pliocene and Pleistocene eras indicate the presence of a complex assemblage of about 20 species of grazing, browsing, and trampling megafauna, which would have had a profound effect on the evolution of California's native plants (Wagner 1989; Edwards 1992). From such evidence as dental morphology of fossils and plant remains in fossilized dung, it has been shown that grazing and browsing were very important activities during the Pleistocene (Edwards 1992). This is also evidenced by adaptations demonstrated by native bunchgrasses in California. Perennial native grasses have extensive root systems that allow nutrient resorption, which in turn allows bunchgrasses to recover from clipping. It has been found that bunchgrasses often show increased vigor, as well as culm and seed production, after being clipped. In addition, many native California bunchgrasses, such as *Danthonia californica*, will develop short forms that lay low to the ground. The low stature of these short forms makes them less noticeable to grazers, which will focus on taller vegetation even if it is less desirable (Edwards 1992).

Over the last 10,000 years, the presence of large grazers has been greatly reduced. By the time of the arrival of the first Europeans in California, only four species of ungulate remained in significant numbers: tule elk, black-tailed deer, pronghorned antelope, and bighorn sheep. With the exception of the bighorn sheep, these species were all severely impacted by the arrival of European settlers, who hunted deer, elk and antelope for hide and tallow (Wagner 1989). With the introduction of livestock by Europeans, California grasslands were once again subjected to a major change in the grazing regime. Since that time, overall grazing of California grasslands has decreased, but grazing still has key effects on grassland community dynamics (Edwards 1992).

Grazing clearly affects the amount of natural mulch present on the soil. As exotic annual grasses senesce, the remains of the grasses flatten along the soil surface, forming a mulch layer that can be worked into the soil through grazing. This mulch layer has been shown to influence temperature at or near the soil surface, which has the potential to create conditions that are more favorable for exotic annual grass seed (Evans 1970). The removal of the mulch layer is also thought to increase the availability of nutrients and to decrease competitive pressure on natives by creating space. This effect is transient, but can be valuable in providing an opportunity for native plants to become established (Vogl 1974). The growth of exotic annuals such as *Bromus mollis* can be negatively affected by the removal of this mulch layer as well (Heady 1956).

Grazing at an appropriate intensity can have other benefits. At Hastings Natural History reservation in Carmel, Stromberg and Griffin (1996) found that stands of native grasses that are currently grazed or have been recently grazed by cattle have higher soil nitrogen levels, although these stands also have lower species diversity than stands that have not been grazed recently (Stromberg 1996). Over-grazing in grasslands can have more negative than positive effects, however, and can result in increased densities of exotic species.

New evidence suggests that moderate grazing may also be beneficial to vernal pool communities. Joe Silveira, a biologist at the Sacramento National Wildlife Refuge Complex, found that the removal of cattle from vernal pool areas had a negative effect on native faunal diversity (Barbassa 2004). Jaymee Marty of the Cosumnes River Preserve conducted grazing exclusion experiments in 72 pools and found that grazed vernal pool areas had fewer exotic annual grasses than ungrazed pools. She also found that native plant species such as goldfields (*Lasthenia spp.*) and meadowfoam (*Limnanthes spp.*) were more successful in grazed areas. Marty found that cattle preferentially grazed exotic grass species, which prevented the exotic plant species from monopolizing the water supply, and created open areas in which low-lying native species could grow. The elimination of weedy exotic grass species from vernal pool areas also reduced plant water use and extended the life of the pools from a mean of 45 days to a mean of 105 days (Barbassa 2004).

Tillage

Cultivation can have a very powerful and lasting effect on the composition of grasslands (Stromberg 1996). Tillage can lead to loss of soil microflora, soil nutrients, native seed banks, and native seed sources, which in turn can lead to invasion by exotic species, particularly grasses (Stylinski 1999). Historical tillage is one of the dominant factors affecting grassland composition at the Sedgwick Reserve in the Santa Ynez Valley (Frank Davis, personal observation). Stromberg and Griffin (1996) found that historically cultivated and uncultivated grasslands formed two distinct groups, characterized by different species. *Nassella pulchra*, *Poa secunda*, and *Chlorogalum pomeridianum* were restricted to uncultivated sites. Cultivated sites were characterized by a more diverse flora, including *Lupinus bicolor*, *Plagiobothrys nothofulvus*, *Thysanocarpus curvipes*, and *Rumex acetosella*. They did not find a significant difference in the proportion of native and non-native plants between cultivated and uncultivated sites, however.

The differences in plant communities on cultivated and uncultivated sites may be due in part to differences in soil properties. Historically, farming was generally done on flat land at low elevations, with relatively nutrient-rich, sandy soil. Soils in historically cultivated grassland areas are generally low in cation exchange capacity, silt, and clay. Soils in historically uncultivated grasslands are usually nutrient poor, with high clay content. The correlation between cultivation history and soil type is probably due to farmers' preferences when locating fields, but the relationship between soil type, and current vegetative community composition remains uncertain (Stromberg 1996).

Gophers and other burrowing mammals

Gopher burrows and associated tailings promote fine-scale patchiness in grassland soils and plant communities. Gopher activity results in areas of bare ground that can support increased densities of exotic annuals (Seabloom 2003). Gopher tailings also bury seeds from the previous year that remain on the soil surface, which promotes germination of exotic annual grass seed (Hobbs 1985). Gopher tailings can also favor the survival of exotic grass seedlings. Exotic grass seeds in general are larger and generate larger radicles than native grass seed. At the same time, gopher tailings have lower density and water-holding capacity than undisturbed soil. Exotic grass seedlings are more likely to survive on gopher tailings than native seedlings because larger exotic grass seeds are more likely to produce roots that can reach down through the tailings to the soil beneath, where water supply is sufficient for growth (Stromberg 1996).

Gopher activity can also promote native plant growth, however. Gopher activity can reduce nitrogen availability at the soil surface by bringing up nutrient-poor soil, which helps to create favorable conditions for native bunchgrasses (Huntley 1988).

Biological Factors

Competition

Research indicates that competition from exotic annual grasses can have detrimental effects on recruitment of native perennial grasses such as *Nassella pulchra*, but that once established, native perennial grasses are superior competitors in California grassland environments (Hamilton 1999). In undisturbed grasslands, relict stands of native perennials will resist invasion by exotics and will even invade stands of exotic annuals (Seabloom 2003). However, when becoming established, the presence of exotic annual seedlings has been shown to suppress perennial grass seedling survival (Brown 1998).

Herbivory

Grasslands come under the influence of herbivory from several sources. One important source of herbivory in grasslands can be livestock grazing, which has been previously discussed. Small mammals are another source of herbivory in grasslands, both in the form of foliage and root herbivory as well as seed predation. Insects can also influence grassland dynamics through herbivory.

Seed predation may be severe in some grassland areas. Small mammals such as kangaroo rats and pocket mice are granivores, and may cache large numbers of seeds (NatureServe 2003). Some grassland bird species are also granivorous (Grzybowski 1980). However, research in tallgrass prairie showed that small mammals do not consume a large percentage of total seed production, and that although seed predation may be severe at times it is generally not a driving factor in community composition (French 1976).

Seed supply

Seed supply plays an important role in dictating the composition of highly invaded grasslands. Some research suggests that seed dispersal may be an important limiting factor of re-invasion by native bunchgrasses into exotic-dominated areas (Jeffrey Corbin, pers. comm.). Most grass seed falls near or directly below the parent plant, though some may be wind-dispersed and others may be dispersed by herbivores (Collins 1985). The limited dispersal of seed from native grass species can have a large effect on community composition, and vegetation already dominant in an area will generally continue to dominate unless subjected to disturbance of some kind (Peart 1989).

Rabbits may be an important agent of seed dispersal in southern California grasslands. Rabbit pellets collected in a vernal pool area in San Diego County contained germinable seed from 18 species. Although the germinable seed content of the pellets was not high (roughly 87 seeds per 1,000 pellets), rabbit-borne dispersal could still have a significant effect on species distribution and dynamics over the long term (Zedler 1992).

Biological soil crusts

Biological soil crusts are often found in arid areas. They generally cover the soil surface where there is no plant cover, and can be up to ten centimeters thick. Biological soil crusts are composed of living organisms, primarily cyanobacteria, and their by-products, which form a crust of soil held together by organic material (USGS 2003).

Biological soil crusts can affect grasslands in several ways. When biological soil crusts increase the roughness of the soil surface, they can increase infiltration of water and increase the amount of water available in the soil. Some biological soil crusts, however, decrease the roughness of the soil surface. These crusts can decrease water infiltration into the soil. Because of this variability, the effect of biological soil crusts on infiltration is site-specific (USGS 2003).

Biological soil crusts can also have an effect on germination of native and exotic plants (USGS 2003). Exotic annual grasses tend to have larger seeds than native grasses in general. These large seeds often require burial in order for germination to occur. Biological soil crusts, which stabilize the surface of the soil, may make it more difficult for incidental burying of seed to occur, and thereby reduce the germination rate of exotic grass seed. Native grasses usually have smaller seeds, but even large-seeded native grasses and forbs are often cached by rodents or have self-burying mechanisms, which would prevent soil crusts from affecting native plant germination rates (USGS 2003).

Succession in Valley Grassland

A general description of successional patterns in California annual grasslands places fields of forbs in early successional stages and dominant stands of grasses in late successional to climax stages. Common grassland species are shown in successional position in Table 1.4. This table, reproduced from Heady 1977, should be interpreted carefully and may require adjustment for local conditions.

Table 1.4. Plants found in early, middle, and late successional stages in California annual grasslands (N=native species). Reproduced from Heady 1977.

Climax	Middle Succession	Early Succession
Avena barbata	*Daucus pusillus* (N)	*Aira caryophyllea*
Avena fatua	*Erodium botrys*	*Briza minor*
Bromus mollis	*Festuca dertonensis*	*Eremocarpus setigerus* (N)
Bromus rigidus	*Festuca megalura*	*Hordeum hystrix*
Bromus rubens	*Festuca myuros*	*Madia spp.*
Erodium cicutarium	*Gastridium ventricosum*	*Lupinus bicolor* (N)
Taeniatherum asperum	*Medicago hispida*	*Trifolium spp.* (N)

Successional patterns in California annual grassland can be dictated by disturbance regimes. Differences in grazing pressure can have distinct effects on the composition of late successional communities. Areas subjected to moderate grazing pressure are usually dominated by taller species, but areas under severe grazing pressure are generally dominated by low-lying species during late successional stages (Sampson 1951).

Thatch buildup at the soil surface can also have an effect on succession in annual grasslands. The removal of thatch from the soil surface reduces the amount of biomass production and the rate of floristic change (Heady 1977). When all thatch is removed from the soil surface, short, broad-leaved grassland species will dominate (Heady 1956). In an experiment at Hopland Field Station, removal of mulch caused the proportion of *Bromus mollis* cover to remain constant. However, when thatch was allowed to build up on the soil, the proportion of *Bromus mollis* cover increased from 0.9 percent to 37.3 percent in three years (Heady 1965). The influence of thatch in grassland succession is derived from changes in physical conditions at the soil surface (Heady 1977).

The long-term succesional dynamics of southern California grasslands have only been investigated in a few studies. Callaway and Davis (Callaway 1993) described cyclical succession of grassland, shrubland and oak woodland in the absence of fire over decadal time scales. Cattle grazing and burning impeded the tendency for grasslands to succeed to shrublands over time.

1.3 Current grassland management (interviews)

Introduction and methods

Our group conducted informational interviews of 35 grassland reserve management experts, practitioners, and others in order to provide some real-world information to the reader about grassland management in southern California. We did not include cattlemen in our survey, although this group has extensive experience and expertise in managing California grasslands, because our focus was on management of grassland reserves for native biodiversity, which is generally not the primary management goal for working cattle ranches. However, many of those interviewed had extensive experience working with California cattle ranchers.

Informational interviews were an appropriate method for our purposes, as opposed to a statistical-based survey, mainly because the population of people who fit our selection criteria was fairly small. Through these information-gathering interviews we were able to assess the opinions, feelings, attitudes, beliefs and reactions of respondents on various topics relating to grassland management (Stewart and Cash 1994). Such interviews provide “soft information” not typically reported in the scientific literature (Desgrosseilliers 2001). These were advantages that more formal survey methods, and strict literature research, could not offer.

It is important to note the limitations of this method of information gathering, though. The main limitation is that a relaxed survey design does not allow later statistical analysis of results and of relationships between variables. Another disadvantage is that results from the interviews cannot be attributed to the entire population of grassland managers or experts, because the group of respondents interviewed was not chosen in a random sampling manner.

A list of the people interviewed and their titles is included in Appendix A. Our goals in interviewing these grassland managers and scientists were to:

1. Assess what they believe to be the key ecological drivers/factors that govern overall grassland composition and abundance of focal species.
2. Determine what they believe to be the main threats, obstacles, constraints, or challenges in reaching their goals. These may be ecological, political, economic, legal, or other in origin.
3. Assess what they believe to be the largest and most critical uncertainties they face in management.
4. Find out what tools they feel are most needed and would be most useful for reaching their goals.
5. Elicit from them experience-based rules of thumb or recommendations about grassland management.

Five core questions resulted from these five goals and were asked of most of the participants. An additional core question was added that asked the respondent to define grassland.

We sought interviews with individuals who either:

1. Actually practice grassland management, preferably in southern California,
2. Study southern California grassland systems in some depth,
3. Have expertise in one or more areas related to grassland management (such as prescribed fire or planned grazing), or
4. Have a combination of this experience and knowledge.

We successfully completed interviews with 20 current or former grassland managers, and 15 others who fit the one of the last three criteria above (mainly scientists who study grassland systems). We also arranged interviews with more than one expert on certain topics (e.g., use of prescribed fire, planned grazing, etc.) in order to get a range of responses and insights on these important topics.

Individuals were identified using a technique termed “snowballing”. Initially, through speaking with people close to the project that know other people knowledgeable about grassland management issues, a short list of people was built. During the interviews, these individuals provided further contacts, and a long list of potential people to interview was assembled.

Keeping in mind time constraints on the number of people who could actually be interviewed, 84 of the people identified from the snowballing were asked for an interview, mainly through email contact. The person contacted was informed of the purposes of the interview and the project, and were given a general description of what topics the interview would cover.

Of the 84 people who were contacted, 48 replied, and 36 did not reply. Thirteen of the people who replied declined to be interviewed. By the end of the interviewing period, 35 interviews were completed. Therefore, the number of people interviewed over the number of people contacted, or the success rate, was 42 percent.

Twenty-five of the interviews were conducted over the telephone, tape-recorded, and then transcribed. Seven interviews were conducted via email for reasons of convenience, and three were conducted in person. Each interview lasted approximately 20 minutes to one hour, with the average interview lasting about 40 minutes.

The interview questions were open-ended, and the responses recorded were subjective experiences, opinions, attitudes, and recommendations. Due to varying levels and scopes of expertise among the interviewees, the interviews were nonstandardized, and they were also non-scheduled. However, most respondents were asked the standard set of six core questions mentioned previously.

It is important to note that because the group of people who were interviewed were not chosen as a random sample, and because the interviews were non-standardized, their responses and the overall results of the interviews may not be applicable to people involved in grassland management issues as a whole. Nevertheless, there were some interesting results obtained from these interviews that can inform grassland management in southern California.

Summary of interview results

The interviews yielded a large variety of opinions, recommendations, and beliefs about many aspects of grasslands and their management. Here, the most common responses, and some of the more unique ones, are summarized in the order of the core questions. In the next section, six major themes that emerged from the interviews as a whole are discussed. These include topics of strong disagreement among respondents, as well as areas of major uncertainty that affect the success of grassland management in the southern California region.

Defining a grassland

The first question that was asked during most of the interviews was “How would you define a grassland?” Responses to this interview question are included in Appendix A. Most respondents chose to describe a grassland as dominated (either in cover or biomass) by grasses. But many also mentioned the presence of forbs and sub-shrubs, and mentioned the characteristics of grassland having an open canopy cover and a low percentage of woody species. Some also made a distinction between perennials and annuals as components of grassland.

While most responses were similar, there was some divergence of opinion about the importance of forb species in defining a grassland. Some said that forb species could be dominant over grasses and the areas could still be considered a grassland, while others stated that forbs are not important components of grassland in terms of their cover.

A few respondents pointed out that a grassland can be dominated in different parts of the year, or in different years, by either annual or perennials, and that therefore a strict definition of an annual or perennial grassland may not be informative because they are not static in their composition. However, some noted the importance of defining annual and perennial grassland discretely if they are to be defined.

Three of the more unique responses were those from Rich Reiner, Rich Minnich, and Robin Wills. Reiner noted the historical importance of fire and herbivory in grassland, and that it should be present in the definition of a grassland. Minnich made a distinction between modern and historic grasslands, and that they should be defined separately. And Wills envisions grassland as a sort of base in which a variety of other habitats and important species occur, such as vernal pools, oaks, and emergent shrubs.

Key ecological drivers

To gain a better understanding of what exactly the respondents view as the overriding ecological forces that drive grassland systems, they were asked, "What do you see as the key ecological drivers or factors that govern the dynamics of grasslands in southern California?" A few drivers or factors emerged as popular responses, mainly:

- Fire regimes in general, or more specifically an altered fire regime
- Grazing
- Climate and rainfall variability
- Soils and soil components, and
- Invasive exotics

Many respondents mentioned the importance of the fire regime as a key ecological driver in grasslands; however, few actually discussed the specific ecological effects of fire, and exactly why and in what ways fire acts as a driver. Of those who did go into more detail about the role of fire, a handful cited the importance of its power to type convert shrubland to grassland if too frequent, or allow the encroachment of shrubs into grassland if not frequent enough. Fire frequency was mentioned as an important detail about this driver, while factors such as fire intensity or timing were discussed less.

An interesting note about the respondents who mentioned fire as an important ecological driver is that five respondents indicated the suppression of fire as a problem, while three others indicated that overly frequent fires are the problem. This apparent divergence of opinion may have resulted from different respondents having different grassland systems in mind. For some grassland areas, the current fire frequency may be higher than, and in other grassland areas lower than, the hypothesized historic frequency. However, this is only conjecture – the real reason for this difference in opinion is not clear. It was clear that most respondents believed that the current and historic fire regimes, including their frequency, are different. The fact that the historic fire frequency for an area may be highly uncertain adds another element of ambiguity to this topic.

Fire was a major recurring theme during the interviews. However, there did not seem to be a strong understanding of the exact role and effects of fire, or at least these were not discussed during the interviews. Fire is treated below as a major theme in the interviews, and an area of uncertainty, in the “Discussion of major themes” section.

Grazing was another common response to the key ecological drivers question. The most notable aspect of those who discussed grazing as a driver was the strong divergence of opinion about whether planned grazing was a good tool to use to manage grasslands or not. Some believed grazing was “good” and others believed it was “bad”, with only a few respondents expressing that the utility and appropriateness of planned grazing was situation-dependent.

Some respondents indicated that both the type of grazer or browser and the intensity of the grazing were important aspects of this ecological driver in grassland systems. These are indeed important because they are decisions that are left to the land manager, and have implications for the ecological effects of this tool.

In addition, the question of the importance of historic grazers or browsers and their relevance to grazing modern grassland areas was a topic of discussion. Most felt that because grassland systems evolved with this type of regular disturbance that it should now be mimicked using livestock (with the assumption that the natural grazers or browsers are not present and won’t be reintroduced in historic numbers). A few respondents disagreed, stressing that grazers and browsers have not been important disturbance forces for thousands of years, and that today’s grassland systems are fundamentally different than grazer-dominated grasslands of the Pleistocene epoch.

Climate – specifically rainfall variability - was the third most commonly cited ecological driver. Respondents noted that this variability makes predicting outcomes of management activities, and predicting which species will dominate a particular year, often impossible. Rich Reiner summed up the variability of rainfall in California well when he jested, “Living in California, the joke is, ‘Gosh, we’ve never seen a year like this. It’s a weird year.’ In reality, that’s the norm here: there is no norm.”

Most respondents cited the variability in both the amount and timing of rainfall from year to year as an important determinant of that year’s dominant vegetation. Mark Stromberg stated, “The inter-year variability is extremely high in California, and it seems to make a huge difference in the relative abundance of grasses and other flowering plants you see in the grassy areas each year.” Rich Minnich described the way that rainfall can affect which species are dominant when he explained, “People always look at this like it’s a one-way street, that the invaders are going on and taking over, and that’s not really correct…It’s shifting back and forth. In wet periods it goes invasive and in dry periods it goes back to the forbs.” Thus, different species respond differently to the precipitation in a particular year, and this can have consequences for the relative abundances of native and exotics.

Soils were also discussed quite a bit as an important ecological driver. Most respondents who mentioned soils emphasized the prevalence of clay soils in grassland areas that are believed to be “natural” (not a result of type-conversion). Andrew Moyes was one respondent who pointed out that serpentine soils are a unique soil type where native grasslands can be found.

When the respondents discussed soils as an ecological factor, most considered it as a determinant of where grasslands are found, rather than a factor in their ecological dynamics. And although soils were mentioned frequently as an important factor, their importance was not usually discussed in great detail, certainly less than when fire and grazing were the topics of discussion.

Other soil-related ecological drivers that were discussed included biological soil crusts, the microbial community, and nitrogen deposition's effects on soils and subsequently, the plant community.

Those who discussed biological soil crusts and the soil microbial community indicated that these topics are beginning to get more attention and may be one important frontier in grasslands research. Trish Smith asserted, "I think soils is the number one thing, and disturbance to soils…I think also soil crusts are a really important factor in grassland resilience and resistance to invasion." Biological soil crusts have been studied in desert systems and have been shown to have important functions, but far less research (almost none) has been done on these components of grasslands in southern California, and essentially none on the management implications of the presence or absence of biological soil crusts. Tina Carlsen was one respondent who discussed the microbial community. She stated,

> Something that is becoming more important and more on people's radar screen is the microbial community. I'm not an expert in this area, but I have this sneaky suspicion that the microbial community and the ways that we've changed plant diseases and introduced exotics like fungi and wilts, this part of the system is going to be important to look at.

Nitrogen deposition has also received increased attention in recent years as well, and is a phenomenon that many lands in southern California are experiencing, including grasslands. Cameron Barrows asserted that managing grasslands for native plant species would be much easier if it weren't for the "annual dumping of nitrogen onto these soils", adding that "The native plants seem to be able to hold their own in terms of the competitive edge versus the non-natives and it's only when these soils become highly…fertilized, that the non-natives really get a competitive advantage…"

Truman Young was one of the respondents who discussed exotic plants themselves as an important ecological driver or factor. He argued:

> In the restoration context…exotic annuals are by far the lion's share of what makes most of these grasslands tick today and what limits restoration. Dominance by exotic annuals may be related somehow to how water is distributed in time and space, in ways that we're just beginning to figure out. Evolutionary history probably plays a role as well. And disturbance history, like grazing, plowing, and other types of disturbance history. I suspect that just the sheer arrival of those annuals at all are the biggest problem, but perhaps there's something about the climate here that makes them particularly good competitors.

Exotics were also cited as a major obstacle or challenge to grassland management later in the interviews. However, most of the important ecological drivers or factors that were discussed were only brought up by one or a few respondents. These include disturbances other than fire and grazing, such as disturbance from cultivation, gopher and other fossorial mammal activity, general herbivory, climate change, and roads and trails.

Historic land-use was also mentioned as having a lasting ecological effect. Mark Stromberg asserted, "I would say that land use history is really important, and not always obvious to you. You need to know the history of the land that you're looking at. Was it farmed? Was it heavily grazed? Did it have sheep on it? Did someone plant the trees that you're seeing?" These respondents noted that the disturbance history of the land, which could include the things Stromberg mentioned, but also disturbances such as discing, historic fire frequency, and shrub-removal or other types of type-conversion activities, can have lasting effects and are therefore important to know.

Herbivory other than that from livestock grazing, such as that from insects and rodents, was mentioned by a few respondents as an ecological driver. The ecological effects of digging and burrowing activities of fossorial mammals was also discussed. Their ability to churn up large amounts of soil in a relatively short period of time was noted, and when present in large numbers, their effects on vegetation and soils can be large. Fred Sproul described the fossorial mammals in the Ramona Grasslands:

> I’ve noticed a lot of digging animals that are a very important component of the grasslands. Pocket gophers, ground squirrels, kangaroo rats, badgers, long-tailed weasels, and probably pocket mice, too…all these gathering and digging animals are part of this component. The amount of pocket gopher digging that happens out here is no small thing.

Finally, climate change and the ecological effects of thatch were mentioned by one respondent each. Megan Lulow discussed how thatch presence or absence might have an important effect on perennial grass germination and growth. And climate change was discussed by James Bartolome, who stated, “Within the next 10 to 20 years with the problem of the ongoing climate change you’re going to have climatic combinations that have not even been seen recently occurring, causing added unpredictability.” Climate change is an ecological driver that may have severe local effects on many habitat types but many of these effects, and their implications for land management, are not completely foreseeable at this time. This may be one reason why the topic was only discussed by one respondent, in that it seems like an intractable problem at the current time.

Obstacles and challenges

In order to identify some of the things that often make managing grasslands in southern California difficult, interview participants were asked “What do you consider in your experience to be the most important obstacles, constraints, or challenges southern California grassland managers face in meeting their management goals?” Respondents addressed the ecological aspects of grasslands, but many more highlighted economic, social, and political factors that can hinder grassland management.

Responses to this question are listed in Appendix A. In general, the responses related to challenges associated with:

- Controlling invasive exotic plants and establishing natives
- Political and social pressures
- Prerogatives of land managers or management entities

- Inappropriate goals
- Public perception of planned grazing and prescribed burning
- Public's lack of appreciation of grasslands
- The proximity of residential and urban areas to wildlands and reserves
- Logistics and money associated with implementing management activities

The most popular responses to this question were those that related to the control and reduction of exotic species. Truman Young stated, "I would call [getting rid of the weeds] the greatest limiting factor… if you get rid of or reduce the weeds, I suspect that the "natural" state of the vegetation would start to reveal itself." Others added that there is also a great challenge associated with re-introducing native grasses, mainly stemming from uncertainty surrounding how best to do so.

Challenges associated with political and social forces were also described by a number of respondents. For example, Elizabeth Painter stated:

> There can be strong political and social pressures to manage for 'grasslands' (including 'feral grasslands'), rather than shrublands, savannas, woodlands, or herblands/meadows. There can be strong political and social pressures to inappropriately burn vegetation. There can be strong political and social pressures to use non-native grazers as a putative 'management tool', without solid science backing up the claims of effectiveness or appropriateness.

Painter seems to be describing how because certain management activities and goals may be popular, they can be applied in inappropriate situations.

Others cited the lack of will of the land manager or land management institution itself as a constraint. For example, Edith Allen explained that because in Riverside County "There's simply no policy to change the vegetation from exotic to native: they're just leaving it as it is. " She added "There's a no burn policy because either they don't have a fire permit, or nobody on the reserve has pushed for that. Sometimes it's a political will issue, sometimes it's a money issue, sometimes it's the interests and training of the land manager, sometimes the land manager is just too busy….the political will, the understanding, and the money are all limitations." Allen points out here that these various constraints can interact with one another and effect the on-the-ground management that occurs at grassland sites.

A number of respondents cited setting inappropriate goals as a major obstacle for effective grassland management. Jaymee Marty summed up this point well when she explained:

> I think that a lot of times managers don't have a clear sense of what it is they want to achieve with management…there's this general feeling of well, we need to manage for biodiversity, but no one really seems to understand what it takes to do that. So I think the biggest difficulty is first trying to figure out what it is we want to see in the grasslands.

For some, goals were seen as sometimes inappropriate when they ignored factors such as the historic grassland composition and extent. Elizabeth Painter cited this as an obstacle for grassland managers, stating that managing a site for grassland, without knowing if that is what the site once was, can have undesirable ecological and economic consequences. The role that the historic composition and extent of grasslands plays in goal-setting was a recurring theme throughout the interviews, and is discussed further in the next section entitled "Discussion of major themes".

Five of the respondents indicated that the black and white perceptions of the public regarding grazing and fire, that are not necessarily science-based, can be an obstacle to grassland management. Wayne Spencer pointed out that this can place a large burden on the land manager to have to convince these stakeholders that these tools are necessary and appropriate. Mike Williams added that in his experience a major challenge is "The perspective of what cattle ranching should be." He adds, "The misconceptions people have in what they think grazing achieves in California is the biggest obstacle of all." In addition, Hugh Safford mentioned how some environmental groups are absolutely opposed to using grazing in any situation, even when it may be highly useful, and that alternately, there are also, "Political and economic issues surrounding maintenance of grazing on landscapes", even when that grazing may be detrimental to a system.

A few respondents described the lack of appreciation by the public (and the scientific community) of the value of grassland systems. Fred Sproul made this point, "Still, even among biologists, is not widely understood how interesting and valuable and precious these grasslands are, and how productive they are…And that's not just the [perception of the] general public, but also the political public, and the decision making public." Tina Carlsen echoed this thought, and mentioned how it feeds into the ease with which grassland areas are destroyed for development. She stated:

> One of the most urgent challenges of course is the conversion of grasslands into urban areas: development pressures in general…I don't think there's been a recognition by the public as a whole of the importance of grasslands. They are not very charismatic, so unless you have some charismatic species depending on it such as burrowing owls or kit foxes, it's really hard to have people get excited about them. That's the real challenge in grassland management, convincing the stakeholders that it's important.

These two respondents describe grasslands as the underdog in the land conservation race, and how this can be a challenge for management. Hugh Safford also adds later in his interview that adding to the difficulty to preserve grassland areas for conservation is the extremely high land values that exist in many areas of southern California. Purchasing land for conservation is that much more difficult when the land value is high due to its being targeted for, and sometimes zoned for, development and urban expansion.

Proximity of reserves to residential and urban areas was mentioned numerous times by the respondents as a management issue limiting in particular the use of fire and grazing as management tools. Jaymee Marty stated:

> In southern CA [encroachment of human populations] is a huge issue, where preserves are oftentimes surrounded by development, and that makes using natural processes such as fire and grazing very difficult when you're surrounded by houses. For smaller preserves that are hemmed in

> by development, I think that's a huge issue and a huge constraint for management.

Lenora Kirby recalled a discussion she had about using cattle as a management tool, "The local politician's aide said 'you can't put cows on this land because all the people will object. Cows are smelly and cows bring flies, and you better not try bringing any cows in.' So, we said 'what would you settle for?' And they said, 'something cute'. On top of everything else I have to have it 'cute' so that the people will accept it."

Using fire as a management tool can be particularly challenging with people nearby as well. Robin Wills states that, "If you are committed to the use of prescribed fire as a primary management tool, there are some huge obstacles. Probably the biggest one right now in California is smoke, and air quality." Because fire produces particulates and can affect human health, it is regulated by air quality management agencies, and these agencies can have the final say as to whether prescribed burning can be used on a particular day. Cameron Barrows mentioned how there is always a risk of fires getting out of control, but that without some controlled fire, you can have large amounts of vegetation built up, increasing the risk of large fire like those that occurred in southern California in the Fall of 2003. He adds, "there's a real catch twenty-two here where people are afraid of fire and they don't want fire but if they don't have it then they're really going to hurt when these big fires happen."

There are additional problems that can arise when reserve areas and urban or residential areas are in close proximity. Mark Webb described some of these as encroachment into reserve areas from people's back yards, illegal access, off-roading, littering, and dumping. But he also mentioned some of the ways in which these problems can be helped, including fencing, zoning enforcement, signage, public outreach and education using volunteer docents, and even patrolling.

Even when fire and grazing are approved by a local community, there are many challenges associated with implementing these tools. For planned grazing, the challenges generally involve the cost of setting up the program and, as Margot Griswold also mentioned, finding someone to run the cows. There was much more discussion about challenges associated with setting up prescribed burns, however.

James Barry and Robin Wills described some of the frustrations that can come with planning a prescribed burn. Barry stated, “Often, we have a prescribed burn set up, and we have our burn team come from all over the state.   Sometimes, on the day the fire is planned, we are shut down because of air quality problems (no burn day). To me that’s been the biggest obstacle, as far as our ecosystem management is concerned.” Wills echoed this point when he stated: “Its very difficult to burn consistently in a lot of counties in the state…in many places, because of nonattainment, there are very few permissible burn day.” He also added, “There are always difficulties with resources and capacity when you talk about prescribed fire. Having the internal capacity, meaning people who are trained and skilled at the command level, having enough engines, and enough resources, are always big challenges. There’s also the huge risk and liability that is associated with lighting things on fire.” Andrew Moyes added that burning can be expensive and is also subject to institutional and political stochasticity, as well as the climatic and air quality factors Barry and Wills discussed. However, using prescribed burning as a management tool was generally described as affordable compared to grazing and other methods.

Respondents said they lacked the resources to implement desired management schemes. Mike Williams lamented that without a grant, he cannot set up and implement an appropriate grazing program at the reserve he manages. Zachary Principe observed that, “Basically we just don’t get to manage the new invasive species or the old invasive species at the level that we would want to.” Andrew

Moyes pointed out that restoration work requires a lot of labor, and John Stechman mentioned that there is often insufficient time for "accomplishing desired implementation, monitoring and reporting."

The small size of reserves, the lack of affordable and/or local seed sources, issues relating to the knowledge (or lack of knowledge) of the land manager, and the uncertainty surrounding the historic composition of grassland were also mentioned during the interviews. Dawn Lawson mentioned the first of these four when she commented that "Its hard to apply big…broad-based management tools, because the patches of ground are so small" in the highly urban (and suburban) setting of southern California.

John Stechman described one of the challenges as simply "keeping up", or "learning what has been and is currently being discovered about ecology and management." Given all of the tasks and responsibilities a typical land manager has in an average week, it may not be surprising that keeping up with literature on current research findings was cited as a challenge.

Finally, the uncertainty that exists surrounding both the historic distribution and composition of grasslands in California, including southern California, is a topic that emerged many times throughout the interviews. When this question was asked, it was cited by a few as causing as presenting a major challenge to managers. For example, Edith Allen stated:

> Sometimes when managers take over an area they're not sure what the vegetation was, and so they're not sure if they should be managing for a different vegetation type, and if they should be managing for a different vegetation type, what should they be managing for? It's a big problem in California that's kind of peculiar to California, because in some of the areas vegetation conversion happened so long ago.

Critical uncertainties

When asked, "What do you see as the largest or most critical uncertainties that exist about grasslands and their management in southern California?" the respondents identified many areas of concern, notably:.

- Weather variability
- Differing responses to management among different grassland areas
- Lack of study of southern California grassland systems
- Timing and other implementation details of management activities
- Competitive balance between natives and exotics
- Historic grassland composition and extent
- Historic fire and grazing regimes

Actual responses relating to these sources of uncertainty and others are included in Appendix A.

Variability of the weather, and specifically variability in the timing and amount of rainfall year to year, was a commonly cited source of uncertainty. Tina Carlsen pointed out that this is a complicating factor in her experimental work. She adds,

> I'm still not convinced that we have a good handle on the interactions between plant dynamics and the weather and climatic phenomena. It's incredibly difficult to predict, from one year to the next, how differences in temperature and rainfall patterns are going to affect species composition and production. We can't seem to predict that in a simple manner, and until we can do that we can't be proactive, we can only respond.

Addressing interannual climate variability, Rich Reiner asserted that "In adaptive management, you tend to have to stick with a particular management scheme long enough to understand that it actually works through years with varying seasonal rainfall patterns."

James Bartolome explained how sites interact with unpredictable climatic conditions in potentially site-specific ways.

> In the work we've done with northern California grasslands, in addition to finding that sites respond differently to management inputs, it also depends on when you do it. On a given site you may have an understanding of what the site is like and predictions for how it will respond under a given set of conditions, but you never know what kind of weather you're going to get in a particular year, and so the site may respond in a way that is totally unpredictable simply because of this year to year variability. We've been calling this the site-time dependency problem, where the two things interact, and so this makes the results of any management input very unpredictable. This time dependency is not a very tractable problem.

Bartolome added that more site-specific research *could* help make this more of a tractable problem. However, that would require time and financial resources that may not be available for many grassland areas.

A few respondents noted the relative lack of study of southern California grasslands systems compared to grasslands in other areas in the state. For example, Wayne Spencer stated:

> Most of the studies on grassland ecology to inform grassland management have been done elsewhere, and [southern California] is a very different system. This is not northern California. The seasons are so different that even basic range management principles (the number of animal units, and how much residual dry matter should be left in grazing) - those kinds of questions have been worked out in a lot of experiments in northern CA, but they don't apply [in southern California].

He and other respondents agreed that this uncertainty affects grassland management in southern California.

Details of implementing management activities, especially fire and grazing programs, include the timing, intensity, frequency, and other variables that will affect management outcomes. Wayne Spencer commented, "The issue of what is the best technique or suite of techniques for managing grasslands for different resource values [is uncertain]. Is it fire? And if so, then the questions are: How often? What season? Or is it livestock grazing? Cattle or goats? Where? How much? What season? Those studies really haven't been done in southern California."

Some respondents mentioned the large uncertainty in how invasive exotics will respond to management treatments. For example, Andrew Moyes stated:

> Some literature suggests that simply removing disturbance will allow native perennials to recolonize annual grasslands. Other sources say that annual grasses can invade perennial types…so any gains made with restoration will inevitably be lost when annuals reinvade. A third scenario is that both annual grasslands and perennial types are stable where they occur and can be type converted to one another with work…This is the model that we believe is most prevalent. You could say that the weed killing and restoration that we're doing is an effort to find combinations of methods that are able to push the annual grassland ecosystem beyond its resilience into a new metastable state as a native perennial type.

Hugh Safford echoed this sentiment when he stated that a major uncertainty was the question "To what extent it is feasible to 'restore' annual grasslands in southern California, when we don't even know what we are restoring them to?' Margot Griswold added that the question of whether we will even be able to restore these systems and have perennial grasslands to manage at all is a major uncertainty. The competitive balance between natives and exotics is not necessarily static either, due to the introductions of new exotic species and factors that can shift the balance, such as rainfall. Therefore, this aspect of the grassland community can be studied, but findings won't necessarily remain valid over time and space.

Regarding site history, respondents made an important distinction between the question of historic composition, and the question of historic extent (or occurrence), each being a separate source of uncertainty for grassland management. These sources of uncertainty apply to northern and central California as well as to southern California. Lastly, the historic fire regimes and grazing occurrence at a site are often unknown with a significant level of certainty. Some noted that this uncertainty can prevent you from understanding the history of a site very well, as well as be able to predict the effects of current fire and grazing regimes on a grassland.

Recommendations and rules of thumb

After establishing what the respondents believed to be some of the major areas of uncertainty about grasslands and their management, we wanted to find out if there were some things the respondents feel fairly certain about. Therefore we asked, "In your experience, what are some universal recommendations, truths, or rules of thumb you can tell us about management of grassland?" This question was intended to yield a list of some recommendations, pieces of advice, and lessons that the respondents have learned through their experience in dealing with grassland systems and/or their management. A list of recommendations, rules of thumb, and truths from the interviews more thorough than what is discussed here can be found in Appendix A.

The responses can generally be organized into three broad classes: responses relating to the occurrence of grassland in California; responses relating to goal-setting and management planning; and responses relating to the actual implementation of different management tools.

Hugh Safford asserted that most grasslands persist due to either azonal conditions, or recurrent disturbance. He also added that infertile soils and water-logged areas tend to support the most "natural" and native grasslands in California, giving examples such as serpentine soils and vernal pools. Elizabeth Painter made the point that if maintaining a high proportion of native grasses in an area requires a lot of shrub removal or other extensive maintenance activity to suppress other native plant species, then the manager should reconsider whether the place really should be a "grassland".

More respondents offered recommendations and rules of thumb about setting goals and planning management, however, than the occurrence of grasslands. Mike Stroud advised that explicit management goals be created. He said, "You have to have goals in your management program, more than just putting up a fence and keeping people out. You need to have goals for your resources, whether it be for endangered species, for critical habitat, for fire control, for public use, or for a combination of those uses." Tina Carlsen asserted that you should not just leave the land lone, citing the importance of active management. Cameron Barrows and Elizabeth Painter both recommended doing your homework to find out about the history of the site, and if the place is really supposed to be a native grassland. Mike Stroud recommended that the manager both collect good baseline information, and information about the ecological components of the site, and also to not rule out any management tool. Related to this was Margot Griswold's advisement that you can't really lock yourself into a plan. She explained that you have to be flexible and keep multiple tools in mind for different situations. Robin Wills stressed the importance of thinking as early as possible about management at the appropriate scale, and thinking about the management of the site as a whole. Finally, Sandy DeSimone advised that the manager look as local as possible for management guidelines, or that they do their own research to create management guidelines for a site.

