THE SANDHILLS CONSERVATION AND MANAGEMENT PLAN

A Strategy for Preserving Native Biodiversity in the Santa Cruz Sandhills

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Prepared for

The Land Trust of Santa Cruz County

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Dedicated to

the early sandhills conservationists, including

Randy Morgan, Alma Schreiber, Stephen McCabe,

Julie Phillips, Celia Scott, Michael Marangio, and

Deb Hillyard;

and to

Bill Reid,

who greatly facilitated all aspects of this work

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EXECUTIVE SUMMARY

The Santa Cruz sandhills are unique communities of plants and animals found only on outcrops of sandy soils derived from marine deposits in Santa Cruz County, central coastal California. They support diverse assemblages of plants that are uniquely adapted to the droughty, infertile soils, including four endemic plant species found nowhere else in the world. Also distinct, the sandhills fauna includes two endemic insects, isolated populations of two lizard species, and the last known population of the Santa Cruz kangaroo rat.

The endemic sandhills communities and species are naturally rare, due to their limited geographic range (Santa Cruz County) and narrow habitat specificity (inland sand outcrops). Habitat destruction due to sand quarrying, urban development, and agriculture has reduced and fragmented habitat. As a result, three sandhills plants (Santa Cruz wallflower, Ben Lomond spineflower, and Santa Cruz cypress) and two sandhills animals (Mount Hermon June Beetle and Zayante band-winged grasshopper) have been listed as federally endangered. Several other endemic and locally unique plants and animals in the sandhills are also very rare and the two sandhills plant communities— maritime coast range ponderosa pine forest and northern maritime chaparral— are listed as sensitive communities in the California Natural Diversity Database. Ongoing habitat conversion, fragmentation, degradation, and genetic contamination threaten the persistence of these unique species and communities. A series of coordinated conservation efforts will be required to preserve biodiversity in the sandhills.

Habitat preservation will be crucial to sandhills conservation. Only 3,960 acres of sandhills habitat remain, including the fragmented and altered habitat found in residential developments. Sandhills habitat is found in 54 sites that range in size from a single acre to 532 acres. Only 207 acres of sand parkland habitat remains and only 57 acres of this rare habitat have the open structure required by many unique sandhills species, including the last remaining populations of the endangered Zayante band-winged grasshopper and Santa Cruz wallflower. Sandhills conservation efforts should preserve all sand parkland habitat. Though comparatively more widespread, the sandhills chaparral communities and ponderosa pine forest are also extraordinarily rare, when compared to other communities in California. Sandhills conservation efforts should endeavor to protect as much of the remaining, intact sandhills habitat as possible, by focusing on large or exceptionally diverse sites, especially those adjacent to already protected habitat. Preservation opportunities are outlined for the eighteen sites with the highest conservation value.

All sandhills habitat requires active management for the persistence of natural community structure and sensitive species populations. Three primarily factors impact habitat even within protected reserves: fire exclusion, exotic plant species invasion, and recreation. In the absence of fire during the last 50 or more years, the open habitat required by many sandhills species has been reduced, and the size of remaining habitat areas decreased by encroaching shrubs and trees. Woody vegetation threatens the persistence of early-successional sandhills and increases the likelihood of catastrophic wildfire in sandhills reserves and adjacent human developments. Fire management is needed to maintain open areas required by sensitive species and to reduce the risk of wildfire. In smaller habitat patches located near development, fire surrogates might be used to accomplish these goals, though adaptive management is needed to

determine their success as disturbance mimics. Fire and fire surrogates may enhance invasion of exotic plant species into closed-canopy communities, necessitating careful planning and monitoring to facilitate success of fire management treatments.

Exotic plant species must be controlled, and where possible eradicated, to increase habitat availability and population densities of many sensitive species. Aggressive exotic plants compete with native sandhills plants and alter habitat conditions for sandhills animals in all sandhills sites. Managers should use adaptive management to explore the relative effectiveness of various methods of controlling abundant European annual grasses and forbs that reduce suitability of Zayante band-winged grasshopper habitat and compete with the endangered herbaceous plants in sand parkland. Managers should eradicate narrowly distributed and less abundant species, including brooms, acacias, and eucalyptus that preclude use of sandhills habitat by native species and alter important ecosystem functions. Preventative measures should be taken to reduce new introductions and newly established species should be eradicated.

Policy makers and managers must work together to reduce the negative impacts of recreation for sandhills species and communities. All sandhills sites receive some recreational use, and many sites are subject to high-intensity recreational uses, which remove vegetative cover, cause erosion, and degrade habitat for sensitive species. The negative impacts of recreation in the sandhills are disproportionately high, relative to other communities, owing to the extreme rarity and fragility of sandhills habitat. Sand parkland communities and any sandhills habitat managed for conservation value (e.g. under easements) should not be open to recreation. In other areas, recreation should be narrowly restricted, carefully planned, intensively managed, and closely monitored using sandhills-specific management strategies designed to minimize negative impacts to sensitive species.

Efforts to re-establish sandhills plant and animal populations in sand quarries and other highly degraded areas can reduce negative edge effects on adjacent intact habitat, increase the likelihood of migration between sandhills preserves, and enhance population density and persistence of many sensitive species. Revegetation or reconstruction projects should follow guidelines created specifically to avoid potential negative impacts these projects might have for the unique ecology of the sandhills, including genetic erosion. In residential developments within sandhills habitat, landscaping practices that consider the unique ecology of sensitive sandhills species can facilitate their persistence.

Ongoing research is needed to inform sandhills conservation and management. Though previous studies have provided important insight into this complex system, the pressing need for conservation action necessitates more information to inform this important work. Research examining the relative effectiveness of management techniques can contribute to regional efforts to improve habitat quality for sandhills species and maintain biodiversity. Research examining the biology of the sensitive species is needed to enhance their persistence. Agencies, researchers, and landowners should partner in these efforts to maximize the benefit from the limited funding available. All management should be conducted within the adaptive management framework so that monitoring can increase knowledge in this system. Research funding should be increased.

Education, interpretation, and outreach programs to increase public awareness and appreciation for the sandhills will be crucial to long-term preservation. When people are aware of the uniqueness, rarity, and fragility of the sandhills, they are more likely to comply with regulations, support local conservation efforts, and actively work to protect habitat. A variety of informative and enjoyable educational and interpretive programs in schools, parks, and museums, can enhance people's lives while increasing sandhills awareness and appreciation. Sandhills conservation groups including the Sandhills Alliance for Natural Diversity should work with local educators and park interpreters to help develop programs and curricula. Sharing the information about the sandhills with the community, beginning with children, will facilitate the long-term conservation efforts on behalf of this unique local treasure.

Sandhills conservation efforts should be more closely coordinated among numerous the individuals and organizations working to preserve biodiversity in the sandhills. Though numerous individuals are involved in sandhills conservation work, currently there is no single individual who works solely on sandhills conservation. Instead, many individuals split their time among sandhills and non-sandhills projects. A Sandhills Preserve Manager position should be established to coordinate and conduct work toward the conservation goals of this plan. Founded in 2001 to provide a forum for collaboration, the Sandhills Alliance for Natural Diversity (SAND) is a group of agency representatives, biologists, planners, individual landowners, and other concerned citizens who work on sandhills conservation projects. Through committees that address many of the key areas of sandhills conservation work (e.g. research and management, land acquisition, education and outreach, etc.), limited resources including expertise, time, and funds can be combined to more effectively attain the conservation goals outlined in this plan.

CHAPTER 1

INTRODUCTION TO THE

SANDHILLS CONSERVATION AND MANAGEMENT PLAN

INTRODUCTION

The inland sandhills of Santa Cruz County support rare biological communities comprised of unique assemblages of plants and animals including two endemic insects and four endemic plants that are found nowhere else in the world. Naturally rare, sandhills habitat has been greatly reduced by development and mining, while undeveloped sandhills sites are being degraded by fire suppression, exotic species, and recreational use.

Recognizing the need for scientific information to confront these threats to native biodiversity in the sandhills, individuals and organizations involved in a variety of sandhills protection and management efforts identified the need for a comprehensive plan to preserve sandhills habitat and species. The Sandhills Conservation and Management Plan (SCMP) was designed to develop a comprehensive strategy for the maintenance of native biodiversity in the Sandhills.

1.1 PLAN GOALS AND OBJECTIVES

Development of the SCMP focused on three main goals: 1) identify and prioritize sandhills sites according to their conservation potential, 2) devise management strategies for protecting native biodiversity within the sandhills, 3) develop a conservation strategy that integrates land preservation and management with other essential components of long term conservation efforts, including research and education. The following sections provide the rationale and primary objectives for each goal.