Recommendations were also offered for the implementation of management tools. Fred Sproul cautioned that the manager start small, and move slowly, with any strong management tool. Jaymee Marty added that before making a major change in the management status quo, the manager should do extensive monitoring of the site before, during, and after the change.

Regarding the use of grazing and fire, Hugh Safford noted that environmental factors, and the timing and intensity of the grazing and fire activities, will affect their outcomes substantially. James Barry stressed that restoring natural fire cycles is very important. Rich Minnich also offered a rule of thumb about using fire as a management tool: he stated that early burning (meaning early Spring before the exotic plants cure) is the key. In using grazing as a management tool, Jaymee Marty advised that a manager leave grazing in place if there is high plant diversity and if there are no apparent detrimental effects from grazing the grassland system. Mike Williams offered the general rule that the more dense cattle are for a period of time, the greater the trampling effects and local-level damage.

For restoration activities, Margot Griswold advised that restoring a grassland takes patience and time. Fred Sproul recommended that it is important to go as local as possible when choosing seed sources. Robert Taylor asserted that native grasses can be very good competitors under the right conditions. But he also cautioned that grasslands are generally under-appreciated, and therefore we shouldn't expect large amounts of funding for their restoration in the near future.

Although these recommendations may be accurate and helpful, Rich Reiner and Sandy DeSimone caution us about making broad statements about what works in managing southern California grasslands. Reiner stated that California grasslands have far less rules of thumb for their management than the Midwestern systems he has studied. And DeSimone reminded us that there are no silver bullets to remove exotics.

Tools and information needed

The final core question was "What tools or types of information do you think are most needed and would be most useful to grassland managers for reaching their goals?" The answers to this question ranged from those related to the general management approach itself, to types of information that would be useful if known, to actual management equipment that would assist the land manager do on-the-ground work. Quotes from the respondents are included in Appendix A.

Zachary Principe stated that the most useful tool is, in a way, having many tools to use. He advised to keep your toolbox open, and don't limit yourself by saying that you can't use fire or that you can't use grazing, because sometime in the future those tools may be useful and feasible for the site you have in mind. He advised that the manager not limit himself or herself and maintain a long-term perspective.

Jaymee Marty cited good monitoring skills as critical to learning from your management activities, and also using monitoring results to adapt and make future management changes based on the response of the system. She added, “I think that most land managers are either afraid or not interested in learning those skills but I really think that the ability to set up a good monitoring program, and then analyze data from that program, is really key. Statistical tools would be included in that, as well as a basic understanding of the monitoring protocols.”

Jon Keeley and Elizabeth Painter suggested we need more information on the historic aspects of grassland sites. Keeley said that we need a broad regional study of current grasslands and what the former distribution of native grasslands looked like. He added, “This sort of research would be very helpful for recognizing where restoration is appropriate, and management options for those native relicts still present on the landscape.” Painter offered a similar suggestion, and that is that we need to understand what was at a site, but also what has happened at a site and what the consequences may be. She suggested that a place to start would be a bibliography of “early historical, Native American ethnobotany, and paleo-botanical/-ecological information.”

Trish Smith stated that useful tools would include any information that would assist the manager “to maintain a trend balanced toward native species cover versus exotics.” She added, “That’s the biggest question out there.” Most of the respondents would probably agree, as this was an unknown that many mentioned during their interviews.

Dawn Lawson noted that she had been hearing more recently about possible negative effects of too-frequent fire on small vertebrates, and that it would be useful for the land manager to know about the effects of fire on things other than perennial grasses so that they don't harm other components of the grassland system. Margot Griswold pointed out that more data and information about the role of soil and soil biota would be key. Tina Carlsen pointed to the large area of uncertainty surrounding the effect of a variable climate on grassland, and suggested a useful tool: "Being able to predict responses based on climate pattern." adding that "They're starting to be able to do that with hurricanes: we should be able to do that with vegetation management." These suggestions may be possible frontiers of further research in southern California grassland management.

The remaining responses to this question were those that identified actual tools to assist the land manager, such as a small range drill, a fire tool that allows the user more control over the fire, and an affordable, small scale seed-collection system for patches of perennials, all suggested by Mike Williams. Mark Stromberg offered another suggestion, and that was to develop "Both a commercial seed source, and a cost effective way to get seeds back out and started on the landscape." He described the seed source as needing to be affordable and aimed at re-populating areas that are far away from natural native seed sources.

The six core questions summarized in this section were the main ones asked of most of the interviewees. However, there were certain topics that the respondents tended to give additional time and thought on. As a result, the interviews as a whole seemed to reveal some general messages about the current state of grassland knowledge and management in southern California

Major themes

To summarize, the major themes emerging from the interviews were:

1. Even degraded grasslands possess conservation value.
2. There is poor understanding of the ecological role of fire.

3. There is a strong divergence of opinion about ungulate grazing as an ecological management tool.
4. There is large uncertainty regarding the historic composition and extent of grasslands in southern California, as well as disagreement about whether that uncertainty is a problem for grassland management today.
5. There is a limited body of management-focused research in California grasslands, and to a greater extent southern California grasslands.
6. Many respondents promoted the principles behind adaptive ecosystem management, even if not promoting the term itself.

Each of these "themes" is described in this section, with the participants' responses included as much as possible.

Conservation value of grasslands

When asked "Do you think that, even though most of the grassland areas are dominated by weeds right now, they still are a conservation priority?", Thomas Oberbauer replied "yes", and explained, "Even the ones that are dominated by weeds are the home for the Stephen's kangaroo rat and burrowing owls, and are foraging areas for raptors. They may be dominated by weeds many years, but possibly if you have the right rainfall pattern you can have a whole series of natives emerge." He cited the Ramona grasslands as an example. Fred Sproul also spoke about the Ramona grasslands, and how their outward appearance to the casual observer does not do them justice. He stated,

> You can come out [to the Ramona grasslands] in the middle of summer and say "I sure wouldn't want to live around here." There is oppressive heat. In thinking about walking across here, you'd just about sooner walk across the Anza Borrego desert in the middle of summer. At night it would be totally different. If you went out at night and had the right equipment, you'd see kangaroo rats and you'd see snakes and you'd see the coyotes and other animals coming out…I think public perception is a big obstacle…. It was only because of the discovery of the endangered Stephen's kangaroo rat that we have any grassland to kick around [Ramona] at all anymore.

This perception by both the public and the scientific community was mentioned by other respondents as well. Dawn Lawson and Lenora Kirby both pointed out that our perception, and not ecological reality, can play a large role in setting conservation priorities. Lawson noted:

> People always want to argue what's a perennial grassland…we say that we can't call this a perennial grassland because the perennials are low. But, there is a big difference between a grassland that has zero perennials, zero seed source, and zero natural persistence of perennials, and one that has even one per square meter. If you had one perennial grass in a square meter, and it was spread throughout the site, the management options available to you if you want to increase the abundance of perennial grasses would be totally different than if you had a site with zero perennials. Its interesting how many people don't seem to get that…I tell people that you've got to think of the abundance and the distribution.

Kirby spoke of the role of perception when speaking of the Ahmanson Ranch, a grassland area located near the San Fernando Valley. She asserted that, "People can bring political pressure, and whether its informed or not, politicians will respond to political pressure. There are people who thought that because Ahmanson had native grass, that it was amber waves of grain, and that it was worth saving." In actuality, the area was dominated by exotic plant species like many other southern California grasslands, and also home to endangered animal species. The perception of the ecological state of the site by the public, although inaccurate, helped to fuel the successful protection of the property from development.

Thomas Oberbauer added to this topic of public perception when he described the recent history of land preservation in southern California, and how appreciation for them has grown. He spoke about how, traditionally, grasslands were recognized as flat areas, with fewer sensitive species than coastal sage scrub and other plant communities, and therefore they were being developed first. Then, conservation of coastal sage scrub meant that some adjacent grasslands were being conserved. He finished by saying that "now what is happening is even the annual grasslands (or the non-native dominated grasslands) are disappearing as well, so the feeling has arisen that those kinds of habitat need more attention." Grasslands are now being recognized as a conservation priority in their own right, in part because they are being reduced in number and acreage.

It seems that certain components of grasslands in southern California, including highly degraded weedy ones, are what bring them the attention and conservation they do receive. These components include remnant perennial bunchgrasses, rare and endangered species, vernal pools, wildflowers, and their value as open space. Increased attention to the importance and ecological role of the grasslands, and hopefully increased study and conservation of them, can result from this appreciation.

The ecological role of fire

There was plenty of discussion about the difficulties associated with implementing a fire management program, and about the historical importance of fire, but almost no mention given to the actual ecological role and effects of fire in grassland. Even when fire was mentioned as an important ecological driver in grasslands in southern California, responses were often left there, with no explanation.

Some respondents mentioned specific areas of large uncertainty associated with fire. For example, the actual historic fire frequency of many areas is not known with certainty, and therefore some believe the current fire frequency is more frequent than historically, while others believe it is less frequent. Mark Stromberg stated "We don't know clearly the fire history, or particularly if it is human affiliated, or too frequent or not frequent enough." Another respondent, Edith Allen, pointed out the uncertainty that exists about the role of fire due to changes in species composition:

> Exactly what the fire cycle is nobody knows, and its really hard to tell now because we have the invasive, weedy grasses mixed with the native grasses, and who knows if the overall productivity is the same as it used to be or whether you've got more fine fuels because the exotics produce more persistent fine fuels. We don't have any reference data so we're not sure how the exotic grasses might affect the fire cycle.

This uncertainty about different aspects of both historic and current fire frequencies and their effects makes prescribing an appropriate fire regime to attain a particular management goal much more difficult.

Another area of uncertainty was mentioned by Dawn Lawson. She stated, “People are so excited about [burning] because it enhances perennial grass cover, but it’s so key to consider what the effects on forbs are, and I even heard someone recently express concern over the effects on vertebrates, like lizards.” She added, “I think that in our quest for simple solutions, like ‘fire kills exotics and it helps the perennials grow’, it may be simplifying and causing a problem for something else. Its just not an easy solution.” Understanding these less studied nuances of fire and its effects may therefore be an important frontier for grassland research, and help to inform the use of fire as a management tool.

Management of grazing

There is a long history of grazing in California grasslands. Nearly all of this grazing has been managed for economic rather than ecological benefits. Many areas have been overgrazed and now show the scars of that intense disturbance. On the other hand, planned grazing for ecological-focused goals has been used to improve the health of the land. Some respondents believe that there is a significant link between the historic role of natural grazers, and the mimicking of that disturbance through the use of livestock today. Others disagree.

Overall, the topic of grazing was one of strong and divergent opinions during the interviews. These differences of opinions revolved around topics such as the appropriateness of using livestock to mimic natural grazers, whether grazing is good or bad (or neither), and the ability to claim one grazing regime as “the best”. While some respondents were split about the use of grazing on grasslands in southern California, there were also a handful who noted that the debate is less contentious than it was a few decades ago.

Elizabeth Painter was perhaps the most outspoken, but not the only, critic of the use of livestock as a management tool. She outlined numerous "myths" about grazing and asserted that "There can be strong political and social pressures to use non-native grazers as a putative 'management tool', without solid science backing up the claims of effectiveness or appropriateness." She challenged the assertion that grasslands have evolved with grazers, that they therefore currently need to be grazed, and that livestock may be used as a substitute for the historic grazers. She made the point that "Pleistocene herbivores are not significant factors in current vegetation…Most breeds of cattle are mesic-area grazers, preferentially feeding primarily on grasses. Roosevelt elk, tule elk, mule deer, and pronghorn are browsers or browser/grazers. There are no simple substitutions."

In contrast, we spoke with a few range specialists who solidly believe in the utility of using livestock to manage for biodiversity values in today's grasslands. One of the challenges that Wayne Spencer mentioned was that "Public perceptions (for example that cattle are good, or that cattle are bad…the black and white perceptions that are not necessarily science-based) are a problem for land managers."

Many respondents recognized both the good and bad aspects and uses of grazing. James Bartolome was one. He offered his view of the debate:

> I think grazing is a useful tool, and it should be part of any grassland management set of tools. It may not be one that you may want to use on a given site - that depends. It depends upon how grazing is applied. It's not necessarily good or bad. I think there are a lot of people who have their minds made up about specific management practices, and grazing is certainly one of them. I think there are people who have an aesthetic and/or personal dislike for grazing as a land management practice. And I think there are reasons for that, in that in many cases grasslands have been damaged by improper grazing management. But, that's something that happened in the past and so the application of grazing in the future doesn't have to be the same or have the same sort of effect.

This contrasts with the situation in the late eighties as described by that Rich Reiner. He stated, "the general consensus among the conservation community was that grazing was bad, and we were removing grazing." He added that this had some very negative ecological responses from some sites where grazing was removed.

Dawn Lawson pointed out that she was getting the impression that people are "finally seeing that you can actually prescribe grazing so that you have your desired effects." Rich Reiner cautioned that there is no simple recipe for doing this, however. He stated, "I think what people who are doing intensive grazing regimes are doing is that they're watching very closely, and moving the animals with respect to what they're seeing on the ground, and that's good. But I don't think there's anything magic about the grazing regimes….I don't think you're going to come up with a grazing regime that is *the* grazing regime." Whether simple or not, though, there seems to be more credit given to grazing as a management tool as compared with the a few decades ago, with the advocates and opponents still a vocal part of the debate.

The question of the historic grassland baseline and its relevance today

The historic composition and extent of grasslands in California was brought up and discussed more than any other topic in these 35 interviews. Debate surfaced over where historic grasslands occurred, what they looked like, and whether these questions are relevant for management of today's California grasslands.

Almost all of the people interviewed at some point mentioned or discussed the fact that the historical distribution of grasslands in southern California (and most of California, for that matter) is unknown with certainty. A few respondents asserted that native perennial grasslands were always rare in the area. For example, Elizabeth Painter stated, "I would first point out that it is unlikely that grasslands were a major vegetation type in pre-settlement southern California. There is little evidence that most contemporary 'grasslands' were dominated by native species of Poaceae before settlement." However, at least one respondent disagreed with this point, at least for one site in Ramona, California. Fred Sproul stated:

> A problem with perception, I think, even among biologists that know a lot, is that this grassland right here is really a grassland and that it wasn't something else that got converted…A grassland that was a grassland and still has some remnants of grassland looks entirely different [than something that was converted]. If you know what you're looking at, you can recognize it.

Most respondents simply stated that we don't know the historic distribution of native perennials grasslands.

Others discussed the uncertainty surrounding historic grassland composition. For example, Truman Young stated, "More than almost anywhere else in the world that I know about, there is doubt about the nature of the 'original' vegetation in inland California grasslands. Therefore there is still debate about where you are trying to get to in restoration." He added:

> There are also side debates about what is natural, such as: Do you include Native American manipulations as targets? or How can you determine what is natural in an ever-changing world? However, I don't think that's what limits us most. I think we're far more limited by the weed problem and by our ignorance of the basics of what it looked like, not whether or not pre-European manipulations such as fire and local plantings moved it this direction or that direction. I think those are very interesting questions, but I don't think that they are as fundamental (at least in grasslands), or that we're going to find that they have as much variation in the answer, as do questions such as: Was this a grassland or a shrubland? Was the perennial grassland dominated by perennials or by annuals? Was it scattered shrubs with bare ground between them? The answers are likely to vary across the state, but as yet we don't know for sure anywhere in these California grasslands because type conversion happened so long ago and so quickly."

A few respondents asserted that historically, these systems were probably not dominated by grasses, and that instead forbs were at least as important or were more important than grasses in the systems. However, most respondents simply stated that the historic composition is still unknown. It is not that this uncertainty hasn't been addressed to some degree in the literature, however. Eric Seabloom noted "I have a mountain…of papers of people arguing back and forth about what the composition was of historic grasslands." Despite this wealth of discussion and study on the topic, there is still no consensus, and perhaps never will be.

Other than disagreement about the historic distribution and the historic composition of grasslands in California, a third type of disagreement was about how much the questions of historic composition and distribution even matter for grassland management today. If the question is though not to be relevant, then management planning and goal-setting may proceed without the question being answered. If it is deemed to be important, then the lack of certainty about the historic composition and distribution of grasslands will be a hindrance to proper management and goal-setting. Of the respondents who addressed the question of whether knowing the historic grassland extent and composition is critical or not, there was an approximate even split.

Some argued that proceeding with management activity for the goal of increasing native grasses, while not knowing the historic composition of the site, may be inappropriate. For example, Elizabeth Painter stated, "Managing for 'grasslands' without knowing that native grasslands were the dominant vegetation may be inappropriate and costly (e.g., the costs of excluding native shrubs can be significant)." Along these lines, Jon Keeley added, "There is a widespread misconception that all annual grasslands today were formerly native perennial grasslands. Trying to restore these to perennial grasslands is futile if they represent areas type converted from shrublands." And again, Margot Griswold echoed a similar sentiment when she stated, "Most grasslands in southern California that are overrun with non-natives are annual grasslands…it might not be appropriate to manage the grassland if you are trying to encourage perennial grassland, because it likely is not supposed to be one. I think that appropriate restoration is one thing that everyone is trying to sort out." The thought that managers may be trying to persue a goal that is impossible to obtain, while spending valuable resources to do so, is thus seen as a waste.

Numerous other respondents, although perhaps agreeing with the points made by the respondents in the previous paragraph, stressed that even if we do not and may never know the historic composition and extent of native perennial grasslands, we need to proceed with management anyway. Three of the most pertinent responses follow. Robert Taylor stated:

> This is obviously an important question, but also one that is unlikely to be resolved much more than we have at present, unless someone invents a time machine and lets botanists use it. In any case, California will not be managed by people as it was by the Indians again at any time before the downfall of civilization as we know it. We've got 35 million people here who aren't leaving any time soon and more are on the way. And the climate may well be changing for the foreseeable future, making past vegetation patterns less relevant for restoration. So we need to work on functional restoration goals and do the best we can. We have some remnants to study and we can try to recreate species compositions observed in those places on a wider scale on sites where historic research and soils evidence suggests grasslands would have been. That's the best we can do, but that's pretty good.

Rich Reiner expanded on this vein when he stated:

> Most of the grasslands that we manage in California today are composed of both native and exotic species…So, the competitive interactions between species are very different from what we might have seen in pre-European grasslands. Studying non-invaded reference sites, if you can find them, doesn't provide a complete picture of how to manage invaded communities because the main ecological drivers, fire and grazing, operate differently in invaded systems…So, my perspective for management of invaded grasslands is not to emulate what we think might have been the original fire and grazing regimes, but to orient management towards tilting the competitive playing field towards natives and away from exotics. The way this is accomplished is by studying the life history of both the exotics and natives, and applying disturbance regimes such as managed grazing and prescribed fires that tend to decrease the viability of the dominant exotics.

Robin Wills' comments seem to agree. He stated:

> It doesn't really matter what grasslands looked like before. What matters is whether or not we can come up with something that makes ecological

> sense as a target. Whether it looked like that pre-settlement or not is sort of irrelevant. Its an ongoing debate and I think people really get stuck and sort of paralyzed from a management standpoint because they can't decide whether or not they want more forbs, whether there should be more perennials in the system, so on and so forth, and it only matters whether or not in your little space and time these things become functional ecosystems that exhibit some measures of health.

Many of these respondents made the point that it is unlikely that we will be able to restore the historic regimes of fire and grazing and other ecological drivers, and that this further separates us from the importance of the historical make-up of these systems. And, like Robin Wills, some pointed out that because the question of historic composition and distribution can cause management paralysis, that it should not be focused on nearly as much as the task of forming logical goals and targets.

Others took a more democratic view of the matter, giving both sides of the argument attention. For example, Cameron Barrows stated, "The concept of replacing a bunch of non-native grasslands with native grasslands may have value, but its not necessarily restoring it back to its natural condition." And finally, Eric Seabloom also responded in a way that gave attention to both sides of the debate when he stated, "This is a really important question, especially when you may have absolutely no clue what was there before. From my personal perspective, I'm probably more in the realm of being interested in increasing the percentage of area covered by native species and I'm a little less concerned about restoration in the sort of strict sense…Restoring something that was there 200 years ago - the site might not be suitable for that anymore." This topic will undoubtedly remain a source of controversy and discussion over the near future.

A deficiency of grassland management science

Large areas of uncertainty and strong disagreement about some of the more fundamental ecological processes and management approaches in these grasslands are in part indicative of a dearth of management-focused research in California grasslands. As a result, the models for grassland management seem somewhat ad-hoc, and are sometimes underlain with what could be described as an almost religious commitment to certain beliefs and principles. This contrasts with a longer tradition of management-focused research, and standard sets of theories, that is the case with some other ecological systems.

Thomas Oberbauer pointed out that there is a paucity of research on specifically southern California grasslands simply because there are few of them under public, protected ownership, and therefore there is not a long tradition of experience with their management. However, he added that the lack of management-focused research is something that is not necessarily as tractable as simply increasing the amount of research done on California grasslands. Modern management and research experiments done on grasslands in California are essentially studying the Mediterranean annual grassland, he noted, and research findings may therefore have limited applicability to the "native California grassland." Research into the management and ecology of California grasslands is further complicated because grassland systems are often composed of, and are themselves, a very heterogeneous set of ecosystems. James Bartolome made this point well when he said:

> When people think of grasslands, I think they tend to think of them as being relatively uniform vegetation types without too much variability. But that's not true - there are many different types of grasslands. In areas like southern California, if you wanted to you could classify and distinguish many different kinds of grassland sites and grassland types. And these types tend to respond idiosyncratically and differently to management, so the challenge for the manager is…(and this is true for most of southern California grassland) there's so little management information that its hard to predict how a particular site is going to respond to a particular management input.

Both inter- and intra-grassland heterogeneity means that there can be no "one size fits all" management approach.

There is an understandable tendency in ecosystem management to want to look for the silver bullet: the management approach that will "work" for the majority of the system under investigation. For example, biological soil crusts and mycorrhizae have received more attention in recent years among grassland ecologists. Another illustrative example is that of Nasella pulchra (previously known as Stipa pulchra). Eric Seabloom described its popularity and the consequences of it:

> A lot of the research in California is really focused on a very few species and in particular, by sheer weight of paper produced, probably eighty percent of it has been on Nasella pulchra (sort of the charismatic mega flora)…I think a big uncertainty, if you look carefully at a lot of the conclusions that people make, is that they are based on work with that species…There are other native perennials that do very different things. The focus on Nasella pulchra has dominated people's conclusions about what works and doesn't work for restoration. There's also been a focus on perennial grasses, and I think other groups of the community are really neglected for that reason.

While some areas receive an inordinate amount of research attention, some of the more fundamental questions remain unanswered. One of these was mentioned by Trish Smith: she asserted "I think that the biggest constraint, or, the biggest unknown, is having any sort of research data to guide us in how we can [manage for biodiversity] with the management tools that are available to us." Another largely unexplored area of research, mentioned by John Stechman, is the estimation of the costs, benefits and risks related to grassland management. Both of these research arenas could help managers make more informed choices about using management tools, and help to establish a baseline of established theory for California grassland management.

Adaptive management is a popular idea, but an unpopular phrase

The final topic of discussion that will be summarized here is the topic of adaptive management. A few of the interviewees mentioned this topic during their interview. Many who described their approach to grassland management listed some of the fundamental characteristics of an adaptive management approach, such as experimentation, and seeking to learn from management and adapt management over time.

However, most who were asked directly about adaptive management per se expressed some anxiousness in using the term to describe their approach. They did not believe the word reflected what they meant in the way it is used today. For example, James Bartolome stated:

> The reason I don't like [the term adaptive management] is because it's been used by management agencies…as a catchall and also as an excuse for not doing the research. In other words, if we just adapt to all the management outcomes then we don't have to do the research we can just respond to what happens. But that's not the way I view proper adaptive management. Proper adaptive management to me is you still do the research, you understand site variability, and then you modify your management based on a growing knowledge base instead of just using it as an excuse to not really study the system. I think that's my main reason for not liking [the term]. I think it's also used in a much looser way than the originators of the term meant it to be used…it covers a multitude of sloppy management practices as it's used now…

Bartolome's feelings were echoed by a few other respondents as well. James Barry notes that his use of the idea of adaptive management differed from how he sees it used by some management entities. He stated, "To me it means more [than being adaptive], it means that you're out there being proactive."

Some respondents described their own approach to grassland management, and often these descriptions were very much like an adaptive management approach. For example, James Barry advised "…where a monitoring system is in place, we always have this feedback loop from our monitoring, and when we find that what we are doing is adversely impacting the natural system, then we readjust." Wayne Spencer described the general approach he and his colleagues are taking for planning a management scheme for a grassland in southern California, He explained:

> We're doing a community model, of the threats, and stressors, and so on. All of the factors that interact and need to be considered as stressors or management tools in the system will be included, and then once we have this model (as a sort of base at least), [we will make] a preliminary management plan based on that…Part of it would clearly be adaptive management, where we don't know all the answers, because it hasn't been tried yet here. We have goals certainly…and we have some ideas of how to [reach them], but they have to be tested and then adjusted over time.

Spencer and other respondents who spoke about adaptive management all described it as being an important and useful way to approach ecosystem management. Although some didn't like the term itself, they did seem to like the underlying meaning that the term has for grassland management. The goal of reducing uncertainty through learning seemed particularly appealing to respondents who discussed the topic of adaptive management.

However, in her comments on the topic, Tina Carlsen made the important point that adaptive management doesn't happen by itself. It needs to be planned for and financed. She stated, "It's important not just to put a fence around [the property] and walk away and forget about it. We also need monetary resources to do active adaptive management, because we still don't know what we're doing so we still need to keep experimenting until we find out."

Part Two. Case study: an adaptive management framework for the Santa Rosa Plateau Ecological Reserve

2.1 Applicability of Adaptive Management

Introduction

Using the adaptive management guidelines (found in Appendix B), we have created an adaptive management framework for the Santa Rosa Plateau Ecological Reserve (SRPER) to demonstrate the application of the discussed guidelines and tools, such as conceptual models and GIS analysis, to the management of a grassland area. We also present this case study as an example of the guidelines and tools for a real place, in the hope that managers of other grassland areas can utilize them.

Case Study Site and Its Current Management

The Santa Rosa Plateau Ecological Reserve is located at the southern end of the Santa Ana Mountains in southern California, near the City of Murrieta. The Reserve is comprised of approximately 8,300 acres, of which the majority is grassland. The SRPER also protects unique ecosystems like Engelmann oak and coast live oak woodlands, riparian wetlands, coastal sage scrub, chaparral, and vernal pools (Santa Rosa Plateau Ecological Reserve 2004). Currently, SRPER management uses prescribed burning, which is not deployed in an adaptive management framework. SRPER makes for an interesting case study site because it contains grassland areas with varying histories of grazing and burning. In addition, SRPER has one of the most active prescribed fire management programs in all of California's grassland preserves. This provides us with an excellent opportunity to develop an adaptive management framework for this site.

Applicability of Active Adaptive Management

Adaptive management approach for the SRPER will make its management more planned, more formal, and more scientifically rigorous than the existing one. The goals of adaptive management stress learning to reduce uncertainties of a system structure and function, and associated best management practices, and encourage an active management despite these uncertainties. There are three types of adaptive management: deferred, passive, and active (Everett et al. 1994). Generally, they differ from each other by the rate of learning they offer, the resources they require to be successfully carried out, and the degree of accountability to their management goals.

To guide us in deciding which adaptive management approach would be most appropriate to our case study site, we used Carl Walters' four conditions, which he believes must be met to justify an active approach over a more passive one: the presence of uncertainty about the best action to take, system performance must be sensitive to the action taken, alternative actions must be differentially informative, no single one of the alternative models for system response must be considered very probable (Walters 1986). The SRPER site satisfies these conditions. When applying the management action of prescribed burning, we do expect various responses depending on fire frequency, duration and intensity. We believe that active adaptive management is the most appropriate approach in this case. As it has been pointed out in the first part of this document, the lack of understanding of the underlying functioning of a system and the associated uncertainties are true to southern California grassland areas. We believe that the Santa Rosa Plateau Ecological Reserves serves as an appropriate representative.

2.2 Mission and stakeholders

Mission—to maintain, enhance, and/or restore native plant diversity and composition of grassland habitat in the Santa Rosa Plateau Ecological Reserve (Principe, personal communication).

In 1991, the four landowners (The Nature Conservancy, Metropolitan Water District of Southern California, the State of California's Wildlife Conservation Board, and the

County of Riverside) and the U.S. Fish and Wildlife Service (interested in protection of Plateau's rare and endangered species) signed a Cooperative Management Agreement for the lands on the Santa Rosa Plateau (Santa Rosa Plateau Ecological Reserve 2004). Today, The Nature Conservancy manages the protected 8,300 acres as one biological unit. Riverside County Regional Park and Open-Space District manages a visitor center and a forty-mile trail system. Metropolitan Water District of Southern California provides an educational grant.

Besides the goals to protect, enhance, restore, and maintain the quality and diversity of the various habitat types, the SRPER provides endless opportunities for research, teaching, nature study and appreciation. Over 40,000 visitors come to the reserve every year to participate in a variety of recreational activities including hiking, horseback riding, mountain biking, and interpretive programs (Santa Rosa Plateau Ecological Reserve 2004).

There are many stakeholders involved with or influenced by SRPER management approach:

- The management entities: the Nature Conservancy, the Metropolitan Water District of Southern California, the County of Riverside Regional Park and Open-Space District, the U.S. Fish and Wildlife Service and the California Department of Fish and Game.
- The Preserve Our Plateau citizens' group and other environmental and social organizations or activist groups.
- The California Department of Forestry and local fire departments.
- Adjacent property owners.
- The governments and residents of nearby cities
- Volunteers at the reserve, such as the Team Stream.
- Visitors and recreational users.
- Managers of other grassland areas

- Research and educational institutions (including scientists, naturalists, and students).

2.3 Site characterization

The SPRER has remained relatively undisturbed for years due its remote location. In recent years, however, a large amount of the surrounding area has been converted to residential development. The 8,300-acre area of the SRPER is currently cooperatively owned and managed by the management entities listed above. The SRPER has been targeted for conservation by these entities because of its relatively good condition, its diversity of habitat types and species of special concern, and its size.

Topography, soils and hydrology

The topography of the SPRER area is highly varied, as are the types of soils present. The topographic region of the SRPER includes mesas, canyons, rolling hills, and regions of flat low-lying land. These variations work in concert with soil type to dictate the types of vegetation present. The soils associations present in the grassland and oak woodland communities of the SRPER are Vallecitos and Las Posas soils, which are shallow soils (0.5-1.2 m), as well as deeper Murrieta Stony Clay Loam. Areas of shallow claypan are also present, particularly in vernal pool areas (Santa Rosa Plateau Ecological Reserve 2003).

The hydrology of the area is as variable as the soils and topography. Ephemeral drainages are most common in the SRPER, including ephemeral streams and vernal pools. Vernal pools are most often located on mesa tops in areas of volcanic basalt. The presence of both ephemeral streams and vernal pools is correlated with rainfall, which in this area is concentrated in the winter months (usually December to May). Deep pools called tenajas, which hold water year-round, can be found along the courses of some ephemeral streams (Santa Rosa Plateau Ecological Reserve 2003).

Climate

The SRPER is influenced by a Mediterranean climate with an average of 22.5 inches of rain each year. The location of the SRPER exposes it to a marine influence that can moderate the local temperature in the summer (SRPER fire plan 2003). Santa Ana winds, which are warm and dry winds that develop under high pressure systems, can counteract this influence, however. This effect can create dangerous conditions for fire.

Flora and fauna

All of the factors discussed above encourage the presence of a diverse collection of vegetation. Within the area of the SRPER, there are areas of eight different vegetation types: southern California bunchgrass prairie, non-native grasslands, Riversidian sage scrub, chamise chaparral, southern oak woodland, riparian woodland, and vernal pool wetlands. The diversity of vegetation at the site supports relatively high faunal diversity, including 23 reptiles, 11 amphibians, 200 birds, 18 small mammals, and 9 large mammals (Santa Rosa Plateau Ecological Reserve 2003). See Box 2.1 for more detail.

Oak woodland and bunch grass prairie are generally found in upland areas and are most common on sites with thin, rocky soils. The regionally endemic Engelmann oak (*Quercus engelmannii*) is the tree species that is most commonly associated with grasslands and savanna areas at the SRPER. Within the grasslands, important species include purple

Box 2.1 Significant animals as identified in the SRPER Fire Plan, 2003

Mammals
American badger
Mountain lion
California ground squirrel
Valley pocket gopher
Coyote
Spotted bat
Pacific kangaroo rat
Dusky-footed woodrat

Birds
Northern harrier
Red-tailed hawk
California quail
Greater roadrunner
Horned lark
California towhee
Western meadowlark
Grasshopper sparrow

Reptiles and amphibians
Western yellow-belly racer
Red-legged frog
San Diego horned lizard
Southwestern pond turtle
Western toad
Pacific treefrog
Granite spiny lizard
Side-blotched lizard
Western whiptail
Gopher snake
California kingsnake
Red diamond rattlesnake
California newt

needlegrass (*Nassella pulchra*), Malpais bluegrass (*Poa secunda*), wild hyacinth (*Brodiaea filifolia*), and the chocolate lily (*Fritillaria biflora*). Within the SRPER, as in most grassland areas of southern California, these grassland species are threatened by intense competition from exotic grasses of Mediterranean origin. Oak savannas and grasslands at the SRPER tend to be heavily invaded by exotic grasses and forbs. The most common non-native plant species at the SRPER are: wild oats (*Avena barbata*), red brome (*Bromus madritensis ssp. rubens*), foxtail fescue (*Vulva myuros*), soft chess (*Bromus mollis*), filaree (*Erodium spp.*), black mustard (*Brassica nigra*), telegraphic weed (*Heterotheca grandiflora*), prickly lettuce (*Lactuca serriola*), and summer mustard (*Hirschfeldia incana*) (Santa Rosa Plateau Ecological Reserve 2003).

Historical and Current Use

The Santa Rosa Plateau has a long and varied history of its land use that can explain today's state of its grasslands. Prior to the European contact in the second part of eighteenth century, Native Americans inhabited the area leading hunting and gathering lifestyle. Natural and anthropogenically caused fires were frequent and varied in intensity. In the mid-nineteenth century Santa Rosa became a ranch primarily used for grazing by cattle and sheep. The ownership of the Rancho Santa Rosa passed through many hands until 1904, when Vails family purchased the property. They are believed to have been wise stewards, keeping a sustainable amount of cattle, grazing only during the wet months, and moving the cattle down the valley's feedlots during the dry summer seasons. They sold the property to the Kaiser Steel Corporation in the mid 1960s. Unfortunately, for the next twenty years, grazing under year-round leases with large numbers of cattle throughout the grasslands and oak savannas of the Santa Rosa Plateau deteriorated these habitats. There is not much documentation about the fire regime during those times, except for that there was a large wildfire in 1980, which burned much of the area (Santa Rosa Plateau Ecological Reserve 2003).

In 1984, The Nature Conservancy of California initiated the acquiring of the Plateau lands, recognizing the value of its habitats, their existing species diversity and endemism. TNC management discontinued grazing within a couple of months every time the new piece of property was acquired (the last one in 1996). Also, in recognition of the historic role of fire within the reserve communities, the management introduced prescribed fires in 1989 as a restoration tool and continues to use them almost every year (Santa Rosa Plateau Ecological Reserve 2003).

Legal Context

The SRPER lies within a larger-scale plan that is approaching the end of a comprehensive planning effort (the Riverside County Integrated Project (RCIP)), which integrates three planning efforts: a County General Plan, a Community and Environmental Transportation Acceptability Process and a Multi-Species Habitat Conservation Plan (MSHCP). This approach allows for higher balance between development and transportation planning, and conservation of 146 listed/sensitive species and their suitable habitat areas. The MSHCP builds upon a previously approved habitat conservation plan that solely addressed Stephens' kangaroo rat. The MSHCP consists of a reserve system of approximately 500,000 acres. Although the County has adopted the MSHCP in June 2003, federal and state permits have not yet been issued (anticipated by spring of 2004) (Riverside County 2004). For more information on the legal context of grassland management in southern California, please see Appendix F.

2.4 Management framework

Our management framework focuses solely on grassland resources within the SRPER area, whereas a comprehensive management plan would take into consideration factors involving other communities and habitat types, in particular chaparral. Ultimately grassland management needs to be coordinated with chaparral management, notably management of the chaparral fire regime, of potential expansion of chaparral into grassland communities, and of species dependent on both chaparral and grassland habitats. Many managers elect to control the invasion of shrub species into grassland communities, especially in areas where the Stephens' kangaroo rat is a species of concern (Price 1994).

Management goals

We have adopted the goals and objectives set out in the SRPER's existing management plan as the basis for an adaptive management framework for the site. The land management goals of the SRPER are to:

- Ensure the persistence of a native-dominated vegetation mosaic.
- Ensure the persistence of native plant and wildlife species of management and monitoring concern.
- Restore or enhance the quality and extent of degraded vegetation communities and other habitat types in a manner consistent with overall conservation goals for species and natural communities.
- Maintain landscape processes and functions.
- Maintain structural characteristics for selected species habitat (Santa Rosa Plateau Ecological Reserve 2003).

These goals specify fundamental desired states for the SRPER. Management goals do not take feasibility into account (see Appendix B). However, there are constraints to management at the SRPER that must be considered before management actions can be chosen.

Management constraints

The environment of the SRPER includes several factors that restrict management activity, including housing surrounding the reserve area and Santa Ana winds that can affect fire activity during fire season. Presently, the primary management activity being conducted at the SRPER is prescribed burning. Prescribed fire has been in use at the SRPER since 1989 and has been applied to all of the vegetative communities present at the reserve (see Table 2.1). Chaparral and grassland communities both contain species that have been shown to recover quickly from fire and sometimes to increase production post-fire(Vogl 1974; Menke 1989; Wills 2001). Burning due to natural ignition as well as burning by indigenous peoples is known to have occurred historically with varying frequency, as well (Santa Rosa Plateau Ecological Reserve 2003).

Table 2.1 Prescribed fire history of the SRPER (1989-2001)

Date	Location
06/13/1989	Unit 2 (445 acres)
12/19/1989	Unit 8 partial (300 acres)
06/06/1990	Unit 7 partial (200 acres)
06/10/1992	Unit 3 (241 acres)
06/11/1992	Unit 6 (88 acres)
06/02/1993	Unit 5 (202 acres)
06/07/1994	Unit 1 (272 acres)
06/08/1994	Unit 2 (445 acres)
06/14/1995	Unit 4 (676 acres)
12/05/1995	Unit 11
06/03/1997	Unit 6 (622 acres)
06/04/1997	Unit 7 (779 acres)
07/21/1998	Unit 6 (88 acres)
07/22/1998	Unit 9 (198 acres)
06/08/1999	Unit 7 (779 acres)
06/05/2000	Unit 3 partial (130 acres)
12/20/2000	Tenaja (40 acres)
10/19/2001	Tenaja (240 acres)

(Data from the SRPER Fire Plan, 2003)

One reason that fire was chosen as the primary management tool for the SRPER was its low cost. It was found that fire was the cheapest of the alternatives that were considered, with an estimated average cost per acre of $5 (Santa Rosa Plateau Ecological Reserve 2003).

Historic livestock grazing has had a significant impact on the area, and managers at SRPER have expressed an interest in re-introducing grazing to the SRPER area (Principe, personal communication). The main obstacles to the use of prescribed grazing at the SRPER are lack of infrastructure (roads, fences, and water sources) and a lack of cattle. There are no cattle ranching activities in the immediate area, and bringing cattle in from elsewhere might not be feasible. If both of these issues were addressed, a pilot grazing program could be implemented.

Given SRPER's experience with controlled burning and the low cost and ecological importance of this management approach, we elected to treat fire as the primary management technique in our adaptive management framework for the SRPER.

Management objectives

The seven management objectives outlined in the current management plan for the SRPER are as follows:

1. Develop active fire management prescriptions for grassland-oak savanna habitat, focused on increasing diversity of native plants, decreasing cover of non-native annual grasses and promoting community structure and composition favored by target wildlife species.
2. Utilize prescribed fire to reduce unplanned fire events from known ignition corridors.
3. Define fire prescriptions that aid in the restoration of degraded grasslands.
4. Quantify effects of varying fire regimes on selected wildlife species.
5. Develop a social environment supportive of active fire management.
6. Investigate active restoration techniques following fire treatments.
7. Identify appropriate spatial scales and patterns for the long-term management of fire (Santa Rosa Plateau Ecological Reserve 2003).

These objectives were developed by stakeholders of the site based on their priorities for the SRPER area. Only the stakeholders can develop objectives that accurately reflect their values and desired state at the site, but the objectives that those stakeholders outline can become more effective and useful if they are stated more precisely.