Identify and Prioritize Sandhills Conservation Opportunities

As demand for land intensifies and unmanaged sandhills habitat degrades, government agencies, regional land conservancies, conservation organizations, and concerned individuals are working to preserve sandhills habitat. At the time this project was initiated, these efforts lacked information crucial to identifying habitat preservation opportunities. Questions posed included: *Where should preservation efforts be focused? Where should management efforts be directed? How can we prioritize conservation options, given the overwhelming need?*

These and other related questions were addressed through the first goal of this project which was to identify and prioritize conservation opportunities in the sandhills through the following objectives:

1. Locate all sandhills habitat
2. Compile data on the preservation status, biological attributes, and management needs of each site
3. Rank sites according to their overall conservation potential
4. Recommend preservation and management strategies for each site
5. Prioritize unprotected habitat for preservation
6. Identify key management opportunities

Devise Management Strategies for Protected Habitat

Although land preservation is a necessary step toward conserving biodiversity in the sandhills, ecological research has shown consistently that land preservation alone will not be sufficient to maintain biodiversity in these unique communities. Even within protected reserves, habitat degradation due to recreational use, fire exclusion, and the invasion and spread of exotic plant species threatens populations of the endangered plants and insects, as well as natural community assemblages. The second goal of this project was to provide management strategies for the maintenance of biodiversity in preserved sandhills sites through the following objectives:

1. Compile available research on the geology, biology, and management of the sandhills and communities with similar biological characteristics
2. Synthesize research into a summary of the system, including its ecology and stresses
3. Evaluate potential management techniques for the sandhills
4. Establish guidelines for sandhills management based on their uniqueness, rarity, and fragility
5. Devise strategies for confronting specific stresses by habitat type and site conditions

Develop an Integrative Conservation Strategy

Though efforts to preserve and manage habitat are essential to sandhills conservation, long-term preservation of biodiversity requires several other components of conservation, including education, research, and cooperation. These essential components of the strategy were integrated into this plan through the following objectives.

1. Examine the role of education, research and cooperation in conservation
2. Determine mechanisms for promoting education, research, and a cooperative approach
3. Integrate these components in the overall strategy for conservation

1.2 Plan Applications and Approaches

From concept to final plan development, the ways in which the plan will be used have been carefully considered in plan formation. Determining the applications as well as audience of the plan influences many important aspects including the topics, level of detail, organization, and tone. Anticipated uses are to obtain information necessary to plan, design, and implement habitat preservation, management, and auxiliary (e.g. research, education) efforts in the sandhills. Considerations of the myriad approaches, multiple organizations involved, and numerous people with different backgrounds using this document, pulled the plan in several directions. The following outlines how the plan can be used and the rationale behind the approach taken to the plan.

Plan Applications

This plan can provide information to aid planning, designing, implementing, and evaluating a variety of conservation efforts. The following is a sample of some of the general applications of the plan and a summary of the types of information the plan contains that will facilitate these efforts, though the examples are not comprehensive nor are different applications mutually exclusive.

Habitat Preservation

Land conservators, planners, and agency representatives will benefit from an understanding of the status of habitat preservation in the sandhills, aspects of sandhills ecology that influence preservation mechanisms and priorities, an overview of the role that individual sites play in a regional conservation strategy, and specific opportunities for land preservation.

Habitat Management

This plan addresses many of the important considerations land managers confront in their efforts to preserve native biodiversity within sandhills habitat. The following components will be especially useful for land managers: synthesis of the biology of the sandhills, description of sandhills threats and their impacts, detailed assessment of the mechanisms by which the threats impact sandhills communities and species, strategies for actively managing sandhills habitat, and specific recommendations for techniques to enhance habitat.

Sensitive Species Recovery Efforts

The sandhills support several sensitive species of targeted conservation concern. This plan provides a detailed summary of the known factors affecting the persistence of seven sensitive species in the sandhills. This information will benefit to regulators, consultants, and scientists, as well as others working to protect and recover these endangered species.

Scientific Research

This plan is designed to address the needs of experienced researchers, new researchers, and individuals and organizations wishing to take a scientific approach to their management. It provides a summary of the research conducted in the sandhills to date, including a sandhills bibliography. This plan also discusses important aspects of research that should be considered in the sandhills to maximize the conservation benefit while avoiding negative impacts, and provides contacts for those interested in beginning sandhills research.

Education

Park interpreters, outdoor or environmental educators, and classroom teachers and administrators interested in developing curricula involving the sandhills will benefit from the overview of the natural history of the sandhills, the description of conservation issues, as well as specific recommendations for programs in sandhills education.

Conservation Action

As a snapshot of current approaches, this plan can be used as a template for strategizing and implementing conservation activities for the sandhills. Organizations involved in sandhills conservation will find the background of this plan useful in informing future efforts as new needs arise.

Plan Approaches

People with backgrounds in science, planning, education, and perhaps art history, who are working as planners, scientists, educators, managers, and policy makers, to provide strategies, regulate uses, manage resources, educate the public, and advise on projects, might use this document to design programs, inform projects, and devise policies. All such applications are valuable, indeed essential to long term preservation of biodiversity in the sandhills.

Unfortunately, a single approach to writing, organizing, and presenting information in the plan cannot maximally benefit all of these varied uses. Scientists might prefer a more detailed assessment of the biology of the system, or perhaps management strategies that are more closely linked to prior theoretical and empirical work available in the published literature. Managers, though potentially interested in such details, may not have time to read through such a plan and would instead prefer a concise manual. While some policy makers might prefer the document provide *the* answers to the burning questions in sandhills conservation, others might want the background and rational presented so that they could make decisions. Clearly, no one document could serve all these needs and after grappling with these considerations, the following approach was used in this plan.

Content

To provide "a comprehensive conservation strategy for the sandhills", this plan aspired to cover as many relevant topics as possible to the greatest degree possible. Recognizing the seemingly infinite wealth of knowledge available on myriad topics such as fire management, decisions regarding what to include (or exclude) reflected the following hierarchy. First, all sandhills specific information relevant to conservation and management was included in the plan. In the absence of empirical knowledge from the sandhills, research from other systems and theory were used to discuss general issues and to devise management strategies that can be cautiously implemented through an adaptive management framework. In the case of issues for which there has been a wealth of information developed outside the sandhills, references and other resources for additional information are provided.

Organization

The plan is organized into chapters, each of which is designed to address a different aspect of the overall conservation strategy. Each chapter contains a summary, introduction, and literature cited sections, though the body varies depending on the different topics. Chapters were designed to be as self-contained as possible. However, essential background information about the sandhills is provided primarily in the first five chapters, which users will find provide important context for the subsequent strategies. In addition, the inter-related nature of many topics covered throughout the plan necessitated that certain themes and concepts be repeated, though excessive redundancy was avoided by referencing other sections or chapters within the plan to which the reader can refer for more information.

Terminology

Due to its emphasis on empirical knowledge and scientific approaches to conservation management, this plan incorporates scientific terms that may be new to some users. Efforts have been made to use lay terms wherever possible. In cases where introducing new terms can enhance readability and facilitate understanding, terms are defined when first used.

Disclaimer

While recommending strategies for planning and implementing conservation and management in the sandhills, this plan does not address important regulatory aspects of such work. Many local, state, and federal regulations govern management activities conducted on both private and public land. Theses regulations are complex and unfortunately beyond the scope of this plan. Plan users, be they managers, policy makers, or regulators, should consult the appropriate agencies and officials prior to designing and implementing projects to ensure that they comply with the regulations.

Of particular concern are regulations governing endangered species. The sandhills support four federally endangered species afforded protection under the Federal Endangered Species Act which is administered by the United States Fish and Wildlife Service, and two plants listed as endangered on the California Endangered Species list, which is administered by the California Department of Fish and Game. Management recommendations described in this plan may impact sensitive species and require permits from these agencies.

1.3 PLAN OVERVIEW

The SCMP is roughly divided into four main sections which include: 1) scientific synthesis, 2) conservation planning project, 3) management strategies, and 4) ancillary conservation strategies.

The scientific synthesis for the sandhills includes detailed information on the physical environment (Chapter 2), biology (Chapter 3), conservation threats (Chapter 4), and seven sensitive species in the sandhills (Chapter 5). These chapters provide the necessary background and context for recommendations and results presented in the subsequent three sections of the plan.

Results of the conservation planning project are reported in Chapter 6, which provides information about the amount of sandhills habitat remaining, the relative conservation potential of sandhills sites, and preservation and management recommendations for each site, and includes maps of the sandhills areas.

The third unit of the plan addresses management of sandhills habitat. It begins with chapter 7, which discuss the importance of several general approaches to sandhills management. These general approaches provide crucial background to specific management strategies as well as a foundation for designing additional management in the sandhills. The following three chapters provide detailed assessments of the three main forces degrading habitat and management strategies to address each threat: fire exclusion (Chapter 8), exotic plants (Chapter 9), and recreation (Chapter 10).

The final unit of the plan addresses ancillary components of a strategy that are crucial to long term preservation. Reclamation and restoration (Chapter 11) can play a crucial role in the maintenance of native biodiversity in intact sandhills habitat. Research (Chapter 12) in the sandhills is vital to informing ongoing conservation efforts. Education, interpretation, and outreach can enhance public enjoyment and appreciation of the sandhills while facilitating conservation (Chapter 13).

The plan finishes with recommendations for the next steps for sandhills conservation as and a brief discussion of how collaboration among individuals and organizations involved in sandhills conservation and management efforts can help turn this plan into action (Chapter 14),

The appendices of the plan include color plates illustrating many of the aspects of the sandhills described throughout the plan (Appendix A), the sandhills flora (Appendix B), the datasheets and instructions used in the Sandhills Conservation Planning Project (Appendix C), attributes of sandhills sites from the planning project (Appendix D), and contact information for several of the human resources for sandhills conservation (Appendix E).