The characteristics of effective management objectives can be summed up by the acronym SMART- specific, measurable, accountable, realistic, and time-fixed (Meffe et al. 2002). The objectives listed above are realistic, and in that respect do not need to be modified. The management staff at the SRPER has also accepted the responsibility for achieving these objectives, so they are accountable. These objectives are not specific, measurable, or time-fixed, however. A time-fixed objective is associated with a projected date of completion. These objectives are not time-fixed, and time fixation is an essential component of measurability. The level of specificity in the objectives is also closely related to their measurability, because if it is not clear what must be done for an objective to be considered complete, it is difficult to determine when objectives have been achieved. In addition, objectives 4 and 7 are more related to monitoring that to management, and could be classified as monitoring goals. We have developed two sample objectives for the SRPER that are related to the existing SRPER management objectives, but that exhibit more of these "SMART" characteristics of effective adaptive management objectives. These sample objectives are:

1. Increase diversity of native grasses and forbs in highly invaded grassland areas by 10 percent by spring of 2010.
2. Reduce non-native plant cover in grassland areas by 30 percent through the application of active fire management by spring of 2010.

Hypotheses

In order to identify management actions that will lead to the achievement of the management objectives for the SRPER, we needed to formulate hypotheses about the behavior of the system. This is an essential element of an active adaptive management approach. We used envirograms and phenograms constructed for selected species found at the SRPER to aid in this process. We also used a small-scale fire model, which is shown in Appendix C.

Fire model

In the fire model, we identified frequency, seasonality, and intensity as three aspects of a fire event that can be controlled by a manager and that directly affect the outcome of a fire event. All grassland managers are working with limited resources, and it would be unfeasible to attempt to test the effects of all three of these factors. Current management at the SRPER is focused on testing the effects of a 7-12 year fire return interval and is not addressing seasonality or intensity (Santa Rosa Plateau

Ecological Reserve 2003). For this reason, we have chosen to focus on frequency in this initial management framework.

Phenograms

Our focal exotic plant species include black mustard (*Brassica nigra*), wild oats (*Avena fatua*), tocalote (*Centaurea melitensis*), and red-stemmed filaree (*Erodium cicutarium*). These species are found at the SRPER and are also common in other areas of southern California. Focal native species include purple needlegrass (*Nassella pulchra*), tarweed (*Hemizonia fasciculata*), California aster (*Lessingia filaginifolia*), thread-leaved brodiaea (*Brodiaea filifolia*), purple clarkia (*Clarkia purpurea*), bush lupine (*Lupinus bicolor*), and the chocolate lily (*Fritillaria biflora*). These species are considered important or representative of conditions at the SRPER. Phenograms for all of these species are shown stacked in Figure 2.1.

In order to test the effects of fire frequency on the vegetative community at the SRPER, it is first necessary to determine at what time of year burns will take place. The literature suggests that spring burns may be more effective in reducing the presence of exotic plant species and the dominance of exotic grasses than fall burns. Parsons and Stohlgren (Parsons 1989) found that frequent fall burns increased biomass of *Centaurea melitensis* from 0 to 46.3% in stands that had previously been dominated by grasses. They also found that fall burning showed a minimal effect on the presence of exotic annual grasses. Spring burning was found to increase the presence of forbs substantially, which is desirable in grasslands dominated by exotic grasses. Spring burning has also been shown to reduce exotic grass seed production and viability (Menke 1992; Meyer 1999). This evidence is supported by the phenograms, which show that burning in March or early April would probably have the largest effect on *Avena fatua* seed production in an average rainfall year.

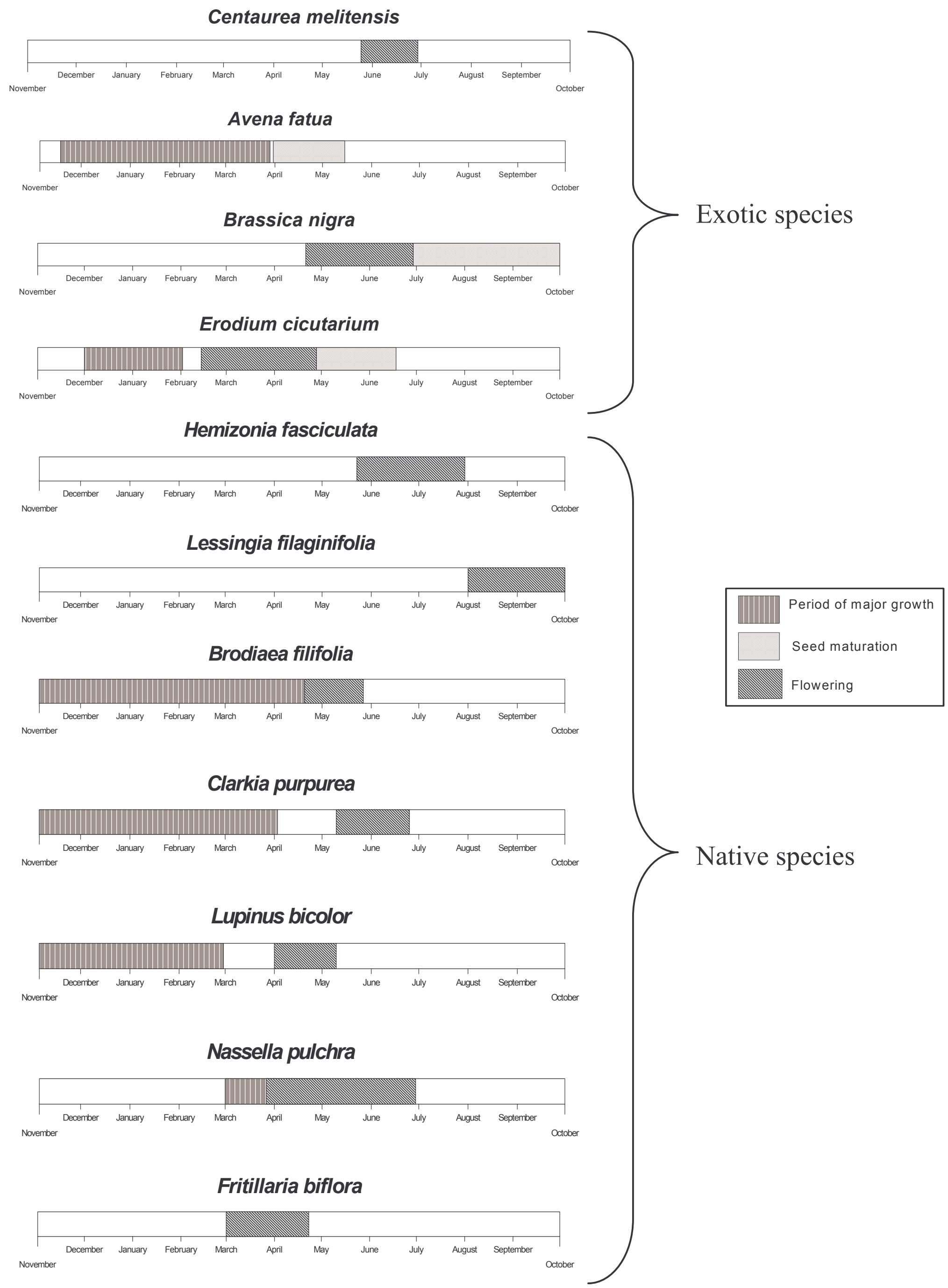


Figure 2.1. Stacked phenograms for native and exotic focal species found at the SRPER.

The phenograms also suggest that burning in late February or early March would have a minimal impact on seed production and flowering for most or all of the native species. There is often a reduction in seed production by native perennial grasses after a burn event, but this effect disappears two or three years post-fire (Menke 1992). It is important to note that the extreme interannual variation in rainfall in California makes it difficult to predict the ideal timing for a burn in terms of absolute date. The months recommended here for burning are based on phenograms created based on average conditions at the SRPER, but it is important for individual managers to be aware of the growth rate of plants at a site in a given year and make management decisions based on the growth stage of target plants.

There are tools available to managers to evaluate fuel moisture loads in grasslands that can be used to determine whether conditions are appropriate for burning at the time when it might be most ecologically beneficial. Fire managers make use of the Palmer Drought Severity Index (PDSI) and Keetch-Byram Drought Index (KBDI) to predict seasonal and daily-to-weekly wildfire risk, respectively. KBDI is also widely used to schedule controlled burns.

PDSI mainly reflects accumulated precipitation anomalies and is increasingly positive in wetter than average years and increasingly negative in drier years. In western forests, wildfire occurrence is negatively correlated with current year PDSI (and associated high green fuel moisture levels) and positively correlated with PDSI in the previous 1-3 years, due to accumulated fine dead fuels (Swetnam and Betancourt 1998; Westerling et al. 2003). The Keetch Byram Drought Index (KBDI) is more responsive to short term rainfall patterns and used to predict the moisture content of the upper soil layer, duff and live herbs (Keetch and Bryram 1968). KDBI is positively correlated with ignition probability and fire severity and is a good predictor of the moisture content of live shallow-rooted herbaceous species in Mediterranean climates (Dimitrakopoulos and Bemmerzouk 2003). The index predicts the water deficit in the upper soil layer in units of 0.01 inches and ranges from 0 (soil saturation at a field capacity of 8 inches of available water) to 800 (maximum drought). At values below 300 the ground layer is predicted to be moist-to-damp and the risk of severe fire low-to-moderate. Fire severity is expected to increase steeply between values of 300 and 500 with greater consumption of coarser fuels. At KBDI values greater than 500, fire is predicted to completely consume surface fuels and persist overnight.

The calculated KBDI values for the Santa Rosa Plateau area are shown in Figure 2.2 (based on weather data obtained from the Temecula weather station of the University of California Integrated Pest Management Program). A KBDI value of 150-300 is appropriate for burning in this area (U.S. Forest Service 2004). Although KBDI values would need to be calculated for many years to draw definitive conclusions about climatic trends in the Santa Rosa Plateau area, Figure 2.2 shows that in most years it will probably be possible to burn in late February, although KBDI values may drop very low in early March. A KBDI record is simple to start, and can be used to monitor fuel moisture levels so that years in which it is possible to burn in early spring can be reliably identified.

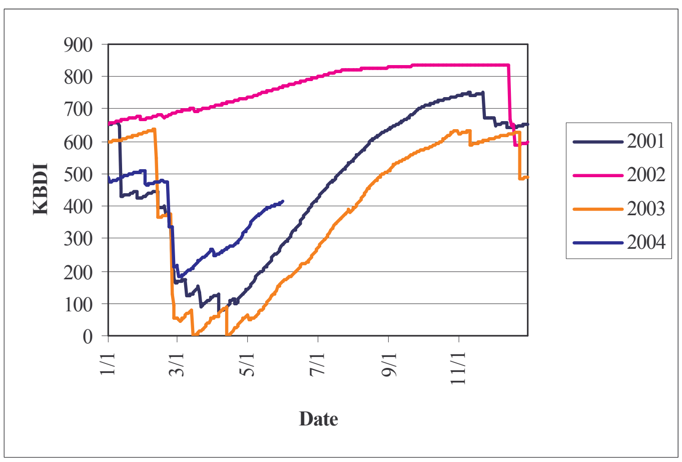


Figure 2.2. KBDI values for the Santa Rosa Plateau area based on Temecula weather data.

The effects of fire return interval are not apparent in the phenograms, but there is literature on the subject that guides the formulation of hypotheses for the SRPER. Unpublished data collected by J. Menke and K. Rice suggests that very frequent burning leads to the volatilization of large amounts of nitrogen and sulfur, so burning at very high frequencies should be avoided (Menke 1992). Menke (1992) recommends burning every three to four years, in order to allow native species as long of a recovery period as possible while preventing the re-establishment of exotic plant species at pre-fire densities. Parsons and Stohlgren (1989) found that following successful prescribed burns, if the burning program was suspended, exotic grasses that had been dominant reasserted themselves within the grassland. They suggest that frequent burning is necessary to maintain the positive effects of a burning program. If the interval between burns is long enough, it may be the case that the community will behave as if the burning program had been suspended, and no beneficial effects of burning will be evident over the long term. For this reason we suggest a burning regime that will test the effects of a 7-10 year fire return interval similar to that currently in place at the SRPER, and the effects of burning at a 3-4 year interval as suggested by Menke (1992).

Fauna

We also examined envirograms for some species of fauna present at the SRPER to determine whether fire would have any detrimental effect on focal faunal species. These envirograms, shown in Appendix E, are based on the format developed by James et al. (1997). These models show the factors affecting present and future populations of a single species. According to our models, species such as the San Diego pocket mouse, burrowing owl, and tarantula should not be significantly negatively affected by prescribed burning during any season as long as not all habitat is burned at one time. However, monitoring will be essential to determine whether this hypothesis is true.

The grasshopper sparrow could be negatively impacted by burning during its nesting season, which is generally between April and August. Since we hypothesize that burning in early March will be most effective, this should not be a concern. The Stephens' kangaroo rat has been shown to benefit from burning through reduction of thatch and shrub cover, and should also benefit from burning during all seasons if habitat patches remain (Price 1994).

According to our models, fairy shrimp species will not be negatively affected by fire, because during the summer fairy shrimp cysts are found in areas with minimal fuel. During the winter and spring vernal pools are in their wet phase.

Hypotheses

The hypotheses formed using the conceptual models for each of the focal species can be generalized into hypotheses that are applicable to all oak savanna and grassland areas within the SRPER. These hypotheses are:

1. Prescribed burning at return intervals of 7-10 years will have no significant effect on the abundance and diversity of native and exotic plant species in grassland and oak savanna areas.
2. Prescribed burns at return intervals of 3-5 years will significantly decrease the abundance of exotic plant species and increase the diversity of native plants, particularly forbs, in grassland and oak savanna areas.
3. Fire will not have a significant negative effect on populations of selected fauna.
4. Fire will have an insignificant effect on the survival of mature oaks.
5. Soil nitrogen levels will be lower post-fire, but fire return interval will not have a significant effect on mean soil nitrogen level over time.

These hypotheses were used to create the experimental framework outlined below.

Experimental design

Based on these hypotheses, we created an experimental design with three treatments. These treatments are:

1. No burning.
2. Spring burning with an average return interval of 3 years.
3. Spring burning with an average return interval of 7 years.

Each treatment will be applied in 4 replicates.

Currently there are 13 burn units in place at the SRPER, but they are not all of equal size and they do not all encompass grassland habitats. For the purposes of this framework, the existing burn units containing grassland were identified, and burn unit 8 was divided into two units, 8a and 8b. In this way, 11 burn units were identified and stratified by size and environmental characteristics. Treatments were then randomly assigned within the strata, with 3 units being assigned to remain unburned. Four units were assigned a 3-year fire return interval, and four units were assigned to a 7-year fire return interval. A burn schedule was then created for these units, which is shown in Table 2.2. Stochasticity was introduced into the 3-year burn schedule by dividing the future into 3-year strata and randomly assigning a burn to one year within each stratum. The same was done for the 7-year treatment.

Table 2.2. Burn schedule for 11 selected burn units at the SRPER. P is the probability that a unit burns in a given year.

Unit	Treatment	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	P
1	3-year			1		1		1					1		1				1	1			1				1	0.36
2	3-year		1		1			1					1	1			1				1				1			0.32
3	Unburned																											0
4	3-year			1	1				1		1					1		1		1				1			1	0.36
5	7-year						1					1							1									0.12
6	7-year	1											1					1							1			0.16
7	7-year				1										1						1							0.12
8a	3-year		1				1		1			1			1				1		1			1				0.32
8b	Unburned																											0
9	Unburned																											0
10	7-year					1							1					1									1	0.16

One of the shortcomings of this burn schedule is that it increases the total acreage burned per year. The current acreage burned per year at the SRPER is around 400 acres, and this burning schedule would increase that value to roughly 700 acres. This is a fairly large increase, and could impact the cost of the program. However, there are several options that could address a cost increase. One would be to use a smaller number of replicates. Although this would decrease the statistical power of any analysis of the data, it could make a prohibitively costly program much more feasible. Another option would be to subdivide burn units into smaller areas. We did not incorporate this action into our management design because we were trying to avoid the cost of creating firebreaks. However, the cost of creating firebreaks is a one-time cost and might be less than the cost of burning an increased acreage each year.

2.5 Monitoring Framework and Implementation

The successful adaptive management program needs to include a well-designed monitoring program to measure the effectiveness of achieving management plan's goals and objectives. This will be achieved by assessing the validity of each of the management plan hypotheses described in the management plan. Therefore, the results of monitoring aid in learning about the system by helping to detect changes in vegetation composition and the abundance of selected floral and faunal species. The management of the SRPER has begun a preparation of a monitoring plan by designing a survey and a sampling methodology. However, an adaptive monitoring plan needs to include additional steps that are outlined below. These steps are recommended by many authors, including Elzinga, et al (Elzinga et al. 1998) and Noon (Noon 2003). They are further discussed in Adaptive Management Primer in Appendix B.

Monitoring Indicators

It is essential to prioritize the species, populations, and communities to monitor, because the resources for monitoring activities are usually limited. Grassland system monitoring indicators must be selected based on such criteria as: rarity of a species, species' sensitivity to threats, and immediacy of these threats, uniqueness or quality of the habitat, vegetation composition, diversity, and density (Elzinga et al. 1998). Ecological indicators provide quantitative information on ecological structure and function of grassland. Direction and quantity of change must be determined (hypothesis). Time frame for monitoring each indicator must be specified. Indicators should reflect spatial and temporal changes in the grassland.

Since physical factors including climate and soils play important roles in determining the composition of grasslands, they can serve as abiotic ecological indicators that can show long-term trends of the site's condition. Soil and its components should be tested for changes in nitrogen. Since erosion is one of the concerns when applying prescribed burning, its process and rates should also be monitored.

Special attention needs to be paid to the chosen biotic ecological indicators: exotic plant species, native plant species and faunal species. The following are some examples of representative ecological indicators for the site:

- Exotic species: black mustard (*Brassica nigra*), wild oats (*Avena fatua*), tocalote (*Centaurea melitensis*), and red-stemmed filaree (*Erodium cicutarium*)
- Native species: purple needlegrass (*Nassella pulchra*), tarweed (*Hemizonia fasciculata*), California aster (*Lessingia filaginifolia*), thread-leaved brodiaea (*Brodiaea filifolia*), purple clarkia (*Clarkia purpurea*), bush lupine (*Lupinus bicolor*), and the chocolate lily (*Fritillaria biflora*)
- Faunal species: the San Diego pocket mouse (*Chaetodipus fallax*), burrowing owl (*Athene cunicularia*), and tarantula (*Aphonopelma eutylenum*), grasshopper sparrow (*Ammodramus savvanarum*), and Stephens' kangaroo rat (*Dipodomys stephensi*)
- Vernal pool species: fairy shrimp species (*Branchinecta lynchi*), and arroyo toad (*Bufo californicus*).

We believe that plant species for which we developed phenograms would be good indicators of change in the system since their responses to burning vary. Perhaps more faunal indicators, representative of the SRPER's faunal diversity, should be chosen that could be easily and effectively monitored (such as other rodents, snakes, lizards, and birds). Especially desirable would be to include indicators that reflect varying spatial and temporal changes in the system. For example, varying spatial changes (local, regional scales) can be well reflected by some bird species, and temporal changes can be observed by the quick responses of many invertebrates

(Haney and Power 1996). The current status of faunal species must be assessed before the beginning of the treatments at all the burn units and the control areas in order to set a baseline state. A good source of animal monitoring information and methods is "Monitoring plant and animal populations" by Elzinga et al. (Elzinga et al. 2001).

Monitoring objectives

The indicators must assist in measure of success or failure of prescribed fire treatments in achieving management goals and objectives for the SRPER.

- Measure the persistence of native plant and wildlife species of concern.
- Measure the improvement in quality and extent of degraded vegetation communities and other habitat types.
- Measure the quality of landscape processes and functions.
- Measure structural characteristics for selected species habitat
- Quantify effects of varying fire regimes on selected wildlife species.
- Identify appropriate spatial scales and patterns for the long-term management of fire.

Monitoring Scale

Scale of monitoring and appropriate methods must be determined in order to quantify the effects of management action of varying fire regimes on selected wildlife species. We recommend the monitoring at the following levels of organization:

- Species or population level— to assess effects on species-population trends. This would be done by using monitoring methods such as abundance and dominance indices and population estimates.
- Community or ecosystem level— to assess effects on species diversity and function of species in community or ecosystem. The monitoring methods can include species diversity indices and functional group and guild analysis

- Landscape level— to assess trends on landscape diversity. This can be achieved by using monitoring methods such as indices of landscape pattern, historic reference condition, and remote sensing and GIS.

Monitoring methodology

Timing and intensity of monitoring are essential to the success of the monitoring plan. Intensity of monitoring depends on cost of methods used in data collection. We recommend quantitative and qualitative monitoring with relatively average intensity that would be conducted once a year within all units. Spring monitoring works well for plants since they can be easily identified during their flowering periods. In addition, the visual observations of post-burn areas should be taken after burns. Quantitative and qualitative monitoring methods can be utilized by sampling and observation. Qualitative monitoring includes: presence/absence assessment, site condition assessment, population size, level of dominance, and population condition. Sampling is the main quantitative monitoring strategy. They must include target level of precision, certainty, acceptable false-change error rate, and magnitude of detectable changes. Specific sampling objectives need to be developed to make sure that the management objectives are reached. Below are the sample objectives based on the management objectives discussed in the previous section:

1. Be 90% certain of detecting a 10% increase in diversity of native grasses and forbs in highly invaded grassland areas with a false-change error of 0.10 by the year 2010.
2. Be 90% certain of detecting a 30% decrease in non-native plant cover in grassland areas with a false-change error of 0.10 by the year 2010.

Sampling methods

Currently, all sampling of grassland composition and structure is conducted along seventy-one 50m transects that are established in the grassland areas: 6-11 transects per fire unit, and four transects in two unburned areas. The point-intercept method, where vegetation is recorded every 1m along transects, is used to quantify the dominant species. In order to identify and estimate cover of rare or uncommon species, four 1m-by-1m plots are randomly placed along the same transects. In addition, to estimate species richness and diversity, all species in a 1m belt along transects are identified and recorded as well (Santa Rosa Plateau Ecological Reserve 2003).

Oak surveys are conducted twice annually: during the spring to measure seedling establishment and juvenile oak survival and growth; and during the fall to assess mature oak mortality and its cause, and to identify patterns of acorn production. The oaks are also surveyed following controlled burns to assess the extent of sustained damage to the trees and seedlings, if any (Santa Rosa Plateau Ecological Reserve 2003).

Most reptile and amphibian species that are monitored are surveyed six times a year for five consecutive days in order to determine community diversity and individual species abundance. This is accomplished using a pit-fall drift fence array design. Each array consists of seven 5-gallon buckets as pit fall traps, connected by shade cloth drift-fences. The captured animals are weighed, measured, marked, and released, and their location is recorded. Post fire monitoring is necessary to assess the mortality of the indicator species (Santa Rosa Plateau Ecological Reserve 2003).

Soil quality needs to be assessed. Nitrogen content in the soil needs to be measured before and after prescribed burn to assess the level of volatization. Some of the methods used for erosion monitoring include placement of erosion stakes and sediment traps, which can be placed on the treatment and control sites at various locations such as ridges, mid-slopes, and foot-slopes.

Implementation and communication of results

The crucial step in successful adaptive management framework is implementation of the management and monitoring plans. Any deviations from the original plans should be documented for the future reference to keep track of methods used. Strengths and weaknesses of the management and monitoring plans should be assessed, especially early in the implementation process. The pilot period of the monitoring plan should help assess the weaknesses and strengths of the management and monitoring objectives, and changes should be made if necessary. The monitoring data should be summarized and analyzed annually in order to detect changes and prevent a backup of data that needs to be analyzed.

Current data analysis of the grasslands monitoring data is to be used to quantify plant composition for each burn unit and to compare composition among units. Differences among units are to be compared based on fire frequency and time since the last burn. The relationship between fire frequency, time since burn, site and species richness and diversity is to be investigated by using analysis of variance (ANOVA). Data analysis of oak savanna monitoring data is to be used to assess the factors that influence oak survival. These factors (canopy position, fire damage, size at the time of previous survey, and site) as well as factors influencing shoot-death and resprouting ability are to be investigated by using logistic regression techniques. (Santa Rosa Plateau Ecological Reserve 2003).
Seasonal climatic conditions and their annual variability must be taken into consideration when analyzing the population trend data obtained from the qualitative and quantitative sampling efforts. Climatic data of parameters such as temperature and rainfall should be collected from the local weather station on a monthly basis.

All the compiled data should then be transformed into useful and meaningful information. Written summaries, or another type of communication of results, should be presented at least once a year to the SRPER management committee. It is also suggested that a comprehensive and formal report be produced every five years. This more comprehensive assessment of the progress of the project can be very helpful in evaluation of the management and monitoring objectives, as well as assessing monitoring and implementation resources. The project and conservation techniques should be refined as needed. Monitoring data needs to be conclusive—achieving management objective. If some negative consequences of management activities occur (i.e. reduction of population size of an indicator species), or the monitoring results indicate that some or all of the five proposed hypotheses are not correct (i.e. a unit of 3-5 years fire interval frequency did not significantly decrease the abundance of exotic plant species and increase the diversity of native plants, particularly forbs and grassland and oak savanna areas), then this is a signal for change. It is also important to realize the time scale involved in testing some hypotheses in a grassland-oak savanna system in Southern California may require decades to be able to detect some trends. The management approach may need to be adapted to complete the cycle of adaptive management. This process of learning and adaptation allows the managers design their activities in a way that can significantly contribute to the learning process.

2.6 Conclusion

The multitude of pressures exerted on grasslands at this time makes active management necessary to control to invasion of exotic species and maintain and increase populations of native species. Uncertainty regarding the response of grassland populations to different management treatments, however, makes it infeasible to define best management practices. Adaptive management is management with an experimental twist, and it is a technique that allows managers to begin management programs even in the face of this uncertainty. A management program is designed as an experiment, and through replication, monitoring, and data analysis, enough can be learned about the system that the management program can be adjusted to answer questions about the system as well as achieve the desired results.

Of course, if designing and implementing an adaptive management program were easy, all managers with questions about their community would do so. Unfortunately, designing an adaptive management program can be a costly process and implementing a program can be even more costly. Many managers do not have the resources they need to implement an effective adaptive management program, and the goal of this project was to address this problem. This paper is designed to streamline the process of creating an adaptive management program by providing many of the resources needed in one package. The case study also provides an example of how and adaptive management framework can be created for a site where there is currently some management already in place.

At the Santa Rosa Plateau Ecological Reserve, a burning program has been in place for about 20 years, and this program is not adaptive in nature. The case study demonstrates one way in which the current program could be modified so that it would provide the benefits of an adaptive management program without incurring extremely large additional costs, but there are many alternatives that could be considered, including the implementation of management techniques other than burning. For many sites in southern California, burning will not be feasible, but we have presented some other management options and conceptual models of grassland species that will allow managers to predict the utility of different management approaches for a particular area.

As more managers begin to practice adaptive management, there is the potential for large advances in grassland management. The idea we would like to communicate with this report is that whether the budget available for management is limitless or miniscule, some aspects of adaptive management can be introduced to the management program to maximize the learning that occurs over time. Uncertainty about the dynamics of grassland systems is one of the largest barriers to effective management, but by learning as much as possible from every management action, we can reduce that uncertainty significantly.

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Appendix A. Interviews

Interview participants

Name	Title(s) and organization(s)
Edith Allen	Editor, Restoration Ecology Professor and Natural Resources Extension Specialist Department of Botany and Plant Sciences and Center for Conservation Biology University of California, Riverside
Julie Ammel	Soil Conservationist, Natural Resources Conservation Service
John Anderson	Hedgerow Farms
Cameron Barrows	Coachella Valley Preserve Southern California Regional Director, Center for Natural Lands Management
W. James Barry	Senior State Park Ecologist, California Department of Parks and Recreation Certified Soil Scientist, SSSA Fellow, California Resources Agency-University of California
James Bartolome	Professor, Division of Ecosystem Sciences Department of Environmental Science, Policy, and Management University of California, Berkeley
Tina Carlsen	Environmental Scientist, Lawrence Livermore National Laboratory
Sandy DeSimone	Director of Research and Education, Starr Ranch Sanctuary
Margot Griswold	Restoration Ecologist and Principal EARTHWORKS Construction & Design
Jon E. Keeley	Research Scientist U.S. Geological Survey, Western Ecological Research Center, Sequoia National Park Adjunct Professor Department of Organism Biology, Ecology and Evolution,

	University of California, Los Angeles
Lenora Kirby	Executive Director, Las Virgenes Institute for Resource Management
Dawn Lawson	Senior Natural Resources Specialist, Southwest Division Naval Facilities Engineering Command
Megan Lulow	Plant Ecologist, Ph.D Candidate Graduate Group in Ecology, University of California Davis
Jaymee Marty	Project Ecologist, Cosumnes River Preserve, The Nature Conservancy
Rich Minnich	Fire Ecologist Associate Professor of Geography, Department of Earth Sciences, University of California, Riverside
Andrew Moyes	Santa Monica Mountains National Recreation Area Graduate student, California State University Los Angeles
Thomas Oberbauer	Chief, MSCP Division of the Department of Planning and Land Use, San Diego County
Elizabeth Painter	Plant Conservation Biologist California Biodiversity Director, Western Watersheds Project
Zachary Principe	Project Ecologist, Santa Rosa Plateau Ecological Reserve, The Nature Conservancy
Rich Reiner	Senior Ecologist, The Nature Conservancy
Hugh Safford	Regional Ecologist, USDA-Forest Service, Pacific Southwest Region Department of Environmental Science and Policy, University of California, Davis
Orrin Sage	Sage Associates
Paula Schiffman	Professor, Department of Biology, California State University, Northridge
Eric Seabloom	Postdoctoral Fellow, National Center for Ecological Analysis and Synthesis

Trish Smith	Senior Project Ecologist, Irvine Ranch Land Reserve Project, The Nature Conservancy
Wayne Spencer	Senior Conservation Biologist, Conservation Biology Institute
Fred Sproul	Botanical Consultant Trustee and Board Member, Wildlife Research Institute Elected Member, Ramona Community Planning Group
John Stechman	La Cuesta Consulting, Certified Rangelend Management Consultant Professor Emeritus, California Polytechnic University, San Luis Obispo
Mark Stromberg	Resident Reserve Director, University of California Hastings Reserve
Michael Stroud	Director of Operations, Center for Natural Lands Management
Robert Taylor	Biogeographer/ Fire GIS specialist Coast Mediterranean Network, National Park Service Santa Monica Mountains National Recreation Area
Mark Webb	Environmental Resource Manager, Open Space Division, Department of Parks and Recreation, San Diego County
Michael P. Williams	Director, UCSB Sedgwick Reserve
Robin Wills	Fire Ecologist, Pacific West Region, National Park Service
Truman Young	Professor and Restoration Ecologist, Department of Environmental Horticulture, University of California, Davis

Responses to selected interview questions

How would you define a grassland?

A grassland to me would have either annual or perennial grasses as the dominant life form. – Tina Carlsen

A vague term meaning an area with a vegetation type dominated by grasses (members of the family Poaceae)… In southern California, two important and distinct types of grasslands are "annual grasslands" and "perennial grasslands." These two types contain some variety, but overall represent such different ecosystem functions and management implications that it is worth differentiating between them. – Andrew Moyes

I think its basically a gradation where you're dealing with dominant species and so if the dominant plant component is grass and in terms of both in cover and biomass, then you're moving into what you would call a grassland. – Cameron Barrows

Grassland is a vegetation [type] dominated by non-woody plants. – James Bartolome

For me, a grassland is any habitat where the understory is dominated by grasses, and where overstory cover is minor. – Truman Young

I would say that grasslands are ecosystems where the predominant cover is Poaceae. Woody plants may be sparingly present (generally less than 5-10% cover). Other herbaceous plants are present but not dominant. – Elizabeth Painter

I think its actually kind of a misnomer…I mean certainly grasses are an important component of [grassland], but there's a lot of grassland habitat which can be quite heavily dominated by annual or perennial forb species. – Eric Seabloom

I would define it as an ecosystem that had a dominance of grasses in its cover and diversity, and so I would probably go with a pretty strict definition, probably more than 70 or 80 percent grasses and forbs (or herbaceous perennials and annuals), and a lack of shrubs or tall shrubs. Sub-shrubs can be included in that, but the boundaries would be a little bit fuzzy about what a grassland actually is. – Mike Williams

[I would define grassland] simply as a function of the dominance of graminoid plants. In the U.S. Forest Service and other land management agencies, we defined a grassland as a vegetation type with less than 10% trees, less than 10% shrubs, and grasses dominating the remaining vegetation. UNESCO (i.e. the rest of the world) defines it using 25% cutoffs, which are probably ecologically more defensible. – Hugh Safford

With annual grasslands, they can be dominated during one part of the year with annual grasses and annual forbs, or during another part of the year by perennial herbs. So it's kind of hard to look at the definition that fits all…I guess grasslands in general have been more or less defined as dominated, or as predominantly, graminoid species…And the other kind of definition, or side board I think I would probably put on it is less than 5% woody species cover. – James Barry

I would define a grassland as a habitat that does not include a significant shrub or tree component. – Jaymee Marty

Let me tell you how I use the term. Basically when I refer to grasslands they are herb-dominated systems. In some cases forbs may outweigh grasses in these associations. – Jon Keeley

I think what you've got to do is turn to the relicts; find the places that still have big plants of native grasses, and use them as your way of defining what a grassland is. They're the models. – Mark Stromberg

Well, a modern [grassland] is exotic annual grassland dominated by forbs from Europe mainly. Grasses and forbs, so it would include the mustards…. [Interviewer: And how would you define a native grassland?] Forbs. With perhaps some grass, but grasses are not important. – Rich Minnich

Grasslands in California are really any plant community type in which there is a significant component of cover occupied by grass, and there is an open canopy structure…any open canopy system that is dominated by herbaceous and grass assemblages. – Robin Wills

A site dominated by grasses. – Sandy DeSimone

There are probably more formal definitions, however to me the grassland ecosystem is defined by a mix of plants and animals adapted to frequent fires, seasonal drought, little shade, and intense herbivory. – Rich Reiner

What do you see as the key ecological drivers or factors that govern the dynamics of grasslands in southern California?

The biggest ecological change that we've seen in the 20^{th} century certainly, and the latter part of the 19^{th} century, is the cessation of fire. – Orrin Sage

…the main ecological drivers, fire and grazing, operate differently in invaded systems. Fires burn a lot hotter and faster than they ever burned historically because of the extra fine fuels added by the exotic annual grasses. The effects of grazing are also different because both the animal grazers and the palatability of the new plant species present are different. – Rich Reiner

…[extreme drought] just wipes [exotic grasses] out: they go through mass seed bank recruitment and mortality because it doesn't rain, so [at one site] we've gone very strongly toward forbs in the last few years, and away from the grasses. People always look at this like it's a one-way street, that the invaders are going on and taking over, and that's not really correct…It's shifting back and forth. In wet periods it goes invasive and in dry periods it goes back to the forbs. – Rich Minnich

…[perennial grasslands] are really an artifact of aboriginal burning, they aren't even an artifact of natural fire occurrence. They're sort of a manufactured human landscape, and they were obtained by active burning by Native Americans in a pursuit of things that supported their lives, food products and fiber sources. – Robin Wills

[Climatic variability] interferes with the work I do quite a bit, from one rainfall and seasonal pattern to the next I see differences in response to various experiments that I'm doing and I try to explain it based on climate without really knowing if that's the case. It can be a real pain in the neck – Tina Carlsen

…with the [human] population that we have, and with our preponderance to move farther and farther out into the brushland for housing sites and other projects, we're constantly changing and we're constantly moving the urban-wildland interface farther and farther into the back country. Therefore we're changing the fire regime and the fire patterns. – Mike Stroud

There is evidence that thatch buildup can be an important driver in grassland community dynamics. With respect to perennial grasses, their vegetation can become decadent and shade their growth meristems. Removal of old vegetation can expose the meristems and invigorate their growth. In terms of annual grasslands, thatch can improve germination by serving as a buffer layer against harsh environmental factors, such as frost. Because of these and perhaps other influences of thatch in grasslands, many of the effects that disturbances such as fire and grazing have on vegetation may be a result of how they impact thatch levels. – Megan Lulow

We no longer have the native or historic herbivores to the same concentration or populations that they were hundreds or thousands of years ago if you will. Then we went through a period where they were replaced by domestic livestock, and now even that is changing because of changes in economics and population levels. So there's probably going to be less and less herbivory on these [grassland] areas. – Mike Stroud

Describe what you consider in your experience to be the most important obstacles, constraints, or challenges southern California grassland managers face in meeting their management goals.

Politically, fire is an issue. A lot of these grasslands are fragments. They're surrounded by houses, and so if you feel that managing them with fire is the most effective way to do that, you're managing at a risk to all of those houses, because at some point in time, fire sometimes get away. And its unfortunate…if you don't do a prescribed fire or manage with fire, then you're left with the fires we had in southern California just a couple of months ago…So there's a real catch twenty-two here where people are afraid of fire, and they don't want fire, but if they don't have it then they're really going to hurt when these big fires happen. – Cameron Barrows

My experience has been that one important obstacle that managers often face in meeting management goals is inappropriate goals, particularly attempting to manage for 'grasslands' without knowing if that was that natural pre-settlement vegetation. This has both ecological and economic consequences. – Elizabeth Painter

Fire is a continual threat in southern California just because there are so many people so close to conservation and restoration lands. That's not so much a threat to the grasslands, but to the coastal sage scrub which in my opinion should not burn every 5-10 years. And we have to manage the whole site which usually includes both coastal sage scrub and perennial grasslands. – Margot Griswold

…the assumption on many people's part, and this goes both from the lay person to the scientist, is that these non-native grasslands have essentially replaced native grasslands, and that assumption,…(not in all cases, but in many cases) may not be true…That's not to say that grasslands don't occur in California, just that the concept of the golden hills of California may be an artifact of more recent disturbance than of reality…But there has always been a native grassland component, or a native grass component (floristic component) to shrublands, and so sometimes during a particular type of management regime, whether its fire or grazing, you can get rid of the shrubs and retain the grassland component of it, so you get these stands of native grasses. And so you say "OK, there's an example of what used to be here", and that may or may not be the case….The concept of replacing a bunch of non-native grasslands with native grasslands may have a value, but its not necessarily restoring it back to its natural condition. – Cameron Barrows

…the exotic grasses are tough, pre-adapted invaders well suited to exploiting human disturbances to gain and hold ground. They took off as soon as they arrived on this landscape. Recent research shows more clearly that there have been serial…waves of invasion. They have various adaptations that help them conquer and hold. – Robert Taylor

If a new weed is introduced, or you have a plant that's been there a long time with relatively low abundance, but it gets the right climatic conditions for the population to explode, you could have a huge problem. You need to have programs in place to detect new species and significant population changes, and you need the money right then and there to go after them. If you don't you could have a significant adverse change that is infeasible to reverse. – Dawn Lawson

My guess is that the biggest obstacle is small patch size, small reserve size, and development, and so it's hard to apply big…broad-based management tools, because the patches of ground are so small. – Dawn Lawson

Where lands were perhaps grazed for a number of years, that situation is changing, perhaps from economics. For example, it may no longer be economical to maintain a sheep herd in a particular area, so that use or that tool is no longer available to us. We're bringing in more horses, and people don't tend to give them enough space or enough room for their pastures, so they tend to graze heavier than other animals. – Mike Stroud

We have native grasslands that are in small patches - they're not large grasslands…they're often interspersed with other habitat types like coastal sage scrub, and oak woodland…Grassland can take fire more frequently than the other habitats can. Therefore fire (although it would be a great tool when you're dealing with native grasslands), when you're dealing with a patch mosaic, is not a viable tool. When you're dealing with relatively small patch grasslands that are interdigitated with other habitat types…how do you manage those small pocket native grasslands in the long term, to make sure they persist? – Trish Smith

What do you see as the largest or most critical uncertainties that exist about grasslands and their management in southern California?