CHAPTER 2

SANDHILLS PHYSICAL ENVIRONMENT

INTRODUCTION

This chapter synthesizes the available knowledge of the distribution, geology, soils, and climate of sandhills habitat, topics which have important implications for sandhills biology, conservation, and management. After providing a definition of "the sandhills", this chapter discusses the origins of their island-like geographic distribution. Aspects of the geology, soils, and climate in sandhills communities interact in complex ways to strongly influence sandhills biology, and therefore are the discussed in the sections that follow. The unique combination of sand soil and maritime climate gives rise to the sandhills communities. Within the sandhills, small-scale variability in climate and soil conditions supports the diversity of species and communities. In addition, sandhills soil characteristics influence the consequences of human activities in the sandhills, as well as invasibility of sandhills habitat by exotic species. As a result, information about the abiotic environment of the sandhills facilitates understanding sandhills biology (Chapters 3-5) and management of sandhills habitat (Chapters 7-11).

2.1 DEFINITIONS AND DISTRIBUTIONS

Assessing the distribution of sandhills habitat requires a definition of "sandhills", an evaluation of their global distribution, and an assessment of the biogeography within Santa Cruz County.

Definition

The sandhills are the unique community of plant and animal species found on Zayante Soils in Santa Cruz County. Several different names have been used to refer to these communities. *Santa Cruz sandhills* refers to the geographic locality of the sandhills, which are found only in Santa Cruz County. *Zayante sandhills* references the unique soils on which sandhills communities are found. Though used as a synonym for "Santa Cruz sandhills" and "Zayante sandhills", the term *Ben Lomond sandhills* is often used to refer specifically to sandhills habitat found in the Ben Lomond region, which differs in some respects from habitat in other areas (e.g. Bonny Doon). To further complicate matters, the word 'sandhills" has been written either as one word or two (i.e. sand hills), with the words capitalized or not. In this document, the sandhills are referred to as the Santa Cruz sandhills, or simply "sandhills".

Sandhills Distribution

The unique community of plants and animals known as the Santa Cruz sandhills is found only in Santa Cruz County, in central coastal California. Other regions of the United States including Texas, Montana, Nebraska, Carolina, and Florida also contain biological communities referred to as "sandhills" (Christensen 1977, MacRobers and MacRobers 1994, Abrahamson and Abrahamson 1996, MacRoberts and MacRoberts 1996, Lessica and Cooper 1999). Moreover, the inland dune formations in Monterey County near Fort Ord and San Louis Obispo County near Los Osos, are also occasionally referred to as "sandhills" (Van Dyke et al. 2001). Other less studied regions of the world undoubtedly support unique communities known as sandhills.

Like the Santa Cruz sandhills, these communities occur on outcrops of sand soil and support unique edaphic (soil based) assemblages of plants and animals. Due to the strong role of soils in determining plant and animal habitat, these communities often have ecological similarities to the Santa Cruz sandhills including high endemism rates, vegetation characteristics, and fire ecology. As a result of their narrow distribution and high diversity, many of these areas are also the focus of conservation efforts.

However, the species composition in these communities is very different if not entirely dissimilar from that of the Santa Cruz sandhills. That is, the individual plant and animal species that occur in the sandhills of Texas are not the same as those that occur in the Santa Cruz sandhills. Thus, from a conservation perspective, these communities are entirely different.

Research in these other sandhills systems can enhance understanding and help inform conservation, in the case where empirical information from the Santa Cruz sandhills is not yet available. However, important differences between these communities and the Santa Cruz sandhills necessitate that such information be applied cautiously to conservation and management in the Santa Cruz sandhills.

Santa Cruz Sandhills Distribution

The Santa Cruz sandhills are restricted to outcrops of the Zayante soils found near the towns of Bonny Doon, Boulder Creek, Ben Lomond, Felton, and Scotts Valley. With the exception of a small habitat patch located immediately east of Highway 17, sandhills habitat is found only in the region west of Highway 17, north of the city of Santa Cruz, south of Big Basin, and in or east of Bonny Doon (Figure A.1 in Appendix A, Figure 6.1 in Chapter 6). Sandhills habitat was historically concentrated between the San Lorenzo River Valley and Carbonera Creek (current Highway 17 corridor); though development has greatly reduced the intact habitat in this area (Chapter 4).

Sandhills communities are restricted to soils of the Zayante series. However, there is not complete overlap between the occurrence of these endemic communities and the mapped boundaries of the Zayante soils. In most areas, this is likely because the Santa Cruz County Soil Survey (USDA 1980) mapped soils using a minimal mapping unit which was too large to reflect the occurrence of patchy soil outcrops occurring within larger, contiguous areas of the same soil series. As a result, small patches of Zayante soils occur within areas mapped as another series (e.g. Maymen series). In addition, large areas mapped as part of the Zayante soil series include patches of non-Zayante soils.

Though Zayante soils occur from the Big Basin area west of Boulder Creek to the town of Corralitos in the east, areas mapped Zayante soils on the western and eastern parts of this distribution do not support endemic sandhills species and communities (Marangio and Morgan 1987), though the reason for this is not clear.

Biological Islands

Sandhills habitat occurs as 'islands' or discrete patches within a matrix of communities that are more widespread within the region, including mixed evergreen forest and redwood forests (Marangio and Morgan 1987). Currently, patches of sandhills habitat vary greatly in size, from less than 0.4 Ha (1 acre) to more than 200 ha (500 acres; Chapter 6).

This variation is due in part to the variability in size of the Zayante soil outcrops, which naturally range in size from just a few acres to more than 2500 acres (USDA 1980). However, habitat fragmentation due to development has reduced the size of many patches and dramatically decreased connectivity.

Despite their close proximity, patches of habitat interspersed by non-sandhills soils and therefore non-sandhills vegetation (e.g. riparian corridors) may have been geographically isolated for millions of years. This island-like nature of sandhills soils and therefore habitat has significant consequences for sandhills biology, including biogeography, evolution, and ecology. This geographic separation of patches also has important implications conservation, including population sizes of sensitive species, the persistence of natural disturbance regimes, and the maintenance of genetic diversity.

2.2 Sandhills Geology

Though the geology of the sandhills habitat has not been specifically examined for purposes of understanding the natural system, some research conducted as part of sand quarry development has provided insight about sandhills geology (Stanley 1983). Two aspects of sandhills geology that provide insight to their biology and conservation are the characteristics of the geologic formation that gives rise to sandhills soils, and the topography of sandhills habitat.

Formations

The sandhills soils are derived from the weathering of uplifted marine sediments and sandstones of the Santa Margarita formation. Formed from sediments deposited in the Miocene Epoch (about 5-24 mya), this formation is a highly weathered arkosic (high feldspar content) sandstone which is 85 to 90% sand, 7-8 % silt, and 4% clay (USDA 1980).

Within the Santa Margarita formation, there are indurated sand dollar beds or facies—fossils restricted to a specific sedimentary environment—below the sandhills soils in the Ben Lomond, Felton, and Scotts Valley region (Figure A.3). These thick beds of sand dollars and other fossils (barnacles, gastropods, etc.) in a matrix of sand sediment have become indurated or hard due to pressure and cementation with minerals (Figure A.4). Below these sand dollar beds, which vary in thickness from 10m to over 40m, there is a layer of loose, course grained sand. Soils typically overlay the facies, though the sand dollar bed outcrops can be observed above the ground at some sandhills sites (Stanley 1983; Figure A.3).

Topography

Due to uplifting of sandhills soils through formation of the Santa Cruz Mountains, sandhills soils are typically found on the tops of hills, mountains, and isolated ridges (Figures A.2 and A.5). The slopes of these formations range from gentle (5%) to very steep (75%), and can vary greatly both within and between different sandhills sites (USDA 1980). The topography of sandhills habitat has very important implications for sandhills biology as it influences species and community distributions, soil conditions, and erosion. In turn, topography influences many aspects of management both indirectly through biology and directly, by determining impacts of human use (e.g. recreation, Chapter 10).

2.3 SANDHILLS SOILS

Understanding sandhills soils benefits from consideration of the important distinctions between sandhills soils and non-sandhills soils, as well as the important variability *within* sandhills soils.

Characteristics of Zayante Soils

The soils derived from weathered Santa Margarita formation have been named "the Zayante Series" by the Soil Conservation Service, now known as the Natural Resource Conservation Service (Figure A.6). Soils of the Zayante series occur on slopes ranging from 5-50%, with sandstone outcrops occurring near some Zayante soil patches. Where Zayante soils predominate, they have been mapped as one of three mapping units: 1) Zayante coarse sand with 5-30 percent slopes, 2) Zayante coarse sand 30-50 percent slopes, and 3) Zayante-Rock outcrop complex. Zayante soils have been classified as sandy, mixed, mesic Entic Xerumbrepts (USDA 1980). Their characteristics are described below.

<u>Development</u>

Like other inceptisols, Zayante soils are poorly developed in that their horizons are only in the earliest stages of development. A typical soil profile of the Zayante soils was described from the sandhills near Henry Cowell State Park consisted of an A horizon (0-30 inches) with gray to grayish brown subhorizons. The A horizon is underlain by a C horizon (30-60 inches) consisting of two brownish gray to very pale subhorizons, under which there is consolidated material or sandstone at a depth greater than 60 in. below the soil surface (USDA 1980). However, the Zayante series also includes soils with bedrock as shallow as 40 inches below the soil surface.