Where are the native grasslands? Where are they supposed to be?…Those are important questions that I don't think are being addressed very well. – Cameron Barrows

The two biggest uncertainties are getting rid of the weeds (I would call that the greatest limiting factor), and the debate about the nature of the "original" vegetation. – Truman Young

[One critical uncertainty is] whether grasslands were the predominant pre-settlement plant communities at sites now covered by 'feral grasslands' (those modern grasslands that are dominated by non-native weedy grasses). – Elizabeth Painter

The hardest part for me is not finding new weeds every year, its which ones do I target to deal with, and which ones do I think are not going to be a threat. I'm making educated guesses, but I'm definitely guessing. – Zachary Principe

A better understanding of how different management tools may be used to both promote native species and control invasive species is needed. For example, prescribed fire applied just prior to seed maturation can be an effective tool in controlling annual grass weeds. However, this is also the time that many native grasses are in flower. A hot fire due to high thatch levels combined with a stressful climate year may set the native species back. In a favorable year for natives, they may be able to readily bounce back. Further research on how and when management tools may alternatively favor different plant groups is needed, particularly in diverse communities. – Megan Lulow

In your experience, what are some universal recommendations, truths, or rules of thumb you can tell us about management of grassland?

I think the first thing, and I can't stress this enough, is to do your homework in advance to determine whether the site really needs to be, or should be, a native grassland, or whether it naturally should be a shrubland of some kind or an oak woodland or something else. I think there's sort of a knee-jerk reaction to replace non-native grasses with native grasses and that just may not always be the right thing to do. – Cameron Barrows

I think you need a good resource management plan - that's key - where you have some good baseline information, and you have good information on all of your sensitive species (plants, animals, insects), wetlands habitats, and other key habitats. Normally you don't have just one type, but you have several types intermixed, so you need to know what they are and how they relate to one another. – Mike Stroud

I would say if there are any universals, its uncertainty about where we're headed, but far more important, universal understanding that the main barrier to getting there is probably weeds, much more than whether or not fire is good or bad, or cattle are good or bad (except as weed control agents), or even what the final state needs to be.– Truman Young

Do the homework. Find as many and as early records as possible for the site ("early" photographs were often taken 100 years after settlement). Find out what types of disturbances the site has undergone since settlement. Find out if there have been Holocene paleo-botanical and/or paleo-ecological studies done for the general area. – Elizabeth Painter

Don't rule out any management tool. In other words, there might be instances where you can use grazing, there might be instances where you might have to pay someone (like a goat herder or someone like that) to come in and control a target species. Herbicides are a tool, prescribed burning is a tool, integrated pest management is a tool (where perhaps you're using one introduced species to control another). – Mike Stroud

Get rid of as many of the non-native plants and animals as possible. – Elizabeth Painter

We should go very slowly with soil disturbance…very slowly and very carefully with *anything* that we do, especially soil disturbance or chemical applications. Sometimes weed abatement is throwing out the baby with the bathwater. There are a lot of herbs in grasslands we'd be eliminating if we do a blanket treatment of any kind. Therefore I'd really caution anybody about doing any massive anything. Chemicals, soils disturbance…the rule of thumb is let's evaluate all factors of the biota, and start small. – Fred Sproul

I would say that you don't want to just leave it alone. That grasslands probably evolved with some kind of usage, whether it was herd usage or human usage. If you leave it totally alone it's going to senesce to the point where you don't have any of the values you were protecting it for in the first place. – Tina Carlsen

Both grazing and fire can have beneficial effects in reducing exotic species and their cover, but environmental circumstances and timing and intensity of disturbance play huge roles in determining the outcomes. – Hugh Safford

Grasslands are humble compared to forests. They don't particularly inspire most people emotionally in the way that big trees do, so most of the public doesn't have a lot of reverence for them. We didn't get a grassland national park until pretty recently (Tallgrass Prairie National Preserve)…The difference between grass species is lost on most people, so teaching folks to appreciate a native grassland takes some work. So we should not expect to have any big bucks for grassland restoration any time soon in this country. – Robert Taylor

Some native grasses (like Nasella pulchra) propagate very well from seed if they have any kind of break from weed competition and if they get anything like a normal precipitation year…Amazingly fecund plants, if given half a chance. – Robert Taylor

I studied range management in Texas…where we were focused more on perennial mid grass and tall grass prairie ecosystems. In those systems there seems to be better-defined management guidelines available. California annual grasslands seem to be a different beast. They really are. – Rich Reiner

The best chance for the use of fire and grazing to restore native cover and species is in systems where the seed pool is dominated by natives, or where native perennials are already present in the system in some numbers. – Hugh Safford

The tighter the cattle are for a period of time, the more trampling effects you have, and the more damage you have on a local level. And that's true about the way you do corrals, the way you do watering areas, anything where you have cattle for any concentrated period of time, you have tremendous trampling effects. – Mike Williams

In the annual grassland, deep, fertile soils on highly insolated slopes are hopelessly overrun with exotics (in other words, the seed pools are nearly entirely exotic) and it will take an enormous investment of time, resources and active replanting to even begin to restore such sites (in other words, not worth the effort). – Hugh Safford

I think the biggest rule of thumb that I can say is that restoring natural fire cycles would be the most important. Certainly it would be nice to restore some of the native grazers also, but we haven't been able to do that in many places. – James Barry

The rule of thumb that I see for California grasslands in general is if a site is grazed by cattle or sheep currently, and the system, particularly vernal pool grasslands, has high diversity and no obvious negative impacts from that grazing, then you should leave the grazing in place. – Jaymee Marty

Find out about biological soils crusts. – Elizabeth Painter

I think a rule of thumb [relates to] the providence of seeds that are used… The timing of blooming and seed set and a lot of other things are what local genotypes really have evolved with. Even if it's the same genus and species, it's the genetic timing of things [that can differ]. – Fred Sproul

If you have a site that has been managed a certain way for a number of years, before making a wholesale change in management, you should do really extensive monitoring of the site prior to making the change and after making the change, or set it up so that you have a control so you can determine what effect your management change is having on the system. – Jaymee Marty

What weed you're going to have to manage and what germinates first, and what plant gets the jump on the others, is really up to a particular year, and what kind of site you have…I know some people hate the term adaptive management, but you have to have a few tools in the toolbox to use, depending on the year. Some years I thought I'd do one thing and ended up doing other things, and you have to be able to make those decisions. I don't think you can lock yourself into a plan. – Margot Griswold

I think that personally from the work that is coming out, or will eventually come out, that early burning is the key to success. Very early - as soon as it cures. In other words, you're burning in late spring. You'll get the best results in knocking down the invasives and proliferating the natives. The later, the worse it gets. – Rich Minnich

I think what's really critical is that as early as possible you begin to think about management at the appropriate scale (whatever that is), and that there's no specific acreage target, and that you begin to think about your site as a whole. Because early on what happens is people become very focused on tiny portions of the landscape and they maybe define one or two burn units and they become very focused in what is happening in those one or to burn units. Ecosystems are open, and they're spatial and nonlinear in their nature, so what happens in one place is very strongly effected by what's happening right next door. So, early on, as much as you can, think about the landscape at the biggest scale and the most complex level that you can, the interaction of vegetation, the mosaic of vegetation types, and how your management in time and space will somehow begin to make sense. It's a hard thing to do, particularly when you have significant knowledge gaps, which we do everywhere, but I really encourage people to begin to make statements about and plans for management of the biggest space that you can, and over the longest time period that you can, so that your management really begins to make sense at an ecosystem scale, if that is possible. – Robin Wills

Just in terms of restoring your grassland, in terms of management, you just have to be really patient; you can't do these things overnight. – Margot Griswold

…Look as locally as you can at the literature for guidelines, and, in the absence of local resources, start doing your own basic research on best management techniques and goals for restoration standards…There is no silver bullet to remove exotics. – Sandy DeSimone

What tools do you think are most needed and would be most useful to grassland managers for reaching their goals?

A small range drill. Most of the range drills are fairly big and they're expensive too. But a smaller range drill might be handy, where you could do very small strips (like a meter wide strip). But to be an effective drill means to be strong enough to go through rocky terrain. – Mike Williams

A fire tool where you can actually burn to an edge and stop and turn it off. Maybe a torch-hose combination, or something like that. Controlled burning is still a big part of the unknown here. – Mike Williams

A seed collection system for perennial patches [would be useful] because there are patches of perennials about as big as a table, and if you could have a low cost seed collection system to go through that and collect/harvest the seeds and turn around and plant next to that, or plant 100 feet away, that would be great. – Mike Williams

Smokeless fire. – Mark Stromberg

A tool that would be really cool would be to cheaply mow the grasslands without tearing them up too much. The idea is to get some more light to the base of the existing perennial grass plants…opening the system up and not losing the nutrients. – Mark Stromberg

Its kind of a pipe dream, but trying to reduce pollution has, of course, benefits to people in general, but in the long term if we could all go towards… something that really eliminated pollution to a large extent, we would be able to much more easily manage these sites for…native grasslands or shrublands or oak woodlands…We could do it much more effectively if it wasn't for this annual dumping of nitrogen onto these soils. – Cameron Barrows

If there's some cheap, effective way to establish seed sources for a lot of these areas that are so far from native seed sources that they're never going to have natives again. We need both commercial seed sources, where people are producing them in an economically approachable price range, but also techniques of getting them out there in the landscape. So it may mean things like developing seed drills that could criss-cross big open fields or open spaces, so we get…narrow strips of seed areas that would act as seed areas for the areas around them. Both a commercial seed source, and a cost effective way to get them back out and started on the landscape. – Mark Stromberg

One comment I've heard from a number of experts is the need to understand what was at a site, what has happened to a site, and what the consequences are. Since we can't have time machines, we need a store of as much early historical, Native American ethnobotany, and paleo-botanical/-ecological information as possible. A readily accessible bibliography would be a starting point. – Elizabeth Painter

I think we need a broad regional study of current grasslands and what the former distribution of native grasslands looked like. Several reports suggest they were patchy and highly fragmented and did not match closely the distribution of grasslands today. This sort of research would be very helpful to recognizing where restoration is appropriate and management options for those native relicts still present on the landscape. – Jon Keeley

I heard someone recently express concern over the effects of too frequent fire on vertebrates, like lizards…fire at the frequency that may benefit perennials may decimate vertebrate populations…What are the effects of frequent fire on things other than perennial grasses? Maybe that's something that having more information on would be valuable for managers so that you don't perpetrate unanticipated consequences. – Dawn Lawson

How to maintain a trend balanced toward native species cover versus exotics [is] the biggest question out there. – Trish Smith

I've spent a lot of time on research of mycorrhizal fungi because I think they are key, and since I think the soil and soil ecosystem are so important, I wish we had more data on the relationship between native grasslands and soil. – Margot Griswold

Definitely for just pure management, keeping the toolbox open [is important], not saying we can't use fire and not saying we can't use grazing. Basically being adaptive, not limiting, because I think people are going to be managing grasslands a lot more intensely as we go. So we'll learn a lot more in the future. – Zachary Principe

I think that probably the most valuable tool for a manager is to have good monitoring skills, and for adaptive management I think the thing that is missing most often is people's understanding of how to set up a good monitoring program, which will give you the data that tells you when to make management changes or what direction to move. – Jaymee Marty

Appendix B: A Primer on Adaptive Ecosystem Management

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The need for active ecosystem management

As more organizations pursue conservation and/or restoration of species and ecosystems, strict protection (such as through the establishment of reserves and the discontinuance of certain land or marine uses) may be sufficient for recovery, however, for other species strict protection may not be enough (Haney and Boyce 1997). Active management (such as mimicking an historic disturbance regime or a multitude of other activities) may be necessary in many cases because some species are dependent upon natural processes that have been disrupted, or are otherwise in need of active intervention on their behalf.

Ecosystem management is not necessarily easy, however. Haney and Boyce (1997) point out that ecosystem management must balance considerations of science, politics, economics, and aesthetics. This intertwining of so many complex worlds presents considerable challenges for those who wish to conserve and maintain biodiversity. Few disagree with the idea that ecosystem management is an important activity for meeting conservation goals. However, the complexity and the uncertainty surrounding this intricate interaction of human and natural realms can be disabling. This has sometimes resulted in simply no action being taken on behalf of species and ecosystems that would benefit from active intervention.

In *Adaptive Management for Renewable Resources (1986)*, Carl Walters sums up the ease with which people may avoid choosing active management as a strategy when he writes, "I have stressed that effective resource analysis takes more than good biology or good economics or good mathematical modeling. Management is done by and for people; even the best ideas will be cast aside in favor of easy courses of action like pretending certainty or waiting for problems to take care of themselves. It is just too easy for people to hide behind platitudes like the need for caution, or the importance of detailed understanding before action, or the need to apply methods or models that have stood the test of time (usually without any real test, of course)." The rationalization of inaction is somewhat understandable given the inherent complexities and levels of uncertainties that commonly exist about ecological systems. Nevertheless, it must be remembered that, "just as ecosystem protection and restoration form the core of ecosystem management, management is essential to ecosystem protection and restoration" (Noss and Scott 1997). Noss and Cooperridor (1994) point out that "all land-use decisions – including a decision to designate a reserve, put a fence around it, and leave it alone – are land management decisions with significant consequences for biodiversity. It is much better to manage biodiversity by design rather than by default." If conservation and recovery of species and ecological systems are our overall goals, it has become clear that we must take action to reach those goals. This "management by design" can be achieved through using a planning process for doing ecological management.

Table B.1. Modes of learning. Modified from Kai N. Lee's "Appraising Adaptive Management" (2001).

Each mode of learning…	**Makes observations...**	**And combines them…**	**To inform activities…**	**That accumulate into usable knowledge.**
Laboratory experimentation	Controlled observations to infer cause	Replicated to assure reliable knowledge	Enabling prediction, design, control	**Theory** (it works, but range of applicability may be narrow)
Adaptive management (quasi-experiments in the field)	Systematic monitoring to detect surprise	Integrated assessment to build system knowledge	Informing model building to structure debate	**Strong inference** (but learning may not produce timely prediction or control)
Trial and error	Problem-oriented observation	Extended to analogous instances	To solve or mitigate particular problems	**Empirical knowledge** (it works but may be inconsistent or surprising)
Unmonitored experience	Casual observation	Applied anecdotally	To identify plausible solutions to intractable problems	**Models of reality** (test is political, not practical, feasibility)

One of the general goals of ecosystem management can be described as active management coupled with learning (in order to reduce uncertainty). There are numerous methods by which one can approach management with learning as a major overriding goal. Four of the most common methods are described in Table B.1 above. Lab experimentation, trial and error, and unmonitored experience have historically played a large role in ecology or in ecological management. Adaptive management, on the other hand, although conceived in the late 1970's, has seen limited application compared to the other modes of learning.

Anderson (2001) described the contrast between traditional and modern approaches to ecosystem management in the following way. The more traditional view of ecosystems can be characterized as static: ideas such as steady states, equilibrium states, and climax communities were dominant. More recently, factors such as history, key dynamics, complexity, unpredictability, openness, and variation (temporal and spatial) have received attention. This contrasting view presents ecosystems as more complicated and unpredictable and highlights our limited understanding.

Definition of adaptive management

The term "adaptive management" has been used in so many ways that its meaning may no longer be clear. For example, Lee (2001) points out: "The Forest Service definition of adaptive management does not emphasize experimentation but rather rational planning coupled with trial-and-error learning. Here 'adaptive' management has become a buzzword, a fashionable label that means less than it seems to promise." This has sometimes resulted in a general disenchantment with, and avoidance of the use of, the term adaptive management.

For our purposes, we will use the definition provided by Elzinga, et al (2001), that adaptive management is "a process in which management activities are implemented in spite of uncertainty about their effects, the effects of management are measured and evaluated, and the results are applied to future decisions." Adaptive management has been called "learning by doing"; it recognizes that usually our understanding of the ecological functioning of an ecosystem or other level ecological unit can be quite incomplete, but promotes action (that is essentially experimental by design) rather than being paralyzed into inaction by uncertainty (Elzinga et al. 2001).

The U. S. Forest Service's People's Glossary of Ecosystem Management Terms offers a somewhat different definition of adaptive management: "A type of natural resource management that implies making decisions as part of an on-going process. Monitoring the results of actions will provide a flow of information that may indicate the need to change a course of action. Scientific findings and the needs of society may also indicate the need to adapt resource management to new information." (USFS 2004a). This definition highlights the stress on adjustment in response to new information, a central tenet of adaptive management. Haney and Power (1996) describe adaptive management as, "a heuristic process coupling science and social values to promote the sustainable management of natural systems." Both of these definitions refer to the role that society plays in designing ecological management.

Another way to view adaptive management is as simply a formalization of conventional ecological management, but with a few added dimensions. Franklin (1997) posits, "…ecosystem management incorporates the philosophy, if not the formality, of adaptive management..." These added dimensions include testing assumptions and adaptation (discussed further later on). He goes on to explain that, "Ecosystem management recognizes that *all* management prescriptions are, effectively, working hypotheses, with substantial levels of uncertainty regarding the outcomes. Recognizing this, ecosystem managers design their activities so as to contribute to the learning process – managing to learn and learning from management. This may involve a highly formalized process…or less formal approaches. In all cases, a scheme that provides for the systematic collection of information and its feedback into the decision-making process is required." If adaptive management shares these characteristics, such as underlying philosophy and testing of hypotheses, with conventional ecosystem management, then formal adaptive management could be a natural progression of it.

Margoluis and Salafsky (1999) have characterized adaptive management as including three basic components, "Testing assumptions – which is about systematically trying different interventions to achieve a desired outcome; adaptation – which is about systematically using the information obtained through monitoring to take action to improve interventions; and learning – which is about systematically analyzing and documenting process and results, and integrating lessons into institution-level decision-making and sharing with broader communities." Some additional characteristics of a formal adaptive management approach are described by Elzinga et al. (2001) when they highlight three goals of adaptive management, which are to: 1) manage currently to the best of our knowledge; 2) learn from management, and; 3) improve management in the future. These authors collectively highlight active management, learning, adaptation, and improvement of management effectiveness as the essential components of a formal adaptive management approach to ecological management.

Gary E. Davis and William L. Halvorson sum up the call for an active and an adaptive management approach to ecosystem management when they describe the evolution of natural resources management ideology in the National Park System. They assert, "Management of natural resources in national parks has struggled to evolve from belief-based advocacy to knowledge-based consensus in the late twentieth century. This evolution paralleled a shift from the view of the park ecosystems as static, isolated, independent landscapes to the scientific understanding that parks are dynamic, integrated with larger landscapes, and affected by human activities far and near. This understanding brought a recognition that parks require active, iterative, experimental, and adaptive management…" (Davis and Halvorson 1996). Another call for an adaptive management style approach to ecosystem management is offered by Everett et al. (1994) when they state, "An approach to public land management is needed that recognizes that although social and biological uncertainties exist, land managers can advance more sustainable ecosystems. A management approach designed for constantly changing systems is appropriate to ecosystem management…" Although both of these authors are speaking of public lands management, the same arguments could logically be made about the management of private lands as well. Finally, Meffe et al. (2002) also call for this approach when they suggest, "The ubiquitous presence of complexity, uncertainty, and surprise in nature encourages us to take an adaptive management approach." A recurring theme in these discussions of adaptive management is the approach's utility at addressing uncertainty.

There are a number of types and sources of uncertainty in the study of natural systems. These include variability in the biological/ecological system itself, variation in sociopolitical and other social systems, estimation errors, bias in models and measurements, and even uncertainty that stems from crafting ambiguous goals, hypotheses, or questions (Everett et al. 1994). Adaptive management not only provides a method for decreasing uncertainty, it also allows the manager to react adaptively to changing circumstances, such as changing biological, physical, chemical, environmental, and socioeconomic conditions within or affecting a system (Everett et al. 1994). Goals, objectives and management actions can be redefined or updated in response to any of these changing conditions, as well as new information and knowledge gained from learning. Furthermore, it has been pointed out that the speed of learning, and therefore the elimination of uncertainties, under adaptive management are often faster compared to traditional management. Walters (1986) states, “The fact that adaptive learning through management ‘experiments’ may proceed much more quickly than through conservative management and basic research has been noticed by some practicing managers for many years…”

The switch to adaptive management may be a difficult change for managers to make. Walters (1986) describes this difficulty when he writes, “It is a sad but understandable fact that most scientists base their research programs not on broad analyses of uncertainties, but instead on the investigative tools…and analytical methods that they learned in university or find popular among colleagues. This means that some ecological/economic research paths are deeply trodden, while other remain untouched.” Possessing a willingness to break away from established habits if it becomes necessary, and being open to new management approaches, are necessities of adaptive management, although it may be difficult initially in an organization with deeply entrenched ideologies and methods, resistant to change.

Types of adaptive management

Three general adaptive management approaches- deferred, passive and active - were described by Walters (1986), and were summarized by Everett et al. (1994). These approaches differ in the rate of learning they offer, the resources required to carry them out, and the degree with which one is accountable to their management goals.

Under *deferred* adaptive management, “no action is taken until systems are sufficiently understood to predict outcomes with fairly high certainty.” Deferred adaptive management offers the slowest rate of learning and the least accountability to one’s management goals, but requires the fewest resources because it is the least active. Because we wish to stress the more active forms of management here, we will not discuss deferred adaptive management further.

Passive adaptive management is “a process of observation and adjustment according to an assumed correct management trajectory. The management model is not viewed as experimental, but as correct until proven otherwise.” Passive adaptive management could be thought of as “cautious adaptive management”, or “adaptive management light.” The best alternative is chosen based on current understanding and it is implemented with the effects monitored and the approach re-evaluated and adjusted, if deemed necessary.

Passive adaptive management offers an intermediate rate of learning, requires more resources to implement compared to deferred adaptive management, is less scientifically rigorous than active adaptive management, usually tests one management technique at a time, and is associated with an intermediate accountability to management goals. Meffe et al. (2002) define passive adaptive management as, “A form of adaptive management in which many of the requirements of a scientific experiment are not met, but the overall process is still approached with learning as a major objective.” One of the major drawbacks of this approach is its lack of statistical rigor that stems from its lack of replication, control, and randomization (NRC 2003).

As a result, it is not a method that can assist the manager elucidate cause and effect or distinguish the effects of management activity, other human forces, or natural processes clearly (NRC 2003).

Even though passive adaptive management has been characterized as lower in cost and less risky than active adaptive management, this may not always be the case. It may be true that, because there are fewer experimental treatments and therefore less monitoring required with passive adaptive management, the approach can nevertheless end up being more costly over time. This is because the same amount of learning would theoretically take longer using passive rather than active adaptive management (Blann 2000). Passive adaptive management has also been characterized as less risky because you are experimenting with fewer of the natural resources under management. However, risk with this form of adaptive management can actually be greater if you choose the wrong single "best alternative" (Blann 2000).

Active adaptive management tends to require the most resources for implementation but offers the fastest rate of learning and the most accountability to one's management goals. Everett et al. (1994) describe active adaptive management succinctly when they write, "Active adaptive management views each goal and management action as an experiment. This process tests hypotheses to maximize short-term information gains…and long-term definition of goals. Alternative pathways can be evaluated for a single management emphasis, and multiple hypotheses can be tested simultaneously." (Walters 1986; Everett et al. 1994). This definition highlights the scientific robustness of the active adaptive management approach. In active adaptive management, one tests multiple management techniques at the same time in different areas (allowing the manager to distinguish between competing hypotheses), and the management design can include replication and control. Meffe et al. (2002) define active adaptive management as, "The form of adaptive management that is most like a scientific experiment, with random assignment of treatments and a full range of experimental treatments and controls." Furthermore, the formalized approach of active adaptive management "…forces participants to state their assumptions and understanding of ecosystem structures, processes, and interactions." (Walters 1986; Everett et al. 1994). Given the multiple benefits of this approach, but also considering the resources this approach can require, deciding whether or not to use an active adaptive management approach can be difficult.

In *Adaptive Management of Renewable Resources* (1986), Carl Walters provides a list of 4 conditions that he claims must be met in order to justify an actively adaptive management approach, over a passively adaptive one. These are:

1) There must be uncertainty about the best action to take.
~~1)~~2) System performance must be sensitive to the action taken.
~~1)~~3) Alternative actions must be differentially informative.
~~1)~~4) No single one of the alternative models for system response must be considered very probable.

In this text, Walters mainly discusses the application of adaptive management to the management of fisheries, and when he speaks of models, he mainly discusses mathematical models. Walters' list is nonetheless applicable to the question of passive versus active adaptive management of grasslands systems in southern California.

In condition number one above, the question of uncertainty is basic – if there existed a sufficient level of *certainty* about the dynamics and responses of the systems to management action, then a learning approach would not be necessary and traditional management would be sufficient. For condition number two, if the different experimental actions that are to be taken do not result in an observable change in the system (meaning the system is insensitive to the action) then nothing can be learned, and resources will have been wasted. A critical question here is what level of sensitivity should count as important: what magnitude and type of a response will count? For the third condition, the manager must apply different actions that will potentially yield a variety of information about the system. Applying two treatments that will answer the same basic question is redundant.

The fourth condition is similar to the first: if there is sufficient certainty as to how the system functions and what the best management interventions are, then there is no need to apply a rigorous active adaptive management program. In addition, however, it also forces the following question: even if there is some uncertainty about the system functioning, is it *enough* to justify an active adaptive management approach? Is there one model of system dynamics that we already have sufficient confidence in as the "correct" one, so that we feel comfortable with not using an active adaptive management approach? This last question may be difficult to answer because there are usually numerous factors to consider, and the level of certainty required to decide you don't need an active adaptive management approach may be unclear. This decision can be thought of as a cost-benefit type of consideration, where the costs are the resources spent on formulating and implementing the active adaptive management approach, and the benefit is the amount of information and knowledge you anticipate to gain about the system, which should in turn translate into more effective management and improved ecosystem function (or the meeting of other management goals). The crux of this tradeoff is how much certainty and information you now have, and how much you need or want to have in order to effectively manage the system to meet your goals.

The active adaptive management approach is, many would argue, the best course of action to pursue in order to learn about a system while actively managing it. However, for many reasons, it may simply not be a feasible approach for some land management entities. There may be inadequate resources, non-replicable management units, lack of true controls, lack of technical expertise, and/or legal and institutional barriers to active experimentation. In these cases one of the other forms of adaptive management may be desirable. We do not intend to either promote or denounce either passive or active adaptive management here. Both have applications in different settings and under different circumstances.

Resources and conditions that promote successful adaptive management

Certain circumstances tend to promote the successful implementation of an adaptive management plan. If many of these favorable ecological, socioeconomic, and institutional conditions are absent in the situation under consideration, then a different type of ecosystem management approach should perhaps be considered. These conditions can generally be characterized as conditions that favor or promote learning and change, and are listed in Box B.1 (below).

Even if not all of these conditions for successful adaptive management are met at the current time or are foreseen to be met in the future for a project, simply being aware of the conditions that are not met, while continuing to pursue an adaptive management approach anyway, can be helpful. You can be more cognizant of and vigilant about potential problems that arise from those conditions not being met.

Because adaptive management can be resource-intensive, planning for the resource requirements of a project is a very important activity. For this reason The Nature Conservancy stipulates a project resources assessment early in the planning stages of a project (TNC 2003a). They have identified seven measures of project resources, which are listed in Box B.2. Each of these measures can be rated on a scale of one (poor) to four (very good), and then averaged to get an overall assessment of the resources.

Box B.1. Conditions that promote successful adaptive management, taken from Meffe et al. (2002).

Ecological conditions

- Large differences in response between treatments and reference areas are likely.
- Data collection is relatively easy and inexpensive.
- Results will develop relatively quickly and clearly.

Socioeconomic conditions

- Stakeholders agree on the desired outcomes of management, but disagree on the means to achieve them.
- Stakeholders are interested in and committed to the process.
- Most stakeholders agree on the facts and underlying models of performance.
- Nonscientific knowledge, from many sources, is included in the modeling and design.
- Sociological and economic knowledge, conditions, and concerns are included in the design.
- Communication is continuous.

Institutional conditions

- The sponsoring organization is committed to learning.
- Eventual management decisions will be linked to the outcomes of the adaptive management experiment.
- Funding and leadership are stable, so later implementation is likely.

These measures are useful in that they include both financial and also personnel, stakeholder, and legal resources that, if planned for and identified early-on, can help promote more successful management. Specifically regarding planning for the financial requirements of adaptive management, it can be important to get as specific as possible about expected costs. It would be a disaster if, in the middle of carrying out an adaptive management approach, you were to realize that it could not be continued because of insufficient funding.

One tool that can assist the land manager, land trust, or other sort of organization, in estimating the costs associated with managing a property is the Property Analysis Record (PAR) software developed by The Center for Natural Lands Management (CNLM), a non-profit land trust with properties throughout California. The PAR software can be utilized throughout the adaptive management planning process for planning, record-keeping, and forecasting long or short-term management and monitoring costs. Visit www.cnlm.org for more information.

Box B.2. The Nature Conservancy's seven measures of project resources (TNC 2003a).

People:	1. Staff leadership (presence of experienced staff member with clear responsibility).
	2. Multidisciplinary team (project receives support from an experienced multidisciplinary team).
Internal Resources:	3. Lead institution (institution(s) with clear leadership and successful collaboration).
	4. Funding (sufficient "operations" and "program" funding to implement and sustain strategies).
External Resources:	5. Collaboration with external partners (involvement of suitable external partners in planning and implementation).
	6. Social and Legal Framework (existence and enforcement of a combination of legal and policy instruments).
	7. Community and constituency support (project favorably received and supported).

Steps in creating an adaptive management plan and doing adaptive management

An adaptive management plan can be seen as having two main parts: the management plan (which includes goals, objectives, and actions) and the monitoring plan (which includes specifics on the monitoring protocol, analysis of monitoring data, and feedback mechanisms to close the adaptive management cycle). In adaptive management, monitoring and management are equally important (Elzinga et al. 2001), and both must be included and planned for in any good adaptive management plan.

Each adaptive management plan will be different, but 4 critical elements have been identified in the National Research Council's "Adaptive Monitoring and Assessment from the Comprehensive Everglades Restoration Plan" (NRC 2003). These are:

- Clear restoration goals and targets
- A sound baseline description and conceptualization of the system
- An effective process for learning from management actions
- Explicit feedback mechanisms for refining and improving management based on the learning process.

These main elements are described and incorporated in the remainder of these adaptive management guidelines.

Haney and Boyce (1997) stress the importance of doing adaptive management formally rather than simply claiming to have adopted the "learning by doing" strategy. It is easy to say that one is managing a system adaptively, but it is essential that the components of adaptive management exist in the approach. Otherwise, saying that one is learning by doing may simply serve as a cover for business as usual. The essential elements of modeling, active management, and monitoring are the keys for adaptive management to learn most effectively from the management actions (Haney and Boyce 1997). These authors also summarize the 4 main parts of adaptive management, previously set forth by Walters and Holling (1990), as: the formulation of a model for the system, manipulation of the system through active management, monitoring to document the response of the system to management, and finally, a reassessment of model predictions and revision of the model before starting the process again.

Similar to the different "key" or "critical" elements highlighted by these various authors, different adaptive management practitioners and authors highlight different *specific* steps for making an adaptive management plan and carrying it out. In general, however, these steps are similar. One list of the steps and sub-steps is given Box B.3.

Box B.3. A suggested list of steps and sub-steps required to create and carry out an adaptive management plan. Modified from Salafsky and Margoluis (2001).

1. Define the project.
    a. Clarify the mission of the group
    ~~a.~~b. Find common ground with project partners
2. Model the site to establish a baseline and understand threats.
    a. Review and compile existing information about the project site.
    ~~a.~~b. Develop an initial conceptual model of the project site.
    ~~a.~~c. Assess local site conditions to refine and improve the model
    ~~a.~~d. Identify and rank threats at the project site
3. Formulate a management, or work, plan.
    a. Develop goals for the project.
    b. Formulate specific objectives for the project.
    c. Identify activities for the project.
    d. Revise the conceptual model with objectives and activities.
4. Create a monitoring plan.
    a. Determine audiences, information needs, monitoring strategies, and indicators (why and what)
    b. Select methods and determine tasks necessary to collect data (how).
    c. Determine when, by whom, and where data will be collected (when, who, and where).
    d. Develop a monitoring plan for project activities.
5. Implement the plans.
    a. Implement the management plan.
    b. Implement the monitoring plan.
6. Analyze data and share results with stakeholders.
    a. Analyze data.
    b. Communicate results to the internal and external audiences.
7. Use results to adapt the management strategy, if necessary.
    a. Put the assumptions to the test.
    b. Adapt the project based on the monitoring results, if needed.
    c. Use results to refine the project and knowledge of conservation techniques.

It is important to note that there may be additional tasks that become apparent and will be necessary for certain situations, and also that some of these steps will not be necessary in other situations. In other words, the list of steps in Box B.3 are not written in stone.

Each of these steps, their associated sub-steps, and some additional steps is described in more depth in the following several sections. It is our hope that these guidelines will serve as a useful synthesis of recommendations and considerations that different authors have included in their respective writings about adaptive management and project management. There exist numerous sources of information on adaptive management, yet each of these sources tends to concentrate on one specific aspect of the process. In creating this set of guidelines, we sought to glean the information from these sources that are the most important, generalizable, and applicable to grassland management in southern California. We have attempted to keep these guidelines as brief as possible, while still providing enough detail to be useful.

There are four features of this synthesis that are worth mentioning here and that have been included in the guidelines to make them more useful, understandable, and applicable to managers of grassland areas. First, interspersed within these guidelines are some tools that we have suggested that will assist the manager in accomplishing a specific step and managing the system more effectively. For example, various types of conceptual models can help you not only characterize your site and state your assumptions, but they can help you to identify some possible management activities.

Second, there are excerpts of actual adaptive management plans included throughout these sections. These were included to provide the reader with real-world examples of how a certain part of the planning process was done by a real manager or management team, for a real place. When possible, we included examples that were from projects for a smaller scale area, rather than large regional projects that would include many parts that are not applicable to the smaller sorts of grassland reserve systems that one would expect to manage in southern California.

Third, when necessary, and because it is difficult to include all of the details one would like to in a somewhat brief document such as this, suggestions for further reading are provided to assist the reader pursue a topic of interest in more depth if they wish. For example, it would be impossible for us to summarize all of the vital topics related to designing a good monitoring plan, such as details on statistics and identification of indicators, so suggestions for further reading are provided for this topic.

And finally, the utility of these guidelines and of the tools that are interspersed within them, are illustrated in Part II of this document for The Santa Rosa Plateau Ecological Reserve with an adaptive management-style management and monitoring framework.

Mission and stakeholders

One of the first steps in creating an adaptive management plan can be to state the mission of the project or the organization heading the project. Often a mission statement for the group or for the specific project can clarify the values that will guide the group's work, their purpose, and the strategies they will use to meet that purpose (Salafsky and Margoluis 2001). This clarification of the group's purpose, strategies and values can be useful to share with newcomers to the group, with collaborators on the project, and with the local community and other stakeholders. It helps to have these points clear in the beginning of a partnership between organizations for a common project, because often two groups do not share the same purposes, values and strategies.

Often the agency or organization charged with management will have a general organizational mission statement. This is the mission that Meffe et al. (2002) refer to in their definition of a mission: "The highest-level stated purpose for an organization's existence; usually synonymous with mandate." However, for a specific project or for the management of a specific place, it is a useful proposition to develop a more targeted and specific mission statement related to that project or site. It can be in the same character as the larger organizational mission, but in addition sets forth the group's intentions for managing that specific area or project. Often, however, this step may not be necessary, especially if the organization's existing overall mission is already sufficient and in-line with the specific project.

When formulating a new mission statement for a project, it is best to bring critical stakeholders to the table, and listen to what they have to say about the project. This is a similar process by which goals are later developed. Mission statements usually possess 4 common characteristics: they are comprehensive, general, visionary, and brief (Meffe et al. 2002). Box B.4 displays two examples of organizational mission statements, and two examples of mission statements for specific ecological management projects.

Box B.4. Mission statement examples.

Organization	Mission Statement
The Nature Conservancy (TNC)	To preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive." (http://nature.org/aboutus/)
Center for Natural Lands Management	The mission of the Center for Natural Lands Management is: (a) to preserve or to assist in the preservation of Natural habitat, native species and functioning ecosystems; (b) to own and/or (CNLM) manage lands in an ecologically beneficial manner consistent with federal and state environmental laws; (c) to promote the conservation values of such lands through education; (d) to promote and facilitate uses of such lands by the public that preserve the conservation values; and (e) to enable and assist the state and federal governments in their obligations to protect native fish, wildlife, plants and their habitats necessary for maintaining biologically sustainable populations of such species for the public benefit." (http://www.cnlm.org/soq.html)
Clymer Meadow Site Conservation Plan (TNC of Texas)	…The Nature Conservancy and its partners will collaborate with local stakeholders to foster grass based agriculture, with the ultimate goal of creating s self-sustaining quiltwork of Texas Blackland Prairie, native pastures and hay meadows, and thriving human communities. (Halstead 2001)
Niobrara Valley Preserve	The biological diversity of the MNV [Middle Niobrara Valley] will be maintained within a landscape that retains fundamental ecological processes. Local hydrogeological forces are paramount, and along with fire and grazing, are critical to the maintenance of biodiversity at this boundary between the Northern and Central Mixed-Grass Prairie Ecoregions. (Niobrara 1999)

The communities of people who may be interested in some way in the site, its management, or issues surrounding the management of the site, should be identified, and their expectations, values (Everett et al. 1994), and level of authority should be understood. These communities of people are called stakeholders. Everett et al. (1994) point out why this information is essential for establishment of goals and management actions: "If a management model operates outside a range of socioeconomic acceptability …the model must be reconsidered, or of the model is constrained by biological realities, society must be informed of the infeasibility of the goal."

The term stakeholders is a broad one that can refer to many different types of people who are, or would like to be, involved in some way with the management of a place. Meffe et al. (2002) delineated five groups of people who should be considered stakeholders, and these five groups are described here:

1) People who live, work, or play in or near an ecosystem. This would include nearby residents, visitors, employees, and others.

~~1)~~2) People interested in the resource, its users, its use, or non-use. These people may be local (or non-local) naturalists, managers from other areas, organizations (like the California Native Grass Association), or ranchers who will be implementing a grazing program of some sort for you.

~~1)~~3) People interested in the processes used to make decisions. Although these types of stakeholders are more often encountered in settings such as federal agency ecosystem planning processes (for example, Environmental Defense), people interested in the legal adequacy of decisions or decision-making processes could possibly want to bear witness to the smaller scale planning efforts we discuss here.

~~1)~~4) People who pay the bills. This may be people within your organization, or from other partnering organizations that are contributing or have contributed to the land acquisition, planning efforts, and the like.

~~1)~~5) People who represent citizens or are legally responsible for public resources. These people may be citizen activist groups (such as Not In My Back Yard or NIMBY), people representing Native American tribes (or are from federal agencies and hold trust responsibilities), and others from governmental agencies. Citizen activist groups are another example, and they would probably only wish to participate if they object to some proposed management activity, such as prescribed burning.

Some of these stakeholders may have a legal right to be present during the planning process, or be informed along the way, while most will probably not have any legal authority. Therefore, it is up to the decision-making body to decide whom to include or keep informed in the planning process.

Different stakeholder groups will have differing motivations for becoming involved with the planning process, and will probably end up playing different roles in that process if included in the process. Although the differing motivations of the various groups can effectively act as a hindrance to an ecosystem management planning process, it can also be a major asset. Having different stakeholders fit into different roles allows a variety of perspectives, suggestions, and helpers for the process. Because stakeholders vary in their opinions, beliefs, knowledge, and experiences, it is useful to include a range of diverse people in the planning process or parts of it (Meffe et al. 2002). The key to including stakeholders in decision-making or information sharing is to choose a variety of people from different backgrounds, and use what they can bring to the table to improve the final products of the management planning efforts.

The degree to which different stakeholders are involved in the planning processes will vary. Some with deep interest in the issues or the area will wish to be closely involved, while others (and probably the majority of stakeholders) will display a casual interest with occasional involvement; these different levels of interest and involvement are called stakeholder orbits (Meffe et al. 2002). These orbits can change as well, with some becoming less interested over time, and other becoming more interested over time.

Haney and Power (1996) point out that, "managers must take the time to identify stakeholders and understand their opinions and concerns. Not all opinions are informed, nor are all values compatible. Therefore, stakeholders must be educated and involved from the beginning, so that their opinions and attitudes can be incorporated, as appropriate, into the development of management goals and prescriptions." Deciding to include certain groups in decision-making, or even choosing to keep them regularly informed about the decision-making that occurs, can be difficult. For example, it is thought to be a good policy to include neighbors in a management planning process. These stakeholders will probably be affected in some way by the management activities at the site, and therefore will probably want to be involved (Meffe et al. 2002). On the other hand, these neighbors may object to certain proposed management alternatives, and may therefore hinder and slow the process of management planning. This could be the case in situations where controversial management actions are proposed, such as prescribed burns. The decision to include or exclude certain stakeholders from decision-making processes is a difficult one because they can both help and harm the process.

In general, decision-making processes that include large groups of stakeholders, and that are open and transparent processes are generally promoted over exclusionary, closed-door decision-making; this is called the principle of inclusivity (Meffe et al. 2002). Often the simple gesture of inviting a person to the table, or keeping them informed and asking for feedback, can be a good will gesture and promote successful interaction in the future. It must be kept in mind, however, that those who may object to some management choice during the planning phase will probably do so eventually anyway, so excluding those groups early on might not make any difference in the long run.

With the increasingly real problems of urban or residential land uses moving closer, and sometimes abutting, reserve boundaries, people in close proximity to a reserve should not be ignored. Taking the time to explain the rationale, necessity, scope, and legality of an action (such as a prescribed burn) to the community can foster trust, understanding, and an improved relationship, which may be useful for future activities (Meffe et al. 2002). There are two general ways in which one can approach these activities. Walters (1986) provides a table, shown in Box B.5, that highlights the distinction between a more "adaptive" way to approach stakeholders, versus a more "conventional" way.

Box B.5. Conventional versus adaptive tactics for policy development and presentation. Modified from Walters (1986), *Adaptive Management of Renewable Resources*.

Conventional	Adaptive
Committee meetings or hearings	Structured workshops
Technical reports and papers	Slide shows
Detailed facts and figures to back arguments arguments	Compressed verbal and visual
Exhaustive presentation of quantitative options alternatives	Definition of few strategic
Dispassionate view	Personal enthusiasm
Pretense of superior knowledge or insight	Invitation to and assistance with alternative assessments

There are a number of actual mechanisms that can be used to get stakeholders involved. These include but are not limited to interviews, websites, displays at local events, informal meetings, focus groups, workshops, and public meetings (Meffe et al. 2002). Some of these ways are more appropriate for certain stakeholder types than for others, and can be used to foster stakeholder involvement and understanding at different points in the planning process.

Table B.2. An example of a stakeholder analysis that was performed by The Nature Conservancy (TNC) for the Middle Niobrara Valley site at the Niobrara Valley Preserve. From Niobrara (1999).

Stakeholder (SH)	**TNC effect on SH**	**SH effect on TNC**	**Unknowns about SH**
Agricultural Interests	Increase the likelihood of agricultural land uses remaining in the valley.	Potential partners in protecting the MNV Site by preventing development.	Will agricultural land uses remain economic-ally viable for the valley?
Recreation Groups	Provide a scenic backdrop for their activities.	Potential to provide economically viable compatible land uses.	Will increased recreation have more positive or negative effects?
Government Agencies	Our protection activities further other agencies' conservation goals	Their protected sites provide a buffer to our preserve.	Will their future policies and management further our conservation goals?
Conservation Groups	Accomplish some other group's goals.	Could potentially become a conservation partner.	Will they be a source of funding for protection/ management?
Municipal/ county/ state government	Potential to steer policy towards our goals.	Zoning and property tax legislation could potentially favor goals.	Will future policies and legislation benefit conservation?
The Scenic River Council	Educate them about our mission and steer them towards our goals	Could potentially accomplish some protection goals for us.	Will this being an active guiding body?
Research and Educational Institutions	Provide site for research and education.	Provide expertise for monitoring and research.	Will they be a source of funding and a way to get our research accomplished?
Media	Potential to accomplish outreach.	Potential to improve the public' perceptions.	Will they be an asset or a liability?
Recreational Property Developers	Limit and direct second home development in the river valley corridor through easement program.	Could potentially make it impossible to achieve protection efforts for the North Mosaic.	How fast will recreational property development occur?

In Table B.2 above, the results of a stakeholder analysis is shown. In it, TNC land managers analyzed and recorded the stakeholders effect on TNC and TNC's effect on the stakeholder. Using this analysis, potential opportunities and partnerships can be identified, in addition to possible areas of conflict.

Characterizing and contextualizing a site

The characterization and contextualization of the system to be managed is the first of a line of activities that leads to the formulation of goals, targets, hypotheses, management approaches, and ecological indicators for monitoring. It is therefore a key and highly informative activity that is discussed in some detail here. The main method of contextualization that we illustrate is the use of Geographic Information System (GIS) information and mapping. This information was included in Part I of this document. The main method for characterization discussed here is the use of diagrammatic conceptual models.

Conceptualization using conceptual models

One of the first and most important steps toward identifying information gaps and developing testable hypotheses is the conceptualization of the system. Walters (1986) states, "…we can develop structural representations or models of how nature might respond to alternative actions, and then use these models to direct the learning trials more wisely. In other words, we should begin adaptive policy design by posing clear hypotheses based on previous experience and functional understanding." Although Walters mainly concerns himself with mathematical models, which have a great deal of use for modeling ecosystems, this statement can also apply to conceptual, diagrammatical models, which we herein promote the use of for grassland systems.

The National Park Service defines a conceptual model as "A visual or narrative summary that describes the important components of an ecosystem and the interactions among them" (NPS 2003). Numerous authors highlight the utility and criticality of constructing conceptual models. A conceptual model has been called "the foundation of all project design, management, and monitoring activities" (Salafsky and Margoluis 2001). Lee (2001) writes, "The essence of managing adaptively is having an explicit vision or model of the ecosystem one is trying to guide…That explicit vision provides a baseline for defining surprise. Without surprise, learning does not expand the boundaries of understanding." Conceptual models play a part in setting management goals, choosing activities, and assessing monitoring results. They illustrate the interactions between targets, key ecological processes, important threats (internal and external), and possible management interventions (Wilson 1999). They also highlight areas of uncertainty which can then be investigated through hypothesis formulation and the application of adaptive management to test those hypotheses.

These models have utility in addition to modeling the natural environment. They can act as tools to assist effective communication with stakeholders. Because the models illustrate so many key factors operating within the management system, they help the land manager explain or justify their proposed management approach to outsiders and colleagues, and gain feedback (WCU 2002). Also, in creating these models, you are essentially documenting a large part of the current understanding of the system. This may prove to be especially useful if there is a change in personnel for the project: it prevents the knowledge that exists about a system in a person's mind from leaving with that person (WCU 2002). In addition, models help us see relationships more clearly (Haney and Power 1996), and help us to focus on those relationships that we judge to be the most important for our purposes. This is an especially useful feature due to the complex nature of ecological systems.

It should be kept in mind when developing a model that conceptual models of ecological systems should be thought of as "living" documents (TNC 2001a): there will probably never be a final version. As the current level of understanding about the system improves over time, the models will have to be updated and adjusted in response, and then used to formulate *new* hypotheses to test with management activities (TNC 2001a).

The National Park Service (2003) highlights three of the major guiding principles and specific steps taken in developing conceptual models. The first principle is relevance, and it expresses that, “Conceptual abstraction must be relevant to audience and scale.” By audience, they stress that you must identify whether the purpose of your model is to inform an audience, influence it, or perhaps both. By scale, they stress that the spatial and temporal scales that are relevant and are of interest to the investigator, are crucially important to identify. We would also include ecological scales of interest as important to identify (e.g. region, reserve, or part of the reserve).

The second principle relates to reliability: “Conceptual abstraction must be underpinned with reliable knowledge.” When it comes to utilizing conceptual models for adaptive management, we can use the models to test hypotheses about the functioning of the system and its expected response to management actions. This inevitably will mean that we will include in our models the representations of things we do not know. These are exactly the things we wish to find out. But, what this principle tells us is that we should rely on what we do know about the system as well. We should build our models reflect both our certainty, as well as to reflect, investigate, and address our uncertainty.

The third principle is termed censorship, and it tells us, “Conceptual abstraction must avoid over-simplification or over-sophistication.” In this principle, the National Park Service highlights the fact that, in order to be most useful, the models we create should reside in a balance between the desire to simplify the ecological system for easier understanding, and the desire to include as many factors that are related to our question of interest as possible in order to be thorough and avoid missing something that may be important. There are no clear-cut ways to attain this balance, other than simple to ask oneself and collaborators periodically if the model seems too simple or too complex.

The first major set of activities one must go through before beginning to make a conceptual model are processes of inventory and information exchange, and these processes continue throughout the adaptive management cycle (Haney and Power 1996). The gathering of existing and new information helps to establish a baseline from which to measure future changes in the system. Haney and Power (1996) explain: "Adaptive management begins with collection and compilation of existing information for each ecosystem to be managed and exchange of information and ideas with stakeholders. Inventory may include biotic surveys, literature searches, public opinion surveys, market analyses, and the preparation of appropriate databases and maps. Collection and interpretation of information provides a baseline against which to measure change, but also helps to identify management options, barriers, opportunities, and goals." The types of information collected should pertain to relevant ecological, socioeconomic, institutional and cultural issues (Haney and Power 1996). It may be useful to overlap this initial information inventory and collection with the identification and inclusion of stakeholders step, which was described in the previous section.

Grant, et al (1997, in NPS 2003) outline 6 steps that one should follow in creating a conceptual model. These steps come after the initial information gathering activities.

1. State the model objectives.
2. Bound the system of interest.
3. Categorize discrete model components within the system of interest.
4. Articulate the relationships among the components of interest.
5. Represent the conceptual model (make the thing).
6. Describe the expected pattern of model behavior (state what you expect the system to behave given some change in it or some action upon it).

In step 1, you ask why are you making the model? This will help to make sure the model has a purpose in the long run, that it is included in the planning process, and that you have a reminder of what you planned on doing with it in the first place. The second step makes you decide what is and is not important, keeping in mind the previously mentioned point about censorship to avoid over-simplification or over-complexity. This is one point in management planning when the question of spatial scales becomes important. Landscape and community scales are probably the two most relevant scales for thinking about grassland areas in the setting of a typically sized reserve. Sheila Peck (1998) highlights some of the significant factors affecting and influenced by biodiversity at these scales in the book *Planning for Biodiversity: Issues and Examples*, an excerpt from which is shown in Table B.3.

Steps 3 and 4 have you define the model components and the relationships between them. Included in the model should be a number of factors (Harwell): the natural and anthropogenic threats (or stressors) that may affect the system, the natural and anthropogenic events (or activities) that occur and have an effect (either positive or negative) on the system, the pathways by which the stressors and events affect the system, and the ecological components of the system that are or may be exposed to the stressors or the events (also called the receptors). During Step 3 you define your targets. Targets are the entities to be influenced or changed by your management activities, and can include specific species, communities, vegetation types, or entire ecological systems (Wilson 1999). Step 5 is where you actually put the components together and show their relationships diagrammatically, and it is the most creative part of the model building process. You decide how you will visually represent the system, and there are usually a number of appropriate and useful ways to do it. Step 6 is related to the development of the management plan. During this step, hypotheses about the reaction of the system to certain management actions that you plan to take (and implement experimentally) are posed. This will be discussed further in the next few sections.

Table B.3. Relevant features and factors related to biodiversity at the landscape and community scales. Modified from Peck (1998).

Hierarchical scale	Factors	Examples/Priorities
Landscape scale	Biotic communities and abiotic factors	Soils
		Hydrologic features
		Community types (species-rich, natural, vulnerable, endemic, rare, etc.)
		Community representation
		Unusual abiotic features (soils, substrates, springs, perennial water sources)
	Key spatial patterns and processes that maintain the communities and selected species populations	Functional associations of ecological communities
		Abiotic gradients
		Extensive blocks of open space
		Connections between natural areas
		Migratory species' routes
		Overall landscape pattern
		Disturbance processes
		Hydrologic processes
Community scale	Categories of species that are especially valuable and vulnerable	Species types (keystone, vulnerable, rare, endemic, specialist, migratory, exotic, endangered, etc.)
	Patterns and processes that affect habitat quality within a community	Vegetation structure (vertical layers, vegetation density, canopy closure, etc.)
		Disturbances (fire, flood, etc.)
		Habitat resources (water sources, breeding and roosting sites, dead branches leaf litter, etc.) and their availability and distribution.

In addition to those steps already listed, more are highlighted by Salafsky and Margoluis (2001), and they include: reviewing and compiling existing information about the site before making the conceptual model (this is the baseline establishment mentioned previously); choosing targets; identifying key threats to those targets and including them in the model; assessing local site conditions and consulting with stakeholders and experts after crafting a first draft of the model, to gain feedback and revise it; and finally, to use the conceptual model to rank the threats, and formulate testable hypotheses.

As mentioned previously, important components of the model include the important ecosystem structures, functions and dynamics (TNC 2001a) that affect the viability (either positively or negatively) of the targets. An example of a threat that could affect target viability is invasive plants, and in that example, the key entities that create, maintain, or reduce that threat should be included in the model (TNC 2001a). For example, roads and overgrazing can lead to an increase in exotic plant species invasion, while specific types of management activity can decrease them. It is also useful to include the desired condition in the model, as well as a hypothesized route from the current condition to this desired condition (TNC 2001a).

One important consideration to include in the modeling, and which may affect the spatial scale covered by the models, is the fact that ecological processes are rarely restricted by the boundaries of a reserve (Haney and Boyce 1997). The activities occurring on adjacent lands can spillover and effect the populations of animals and plants on the reserve. Therefore, a management approach that takes the adjacent land uses and owners into consideration is important.

The importance of physical drivers, which can include climate, soil, and geologic substrate, is highlighted in The Nature Conservancy's "Developing a Conceptual Scientific Framework for Conservation in the Arid West" (TNC 2001a). It states, "It is critical to understand the physical template of a system and how physical factors constrain ecosystem dynamics. In the Arid West, systems are often sensitive to climatic variation (especially rainfall) and long-term climate change, and these relationships are integral to a thorough understanding of the conservation needs of targets." They also propose that these physical factors often can be even more important than biological and anthropogenic factors when it comes to system structure, function, and change over time.

It is also recommended that you clearly identify which linkages and relationships in your model are assumptions, which are based on data, and which are based on opinion (even expert opinion) (TNC 2001a). By doing this, matters requiring further study can be identified. In addition, these areas of the conceptual model will most likely be those that will change as knowledge is gained, so highlighting them as weak spots early on can be useful.

After the conceptual models are crafted, shared with stakeholders, and revised, they can be put to use. The model will have helped to elucidate some key threats to the targets, as well as some key uncertainties that exist about the system and its dynamics. The model can therefore be used to (1) rank threats and prioritize management interventions, and to (2) formulate hypotheses that will be tested through management. Ranking threats is discussed in the next section.

Formulating hypotheses

Haney and Power (1996) state "Regardless of whether we have developed schematic or mathematical models, management cannot be guided by good science without a set of hypotheses outlining how we believe the ecosystem will respond to treatments… Hypotheses and models help us identify the management practices most appropriate to achieving our goals." In fact, this formulation of hypothesis (which are later tested through management activity) is one of the central aspects of adaptive management that differentiates it from conventional ecosystem management. Conceptual models are helpful tools one can use to formulate those hypotheses.

There will undoubtedly be too few resources to be able to test all hypotheses in order to fill all the information gaps that are identified. Therefore, only the key uncertainties should be identified and targeted through management activity. The key uncertainties are those that stand in the way of you selecting with confidence from a choice of management activities. Formulate hypotheses about those key uncertainties, and then test them (MacDonald et al. 1998). Lee (2001) makes this point when he states, "Adaptive management emphasizes…that ignorance of ecosystems is uneven. Management policies should accordingly be chosen in light of the assumptions they test, so that the most important uncertainties are tested rigorously and early."

In this document, we gave attention to the use of simple diagrammatical conceptual models because simple models tend to be more easily understood than highly complex ones, are more attractive to decision-makers, are more easily used as a device for communication of ideas between parties, can represent many ecosystems very well, and are often all that is available in the face of noisy data and large uncertainties as to a system's dynamics (Walters 1986). As a final note, however, despite their usefulness, Walters (1986) reminds us that models do not give us all of the answers we may need or want (see Box B.6).

Box B.6.

"…resource managers must learn to live with some very substantial uncertainties. Modeling helps to clarify and highlight these uncertainties, but cannot usually resolve them by decomposition (reduction) of relationships into smaller and more understandable (researchable) pieces. This means in the end that many key management decisions are essentially *gambles*, no matter how nicely we may try to package the justification for these decisions by presenting reams of data and elaborate calculations. Indeed, when uncertainties are revealed in public debates it is often argued that inaction (wait and see, do more research) is preferable to the indignity of gambling." - Carl Walters (1986), *Adaptive Management of Renewable Resources*

Threats assessment

Under The Nature Conservancy's threats assessment methodology, threats (which are conditions and activities that negatively effect targets) are identified, evaluated, and ranked (Halstead 2001). Each threat is composed of two parts: the ecological stress, and the source of the stress. The principle behind TNC's threats assessment approach is that "assessing and abating critical threats on a site will improve the long-term viability of conservation elements." (Halstead 2001). The two types of threats that are defined in this method are direct threats (which are factors that directly and immediately impact the condition of a specific target or targets) and indirect threats (which are factors that underlie the direct threats, or that lead to them) (Salzer and Margoluis 2002).

Table B.4 is an example of a threat summary that resulted from a threats assessment for a reserve in Texas named Clymer Meadow, part of the Northern Blackland Prairie. Three different habitat types were assessed and seven threats identified that adversely affected these target habitat types. The magnitude of each of the threats, for each of the habitat types, was determined and averaged to get the overall threat rank. This method helped the managers at Clymer Meadow to prioritize which threats they should work to abate first. By directing management actions at abatement or prevention of the worst threats first, resources are then used more efficiently than if they were devoted to abating or preventing the least threatening factors first.

Table B.4. Threat summary for Clymer Meadow site (taken from Halstead (2001)).

Threats Across Systems	**Tallgrass Prairie**	**Riparian Forest**	**Wet-lands**	**Overall Threat Rank**
Residential and commercial development [1]	Very High	Medium	High	**High**
High intensity agriculture [2]	Very High	Medium	High	**High**
Development of roads or utilities [1]	High	Medium	High	**High**
Construction of ditches, dikes, drainage or diversion systems [1, 2]	Low	Medium	High	**Medium**
Invasive/alien species [1, 2]	High	Low	Medium	**Medium**
Incompatible grazing practices [2]	Low	Medium	High	**Medium**
Elimination of natural disturbance regimes [1, 2]	High	Low	Medium	**Medium**
Threat Status for Elements and Site	**Very High**	**Medium**	**High**	**High**

[1]Threats related to development; [2] Threats related to agriculture

Developing a management plan

While considering the hypotheses we wish to test and the threats we wish to abate or prevent, management goals are formulated and the conceptual models are refined and updated. Then, from these goals, specific management objectives are formulated. Finally, the management activities can be chosen and planned. These are the main steps in creating the management plan, which "describes the explicit goals, objectives, and activities designed to address the threats identified in the conceptual model." (Salafsky and Margoluis 2001). In adaptive management, the management plan also designs management activities to test hypotheses, as already mentioned.

Defining goals

Goals are "broad statements of the desired state toward which the project is directed." (Salafsky and Margoluis 2001). Management goals must be clearly articulated statements, should define the desired state of a conservation target, and should incorporate a long-term perspective (Wilson 1999). Finally, goals should be a result of the conceptualization (and contextualization) of the site, interchanges with stakeholders, and any relevant cultural, socioeconomic, and legal considerations (Haney and Power 1996).

Specific priorities, as well as potential difficulties in achieving those priorities, should be noted and made explicit in this stage of the management planning process (Haney and Power 1996). However, the planning team should not be overly concerned at this stage with exactly how the goals will be achieved. Feasibility should not be a concern at this early stage, because if it were considered here, fundamental goals may not be documented and may be abandoned simply because they are suspected to be difficult to reach.

Goal statements can be described as "visionary, general, and qualitative" (Meffe et al. 2002). This may sound similar to a group's mission statement, and in fact, a goal has been defined as “A broad general statement that further defines an organization’s mission or mandate.” (Meffe et al. 2002). However, goals are much more brief and more focused on specific management considerations.

The terminology used in statements of goals should be carefully chosen to convey the exact intentions of the management. The careful choice of terms will prevent confusion and misunderstanding between stakeholders. Terms that are often thrown around without common understanding in ecosystem management can end up being used in the wrong context, and may have many underlying meanings, or different meanings for different people. As an example, the words restoration, remediation, rehabilitation, and even reclamation, all have meanings that are different, but that may be difficult to clearly delineate from one another – people in the same field may have different definitions for these terms.

Refining the conceptual models

Goal setting and system conceptualization (from the previous section) are so interconnected and inform each other so much that these two steps can be done concurrently. Alternatively, if the conceptualization of the system occurs first, and the goal setting second, it is advisable that the conceptual models by revised according to the goals. For example, after setting your goals, you may determine that one or a few ecological levels are most relevant for you to think about for managing the area. Which level(s) you choose to think in terms of will depend ultimately on your management goals. Because the relevant levels or scales should be reflected in your models, you may need to go back, after developing goals, and alter the scale of or the factors present in your models.

Historical reference state factor

The restoration reference state is the “the condition of the ecosystem used as a reference to evaluate the success of the restoration”, and it can be difficult to establish (NRC 2003). A variety of methods can assist in the formulation of an idea of what the restoration reference state is. These include biological surveys (current and historical), historical land surveys, aerial photographs from the past, land use records, soil maps, and others. If these resources are available, you may want to consider utilizing them to establish some idea of what vegetation types were present at some point in the past and what their relative abundance and patterns were.

The question of historic composition and extent can be a vital consideration at this stage in the management planning process. There are differing opinions about how important historical considerations are in planning for ecosystem management, and the ultimate answer is up to the individual land manager or management team.

Setting objectives

Moving from broad, visionary statement about the intentions of the management to specific, quantitative, explicit statements of what the project will attempt to achieve can be a daunting task (Meffe et al. 2002), and probably the most challenging task thus far in the process of developing an adaptive management plan (Box B.7).

Box B.7.

"Moving from goal to objective is a particularly daunting step in strategic thinking. Dedicated members of an ecosystem group, whether natural resource professionals or community members, hesitate to make such choices. Recognizing that we cannot do all things is hard enough, but actually listing those things that we will do and, by their absence, those things that we will not do is a tough intellectual and emotional task. When we fail to make explicit choices, however, we run the risk of wasting our capacity by spreading ourselves too thinly – never doing anything well enough or thoroughly enough to make a difference. But when we focus our capacity on a smaller number of actions, we can significantly advance conservation."

–Meffe et al. (2002) *Ecosystem Management: Adaptive, Community-Based Conservation*

One or more objectives should be formulated for each of the goals stated in the previous step. From the large excess of objectives one could think of, only a few can ultimately be chosen and pursued (Meffe et al. 2002). Elzinga et al. (1998) outline 5 important functions of the management objective. The management objectives help to:

- "Focus and sharpen thinking about the desired state or condition of the resource.
- Describe to others the desired condition of the resource.
- Determine the management that will be implemented, and set the stage for alternative management if the objectives are not met.
- Provide direction for the appropriate type of monitoring.
- Provide a measure of management success." (Elzinga et al. 1998)

Because objectives state the desired outcomes of the project in specific terms, it is important to have the people who will be responsible for their achievement involved with the formulation of objectives, as well as those who are paying for the project (Meffe et al. 2002). Additionally, the objectives should relate to the outputs and results of the efforts, rather than the inputs and methods of achieving them. The inputs and methods are details that are decided in the next step, management activity planning. For now, the focus should still be on results. And finally, objectives should be detailed and full of information, in contrast to the general goals stated earlier (Meffe et al. 2002). Meffe et al. (2002) present an acronym ("SMART") that can help you remember some of the important details related to stating objectives. The acronym and its meaning is described in Table B.5 below.

Additional details that other authors recommend be mentioned in the objectives are the species or habitat indicator, the location of management activity, the attribute targeted for management, and the management action(s) that will be taken (Elzinga et al. 1998). However, some of these details may not be planned as of yet, and in this case, setting objectives can be accomplished concurrently with the next few sections.

Table B.5. The “SMART” characteristics of well-stated objectives. From Meffe et al. (2002), with examples changed to be more relevant for grassland systems.

S is for **Specific**
Defines a positive change that can be made in the condition of the ecosystem (or part of the ecosystem). If your goal were to “restore native biodiversity”, the objective related to that goal would address the status of a particular ecological community, species, population, habitat, or process. An objective such as “increase the abundance of rare species” is not specific enough. A good objective with adequate specificity would be “double the number of suitable burrows for the burrowing owl”.
M is for **Measurable**
Is quantitative, providing a way to measure whether or not the objective has been achieved. The quantitative part of the objective can take many forms, such as: numbers (“300 acres covered by grassland dominated by native grass and forb species”); comparisons (“reduce the number of new invasive plant species that become established each year by half”); or ranks (“achieve the lowest rate of exotic species invasions per year in the reserve system”). The objective to “reduce thatch build-up in the grasslands” is not measurable. The objective to “reduce thatch density in the exotic-dominated grassland areas by 50 percent” is measurable.
A is for **Accountable**
The group has accepted responsibility for addressing the objective. More importantly, one or more persons have accepted responsibility for doing the work. The best objectives have deep commitment by the group and its members. Accompanying the list of objectives can be details about who will be in charge of accomplishing which objectives.
R is for **Realistic**
Has a realistic possibility of happening. This can mean that the technical capacity is adequate, the sociopolitical climate is accepting, the land or water resource can support the intended organisms or uses, the organizational resources are available, and the objective is within the group’s sphere of responsibility or influence. The objective to “restore native perennial grasslands to 50 percent of Riverside county” is not realistic. The objective to “restore native perennial grasslands on 50 percent of the Riverside Grassland Preserve” might be realistic.
T is for **Time-Fixed**
It states when it will be done. Along with a final deadline, good objectives also include milestones (intermediate deadlines). The time frame needs to be specific to avoid confusion. An objective to “quadruple the number of conservation easements in four years in Orange County” probably does not give enough guidance, while the objective to “double the number of conservation easements in Orange County in 2 years, and then double the number again in 2 more years” is a better version. An objective to “break ground on the visitor and environmental education center by 2005” is not specific enough; “break ground on the visitor and environmental education center by March 31, 2005” is better.

Choosing activities

The next step in developing your adaptive management plan is choosing the activities that will meet your objectives, and designing their implementation in order to test your hypotheses. Haney and Power (1996) provide some additional guidelines. These relate to choosing management units and other considerations, and are listed below.

- Ideally, implementation of management practices should allow components of the model to be tested.
- Large management units, in which ecological gradients are retained, are better than smaller units.
- Where possible, allowing natural processes, such as fire, flooding, and disease, to run their course is also recommended.
- Management units should be selected based on natural landscape features.
- Management units also should contain a range of gradients.
- Additional fragmentation of the landscape should be avoided.
- Linkages between similar cover types in different management units may be desirable.

Not all of these ideal situations may be achievable at a particular site. There may be too few resources, including time, personnel, money, or even space at the site, to include all of these many management variations. Nevertheless, whenever feasible, replication and control should be included in the management approach (Haney and Boyce 1997).

A type of ecosystem management that is a good descriptor for much of current grassland management is called "ecological process management". This type of management approach seeks to preserve, replace or mimic the natural processes that once occurred in a system, but that may be altered presently or at risk of being altered. This approach is often used because natural disturbance regimes for many ecological systems are considered integral for their functioning (Haney and Boyce 1997). It should be cautioned, however, that excessive levels of disturbance may be detrimental to the system. It has been found that in most cases, intermediate levels of disturbance yield the best species richness (Haney and Boyce 1997).

Box B.8.

"Experimentation has three components: (1) a clear hypothesis, (2) a way of controlling factors that are (thought to be) extraneous to the hypothesis, and (3) opportunities to replicate the experiment to check its reliability….
Hypotheses, controls, and replicates are all important to reliable knowledge, but none is easily achieved in conservation practice. "
– Lee, "Appraising Adaptive Management" (2001)

Three key components of an experimental approach to ecosystem management are listed in Box B.8 (above). When designing the management activity implementation, there are some additional key features to include that will help to more accurately test your hypotheses, listed below (MacDonald et al. 1998). Some of these features are key features of active adaptive management itself.

- Contrasting treatments (including control treatments) to enhance the ability to detect causal relationships, and to simultaneously evaluate multiple hypotheses.
- Replicates, if possible, to reduce bias in the results and to account for more variability between treatment sites.
- Interspersion of treatments, where treatments are mixed temporally and spatially to reduce the number of confounding factors.
- Independent response among areas (attempt to choose treatment sites that are independent from one another).

There are a variety of details about the actual implementation of a particular management activity (such as prescribed fire or planned grazing) that can be altered to bring about a wide range of results. Box B.9 lists the characteristics of disturbance management actions that can often be controlled by the manager to produce a certain outcome.

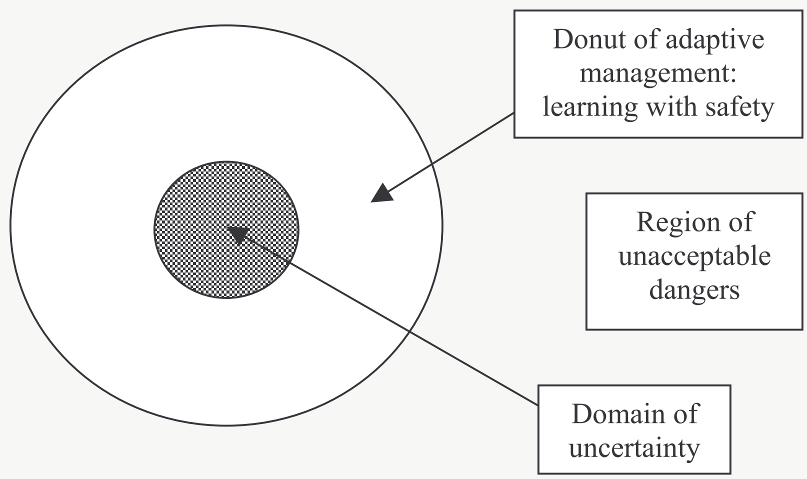
Box B.9. Characteristics of natural disturbances acting on ecological systems. Taken from Noon (2003).

- Frequency (number of occurrences per unit time)
- Extent (area over which the event occurs)
- Magnitude:
  - Intensity (degree of effect on the biota)
  - Duration (length of stressor event)
- Selectivity (portion of the biota affected)
- Variability (probability distribution for each of the above)

Management action and risk

How do we know what amount and intensity levels of management actions are appropriate as a starting point for experimentation? One way to answer this uses the balancing of risk and action to help steer the management design towards a good starting point. One way of representing the trade-off that often exists between learning through management intervention, and the risks that may result from too much or too intense management intervention, is Koonce's Donut. In brief, the donut, recreated in Figure B.1, represents the area of risk-taking that one desires to reside in when doing management activities. Areas outside the donut represent a region of unacceptable risk, and the area within the donut hole represents the area where activities are too safe, and therefore learning is too slow, or absent altogether (Walters 1986). The hole can also be understood as the uncertainty that exists about management of the system.

Figure B.1. Koonce's donut. Modified from Walters (1986).



Developing a monitoring plan

A large literature exists on the design of a monitoring plan and on individual aspects of monitoring and it is beyond the scope of this report to review all of the relevant material. Therefore, this section is kept brief and recommendations for further readings are provided.

The monitoring plan is one of the most important aspects of the overall management plan. Franklin (1997) states, "Scientifically designed, socially credible, sustained monitoring is an essential part of the management program to objectively measure the effectiveness of the management programs in achieving the desired goals – along with clear mechanisms for feedback to and adjustments in management practices." We discuss these essential elements – monitoring, feedback, learning and adaptation – in the next few sections.

Monitoring serves two broad purposes in adaptive management: first, it helps us determine whether or not our efforts have or have not been successful; and second, it helps us determine if our assumptions about the system, displayed in the conceptual model, are correct or are in error (WCU 2002). These two functions of monitoring both lead to learning. As part of the feedback cycle of adaptive management, monitoring results are used to asses and alter (if necessary) a variety of aspects of the management plan: targets, goals, the conceptual model(s), strategies, and management activities (Wilson 1999).

Monitoring can be defined as “the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective.” (Elzinga et al. 1998). In adaptive management, monitoring is both driven by objectives, and is only initiated if opportunities for management change exist (Elzinga et al. 1998). Similarly, taking an adaptive management approach in the first place would also be futile in this case because you are unable to adapt after learning.

A solid link must be forged between monitoring, analysis and feedback, which are all central aspects of adaptive management. There is also a solid link between the monitoring information and it’s reaching the decision makers, which is important for the adaptive management cycle to work effectively (Palmer 2003).

Salafsky and Margoluis (2001) advise that a monitoring plan 1) describes how one will assess the success of the project interventions, in order to know whether the goals and objectives named in the management plan have been achieved, or what is needed to improve the plan or the project, 2) begins with an identification of the internal and external audiences and what information they will need, 3) next, lays out the monitoring strategies for data collection in order to meet the informational needs (including identification of indicators), and 4) includes the how, when, by whom, and where details of the data collection effort. Some of the more general steps for the design of an ecological monitoring program are shown in Box B.10, which is taken from Noon (2003). Another list of steps comes from Elzinga et al. (1998), and is displayed in Box B.11 (on the next page).

Box B.10. Steps in the design of a prospective environmental monitoring program. Taken from Noon (2003).

- Select an "optimal" set of condition indicators (detects stressors acting on resources)
- Determine detection limits for the condition indicators
- Establish critical decision values for the indicators (trigger points)
- Establish clear connections to the management decision making process

These steps are not required to be completed in this order, and there are many feedback loops within the steps, where you will return to a previous step before moving to a new step. Some of these planning activities (like assessing resources available for monitoring) can be completed earlier, such as during the management plan development section.

One could also foresee adding a few additional steps not mentioned in these two lists from Noon (2003) and Elzinga et al. (1998). First, after choosing ecological indicators (described further in the next section), you will need to assess the current status of those indicators in order to set a baseline state. These indicators may turn out to be the same features and components of the system that were studied in the conceptualization step earlier in the adaptive management planning process. At that time, existing baseline data could have been compiled, or additional baseline data collected. These data may serve as a good indication of the current state of the indicators (if an excessive amount of time has not elapsed or if there haven't been some large sorts of disturbances).

Box B.11. Six major steps and their associated sub-steps involved with the monitoring process, from planning to implementation and reporting results. Steps are modified from Elzinga, et al (1998).

Complete background tasks
- assess resources avilable for monitoring
- determine scale of monitoring
- determine intensity of monitoring (quantitative, qualitative, demographic)

Develop objectives
- select indicator(s) for each management goal
- identify sensitive attributes of the indicators
- specify direction and quantitiy of change
- specify time frame

Design monitoring methodology (See Figure B.3 for detail on this step)

Implement monitoring as a pilot study
- collect field data and evaluate field methods
- analyze pilot study data
- reassess time and resource requirements
- review monitoring plan and make any changes that are necessary

Implement and complete monitoring
- collect field data
- analyze data after each management cycle
- evaluate monitoring

Report and use results
- complete periodic reports
- complete final analysis and report
- circulate and/or publish report

Second, because resources are usually limited for monitoring activities, it is vital to prioritize the things which you would like to monitor. Prioritizing the species, populations, and communities to monitor can be performed using a variety of criteria. Examples include the rarity of a species, the sensitivity of the species to threats, the immediacy of those threats, the difficulty that will be involved with the monitoring of the entity, public interest, uniqueness or quality of the habitat, and many more (Elzinga et al. 1998).

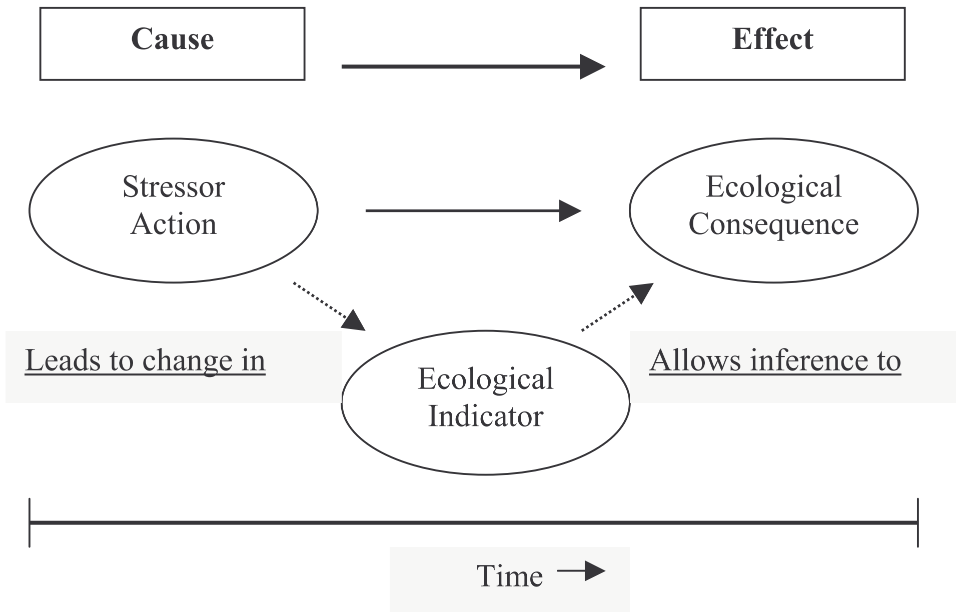
After priorities for what to monitor are set, one must decide at what scale and at what intensity they will be monitored. The scale describes the spatial extent over which the entity will be monitored, such as a single quadrat, or the entire range of a species as well as the resolution at which measurements will be made. The intensity of the monitoring relates to the complexity and the cost of methods used to collect information (Elzinga et al. 1998). This can range from low intensity, such as a single transect along which plants will be counted once every five years, to high intensity, such as estimating the demographic parameters (birth rate, death rate, and so on) of a population by monitoring each individual in it. This latter example would require much more labor, time, and money than the prior example.

Ecological indicators

An ecological indicator is defined as “a characteristic of an ecosystem that is related to, or derived from, a measure of [a] biotic or [an] abiotic variable, that can provide quantitative information on ecological structure and function. An indicator can contribute to a measure of integrity and sustainability” (AES 2004). Indicators are necessary to identify because it would be impossible to monitor every aspect of an ecological system. Therefore, parts of the system are chosen to monitor that are suspected to be indicators of the response and the overall condition of the system (Haney and Power 1996). Figure B.2 displays the fundamental role of the ecological indicator diagrammatically. The indicator represents a link of inference between the stressor-cause (i.e. natural disturbance, management action, etc.) and its ecological effect.

There are some important considerations in choosing appropriate and useful indicators to monitor. Noon (2003) asserts, “Even if a monitoring program is fully funded and implemented for many years, it will fail if the wrong indicators were selected. Thus, *the ultimate success or failure of the program may be determined by*

Figure B.2. Conceptual diagram of a prospective environmental monitoring program. Indicators are selected in the context of known or suspected stressors to the ecological system. Taken from Noon (2003).



this one step." Because the step of choosing ecological indicators is described as so essential, the following list of sets of critical considerations in the choice of indicators was compiled. In general, good indicators are characterized as:

- Appropriate, practical, and informative (NRC 2003).
- Relevant, practical, responsive, and of or reflecting an appropriate spatial and temporal scale (Jackson 2000).
- Relevant to restoration goals, related to the filling of knowledge gaps, related to models, important to stakeholders, possessing (if possible) a "normal" natural variability that is known, and technically feasible to monitor (NRC 2003).
- Responding quickly enough to a stressor to catch adverse changes in the system or target before they become irreversible (Haney and Power 1996).

It is also recommended that one or more indicators of long-term trends (such as climate fluctuations like El Nino or climate change, in general) should be included in the list of indicators that will be monitored, if possible (Haney and Power 1996).

One way to approach the selection of a suite of indicators is to use a hierarchical approach, where different indicators of the system response are chosen at all relevant levels of ecological organization for monitoring (NRC 2003). For example, ecosystem-level indicators (such as ecosystem driver indicators like weather cycles and precipitation), community-level indicators (such as species diversity), population-level indicators (such as dominance of an invasive exotic plant species, or abundance of an endangered animal species), and abiotic indicators (such as soil organic matter, soil nitrogen, or many other indicators) can be chosen (NRC 2003). These are just a few of the ways in which a hierarchical selection of indicators can allow you to monitor the system's responses to both management activities and changing environmental conditions, in a relatively comprehensive way (NRC 2003).

It would also be desirable to include indicators that reflect varying spatial and temporal changes in the system. For example, some bird species can signal changes at local scales, some at regional scales, and some can reflect changes over both scales (Haney and Power 1996). As another example, invertebrates tend to respond quickly to changes in management actions. Another example is vegetation, which can reflect both long and short term changes, depending on the specific vegetation used as the indicator (Haney and Power 1996). As you can see, the list of possible indicators can grow quickly in this attempt to cover all the bases. The list must usually be pared down, however, in order to remain feasible.