<u>Depth</u>

In many areas, sandhills soils are deep and loose soils and resemble beach sand in this respect. The sandstone from which the soil is derived can be several meters below the soil surface. In other areas, the soil is thin and underlain by loosely consolidated rock (sandstone). These conditions are characteristic where erosion has occurred. Soil depth influences water availability, plant root penetration, and therefore plant community composition (Section 3.2).

Texture

Formed from the weathering of the Santa Margarita formation sandstone (Section 2.2), Zayante soils are coarse textured sandy soils comprised primarily of sand particles, or particles between 0.05 – 2 mm in diameter. Particle size distribution varies within Zayante soils, however these soils are typically greater than 90% sand with small, clay particles comprising less than 4% of the soil by volume (USDA 1980).

Soil Moisture Availability

The coarse texture results in low soil moisture availability for plant growth, as the relatively large particles have lower surface area to which water can adhere. As a result, sandhills soils typically have less than 10% soil moisture by volume throughout much of the rainy season (November to April) and undetectable soil moisture in the top 20 cm (McGraw 2004). The coarse texture also allows high levels of leaching of cations (bases), resulting in moderately to strongly acidic soil pH (USDA 1980).

Organic Matter and Nutrient Availability

Though coarse texture of sandhills soils also influences soil nutrient availability, and nitrogen, phosophorus, and potassium can be readily leached from the root zone. Though no studies have specifically compared nutrient availability between Zayante soils and the adjacent soils which support mixed evergreen and redwood forests immediately adjacent to the sandhills communities (e.g. Nisene-Aptos Complex), the light color of the soils suggests that Zayante soils have low levels of organic matter and nutrient availability (USDA 1980; Figure A.6).

Variability Within Sandhills Soils

Climate, parent material, topography, biota, and time interact in complex ways to influence soil development (Brady and Weil 1996). Small-scale variability in these factors has created a wide range of local variation *within* sandhills soils. Observations of sandhills habitat throughout the region strongly indicate that these differences can have important consequences for the biological communities and species supported. The following is a list of factors likely responsible for variation in soils and thus communities; however, the specific roles of geology and soils in influencing sandhills communities remains poorly understood.

Depth

Erosion can greatly influence soil depth. Natural forces including wind, water, and gravity transport soil in the sandhills. In places where plant cover is sparse and slopes are steep, such as in sand parkland (Section 3.2), erosion can maintain thinner soil conditions. Anthropogenic forces that remove vegetation such as grading and recreation greatly impact soil depth, as they either remove soil directly and/or facilitate erosion by removing the vegetation and soil crusts that binds soil.

Biological Soil Crusts

In undisturbed areas away from woody vegetation, sandhills soils often have a biological soil crust—a surface layer ranging of varying thickness which is more compact, hard, and brittle when dry than the soil beneath (J. McGraw, pers obs.; Figure A.7). Though there has been no known research into the composition in the sandhills, soil crusts in other systems are comprised of a variety of organisms including cyanobacteria, lichens, fungus, mosses and liverworts (Belnap 2003).

The biological soil crust is not uniformly distributed throughout the sandhills habitat. Instead, like the plant and animal species of the sandhills, it differs greatly depending on microsite characteristics (vegetation, slope-aspect, etc,) likely due to responses of the individual organisms to water, temperature, soil conditions, and disturbance, among other factors (J. McGraw, pers obs.).

Biological soil crusts play many important roles in other systems including enhancing nutrient availability, facilitating plant establishment, and reducing erosion. The stickiness of the crust acts to gather dust that falls on the soil surface, and thereby enhances availability of many plant-essential nutrients. Crust organisms themselves provide a source of carbon and nitrogen to soils. In addition, the roughened surface of soil crusts traps seeds, thus enhancing plant establishment in open areas. Crusts reduce erosion caused by wind and water by linking soil particles together in filamentous sheaths. Stability provided by the crust allows other plants to establish, thus crusts also indirectly reduce soil erosion as well (Belnap 2003). This role of crust may be especially important during high rainfall events on the steep (>50%), sparsely vegetated slopes of sand parkland ridges.

Biological soil crusts are easily removed by disturbance. Natural soil disturbances including gopher mounds and wildlife trails remove crusts and create bare sand conditions at small spatial scales within the sandhills (McGraw 2004). Anthropogenic disturbances including recreation in arenas and wide trails remove crusts over larger areas and can thus have important implications for soils, plants, and animals. Though these effects have not yet been studied in the sandhills, research from other systems suggests that management must consider impacts on biological crust.