The scheme by which the indicators, once chosen, are monitored is also important and can have consequences for their ultimate utility. It is recommended that the indicators be monitored with an appropriate timing, frequency, and duration to be able to detect a response or a non-response (Nyberg 1999). Question such as the following arise: should monitoring an indicator be done at a certain time during a season or a year? Should monitoring an indicator be done once a month or once a decade? Should invertebrate traps (for example) be left out for one day or one week? These are just a few of the questions that will be relevant.

The monitoring and the indicators themselves should be done at and should reflect the appropriate spatial and temporal scales that match the scales of the targets, the major ecological processes, and the management activities (Wilson 1999). Finally, the timing of monitoring needs to account for or plan for any time lags that may be anticipated to occur between management activity or other relevant event and the effect becoming evident in the indicator(s) (Wilson 1999).

A few of the most relevant questions associated with the monitoring activities are presented in Table B.6 (on the next page), taken from Gaines et al. (2003). There will be different sorts of questions that are deemed relevant depending on which level of ecological organization is the focus. A sampling of the many possible monitoring methods that can be used to answer the monitoring questions is shown on the right of the table in Table B.4. Note that some methods can be used to answer more than one monitoring question.

Monitoring techniques

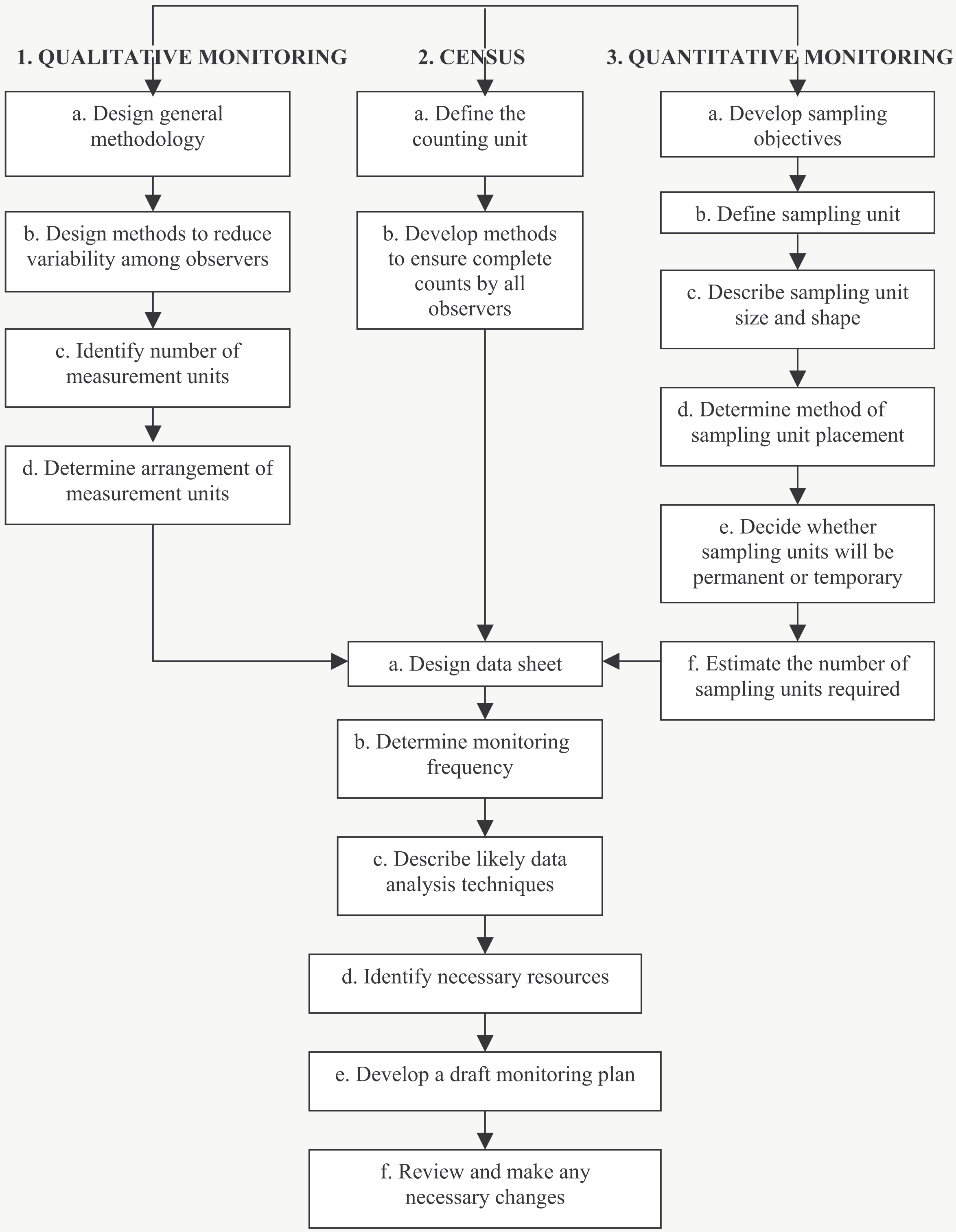
Monitoring can, in general, be separated into qualitative and quantitative techniques (Elzinga et al. 1998). Qualitative monitoring includes things like presence/absence assessment, site condition assessment, *estimates* of things like population size or level of dominance, assessment of population condition, and photo points, to name a few (Elzinga et al. 1998). Examples of quantitative monitoring are sampling, censusing, and demographic monitoring.

Table B.6. Monitoring questions and methods for each level of ecological organization. Taken from Gaines et al (2003).

Monitoring scale	**Monitoring questions**	**Monitoring methods**
Landscape level	Trends in landscape diversity	- Indices of landscape pattern - Historic reference condition - Remote sensing and GIS
	Trends in habitat availability and distribution	- Indices of landscape pattern - Historic reference condition - Remote sensing and GIS
	Trends in landscape elements (e.g. edge fragmentation, interior forest)	- Indices of landscape pattern - Historic reference condition - Remote sensing and GIS
Community or ecosystem level	Management actions or natural disturbance affects on species diversity	- Species diversity indices
	Function-role of species in community or ecosystems	- Functional group and guild analysis
	Level of protection of areas with high species richness	- Rapid assessment - GAP analysis
Species or population level	Species-population trends	- Abundance indices - Population estimates
	Affect of management actions or natural disturbance on a species-population	- Abundance indices - Population estimates
	Probability of species or population persistence	- Qualitative population viability analysis - Quantitative population viability analysis
Genetic level	Genetic diversity within a population-species	- Morphological variation - Allozyme analysis - DNA analysis
	Genetic diversity among populations	- Morphological variation - Allozyme analysis - DNA analysis
	Effects of management activities or habitat fragmentation on species diversity	- Morphological variation - Allozyme analysis - DNA analysis

The steps involved with designing the monitoring methodology to use for qualitative, quantitative, and census approaches are displayed in Figure B.3.

Figure B.3. Steps for 3 types of monitoring approaches. This Figure is also detail for the "Design monitoring methodology" step from Box B.11. Taken from Elzinga et al. (1998).



Because sampling "involves assessing a portion of the population with the intent of making inferences to the population as a whole" (Elzinga et al. 1998), questions of statistical rigor underlying these inferences become important. The following, taken from Elzinga, et al (1998), are a few of the statistical considerations that should be made explicit in each sampling objective:

- target level of precision
- power (the level of certainty you want that you will be able to detect a particular change given that it has happened)
- acceptable false-change error rate (the acceptable threshold value for determining whether an observed difference actually occurred or if the observed difference resulted from a chance event)
- the magnitude of the changes you are striving to detect

At the end of this process of preparing a monitoring plan, the result might resemble the outline of a sample monitoring plan presented in Box B.12 or B.13, or it could look quite different. As long as the essential elements of the plan are included, many formats are possible.

Common problems encountered in monitoring

Monitoring, although one of the most important steps in adaptive management and other forms of ecosystem management, can also become the Achilles heel that prevents a successful adaptive management approach. The most obvious reason is the cost of monitoring. Lee (2001) sums up this difficulty: "Information is expensive… Unfortunately, would-be adaptive managers have often jumped too quickly to thinking of information gathering as monitoring. That *is* what an adaptive approach leads to, but it should emerge from a skeptical appraisal of what kinds of information one can afford to collect…" This prioritizing can help lead to increased cost efficiency. However, no matter how much you prioritize your monitoring

Box B.12. Elements of a monitoring plan. Modified from Elzinga, et al (1998).

I. Introduction
Species, need for study, management conflicts.
II. Management objective(s)
Includes rationale for the choice of attribute to measure and the amount of change or target level.
III. Monitoring design
a. Sampling objective
Includes rationale for choice of precision and power levels (if sampling).
b. Sampling design
Describe the methods clearly. What size is the sampling unit? How are sampling units placed in the field? How many sampling units?
c. Field measurements
What is the unit counted (for desntiy)? How are irregular outlines and small gaps of vegetation treated (for line-intercepts)? How are plots monumented (if permanent)? Include all the information needed for someone else to implement or continue the monitoring in your absence.
d. Timing of monitoring
What time of year, both calendar and phenologically? How often?
e. Monitoring location
Include clear directions, maps and aerial photographs describing the study location, and the location of individual samplinf units (if permanent).
f. Intended data analysis appraoch
IV. Data sheet(s) example
V. Responsible parties
VI. Funding
VII. Management implications of potential results

activities and focus on the most important activities, good monitoring programs are costly (Franklin 1997).

In addition, there is the difficulty of deciding what to monitor, and how and where to monitor it in order to obtain representative, efficient, and effective measurements. These are technical questions that can be difficult to answer, even for a seasoned ecologist, and this can represent a barrier to effective monitoring for many land managers (Franklin 1997). Noon (2003) summarized some additional deficiencies that are commonly found in monitoring programs, and can serve to undermine their usefulness. These include:

- A minimal foundation in ecological theory or empiricism
- Little or no logic justified the selection of the condition indicators
- No obvious linkage to a cause-and-effect interpretation of the monitoring signal
- Critical indicator values that would trigger a policy response were not identified
- No connection between the results of monitoring and decision making
- Inadequate or highly variable funding

Noon (2003) also states "environmental monitoring programs are often discussed in abstract terms, have little theoretical foundation, try to measure too many attributes, have vague objectives and have no institutionalized connections to the decision-making process. The result has been a shallow comprehension of the need for, and components of, effective monitoring programs." Simply being aware of these pitfalls of monitoring plans should help the land manager avoid some of them. For example, by planning for and creating processes for linking monitoring results to decision making, such as through the cycle depicted in Figure B.4 (a few sections below), this pitfall may be avoided, strengthening the monitoring plan.

Implementing plans

Until now, all of the activities described have involved planning for this implementation step. It took a lot of time and energy, but produced only plans, and not results. The implementation step is when these plans become reality and the fruits of these planning activities are realized. Salafsky et al. (2001) offer "just do it!" as their number one piece of advice for this step in the process. They also add, "Adaptive management is not a theoretical exercise. Instead, it is fundamentally about taking action. As a result, the most critical step in the entire process involves implementing your management plan."

The implementation stage can be vitally important, but also challenging and frustrating, because it is the first time (other than the pilot monitoring period, if done) when the management and monitoring plans are put into practice. Any shortcomings will become obvious, and additional work will follow to change the plans and smooth out the rough edges. Also, this is the time when the management activities are judged against the goals and objectives (Meffe et al. 2002). And, old methods and ways will have to be cast aside in favor of following the new plans, which can be difficult when people are used to the status quo.

Salafsky et al. (2001) describe two common problems encountered with the implementation of the management plan. The first is the phenomenon of "planning paralysis" where the preoccupation with the numerous planning activities that must be completed before taking action makes switching gears into implementation a challenge. They call the second problem "model rigidity" where the time and effort spent creating the conceptual model(s) makes the planners regard them as "set in stone", rather than as the living, flexible documents they were intended to be.

Deviations from the original plan may be needed if special circumstances arise. It is a good idea to decide ahead of time what types of deviations will be accepted and what types won't, so as not to end up with management and monitoring practices that are highly deviant from the plans (Nyberg 1999). In addition, the deviations from the management and monitoring plans that do occur should be documented for future reference (Salafsky et al. 2001). This is part of good science – keeping track of the actual methods that were used.

It has been suggested that before a monitoring plan is approved for use that is go through a pilot period where it's strengths and weaknesses can be assessed and needed changes can be made (Elzinga et al. 1998). This also helps to prevent wasting resources on a monitoring approach which may turn out to not allow you to detect or measure what you would like to. After the pilot period, a series of important questions can be asked about the plan, such as the following, taken from Elzinga et al. (1998): Can the monitoring design be implemented as planned? Are the costs of monitoring within estimates? Do the assumptions of the ecological model still seem valid? And, for sampling situations, does the monitoring meet the standards for precision and power that were set in the sampling objectives?

If the answer to the last question is "no", then there are a number of options for adjustment in the monitoring design that can be made. These include reconsidering the design, re-assessing the scale, lobbying for additional resources to be devoted to this monitoring project, accepting lower precision, accepting higher error rates, or starting over entirely (Elzinga et al. 1998).

There are three general outcomes that can result from the pilot period implementation of the monitoring plan. Either the objectives of the plan were met, or they were not met, or the data were inconclusive (Elzinga et al. 1998). If the data were inconclusive, than the monitoring design should be altered. Identifying these faults or failures in this pilot period will inform the finalization of the plan.

Salafsky et al. (2001) suggest that a data management system be set up prior to the implementation of the monitoring plan, in order to ensure the data that is produced from the monitoring activities has somewhere to be organized and stored. The time that will be needed to manage the data need to be considered as well. If the amount of data collected is too great, or if the data management process is overly time consuming, the data will not be recorded and may be lost (Salafsky et al. 2001). Prioritizing and streamlining the types of and amounts of data that will be collected can help the first problem, and using a database such as Microsoft Access (which is fairly simple to use and can store many different sets of monitoring data) can help with the second issue.

Analyzing data

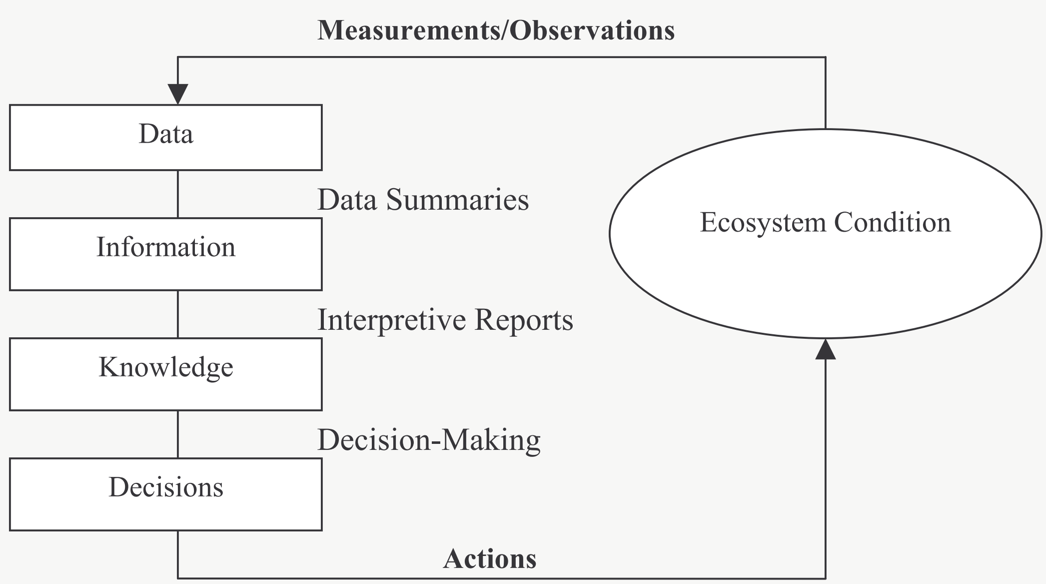
In this step, the data collected during implementation of the monitoring plans is analyzed and the information gained is used to evaluate the hypotheses posed in the management plan. Figure B.4 depicts the stepwise order in which you can summarize monitoring data, analyze and interpret it, report the results of the analysis, and make decisions based on the knowledge gained.

Data analysis is the transformation of raw information through analysis into useful and meaningful information (Salafsky et al. 2001). The two major questions that the data analysis should answer are:

- Did we achieve any of our objectives, and if not, why not?
- What does the information tell us about the hypotheses we posed earlier?

In keeping the specific objectives and hypotheses that were previously created in mind, one can avoid becoming overwhelmed by the data and all of the possible lessons it could reveal (Salafsky et al. 2001).

Figure B.4. Flow of monitoring information in the adaptive management cycle. Taken from Palmer (2003).



As mentioned previously, it is a good idea to analyze data on a regular, periodic basis to avoid it piling up into one exhaustive analysis period. Because most of the analysis will most likely consist of statistical treatments of the data, and because this analysis can be time consuming and require a period of learning about statistical data analysis techniques, breaking the analysis into smaller pieces can be a wise approach.

When it comes time to analyze the monitoring data and information that has been collected, there are a few general ways to do it. Visually, many different types of graphs can be used to interpret the nature of the data. The other major ways are statistical approaches. Statistics are extremely important in sample-based monitoring, which is often the bulk of the monitoring that will be done. Elzinga, et al (1998) point out "Statistics enables us to make management decisions even when we have access to only part of the information…The use of statistics enables you to derive an unbiased estimate of [a measure] and, more important, assess how good the estimate is." There are two basic statistical methods that are most often used to analyze data (Elzinga et al. 1998). The first is parameter estimation where a parameter is estimated (with confidence intervals), and this method is used for cases where the associated objective states a target or a threshold level of something to measure. The second method is the use of significance tests to compare two or more sets of information from different times or different areas, and this method is used when an objective aims to detect change, difference, or trends between things over time or space.

Communicating results

After analyzing the data, the results of the analyses should be documented and communicated to key audiences. The main way this is done is through the writing of reports, and more detail on this is included below. However, as both report writing and reading can take a substantial amount of time, and because reports tend to pile up (unread) on people's desks, other options for communicating results might be considered (Salafsky et al. 2001). For example, giving a presentation at a meeting reduces both the time of preparation (making a PowerPoint presentation almost always is faster than writing a report) and the time to communicate the results, as the audience only has to sit through the presentation to obtain the information. Presentations also offer an advantage over reports in that communication can flow both ways between you and the stakeholders. Because feedback is a valuable type of information that can be used for the final step in the adaptive management cycle, this is an attractive feature of this method of communication. Additional options for communicating with stakeholders were presented in Box B.5 previously.

If written reports are chosen as a way to communicate results, reporting of management successes and failures and results from monitoring can take many forms. Periodic summaries should be completed about once a year (Elzinga et al. 1998), giving you the chance to analyze the monitoring results at least this often (so analysis is not put off for too long), and to communicate the results to the project team and stakeholders. This also gives you the chance to assess the management and monitoring approaches and suggest changes to them.

Less frequent, but more formal, monitoring reports should also be prepared. This can be done after a specified monitoring period, or when an objective is reached, or when some major alteration to the management and monitoring approach is warranted (Elzinga et al. 1998). Much of the information in the report will come directly from the already prepared monitoring plan and from the annual summaries. A sample of the content of one of these more formal reports is shown in Box B.13, taken from Elzinga et al. (1998). The formal report is more suitable than the annual summaries for distribution to outside stakeholders, and can be a valuable record in case a change in personnel occurs for the project (Elzinga et al. 1998).

In a small, non-complex management setting, the data summaries and interpretive reports shown in Figure B.4 may only need to constitute a single document, and also, Box B.13. Sample outline of the content of a formal monitoring report. Taken from Elzinga et al. (1998).

Executive summary

I. Introduction

II. Description of ecological model

III. Management objective(s)

IV. Monitoring objective(s) and design

V. Data sheet example

VI. Management implications of of potential results

VII. Summary of results
   Inlcudes tables and figures communicating the results as well as general natural history observations.

VIII. Interpretation of results
   Describes potential causes for the results observed, sources of uncertainty in the data, and implications of the results for the resource.

IX. Assessment of the monitoring project
   Describes the time and resource requirements, efficiency of the methods, and suggestions for imporvement.

X. Management recommendations
   a. Change in management
      Recommends changes based on results and the management implications identified in Section VI.
   b. Change in monitoring
      Includes analysis of costs vs. information gain, effectiveness of current monitoring system, and recommended changes in monitoring.

XI. References
   Includes grey literature and personal communications.

XII. Reviewers
   List of those who have reviewed drafts of the report.

the monitoring data collectors may be the same people who do the decision-making. This presents far fewer challenges for the cycling of information in the adaptive management cycle than if the management entity is large and complex (or if the project is of a large size, such as an ecoregional level), where the decision-makers could be many levels removed from the monitoring activities and results, and where numerous reports and summaries may need to be prepared. The management entities charged with managing southern California grasslands are probably most often the former case, where the flow of information depicted in Figure B.4 has a better chance of being completed successfully.

Iteration: closing the adaptive management loop

Although it has seemed like *every* step in the adaptive management process has been presented as very important (and they indeed are), this one really is very essential (as Box B.14 describes)! It forms the essence of the entire adaptive management approach.

> Box B.14.
>
> "Finally, you've come to the last step in the adaptive management process. Despite all the hard work that you have done, this is not the time to sit back and relax. Instead, you have now come to the most crucial step in the whole process. It is now time to use the results of all your hard work. Unfortunately, all too often it seems that project teams don't make use of all the gold that they have mined and refined…To make full use of your gold, you have to use your results to adapt and to learn." - Salafsky et al. (2001).

Return to the conceptual models. Return to the assumptions that were identified in those models and to the hypotheses you posed based on those assumptions. Determine which assumptions have been confirmed, which have been proven false, and which need further testing to determine their validity. This assessment should lead to an analysis of the actions that are taken as management activities. Some key questions to ask at this point are the following:

- What new approaches could be used to answer additional assumptions?
- What new lessons have been learned about the system that can improve management actions in the next iteration of adaptive management?
- What were the surprises or crises encountered in the adaptive management cycle, and why were they not anticipated?
- What actions are no longer necessary, because certain assumptions have been either confirmed or denied?
- What management actions have been shown to be unnecessary or harmful, and therefore should be abandoned?
- How can the conceptual models be altered to reflect what was learned about the systems, the assumptions, and newly formed hypotheses?

- How should the project/management goals be changed (if at all) to reflect what has been learned?
- How should the specific management objectives be altered in response to either changes in the goals or in response to new information about how the existing goals can be attained?

If your results signal the need for change, then change is what needs to happen (Salafsky et al. 2001). The willingness to change is not only an integral part of the adaptive management approach, it is a necessity in a world that is itself constantly changing. The inertia that can build up from doing something one way for a long time can be difficult to stop, therefore planning from the beginning for the inevitability of change and how new information will be used to lead to change is important.

Management activities, the experimental set-up and other details of those activities, and the conceptual model are all areas that should be changed (if change is signaled) in response to the new information. Updating the conceptual model will help to document what has been learned as a record for the future, and to avoid making the same mistakes in the future (Salafsky et al. 2001), and helps to communicate the lessons to others (such as colleagues and other stakeholders).

Salafsky, et al (2001) state, “In a conservation project context, learning requires your organization to have a commitment to figuring out how to do your work better and to using and benefiting from your mistakes rather than hiding them.” Thus, the commitment to learning should not only come from a few people charged with a project, but instead is more successful if supported by the organizational culture.

In addition, the learning that takes place should focus on trying to improve or solve long term, problems, not just immediate ones (Salafsky et al. 2001). This type of learning has been termed “double-loop learning” which, “involves not only dealing with the situation at hand, but also changing the very fundamental ways in which the organization functions, so as to be able to deal with other similar situations in the future. Adaptive management is fundamentally about double-loop learning." (Salafsky et al. 2001).

As a final note, in case it has not become obvious at this point, we should stress that the adaptive management process described in these guidelines are not run through once – the steps that make up the cycle are gone through repeatedly over time. This is the key to *continued* learning and *continued* improvement in management (Salafsky et al. 2001).

Final thoughts

In conclusion, a list of some major lessons and pieces of advice that should be kept in mind while moving through the steps of adaptive management are presented in Box B.16. Each is explained further in Salafsky et al. (2001). They relate to characteristics of the people, projects and organizations involved with the adaptive management process.

> Box B.15.
>
> "…adaptive management should become the common standard. The basic idea behind it is so simple that it is hard to argue with it. Even if you don't do it perfectly, it is hard to argue that you shouldn't learn."
> -Dale Lewis, Zambia Admade Project, in Salafsky et al. (2001).

An additional principle to keep in mind comes from Salafsky et al. (2001) (Box B.15). Although the adaptive management process, when actually attempted, is not necessarily smooth, neat, or easy, and it can be frustrating, take a long time and effort, and can be messy, it is nevertheless gaining quickly in popularity, in practice, and even in success.

Box B.16. Eight principles to keep in mind while moving through the steps of adaptive management, from Salafsky et al. (2001).

Principle 1: Do adaptive management yourself
Perhaps the most important principle is that project team must be responsible for performing effective adaptive management.

- Involve regular project staff members
- Help people learn about adaptive management

Principle 2: Promote curiosity and innovation

- Innovate to survive in a changing world
- Start with managers at the top

Principle 3: Value failures

- Learn from your mistakes
- Create a safe-fail environment

Principle 4: Expect surprise and capitalize on crisis

- Use surprises to point to flaws in your understanding
- Use crises as opportunities for action

Principle 5: Encourage personal growth

- Hire people who are committed to learning
- Invest in helping staff develop skills and experiences

Principle 6: Create learning organizations and partnerships

- Promote organizational learning
- Build teams of project partners

Principle 7: Contribute to global learning

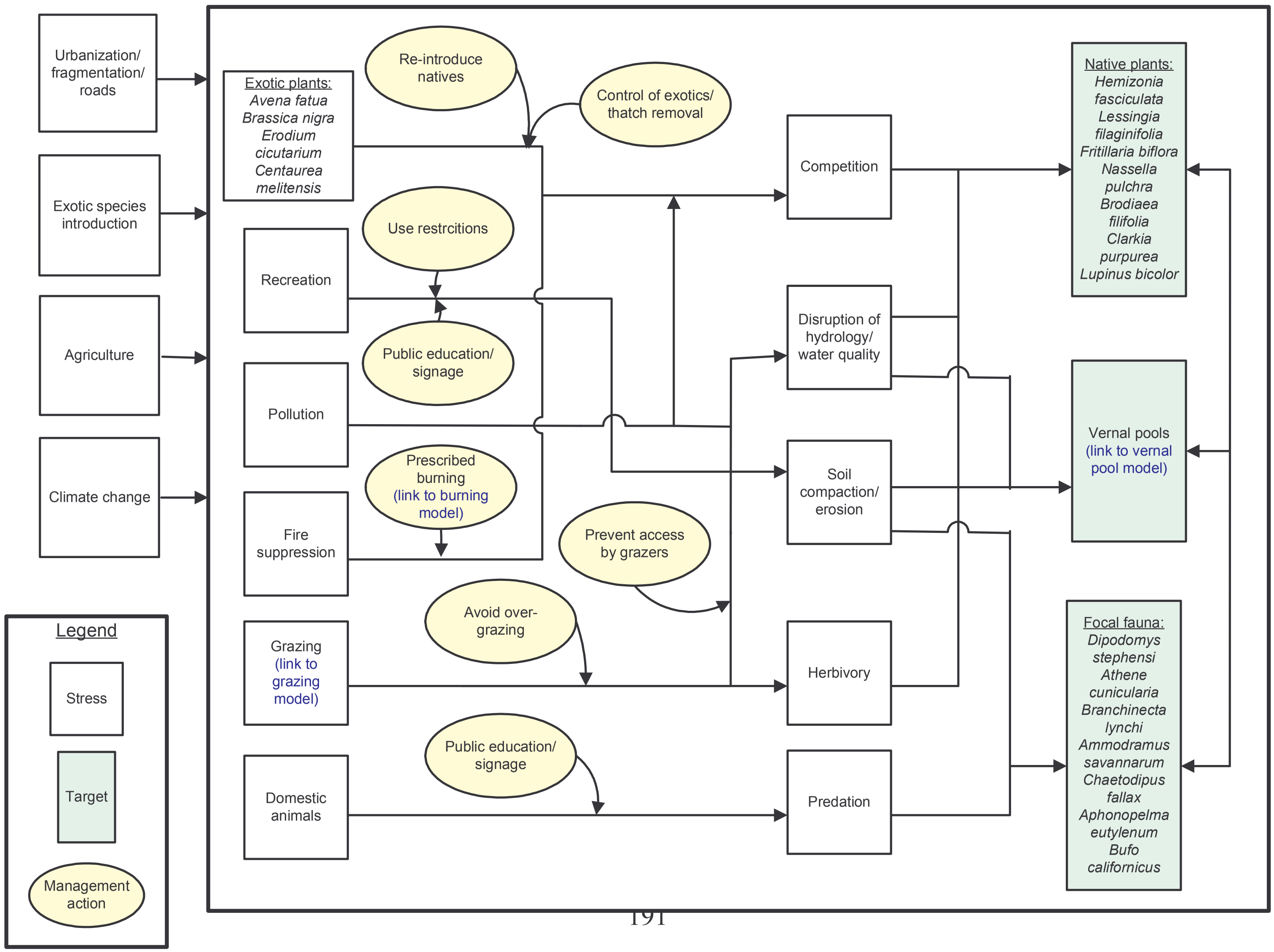
- Encourage everybody to do good science
- Get the word out to help other people find you

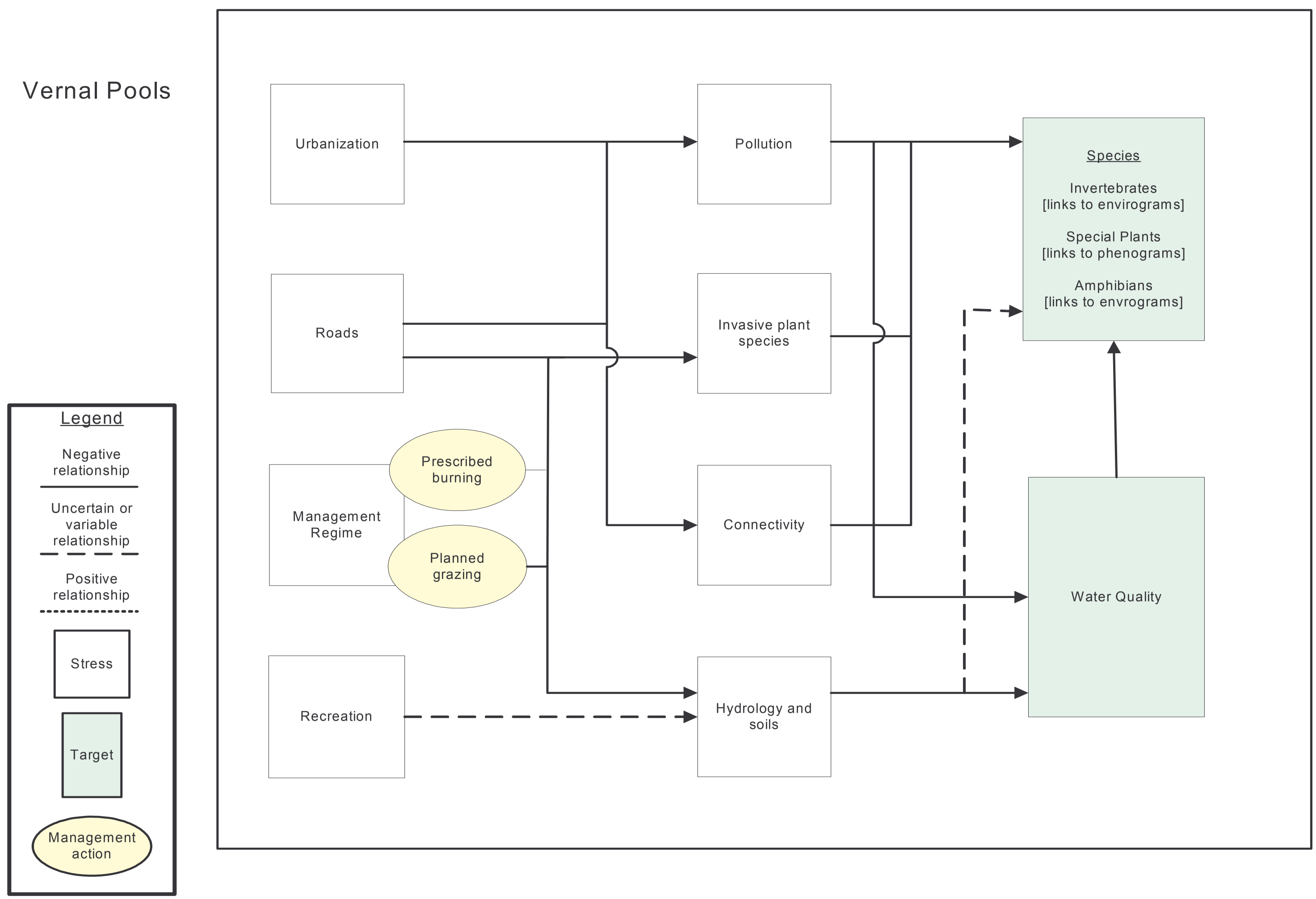
Principle 8: Practice the art of adaptive management

- Treat adaptive management as a craft
- Pay attention to your intuition
- Practice, practice, practice

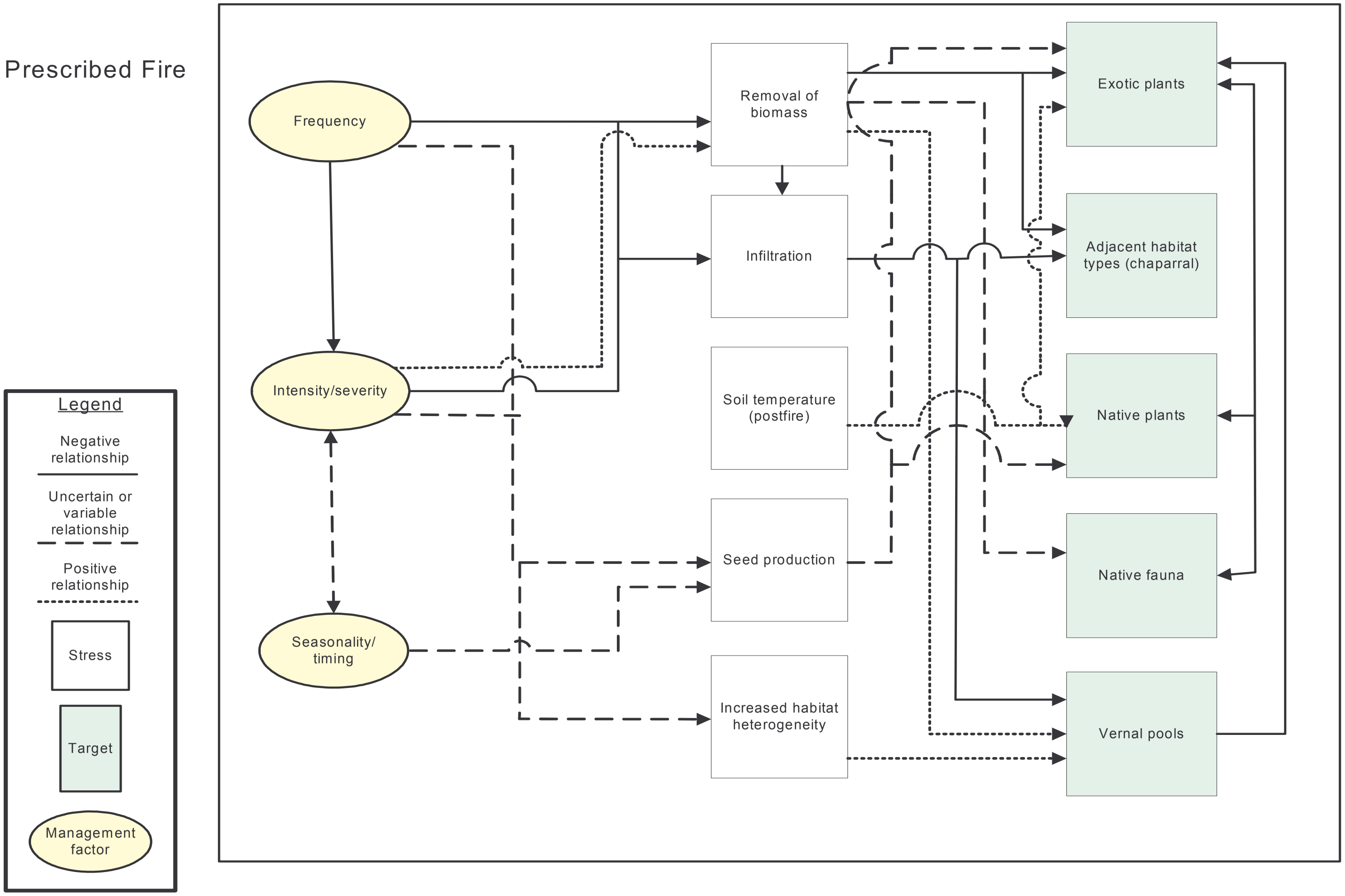
Appendix C: Conceptual Models

Regional Model

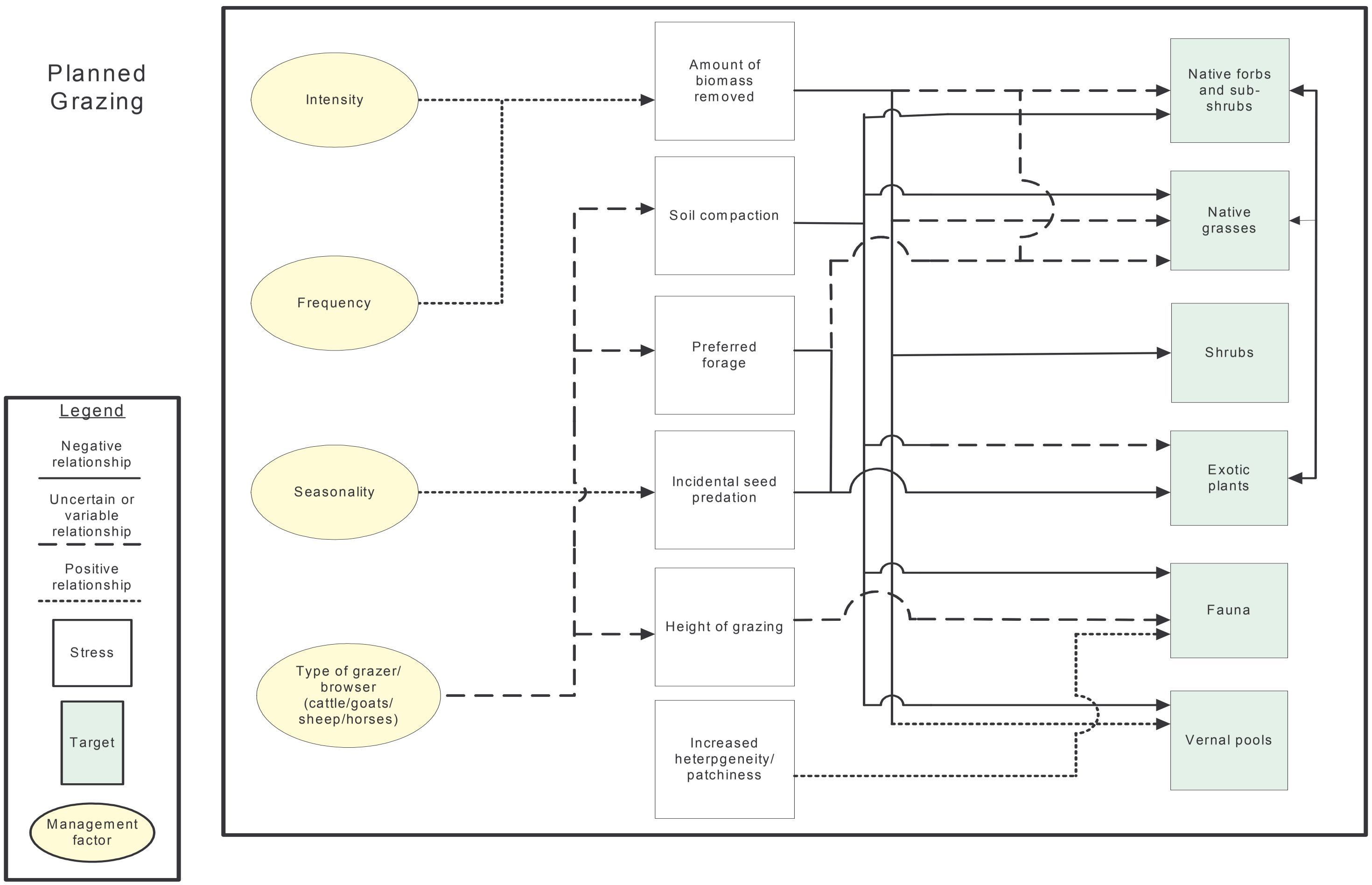



Vernal Pools
Legend
Negative relationship
Uncertain or variable relationship
Positive relationship
Stress
Target
Management action
Urbanization
Roads
Management Regime
Prescribed burning
Planned grazing
Recreation
Pollution
Invasive plant species
Connectivity
Hydrology and soils
Species
Invertebrates [links to envirograms]
Special Plants [links to phenograms]
Amphibians [links to envrograms]
Water Quality

Prescribed Fire

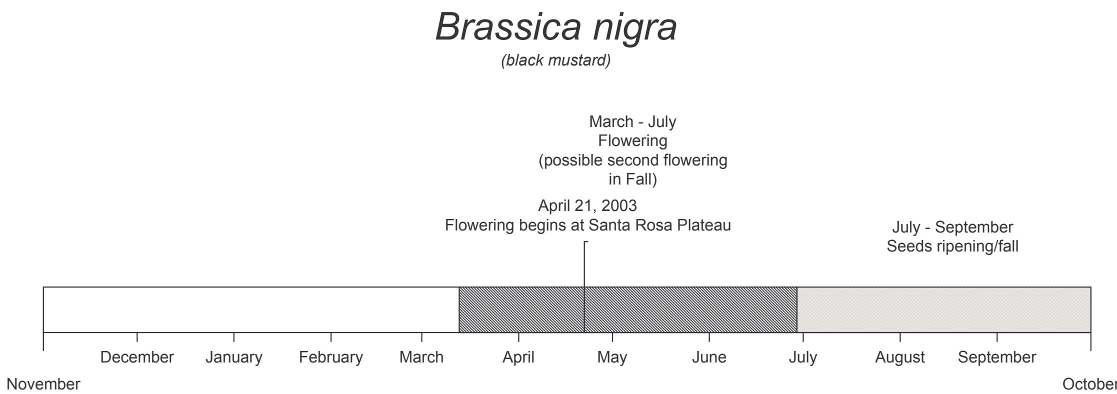


Planned Grazing



Appendix D: Phenograms

Black Mustard (*Brassica nigra*)



Other names
Brassica nigra (L.) Koch, Sinapis nigra L., trieste, wild mustard

Status
Global Heritage Status Rank: G?
National (United States) Heritage Status Rank: NE
Federal Endangered Species Act: No special status
California State Endangered Species Act: No special status

Distribution
Black mustard was introduced to the United States from its native Europe, and is now a common weed on cultivated lands, roadsides, other disturbed sites, and on dry grassy slopes (Munz and Keck 1973). It is abundant in most of the California Floristic Province below an elevation of 4500 feet (Charters 2004). It is thought by some to have been widespread in California by the time of Spanish occupation (Robbins et al.).

Natural History
Description
Brassica nigra, or black mustard, is an annual forb/herb belonging to the mustard (Brassicaceae) family. Mustards produce stemmy, dense growth (Madson 1951). Estimates of the height of growth of black mustard range from an average of 3-4 ft (magdalin.com 2000-2003) but some estimate it can reach 8 ft in height (Charters 2004), with a width of 2 feet across on average (ibiblio.org 1997-2000).

The plant produces small yellow flowers and seedpods that are long and pointed, and that contain roughly 12 dark brown seeds each (magdalin.com 2000-2003). The petals are about 7-11 mm long and the seeds are about 2 mm wide (Jepson 1993). These seeds are edible, and in fact, black mustard is one of the mustards that are cultivated to produce mustard (including in California). The leaves and lower stems are covered in bristly hairs, and the 1-2 cm long seedpods surround the flowers in dense clusters (Sievers 1930).

The seedlings of the black mustard plant have broad cotyledons, which are kidney shaped and have a deep notch at the tip. The first true leaves are deep green on top and lighter colored underneath (Fischer et al. 1978).

Ecology
Black mustard possesses many attributes of a weed, such as rapid growth, copious seed production, and an ability to grow in the absence of mycorrhizal fungi and other soil microorganisms (Riefner et al. 2000). The plant can grow to a bulk of 12,000 pounds of biomass per acre (UCSAREP 2004). The plant is a C3 weed, a winter annual, and has seeds that have been shown to survive in the soil for over 20 years (CWC 1985).

Habitat
Black mustard can grow in a variety of soil types: it grows well in sandy, loamy, and clay soils (but not very heavy clays), as well as in acidic, neutral, and alkaline soils, although it grows best in very acidic soils (ibiblio.org 1997-2000). The plant tolerates soil pH between 4.9 and 8.2 (Duke 1983). It requires well drained but moist soil.

The plant can also grow in a variety of climatic conditions (Duke 1983). It can grow in conditions of no shade or semi-shade, and tolerates harsher maritime weather as well. Annual precipitation ranges of 30-170 cm and annual average temperature ranges from 6-27 degrees C are tolerated by the plant (Duke 1983).

Reproduction
Black mustard plants bloom beginning in March or April, until July (Munz and Keck 1973; Charters 2004; ECNCA 2004). Seeds are then produced from July to September (ibiblio.org 1997-2000).

The plant's flowers are scented and are hermaphroditic, possessing both male and female organs and therefore the plant is able to self-fertilize (ibiblio.org 1997-2000). The plants are also pollinated with the help of bees and flies.

Management/Threats
Black mustard is one of the most widespread plants in southern California (Charters 2004), and due to its extreme success as a weedy exotic, it is often the target of management activity.

One report describes the restoration activities occurring to eradicate a single-species, 6-foot high, dense forest of black mustard from a coastal area near San Onofre Beach in southern California, and is summarized here (Riefner et al. 2000). The high fertility soils of the area (both from natural causes and form agricultural runoff, and which the natives plants do not need) caused there to be an annual eruption of the plant, which out-competed the natives for water and sunlight. The restoration work at the sites was ultimately highly successful in eradicating most of the dense areas of black mustard, and the approach was 3-pronged. The restoration team inoculated the soils with mycorrhizal fungi (which was absent under the mustard stands), planted native perennial seed with a technique called land imprinting, and planted islands of native bunchgrasses that had been grown and inoculated with mycorrhizae in pots.

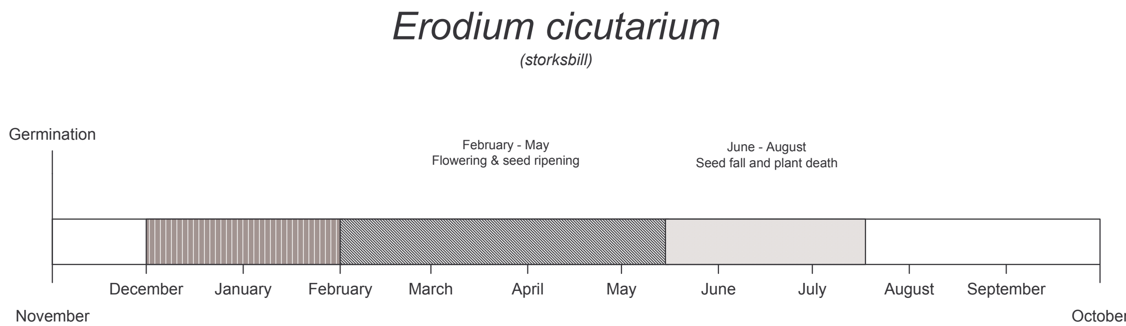
The mycorrhizal network provided a needed component in the soil for the native perennials. Mycorrhizae help to establish natives and suppress exotics, and help to maintain or build soil structure and promote a healthy soil microflora (Riefner et al. 2000).

Unsuccessful attempts at the San Onofre sites included herbicide application, and mowing followed by herbicide application. However, mowing followed by leaving the dead material in place and imprinting native seeds on top of it was successful in suppressing the mustard. California brome grass (*Bromus carinatus*) was a prominently successful native perennial at the site, and not only germinated well after imprinting under the dead mustard mulch, but also propagated the mycorrhizal network.

The mulch served to increase the abundance of soil microbes, which then (the restoration team asserts) consumed the soluble nitrogen in the litter and the soil, depriving future generations of mustard of the soluble nitrogen that fueled their rapid growth. Once the native perennials became more established, their root networks and the mycorrhizae would take over the job of the mulch, taking up the soluble nitrogen and passing it to the native plants rather than the mustard.

As far as using other techniques to control the plant, grazing of mustards is done, and mustards are described as an important fodder crop (Horn 1985), however, the seeds and the seedpods of black mustard have been shown to be toxic to grazing animals when eaten in large quantities (ibiblio.org 1997-2000). Black mustard rapidly drops its seed once they become ripe (ibiblio.org 1997-2000). This could indicate that it is important to target the plant before seed ripen. In general, mustards are sensitive to herbicides such as glyphosate, 2,4-D and other broadleaf herbicides (UCSAREP 2004). Flowering mustards can grow back moderately after mowing, and will flower again and set seed if they do re-grow (UCSAREP 2004).

Storksbill (*Erodium cicutarium*)



<u>Other names</u>
Erodium cicutarium (L.) L'Her. ex Ait., pin clover, alfilaria, alfileris, pin grass, redstem storksbill, filaree, redstem filaree, cutleaf filaree, purple filaree, cranesbill, heronbill.

<u>Status</u>
Global Heritage Status Rank: G?
National Heritage Status Rank (United States): NE
Federal Endangered Species Act: No special status
California State Endangered Species Act: No special status

<u>Distribution</u>
Worldwide, Erodium cicutarium occurs below latitudes of 70 degrees north and south in Eurasia, North America, South America, central and southern Africa, New Zealand, Australia, and Tasmania (Hulten 1968). The plant is a European weed naturalized in the southwestern United States and Mexico (Dictionary.com 2004). The plant is also widespread outside of California throughout the United States, but is not found in Florida or Louisiana (Hulten 1968; Jepson 2003).

The largest populations of Erodium cicutarium in North America are found in California in annual grasslands (USFS 1937; Heady 1977). It was one of the very first exotic plants to invade North America, in the early 1700's by Spanish explorers (Webb et al. 1988).

<u>Natural History</u>
Description
Erodium cicutarium is a forb/herb in the Geranium family that can be either annual or biennial (USDA-NRCS 2004). Depending on the climate, the plant can be either warm or cool-season (Munz and Keck 1973; Urns 1973), although it is usually a winter annual (Duke 2001).

Young plants have leaves that form a rosette at the base, and older plants have hairy, dark green leaves up to a foot long, but that are usually 1-5 inches long. The plant's styles are 1-2 inches long, coil in a mature plant, and wrap around the base of the fruit (USFS 2004b). The adult plant has reddish colored stems (Dictionary.com 2004). The plant produces flowers that are purple with red at the base. The slender fruits it produces are sharp and stick up straight (hence the nickname pin clover). The fruit produced are a 0.5-1.5 inches length, containing ellipsoid seeds 0.1-0.2 inches in length (Duke 2001), and that are pinkish-tan in color.

Ecology

Rodents, desert tortoise, big game animals, and livestock eat the Erodium cicutarium plant, and the seeds it produces are eaten by game birds, songbirds, and rodents (USFS 2004b) The annual productivity of the plant is highly dependent on soil moisture, which relies on rainfall. The plant is also negatively affected by air pollutants, especially sulfur dioxide, and even has been found to be reduced in number in southern California ranges because of this pollutant (Thompson et al. 1980).

Erodium cicutarium is characterized as a pioneer on disturbed sites. It is also a residual or secondary colonizer on because it can establish from seeds on site as well as from seeds carried by animals (Felger 1990). In annual grasslands, the plant does best in early to mid stages of the community development, and displays an intolerance of mulch layer buildup characteristic of older communities (Biswell 1956). When this happens, the plant is often replaced by ripgut brome (*Bromus diandrus*) and slender wild oat (*Avena barbata*).

Habitat

Erodium cicutarium is most often found on disturbed sites and in grassland and shrub land below an elevation of about 7000 ft (Jepson 2003). It can also be found in a variety of other habitat types, such as desert areas and riparian areas. In riparian areas, the plant is an indicator of a recent or frequent disturbance (Lisle 1989). It prefers open conditions, but will tolerate some shade, albeit with some loss of vitality (Bentley and Talbot 1948).

The plant grows in soils that are well drained, ranging from clay to loamy to sandy, and tolerates moderately acidic to moderately alkaline soils (Biswell and Gilman 1961; Brotherson et al. 1987). Because the plant is a native to Mediterranean climate, it flourishes in the southwestern United States, but will also tolerate a range of climates including warm and tropical to cold and rainy (USFS 1937). It can also grow in snowy regions because its fast life cycle will be completed before frost sets in.

Reproduction

Erodium cicutarium generally flowers in California from February to May (Jepson 2003). In California, plants germinate in late fall (with the onset of the first rains). At one location in California (O'Neal, CA, located near Fresno), in the early part of the century, it was recorded that for Erodium cicutarium, germination commenced in November, the early leaf stage occurred in December, flowers bloomed in March, seeds ripened in May, seeds disseminated in June, and the plant died in July (Gordon and Sampson 1939). The timing of these events will vary based on location and climate.

The plant reproduces sexually, and germination is initiated with seasonal rains, and when soil temperatures are roughly 21 degrees C in the day and 4 degrees C at night (Juhren et al. 1956). Heavier rains bring about higher rates of germination (Biswell and Gilman 1961). The styles uncoil from around the seed when moist, and drive the fruit into the ground (Felger 1990), to depths up to inch. Two to four months following germination, the plant reaches sexual maturity (Griffin 1974). Seeds can be carried by animals and cached in burrows by rodents, and seeds in the seed bank can remain viable for many years (Burgess et al. 1991).

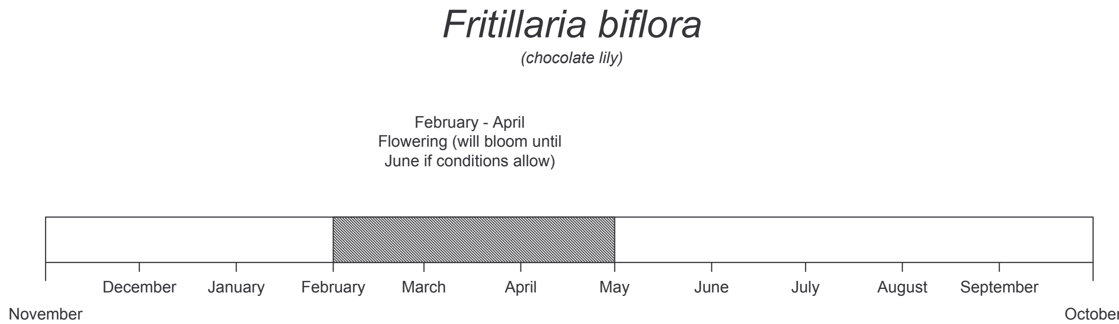
Management/Threats

The plant is used as an important forage for cattle, horses and sheep in southwestern U.S. states (USFS 1937), and the plant is characterized as having good palatability for cattle and sheep in California (Robbins et al.; USFS 2004b). Under heavy grazing pressure, the plant does well – when grazers eat the fruits, the plant can quickly produce new stems with new fruits, which are lower to the ground and inaccessible to horses and cattle (Humphrey 1950).

Frequent prescribed burning can favor Erodium cicutarium, and other forbs, over annual grasses (Biswell and Gilman 1961; Hulten 1968). It helps to remove the mulch layer that can inhibit the growth of the plant (Biswell and Gilman 1961). During the first growing season after a fire, the density of the plants is lessened, but their biomass is increased (Callison et al. 1985).

Moderate fire can kill mature plants, but seedlings have been known to survive light to moderate fires typical of grass fires, especially if protected under a litter layer. Seeds under a litter layer can survive moderate fire. Severe fire will kill seeds, even under the litter layer, but will not kill seeds that are buried a half-inch or more under the soil (USFS 2004b). Dead Erodium cicutarium plants contribute to fuel loads.

Chocolate Lily (*Fritillaria biflora*)



<u>Other names</u>
Mission bells, Cleopatra of the fritillaries, black fritillary.

<u>Status</u>
Global Heritage Status Rank: G3G4
National Heritage Status Rank (United States): N?
State Heritage Status Rank (California): S?
Federal Endangered Species Act: No special status
California State Endangered Species Act: No special status

<u>Distribution</u>
The chocolate lily is endemic to California and is found mainly in coastal counties of California and Baja California, Mexico (Reiser 1994).

<u>Natural History</u>
Description
The chocolate lily is a perennial forb/herb bulb in the lily (Liliaceae) family, and is native to California (USDA-NRCS 2004). It is an early spring-blooming and has a short light green stem with oval leaves about 5 inches in length. The plant's flowers are bell-shaped and brownish-purple, with green and purple coloring on the inside (Charters 2004). The plant can grow to a height of 16 inches (Charters 2004).

Habitat
The chocolate lily grows in mesic areas in coastal sage scrub, chaparral, and perennial grasslands (Reiser 1994). The plant prefers heavy clay soils in open slope areas, mesas, and serpentine barrens below 3000 feet elevation (Charters 2004).

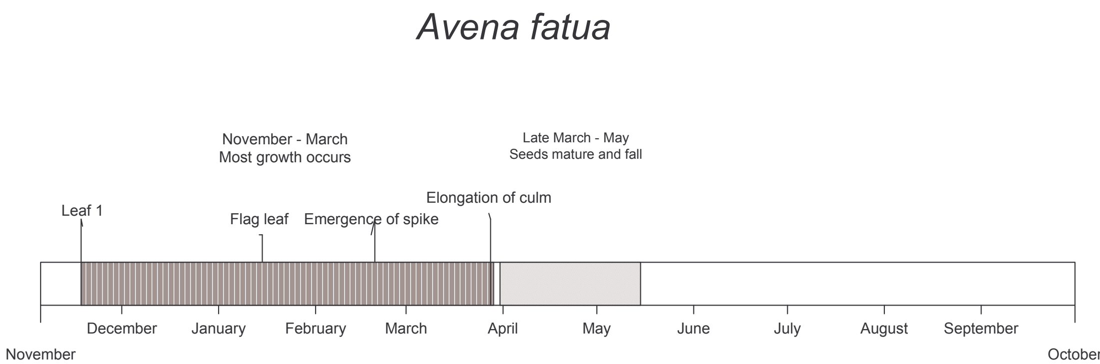
Reproduction

The chocolate lily blooms typically from February until April, but if appropriate rainfall and temperature conditions persist, it can bloom as late as July (Charters 2004).

Management/Threats

The chocolate lily is uncommon and is severely declining in some areas of California. In coastal central California, the species is more abundant, but populations in San Diego, Orange and Riverside counties are diminishing, and some suggest these populations should receive legal protection (Reiser 1994).

Wild Oats (*Avena fatua*)



<u>Status</u>
Global Heritage Status Rank: G?
Federal Endangered Species Act: Not listed
California State Endangered Species Act: Not listed

<u>Distribution</u>
This species is found throughout North America (NatureServe 2003).

<u>Natural History</u>
Description
This plant is an annual herb in the grass family.

Ecology
This plant is not native to California. It is listed by CalIPC on the Annual Grasses list, which lists plants that are widespread and abundant in California and pose a significant threat to wildlands (Anderson 1999).

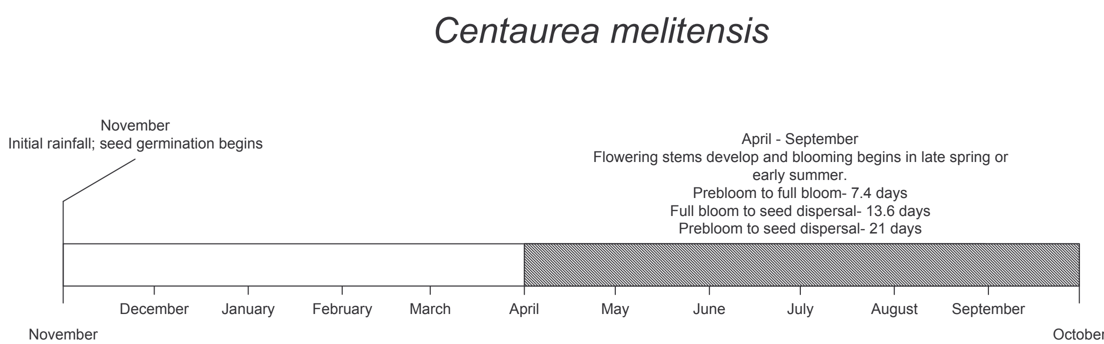
Habitat
This plant is found at lower elevations in California and is common on coastal slopes and in coastal sage scrub communities. It is generally found on deeper soil and at disturbed sites (Anderson 1999).

Reproduction
This species begins flowering in late February or early March, and seeds mature and fall from April to May (Cudney 1989). Wild oats are capable of vegetative reproduction, but reproduce primarily by seed (Calpas 2001).

<u>Management</u>

Calpas (Calpas 2001) recommends mowing for the control of wild oats. Mowing should be performed when the majority of individuals have reached the shot-blade stage. Early mowing can allow regrowth and consequent seed development. Mowing can be an impractical option on rough terrain, however. Burning during the shot-blade stage would likely have the same effect, with the added benefits of mulch removal.

Tocalote (*Centaurea melitensis*)



Status
Global Heritage Status Rank: G?
Federal Endangered Species Act: Not listed
California State Endangered Species Act: Not listed

Distribution
This plant is found throughout the southwestern United States (NatureServe 2003).

Natural History
Description
This species is a winter annual found throughout California, and which is especially abundant in the Central Valley region. This plant has yellow flowers and long spines near the flowerheads (DiTomaso). The corolla is generally between 10 and 20 millimeters in size, and the spines are five to 10 millimeters long (Jepson 1993).

Ecology
This species, as well as all other species of Centaurea found in California, is not native to California. It is listed by the California Invasive Plant Council (CalIPC) on list B, which lists "wildland pest plants of lesser invasiveness" (Anderson 1999).

Habitat
This species can survive in most southern California habitats with the exception of deserts and habitats above 7000 feet. This plant prefers full sunlight and well-drained soils (DiTomaso 2004).

Reproduction
This star thistle generally begins flowering in April and continues through September. No germinable seeds are produced until two percent of seedheads have commenced flowering (Benefield 2001). Once mature, seeds are transported by animals and

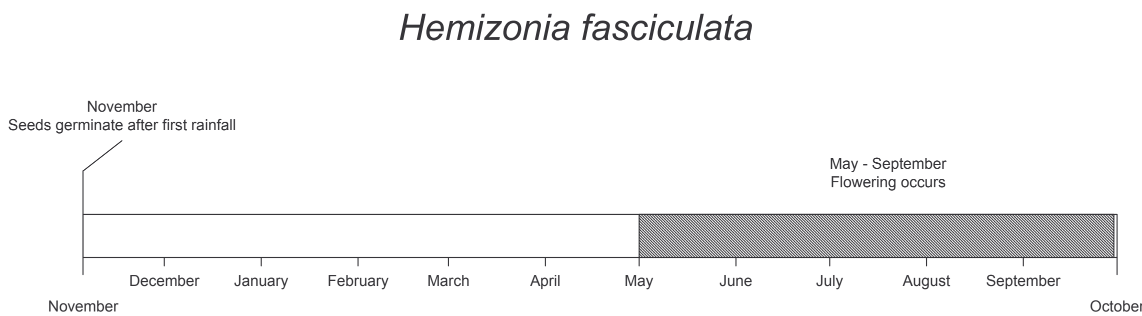
sometimes humans. Short bristles on the exterior of the seed are covered with microscopic barbs that adhere to fur and clothing, which allows seeds to disperse, although seeds generally do not disperse farther than a few feet (DiTomaso 2004).

Management

The University of California's Weed Research and Information Center website offers an excellent summary of control options (http://wric.ucdavis.edu/yst/manage/management17.html).

Burning and mowing can both be used to control this species effectively, but must be implemented during the very early flowering stage to obtain fullest control (before more than two percent of spiny heads begin to flower). Due to tocalote's spiny nature, livestock often avoid grazing in heavily infested areas, which makes using grazing as a technique to control this plant a challenge. However, grazing can be used to control this species if applied very early in the season when this plant is still palatable to most grazers. Grazing will be most effective from the time the plants begin to bolt to the time when the spiny seedheads begin to bolt. Goats can be used to graze this species later into the season (DiTomaso 2004).

Slender tarweed (*Hemizonia fasciculata*)



<u>Status</u>
Global Heritage Status Rank: G4
Federal Endangered Species Act: Not listed
California State Endangered Species Act: Not listed

<u>Distribution</u>
This species is found outside California, but is restricted to western North America (CalFlora 2004).

<u>Natural History</u>
Description
Slender tarweed is a sticky annual herb with yellow flowers. It is native to California (CalFlora 2004).

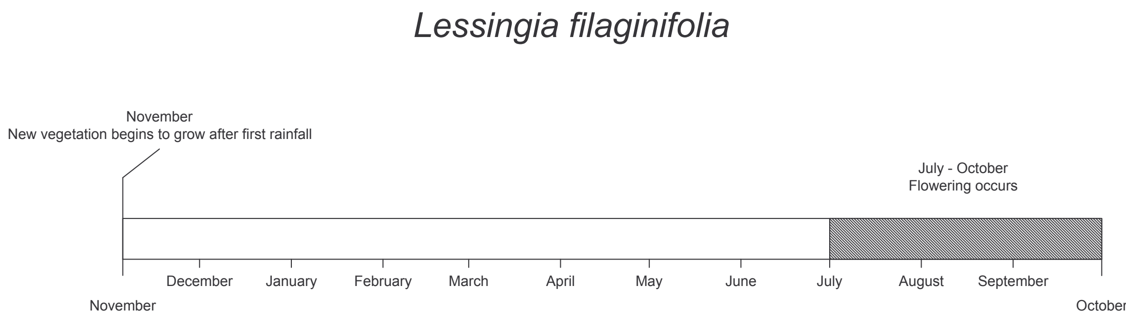
Ecology
Slender tarweed grows a deep taproot and so can utilize resources unavailable to Mediterranean grasses. This allows this species to bloom later than most other California grassland plants. The sticky resin coating on the outside of the plant serves to prevent water loss as well as to repel herbivores (Strong 2000).

Habitat
This plant is found at elevations below 1000 feet in California. It is most commonly found in coastal sage scrub, dry coastal grasslands, and areas of oak woodland (Armstrong 2004; Charters 2004).

Reproduction
This species blooms between May and September (Charters 2004).

<u>Management</u>
This tarweed does very well in open areas and is very competitive with exotic annuals. It is often found in disturbed areas (Armstrong 2004).

California Aster (*Lessingia filaginifolia*)



<u>Status</u>
Global Heritage Status Rank: G?
Federal Endangered Species Act: Not listed
California State Endangered Species Act: Not listed

<u>Distribution</u>
This plant is found throughout southern California and along the northern California coast. It is rarely found outside California (CalFlora 2004).

<u>Natural History</u>
Description
The California aster is a native perennial with lavender flowers with yellow centers (LasPilitasNursery 2004).

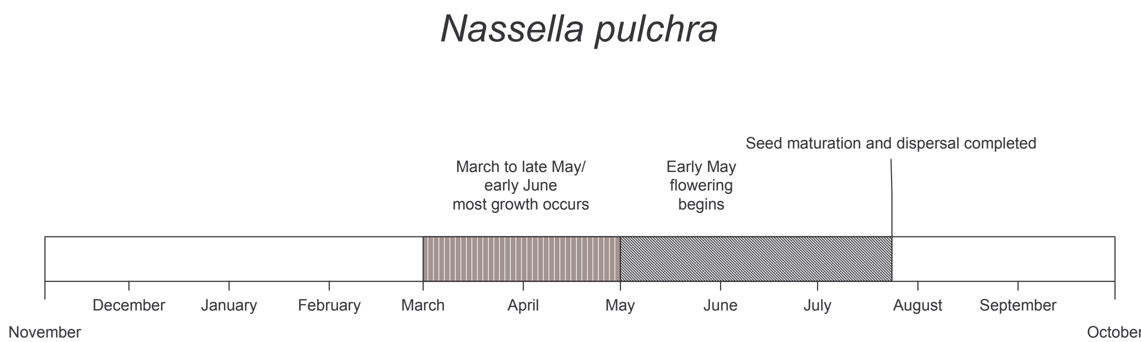
Ecology
This plant is stress and summer deciduous, and usually loses its leaves after flowering (LasPilitasNursery 2004).

Habitat
This aster's range extends from the California coast inland up to 8000 feet in southern California .

Reproduction
This aster generally flowers between July and October in southern California (Charters 2004).

<u>Management</u>
Several species of butterfly utilize this plant as a food source (LasPilitasNursery 2004).

Purple Needlegrass (*Nassella pulchra*)



<u>Other names</u>
Purple stipa, Purple tussockgrass

<u>Status</u>
Global Heritage Status Rank: NE
Federal Endangered Species Act: No special status
California State Endangered Species Act: No special status

<u>Distribution</u>
Purple needlegrass occurs on the west side of the Coast Ranges from northern Baja California north to the Oregon border. The species also occurs in the Central Valley and the foothills of the Cascade Ranges and Sierra Nevadas, and on the Channel Islands. It is native to California, and it is also found outside of California, but is confined to western North America. It occurs in grasslands, oak and pine woodlands, mixed evergreen forests, chaparral, and coastal scrub. It is most prominent in the California prairie or valley grassland (US Forest Service Edyta which year?)

<u>Natural History</u>
Description
Nassella pulchra is a monocot in the family Poaceae. It is a perennial forb. This bunchgrass possesses tough basal leaves that stay green most of the year. Culms are 24 to 39 inches tall, producing an open, nodding panicle 4 to 8 inches (10-20cm) long. Leaves are 0.03 to 0.14 inch wide. Each seed has strong purple shading and a long, thread-like awn attached, which makes the seed resemble a needle and thread. The species expands vegetatively when fragmented. Stands with fire and grazing exclusion are likely to be low density with larger individuals and more litter accumulation. With fragmenting disturbance, stands are higher density when small and less litter accumulation, at least in the short term. Bunches are roughly circular when undisturbed and more irregular with fragmenting disturbance. Purple

needlegrass is mycorrhizal and has a rooting depth of at least 25inches in deep soils. However, roots can extend down 20 feet and tap the soil moisture in drought conditions so effectively that large, older plants can out-compete young plants nearby. These plants can live as long as 200 years, and perhaps hundreds more. One study found mortality of mature individuals was 2 to 6% annually over a 7-year period. Eventually, the plants space themselves relatively far apart so that all can survive droughts (U.S. Forest Service Edyta which year?)

Ecology
There is a general agreement that *Nassella pulchra* is suppressed by competition with nonnative annuals. However, invasion by nonnative grasses and forbs has been less complete on serpentine soils. Competition from exotic annuals restricts growth and flowering of purple needlegrass more than intra-specific competition; intra-specific competition decreases productivity significantly only in the absence of exotic annuals. Both inter- and intra-specific competition affected flowering culm production more than vegetative production (Dyer 1993).

Purple needlegrass response to disturbance is unique. It is seldom present on formerly cultivated sites, regardless of grazing history. This species is well adapted to light grazing and defoliation by fire but not to high-intensity continuous grazing, particularly under drought conditions (U.S. Forest Service which year?)

Habitat
Purple needlegrass habitats occur in areas with a Mediterranean climate of mild, moderately wet winters and warm to hot dry summers. Where purple needlegrass occurs in mesic grasslands or in the understory of woodlands, chaparral and coastal scrub, shrubs may gradually exclude herbaceous vegetation in the absence of periodic disturbance. In a wide-ranging survey of northern California, very few purple needlegrass individuals were found in areas with more than 50% cover of woody species.
The plant's growing season is 7 to 11 months long. This species occurs on a variety of soil types but is well adapted to those with high clay content, where it is know to outcompete exotic annuals (Stromberg 1996). It thrives in deep, well-drained soils, and grows well where nonnative annuals are suppressed and is generally more dominant on serpentine-derived soils than on other soil types.

Reproduction
Nassella pulchra is pollinated by wind. It produces large quantities of viable seed. Under favorable conditions, 2-year-old plants are able to produce see. In dense healthy stands seed production may be up to 227 pounds per acre. Defoliation from grazing or fire during periods of rapid growth or flowering may decrease seed production. The seed has a twisting awn and is pointed, which increases self-burial. Seed banking is relatively low compared to that of associated nonnative annual grasses. Reported germination rates are varied. Gulmon (1992) reported germination

rates from 80 to 93.7% on leached litter, fresh litter, and topsoil. Ahmed (1983) found mean germination rates ranging between 30 to 75% for seed collected in summer and germinated in Petri dishes in October. Germination has been shown to be reduced and slower in the presence of annual competitors, which can further reduce the competitive ability of the species in the presence of exotic annuals.

Fire may increase germination and emergence in the first postfire growing season. Seedling success is influenced by climate, competition from annuals, grazing intensity and duration, and fire.

Summer drought and cold temperatures in winter induce dormancy. Vegetative growth is greatest from March through late May or early June, depending on the onset of drought. Vegetative growth increases with precipitation in the fall, which occurs in November. Flowers begin to develop in early May, and seed is mature and dispersed by late July. The length of time from flowering to seed ripening is similar to that of exotic annual grasses, but those species begin flowering approximately 1 month earlier (U.S. Forest Service which year?).

Management/Threats

Purple needlegrass is an important source of forage for livestock in California. Valley and foothill grasslands and savannas comprise only 15% of California's land area but are now about 80% of the land used by livestock. This species has a moderate protein value and is highly palatable to livestock and wildlife (U.S. Forest Service which year?).

Livestock grazing can increase purple needlegrass cover and reduce that of nonnative annuals (Bartolome 1981, Edward 1992). One study noted a decrease in purple needlegrass cover from 65 to 10% with only several years of grazing exclusion. Large increases in cover have been reported for winter and spring grazing on sites studied in southern California. Grazing in spring may be more detrimental to mature individuals. Since nonnative annuals are better adapted to development under their canopies than purple needlegrass, spring grazing generally increases purple needlegrass seedling establishment (Bartolome 1981, Langstroth 1991).

The species is often used in restoration projects, where it is established as transplants, drilled seed, or broadcasted seed. It has been used for competitive reseeding after prescribed burning of grasslands invaded by yellow starthistle (Centaurea solstitialis) and exotic annual grasses. Prescribed fire has been used to reduce dominance of nonnative annuals and to limit encroachment of woody species (Gaidula 1978).

Effects of fire are very important to consider in the management of this species. After defoliation by fire, purple needlegrass grows new tillers from meristems at the ground surface (Langstroth 1991). However, growth during the fall after fire is limited because of carbohydrate loss, but increases in spring. Mowing treatments have produced similar, though less pronounced effects, suggesting an important effect of postfire nutrient release. One study comparing mowing and burning found that production of purple needlegrass tillers was increased 3- to 4-fold by burning and 2-fold by mowing (Ahmed 1983).

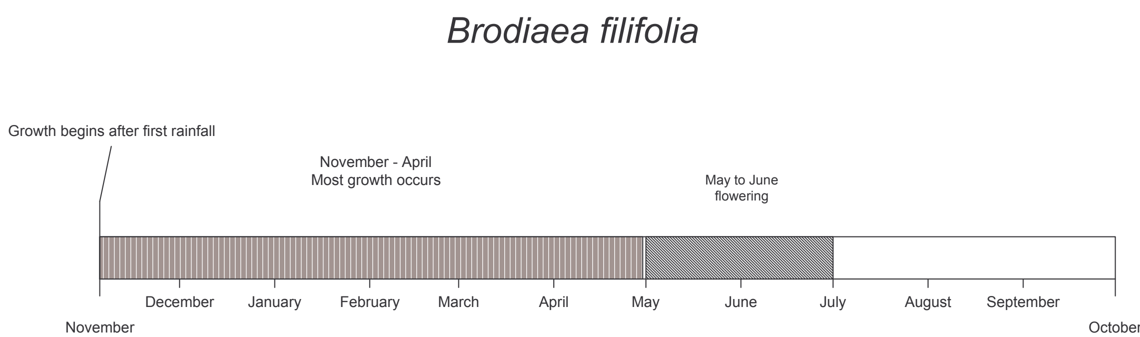
Tussocks that are old or grow on mounds generally have higher biomass accumulations and greater immediate damage from fire (hottest temperatures) than young or intermound plants. Postfire grazing greatly increases fragmentation. Many researchers state that, prior to heavy continuous grazing by domestic livestock in the 1800s, intermittent grazing and periodic fire interacted to be important means of purple needlegrass regeneration (Ahmed 1983, Bartolome 1981, Dyer 1993, Langstroth 1991, White 1966).

However, there is debate about the effects of fire seasonality on purple needlegrass. Some have cautioned against prescribed burning in spring because this causes greatest carbohydrate loss and reduces purple needlegrass seed production by removing flowerstalks (Bartolome 1981, Langstroth 1991). But, fire in spring also burns nonnative annuals in their period of rapid growth and may therefore produce a net benefit to purple needlegrass. One study compared burning in June, August, and September and found each produced significant ($p<0.05$) increases in growth rates and basal area of purple needlegrass with no significant effect of fire seasonality (Ahmed 1983).

Several researchers have noted short term increases in purple needlegrass seedling establishment and seed viability following fire (Ahmed 1983, Dyer 1996, Langstroth 1991). Dyer and others (1996) tested prescribed burning and domestic sheep grazing effects on planted seedling and natural seedling establishment. Fire slightly increased purple needlegrass emergence for 1 year, but only 0.01% of seedlings survived 4 years. No treatment had any significant effect on 4-year survival, indicating that in some cases, establishment and survival to maturity may be influenced more by annual climatic variation or other factors than by management practices.

Most research regarding fire effects on purple needlegrass have studied its recovery in inland habitats. Few have studied its response to fire in coastal grasslands. Hatch and others (1999) found that prescribed burning and grazing in purple needlegrass-dominated coastal prairie had no significant effect on foliar cover or frequency of purple needlegrass. The authors commented that fire and grazing differentially affected California oatgrass, tussockgrass, and purple needlegrass, making restoration efforts in coastal prairie difficult because treatments that improve one species' status may be detrimental to other native species. They concluded that, in contrast to inland habitats, fire and grazing manipulation are likely to be of limited value in restoring coastal prairie.

Thread-leaved Brodiaea (*Brodiaea filifolia*)



Other names
Threadleaf Brodiaea

Status
Global Heritage Status Rank: G2
Federal Endangered Species Act: G2
California State Endangered Species Act: Endangered

Distribution
Thread-leaved Brodiaea is endemic to southern California (Los Angeles, Orange, Riverside, San Bernardino, and San Diego counties) and found in valley grasslands, foothill woodlands and coastal sage scrub at elevations up to 1000 feet (Calflora)

Natural History
Description
The species is a monocot in the family Liliaceae, a perennial herb (bulb), with a flowering stem, 8 to 16in tall. It has several short, narrow leaves arising from its underground bulb. Flowers are violet to red-purple in color. The fruit is a capsule. (Calflora)

Ecology
The total number of individuals of this species and the extent of occupied habitat vary on an annual basis in response to the timing and amount of rainfall, as well as temperature patterns. Fewer than 2,000 individuals have been observed in most populations. This species relies on seasonal rainfall and drier conditions reduce the number of individuals in populations by reducing germination and survival rates. Habitat loss and degradation from other factors, including development, discing, and grazing, when combined with adverse climatic conditions, increase the level of threat to the involved species (California Department of Fish and Game).

Brodiaea filifolia occurs in the vicinity of California gnatcatcher populations in northern San Diego County, but primarily inhabits a different habitat type (mesic grasslands). The species is known to co-exist with the Stephen's kangaroo rat at only one locality in Riverside County (California Department of Fish and Game).

Habitat
This species typically occurs on hillsides, in valleys, and on floodplains in mesic, southern needlegrass grassland and alkali grassland plant communities in association with clay, loamy sand, or alkaline silty-clay soils (CDFG 1981, Bramlet 1993). Sites occupied by this species are frequently intermixed with, or are near, vernal pool complexes, such as near San Marcos (San Diego County), the Santa Rosa Plateau (Riverside county), and southwest of Hemet in Riverside County.

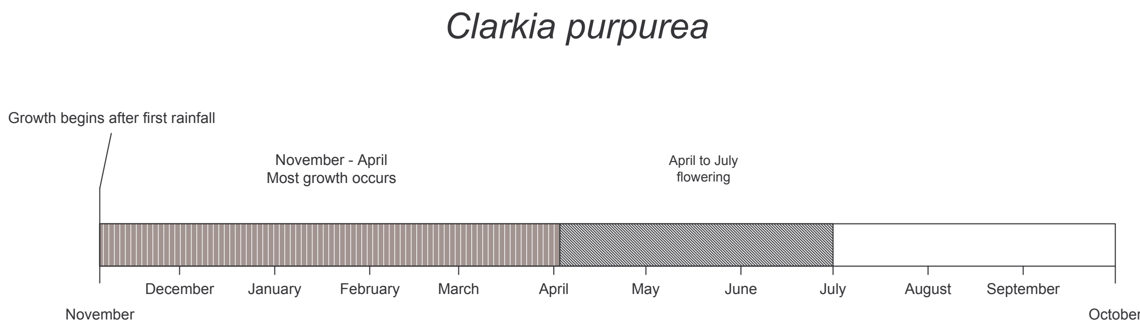
Reproduction
Brodiaea filifolia is known to hybridize with *B. orcuttii, B. terrestris*, and possibly *B. jolonensis*, where these species coexist. Hybridization among these Brodiaea species is a natural phenomenon. However, these plants have relied on relatively species-specific native bee species for pollination in the past and the introduction of non-native honeybees, which tend to be species-generalist, may have increased the occurrence of hybridization (The Nature Conservancy). The plant blooms May through June.

<u>Management/Threats</u>
Populations of the species have faced one or more of the following threats: habitat destruction and fragmentation from agricultural and urban development, pipeline construction, alteration of wetland hydrology by draining or excessive flooding, channelization, off-road vehicle activity, cattle and sheep grazing, weed abatement, fire suppression practices, and competition from alien plant species. For example, in Riverside County, California, most of the annual alkaline grassland near the San Jacinto River and southwest of Hemet has been urbanized or converted to dryland farming or more intensive cultivation. Additionally, *Brodiaea filifolia* is vulnerable to deep discing or repeated discing. Thus, areas that were disced and have partially recovered after being left fallow for a period of time tend to support reduced and gradually declining populations of *B. filifolia*, if any have survived at all (California Native Plant Society).

The most significant threats to this species have been urbanization, conversion of land to agriculture, and discing for fire and weed control. By 1994, about 82 percent of its habitat had been cultivated or overlain by urban development and was no longer available as habitat for conservation or recovery of this species (U.S. Fish and Wildlife Service).

Many vernal pools on Otay Mesa and in San Marcos (San Diego County) have become dominated by *Lolium perenne*, the exotic perennial ryegrass commonly planted in lawns and elsewhere. Ryegrass has displaced native species such as *Brodiaea filifolia* in areas where significant populations are known to occur. In Riverside County, *Crypsis schoenoides*, an aggressive exotic grass, has been seeded as a food source for migratory waterfowl along the San Jacinto River. This species is becoming widespread and has replaced, or is in the process of replacing, native vernal pool (and other) native species, including *B. filifolia* on the San Jacinto Wildlife Area and in other areas west of Hemet (Calflora). In San Diego County, aggressive non-native species such as *Cynara cardunculus* (wild artichoke) and *Foeniculum vulgare* (fennel) are impacting grassland habitat supporting populations of *Brodiaea filifolia* (California Native Plant Society).

Purple Clarkia (*Clarkia purpurea*)



Other names
Winecup clarkia, purple clarkia, purple godetia

Status
Global Heritage Status Rank: G5T5
Federal Endangered Species Act: N5
California State Endangered Species Act: No special status

Distribution
This species is native to California, and is also found outside of California, confined to western North America. It occurs under dry conditions in coastal and slope areas below 1500 feet. The species may be found in many plant community types, usually at lower elevations throughout cismontane southern California, but its range extends north to Washington and east to Arizona. It is prominent on serpentine soils within coastal prairie grasslands (CalFlora 2004).

Natural History
Description
Clarkia purpurea is a dicot in the family Onagraceae. It is an erect-stemmed annual herb up to a foot in height. The flower is lavender to purple or dark wine-red, often with a purple spot near middle or above. The flower petals are less than 15mm long, and the plant's leaves are 1.5 to 5cm in length (USDA).

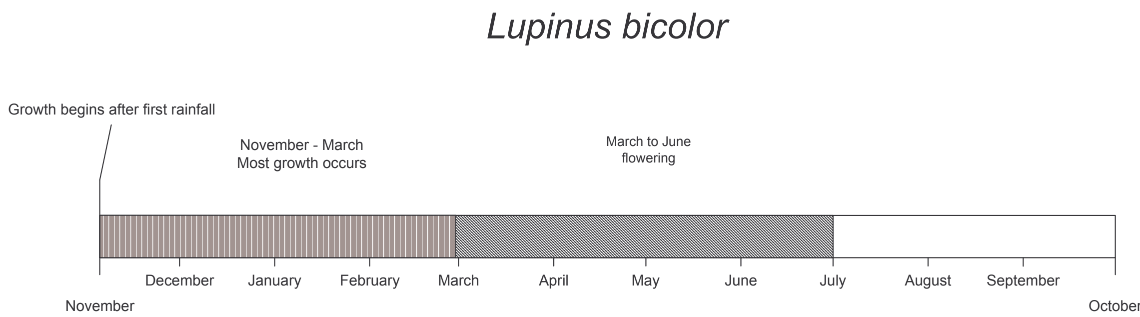
Ecology
Given excellent drainage (modification of compacted or other water-holding soils may be necessary) and full or nearly full sun (tolerates summer afternoon sun), the plant grows especially well (CalFlora 2004).

Habitat

The species occurs in many plant community types, including valley grassland, coastal strand, northern coastal scrub, chaparral, foothill woodland, yellow pine forest, and mixed evergreen forest (Calflora).

Reproduction
Purple clarkia generally blooms from April to July. The fruit is generally an elongated capsule and is nut-like. The seeds are generally numerous are 0.5–2 mm in length, and brown or gray in color (USDA).

Bicolored lupine (*Lupinus bicolor*)



<u>Other names</u>
Annual Lupine, Miniature lupine, Pygmy-leaved Lupine

<u>Status</u>
Global Heritage Status Rank: NE
Federal Endangered Species Act: NE
California State Endangered Species Act: NE

<u>Distribution</u>
Lupinus bicolor is found in California, and also outside of California, but is confined to western North America, generally below an elevation of 8500 feet (Calflora).

<u>Natural History</u>
Description
This species a native dicot in the family Fabaceae, and is an annual or perennial herb. The plant is fuzzy with gray leaves and small blue clustered flowers (¼ to 1 inch). Flowers are blue and white, and the plant's fruits are oblong (Calflora).

Ecology
The plant is adaptable to a variety of soils, but is mainly found in sandy places. It prefers full sun and open areas. The plant is also fire resistant (Native Plant Network).

Habitat
The species occurs in many habitats including: forests, woodlands, scrublands and grasslands (Calflora)

Reproduction
The plant typically blooms from March through June (Calflora)

Management/Threats

The plant is useful in revegetation mixes as it can grow on some disturbed sites. It also adds nitrogen to the soil to the benefit of other plants in the community. It makes a good ground cover since it possesses fire retardant properties, and it seeds and reseeds well (Native Plant Network).

Appendix E: Envirograms

Stephens' Kangaroo Rat (*Dipodomys stephensi*)

Status
Global Heritage Status Rank: G2
Federal Endangered Species Act: Endangered
California State Endangered Species Act: Threatened

Distribution
Endemic to California (NatureServe 2003).

Natural History
Description
The Stephens' kangaroo rat is a medium-sized rodent in the family heteromyidae. This kangaroo rat can be up to 300 millimeters long, with a tail that can be up to 1.5 times as long as the body. The body is buff-colored above and white below, with a dark dorsal stripe and a white tail stripe about half the width of the dorsal stripe. The hind legs are large and the hind feet have five toes (Bleich 1977).

Ecology
This species is a nocturnal granivore that lives in underground burrows. These burrows may be abandoned pocket gopher or California ground squirrel burrows (Burke 1991). Common predators of the Stephens' kangaroo rat are owls and small carnivores such as domestic cats and coyotes.

Habitat
Populations densities vary widely from year to year, but a typical density would be 20-40 per hectare (Bleich 1977; Price 1989). This species is endemic to California, where it has been subjected to substantial habitat loss (Price 1989). The preferred habitat of this species is annual grassland, but coastal sage scrub with open shrub cover is also suitable. Species abundance has been shown to decrease as plant density increases, and annual grassland habitat areas can become unsuitable when invaded by exotic annual grass species such as *Bromus diandrus*, which grow in very dense stands (Burke 1991).

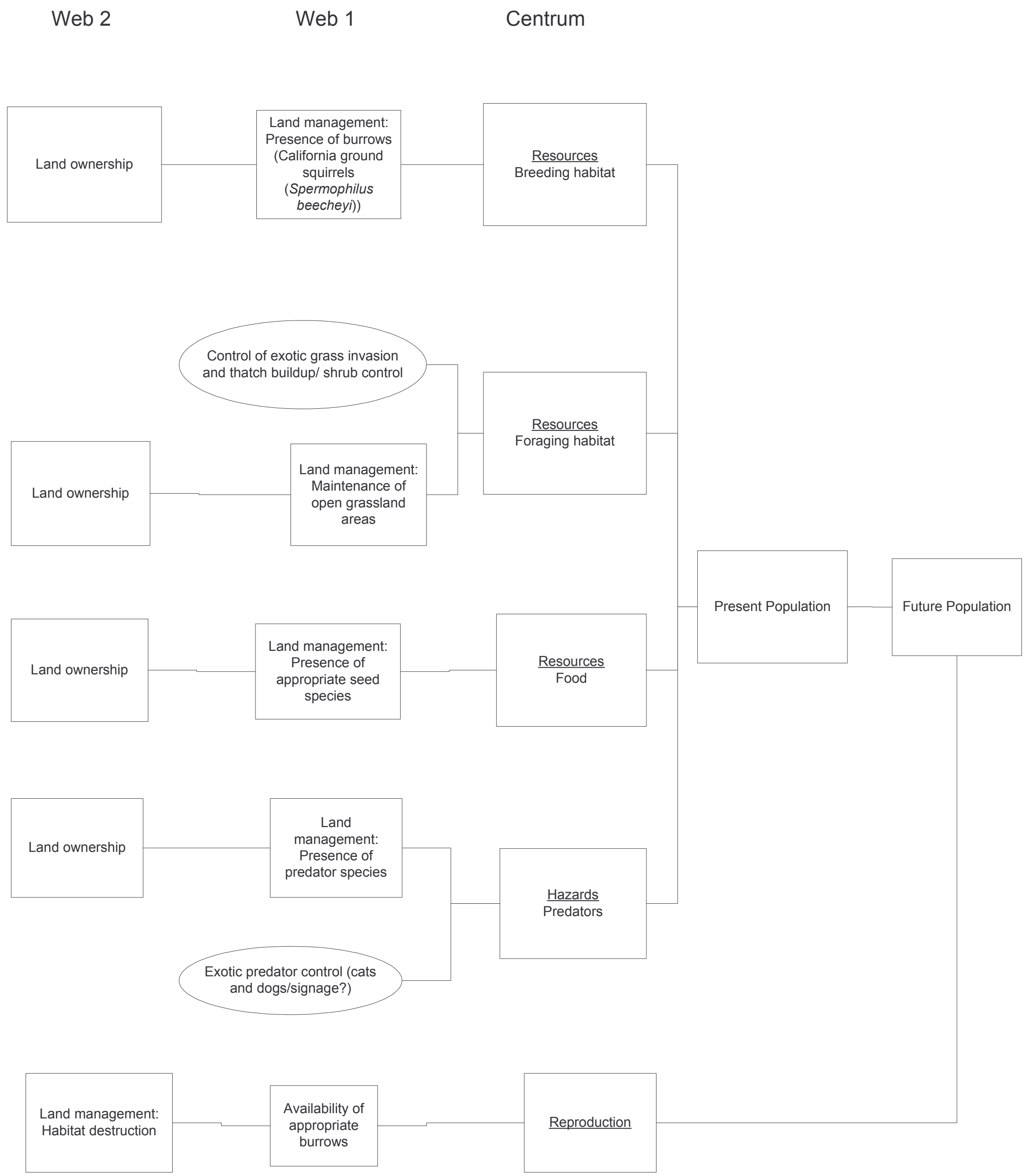
Soil maps can be used to accurately predict the presence or absence of Stephens' kangaroo rat (Price 1989). This species is usually found in relatively flat areas with loose, well-drained soils.

Reproduction

This species produces an average of one litter per year, but reproduction may vary with rainfall from year to year. The average litter size is 2.5 young, born in late spring to as late as July (NatureServe 2003).

Management

The loss of habitat appropriate for this species in Southern California necessitates that management address habitat suitability. Extremely dense vegetation can negatively affect the presence of this kangaroo rat, and shrub removal has been shown to increase Stephens' kangaroo rat densities in Riverside County (Price 1994). Grazing and burning can also decrease vegetative density. Grazing, however, can have negative impacts on this species as excessive grazing activity can result in soil compaction and the loss of burrows due to crushing (Biosystems Analysis 1989).



Envirogram for the Stephens' kangaroo rat (*Dipodomys stephensi*). Potential management practices are noted in ovals. This envirogram format was developed by James et al, 1997.

Burrowing Owl (*Athene cunicularia*)

Status
Global Heritage Status Rank: G4
Federal Endangered Species Act: Not listed
California State Endangered Species Act: Not listed

Natural History
Description
The burrowing owl is a small, long-legged owl with a stubby tail. The body is marked with brown and white spots and bars, with a white chin stripe. The average length of the burrowing owl is 24 centimeters (NGS 1983; Peterson 1990).

Ecology
This owl lives in open areas and spends much of its time on the ground and on low perches. It can be found at densities up to 8 pairs per square kilometer in California. This species feeds primarily on large insects and small mammals, but will eat small amphibians and birds on occasion. The burrowing owl will hunt during day or night (NatureServe 2003).

Habitat
The burrowing owl is widespread across most of its range, but populations in Southern California have been declining due to habitat loss. Burrowing owls are found in dry grassland areas and open desert areas. This bird has also been found nesting in vacant lots.

This owl nests in underground burrows, usually abandoned pocket gopher or California ground squirrel burrows. Aboveground nesting attempts are not successful (Cavanagh 1990). The presence of burrows is also important to the burrowing owl as a source of shade when temperatures rise (Coulombe 1971). Average distance between burrows is roughly 166 meters, and owls will defend burrows if another individual comes within roughly 10 meters (Martin 1973).

Reproduction
The burrowing owl breeds once each year, with an average clutch size of six or seven. The incubation period is roughly 30 days, during which the male owl provides food. Young owls begin foraging at four weeks and achieve sustained flight at six weeks, with 3-5 owls fledging from each clutch (NatureServe 2003).

Management
Loss of appropriate habitat has led to a decline in the number of burrowing owls present in California since the 1940's. Conversion of grassland areas to agriculture was one of the most widespread sources of habitat loss, but soil compaction caused

by grazing and poisoning of ground squirrels have contributed to this habitat loss as well by negatively affecting the availability of burrows (Grinnell 1944; Zarn 1974a; Remsen 1978). The use of artificial nesting boxes has been successful in several areas (Collins 1977).

Predation by domestic dogs and cats can be a significant source of mortality for burrowing owls (Martin 1973). Collisions with automobiles can also be a concern if habitat is located adjacent to a roadway (Polite 1988-1990).

Envirogram for the Burrowing Owl (*Athene cunicularia*). Potential management practices are noted in ovals. This envirogram format was developed by James et al, 1997.

Vernal Pool Fairy Shrimp (*Branchinecta lynchi*)

<u>Status</u>
Global Heritage Status Rank: G2G3
Rounded Global Heritage Status Rank: G2
Federal Endangered Species Act: Threatened
California State Endangered Species Act: Not Listed

<u>Distribution</u>
This crustacean is endemic to the Central Coast Mountains, South Coast Mountains, and Central Valley of California, with distinct populations located on the Santa Rosa Plateau in Riverside County (USFWS 1992).

<u>Natural History</u>
Description
Branchinecta lynchi is a freshwater fairy shrimp with an average size of 25 millimeters (NatureServe 2003).

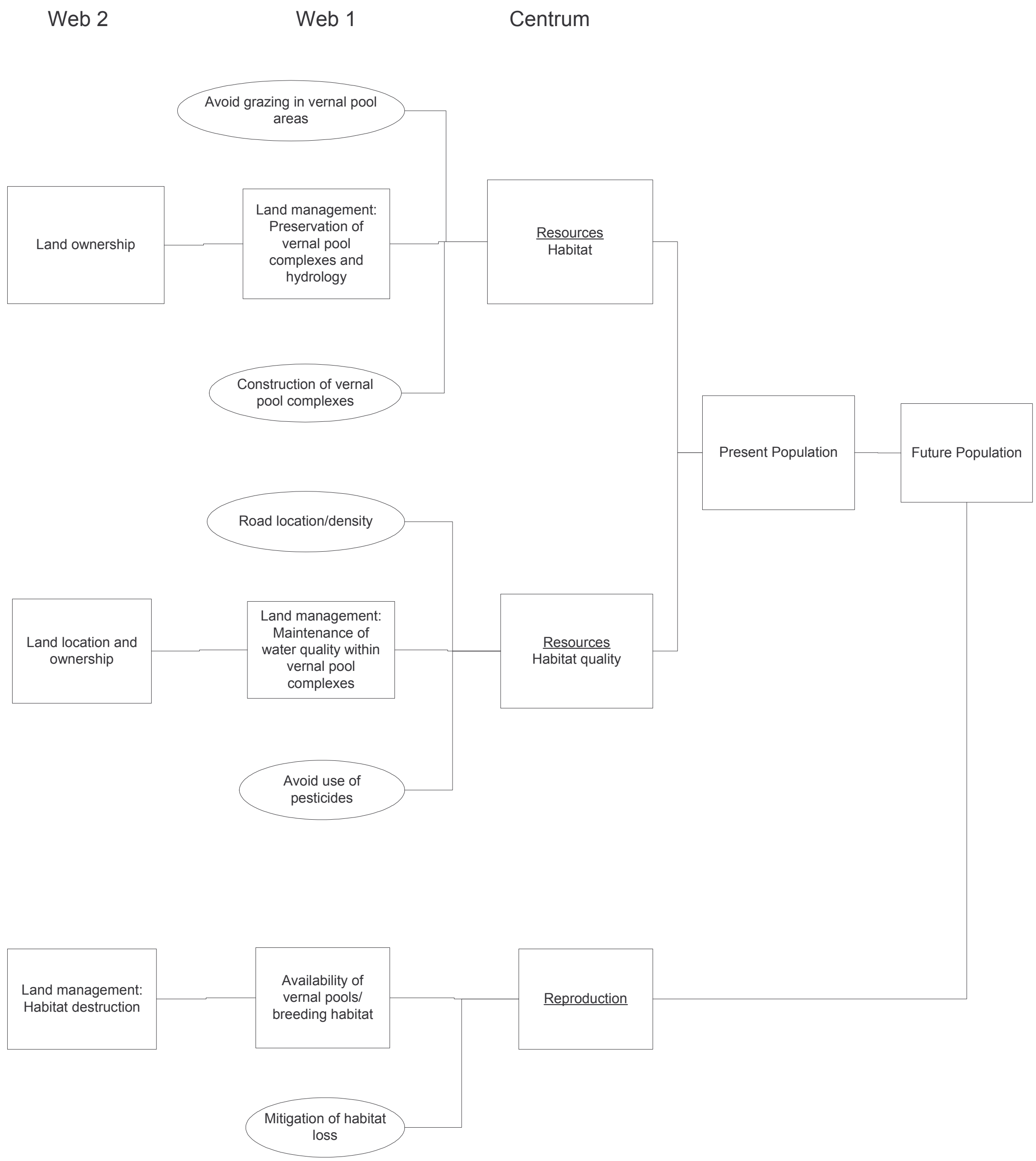
Ecology
The vernal pool fairy shrimp feeds on detritus and smaller invertebrates (NatureServe 2003).

Habitat
The vernal pool fairy shrimp is restricted to ephemeral pools filled by winter rains. These pools are most commonly found on mesa tops, in grass-bottomed swales and basalt flow depressions such as those found at the Santa Rosa Plateau in Riverside County (Eng 1990). This fairy shrimp can be found in these habitats from as early as December to as late as May (Eng 1990).

Reproduction
The female fairy shrimp deposits fertilized eggs on the bottom of the pool or swale. The eggs, or cysts, survive in the soil through the dry season, and hatch when the pool is next filled. Some pools do not fill every year, but fairy shrimp cysts have been shown to remain viable in the soil for many years (Reference). The immature shrimp mature very rapidly and reproduce before the end of the wet season (NatureServe 2003).

<u>Management</u>
The vernal pool fairy shrimp occurs in soft and poorly buffered waters (Eng 1990) and is therefore vulnerable to changes in air quality and effects of atmospheric deposition.

Fairy shrimp and other vernal pool fauna are also sensitive to changes in the hydrology of the pools within which they are found (reference). One common effect of grazing can be the congregation of cattle near riparian and vernal pool areas. Soil compaction and disruption associated with trampling by cattle can be detrimental to this species for this reason.



Envirogram for the vernal pool fairy shrimp (*Branchinecta lynchi*). Potential management practices are noted in ovals. This envirogram format was developed by James et al, 1997.

Grasshopper Sparrow (*Ammodramus savvanarum*)

Status
Global Heritage Status Rank: G5
Federal Endangered Species Act: Partial status
California State Endangered Species Act: Not listed

Distribution
The grasshopper sparrow is a widespread species throughout North America. This species has been reduced in California, however, due to loss of grassland habitat (NatureServe 2003).

Natural History
Description
The grasshopper sparrow is small with a short, narrow tail and buffy, unstreaked breast and sides. It has a flat head with a dark crown with light central stripe and light eye rings. Most adults have an orange spot near the eye (NGS 1983).

Ecology
This sparrow is territorial, but territories are small, generally less than two hectares (Wiens 1969; Ducey 1980). This species sometimes winters in coastal Southern California, and migrants arrive in California between March and May, and move south beginning in August (Dobkin 1988-1990).

Grasshopper sparrows feed on small insects as well as other small invertebrates. They also feed on seeds and grain (Terres 1980). This species forages on or near the ground under dense cover and will scratch in litter to locate food (Bent 1968).

Habitat
This sparrow is found in open grassland areas and oak savannahs. It is most common in grasslands containing a variety of successional stages that provide thick cover as well as singing perches and bare ground (Bent 1968; Blankespoor 1980; Vickery 1996).

Reproduction
This species generally breeds between April and August, and is usually able to produce two broods (George 1952; Bent 1968; Smith 1968; Stewart 1975; Vickery 1996). This species has also been shown to renest up to four times after unsuccessful nesting attempts (Vickery 1996).

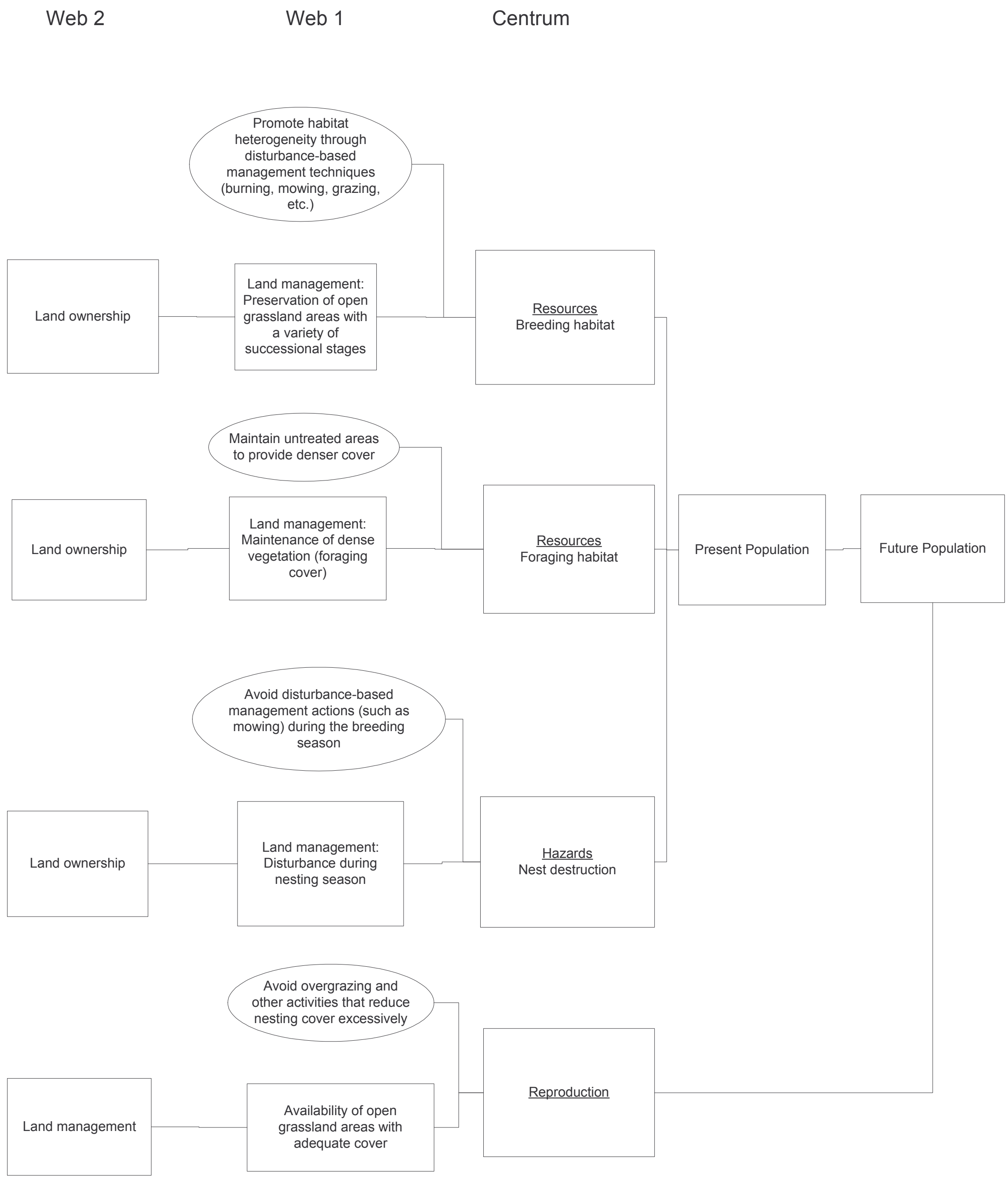
Management
Management treatments such as burning, grazing, and mowing can have positive effects on grasshopper sparrow populations, but should be avoided during the nesting season (Stewart 1975; Whitmore 1981; Vickery 1996). Treatments can be performed

in the spring before the arrival of migrants, or in the fall after the nesting season. Fall treatments are appropriate for the management of a similar bird, the bobolink, and may also be suitable for the grasshopper sparrow. Bollinger (Bollinger 1988) also suggested leaving adjacent areas untreated to provide a refuge for later-nesting birds and juveniles.

Prescribed burns have been shown to increase grasshopper sparrow presence in grasslands throughout the species' range. However, Huber and Steuter (Huber 1984) and Johnson (Johnson 1997) found that sparrows avoid spring-burned areas the summer following a burn event, and in many areas an increase in population postfire follows a decline lasting between one and four years after fire events (Bock 1987; Heckert 1994; Madden 1996; Johnson 1997). These declines are probably due to loss of cover and food sources (Forde 1984).

Mowing may be more beneficial to the grasshopper sparrow than prescribed burning in some areas (Bollinger 1988; Swengel 1996). In Nebraska, mowing was shown to have positive effects on grasshopper sparrows (Delisle 1997). In New York, grasshopper sparrows preferred mown sites to burned sites if the mowing was performed late in the season to avoid nest destruction (Bollinger 1995).

Grazing can be detrimental to grasshopper sparrows in dry areas, as it may reduce cover and grass density to an unacceptable level (Bock 1984; Bock 1984; Bock 1993). In areas with high vegetation density, however, grazing can be highly beneficial to grasshopper sparrows by increasing the patchiness of the landscape and providing vegetation cover of varying heights (Skinner 1974; Kantrud 1981; Whitmore 1981).



Envirogram for the grasshopper sparrow (*Ammodramus savvanarum*). Potential management practices are noted in ovals. This envirogram format was developed by James et al, 1997.

San Diego Pocket Mouse (*Chaetodipus fallax*)

<u>Status</u>
Global Heritage Status Rank: G5
Federal Endangered Species Act: Not listed
California State Endangered Species Act: Not listed

<u>Distribution</u>
This species is restricted to southwestern California and the southern edge of the Mojave Desert (NatureServe 2003).

<u>Natural History</u>
Description
This species is a mouse with small, rounded ears and small hind feet (Erickson 1999). The body is dark above and white below, with a buffy band separating the two.

Ecology
The San Diego pocket mouse is a solitary, nocturnal species. It feeds on seeds, which it has been observed to store in its burrow (NatureServe 2003).

Habitat
This species is found in open areas with sandy soil. Soil type is important to this species because this mouse constructs a burrow, in which it sleeps and gives birth (NatureServe 2003).

Reproduction
Breeding occurs between March and April (Miller 1964).

<u>Management</u>
The San Diego pocket mouse will feed on exotic grass seed, but prefers native grass seed and can therefore benefit from the presence of native grass species (eNature.com 2004). Since this is a burrowing species, it may be negatively impacted by activities that compact the soil, such as excessive grazing.

Envirogram for the San Diego pocket mouse (*Chaetodipus fallax*). Potential management practices are noted in ovals. This envirogram format was developed by James et al, 1997.

Tarantula (*Aphonopelma eutylenum*)

Status
Global Heritage Status Rank:
Federal Endangered Species Act: Not listed
California State Endangered Species Act: Not listed

Distribution
This species is found throughout southern California (Smith 1986).

Natural History
Description
The female of this species is generally roughly 43 millimeters in length. The carapace and legs are brown, and the abdomen is dark brown or black. The male has an average length of 42 millimeters, and has olive-brown legs. The carapace is a pale grey-brown (Smith 1986).

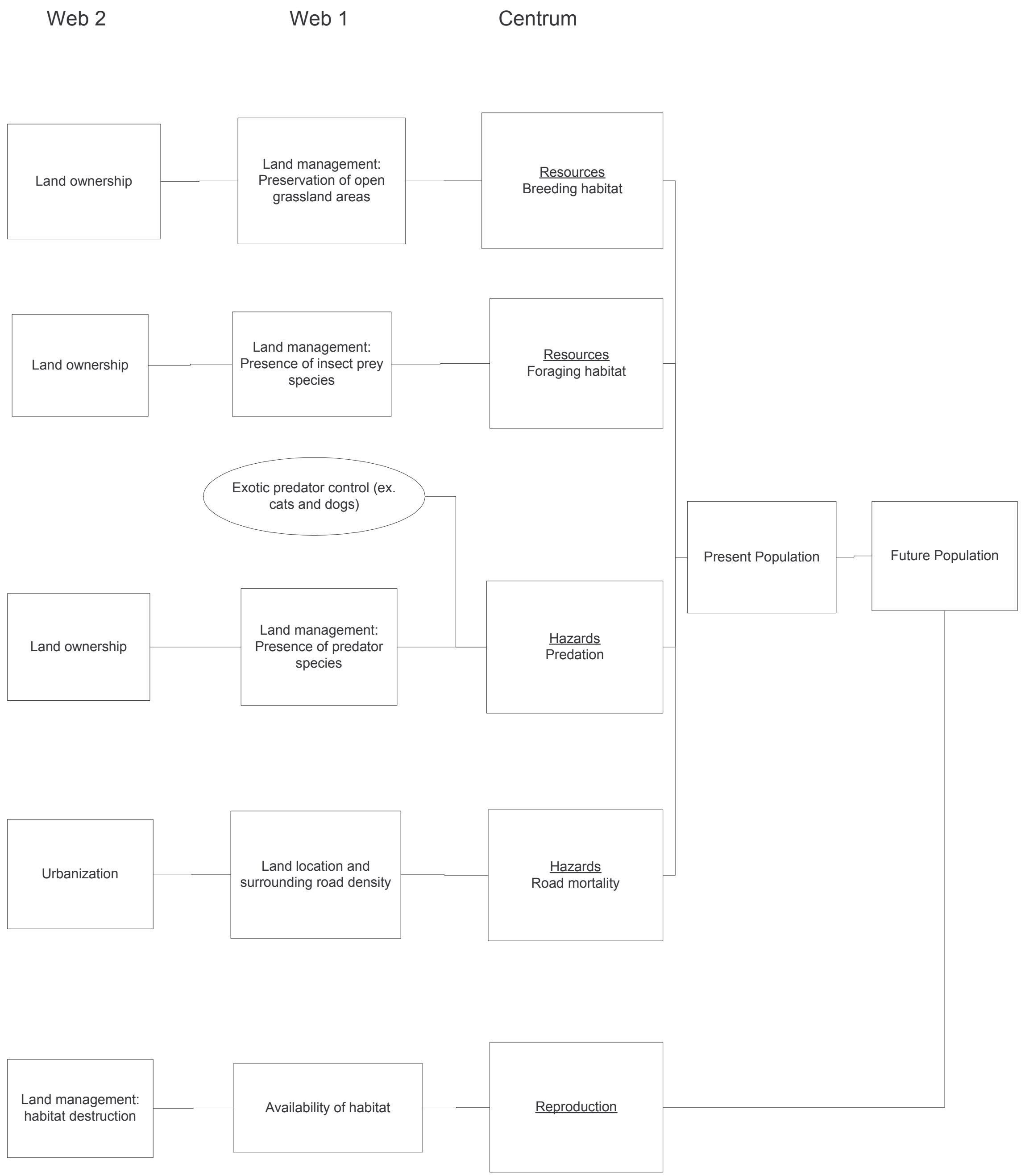
Ecology
Male tarantulas live only a few years, but females may live to be 20 years old or more (eNature.com 2004).

This species is nocturnal, and hunts by touch. During the day, these spiders take refuge in burrows. This species also hunts by constructing a silky web at the opening of its burrow. When passing prey disturbs the web, the tarantula emerges and administers a bite that is venomous to prey but not harmful to humans (NGS 1997).

Habitat
This species is found in grassland or shrubland, and is a burrowing species (Smith 1986).

Reproduction
500 to 1,000 young may be produced by each female tarantula each mating season. Tarantulas molt once each year until they reach maturity, but females may continue to molt after reaching maturity (NGS 1997).

Management
Since this is a burrowing species, it may be sensitive to activities that compact soil. It may also be vulnerable to predation by domestic animals such as dogs and cats. Male tarantulas undertake a migration in search of females in order to mate, and often encounter roadways in their search. Road mortality may be another important source of mortality in areas with high road density.



Envirogram for the California ebony tarantula (*Aphonopelma eutylenum*). Potential management practices are noted in ovals. This envirogram format was developed by James et al, 1997.

Arroyo Toad (*Bufo californicus*)

Status
Global Heritage Status Rank: G2G3
Rounded Global Heritage Status Rank: G2
Federal Endangered Species Act: Endangered
California State Endangered Species Act: Species of special concern

Distribution
This species once ranged from San Luis Obispo County south to Baja California, but is now thought to be extirpated in San Luis Obispo County. Known populations are found in the Los Padres National Forest (Santa Barbara and Ventura Counties), Orange, Riverside, San Diego and Imperial Counties (USFWS 1994).

Natural History
Description
This species is a medium-sized toad that is light olive green to brown in color. It is uniformly warty, with pale, oval parotoid glands and a light area in the middle back and on the sacral humps. This species has a dark-spotted dorsum and is light below (Stebbins 1985).

Ecology
This toad forages in open areas beneath riparian trees and shrubs. This species feeds mainly on insects, but will sometimes cannibalize newly metamorphosed individuals. Newly metamorphosed toads are active during daylight hours, but adults are primarily nocturnal (NatureServe 2003).

Habitat
This species is found washes and streams and adjacent upland areas of grassland or shrubland. It is also found in riparian woodland areas with sandy soil, in which adults burrow for shelter. This species has been observed to migrate between breeding pools and nonbreeding habitat (NatureServe 2003).

Reproduction
This species breeds from March to June (Stebbins 1954). This toad lays eggs in gravel or on clean sand at the bottom of pools or in still stream areas with little or no emergent vegetation. Metamorphosis then occurs in June or July (USFWS 1993). Newly metamorphosed individuals stay near pools for up to several weeks until pools become dry (NatureServe 2003).

Management
Habitat loss is the major threat facing this species in California. Soil compaction and disruption associated with trampling by cattle can also be detrimental to this species. Domestic predator species such as dogs and cats may also pose threat to this species.

Envirogram for the arroyo toad (*Bufo californicus*). Potential management practices are noted in ovals. This envirogram format was developed by James et al, 1997.

Appendix F: Legal Context

The management of southern California grasslands is regulated by a number of complex mandates, regulations, and policies. The Natural Community Conservation Planning (NCCP) program is a cooperative effort to protect species and their habitats, including grasslands. The program began under the State's 1991 NCCP Act and is broader in its orientation and objectives than the California Environmental Species Act (CESA) or Federal Environmental Species Act (FESA). By prohibiting activities that harm listed species or their habitat, FESA and CESA introduce inevitable legal and political conflicts between conservation and development. Main goal of NCCP Act was to overcome the limitations of a conventional single-species, project-by-project approach to conservation, which was considered unsatisfactory to conservation advocates and development interests. The collaboration between the state and federal wildlife agencies in overseeing the planning process makes it easier for the plans to be approved simultaneously under the federal HCP and the state NCCP Act (Pollak 2001).

The Department of Fish and Game and the U.S. Fish and Wildlife Service provide the support, direction, and guidance to NCCP participants. The Department has previously adopted both process guidelines and conservation guidelines for the Southern California Coastal Sage Scrub NCCP pilot project. NCCPs within the CSS planning region that incorporate CSS habitat must comply with those guidelines (USFWS 2004). This initial effort focusing on the coastal sage scrub habitat of Southern California protected the California gnatcatcher and approximately 100 other potentially threatened or endangered species. The habitat scattered on more than 6,000 square miles of five counties: Orange, San Diego, Riverside, Los Angeles, and San Bernardino (Pollak 2001). Since coastal sage scrub is naturally variable, patchy, and embedded in a matrix of other habitat types such as grassland, chaparral, oak woodland, vernal pools, and riparian zones, these habitats benefit from CSS conservation as well (DFG 2004).

One of the first Multiple Species Conservation Programs (MSCP) in Southern California was established by the San Diego County Board of Supervisors in October 1997 in efforts to protect parks and open space. The MSCP strives to conserve diverse vegetation communities that are habitats for many species of animals and plants. There are still many uncertainties concerning grassland conservation within the MSCP plans. As an illustration of recent and current issues that make conservation of southern California grasslands more difficult, below are three examples of documents dealing with problems faced by the Multiple Species Conservation Program in San Diego County.

1) According to the final MSCP document, prepared in August 1998, the wildlife agencies have agreed to provide additional habitat-based assurances for uncovered species (San Diego County 1998). Following this approach, they classified vegetation communities as "sufficiently" conserved, "significantly" conserved, and other. Some of the factors used for this classification include: extent of the vegetation community and its condition conserved inside and outside the MSCP study area, current and future development of the vegetation community to other vegetation communities, potential for uncovered species dependent on the vegetation community, patch size, habitat values, conservation level, and functionality of linkages between patches. Some of the sufficiently conserved vegetation communities include: riparian areas, disturbed wetlands, and the portion of coastal sage scrub that comprises the range of the California gnatcatcher, while some of the significantly conserved ones are coastal sage scrub and chaparral. Grasslands (and oak woodlands), however, are neither sufficiently nor significantly conserved by this MSCP. Therefore, in a case when an uncovered species that depends on grassland (or oak woodland) is listed, the federal and state ESA requirements will come in effect at the time of listing (San Diego County 1998).

2) According to the participating scientists who gave a biological opinion on the County of San Diego MSCP in May 1998, the existing database does not distinguish between native and non-native grasslands (since they are not distinguishable on aerial photography which was the major source of information used to generate the vegetation maps for the MSCP planning area) (San Diego County 1998). The scientists recommended that future detailed on-the-ground surveys should be conducted to distinguish between native and non-native grasslands, since this will result in a higher preservation level of native grasslands than non-native ones.

3) In 2001, during the Independent Science Advisors' Review of North county subarea plan of County of San Diego MSCP, science advisors evaluated grassland component of the habitat evaluation model and found the purpose of the existing grassland component of the model unclear, particularly in relation to Steven's Kangaroo Rat (SKR) (DFG 2001). Many interrelated and interdependent aspects of SKR and grassland components cause this. A degree of suitability for SKR of a grassland patch depends on its fragmentation, edge effects, suitable soils, nearby development, and connectedness by roads (especially dirt roads). The optimal conditions for SKR might not favor other native species. Such contradictions make it difficult to create most adequate model and management action plan for grassland. Advisors agreed that management must be determined on a site-by-site basis and decided to continue working on the grassland model they created (DFG 2001).