Aspect

Aspect plays a crucial role in sandhills soil development via positive feedbacks between microclimate and vegetation (USDA 1980). Sandhills soils on north-facing slopes are cooler and moister due to the lower incidence of solar radiation. As a result, plants on these slopes face reduced desiccation stress, resulting in greater plant cover on north slopes (Figure A.8). These soils are deeper, have a darker surface layer indicating their higher organic matter, nutrient availability, and moisture retention, and therefore support greater plant growth (McGraw 2004).

Conditions on south, west, and east aspects, in contrast, are hotter and drier and are thus less productive. As a result, soils are light colored, reflecting their lower organic matter, nutrient availability, and thus water holding capacity, which together prevent establishment of dense perennial vegetation. Plant species composition is very different between north slopes and slopes with south, west, and east aspects (Section 3.4).

Trees

Even on slopes of the same aspect, sandhills soils vary greatly depending on their proximity to trees. While soils away from trees on south aspects are very light (indicating their low organic matter, nutrient availability, and water holding capacity), soil underneath the canopy of a trees (e.g. ponderosa pine, coast live oak) are dark and more closely resemble north aspect soils. Soils under trees had twice the nitrate and more than twice the phosphorous of soils away from trees in sand parkland (McGraw 2004).

Presumably the same positive feedback loop acting to increase soil development on north aspects facilitates soil development under trees: lower temperatures and thus reduced desiccation stress allow increased plant growth which increases soil nutrient availability due to inputs from decaying plant matter which in turn increases plant growth, thus enhancing soil development under trees. These processes likely also increase soil development under long-lived shrubs in the sandhills (e.g. *Arctostaphylos* sp., *Ceanothus* sp); however this has not yet been examined empirically.

2.4 CLIMATE OF THE SANDHILLS

The climate of the sandhills, combined with the sand soils, creates the unique conditions for plant and animal life which make the sandhills a biological treasure found nowhere else in the world (Marangio and Morgan 1987). Understanding the sandhills climate is essential to understanding the ecology of the sandhills communities and devising effective strategies for managing their native biodiversity.

Precipitation

Santa Cruz County experiences a Mediterranean climate, with cool wet winters and hot dry summers. Most of the precipitation occurs as rainfall during a distinct rainy season between November and April. Mean annual precipitation ranges from 100 cm – 140 cm depending on orographic (rain shadow) precipitation, which depends on the site elevation and local topography.

Sandhills experience high interannual variability in rainfall, with excessively dry years and very wet years being common. For example, while the Quail Hollow sandhills in Ben Lomond averaged 124 cm of rain over the past 30 years, the standard deviation was 51cm of rain. Between the 1973 and 2003, there were three years with less than 60 cm of rain (or half the average) and four years with greater than 200 cm of rain (Western Regional Climate Center 2004).

Given the importance of water as a limiting resource for plant growth in the sandhills (Section 3.2), the rare species and communities are greatly affected by precipitation variability with the effects depending, in large part, on the *pattern* or seasonality of rainfall. Three important patterns include the onset of fall germinating rains, the mid winter drought, and the quantity and duration of rainfall through the spring (J. McGraw, unpublished data).

Though the first storms of the season typically occur between mid-October and mid-November, the first significant rainfall event can occur as early as late September or as late as mid-December. Occasionally, summer thunderstorms (especially August-September) bring lightening and early rainfall to the region, though they typically provide less than 5 cm of rain (Western Regional Climate Center 2004).

Between mid-December and early March, there is often a distinct mid-winter drought in the region which results in 2-4 weeks of zero or trace precipitation. During this period, temperatures exceed the monthly average and soils can experience significant drying, owing to their droughty nature (Section 2.3).

Spring rainfall is highly variable and accounts for much of the interannual variability in rainfall in the sandhills. The amount of precipitation after the spring equinox (March 22), and therefore the annual rainfall, is most greatly affected by the number of rainfall events (storms) that occur, rather than the amount of rainfall per event. That is, years with above average spring rainfall (and therefore annual rainfall) have a greater number of rainfall events after the vernal equinox, often continuing until late May or early June. In contrast, low rainfall years (and springs) are characterized by few storms providing more than 5 cm of rain after the equinox (J. McGraw, unpublished data).

Temperature

Though the official mean annual temperature of areas in Santa Cruz County such as Ben Lomond is about 22º C (58º F; Western Regional Climate Center 2004), mean annual temperature in the sandhills communities is likely much higher due to the open nature of the vegetation and the white sand soil which increases re-radiation of solar energy. In the winter, temperatures are much warmer than in adjacent, non-sandhills communities.

Temperatures in the sandhills can be very hot in the summer. Measurements taken 45 cm above the soil surface using weather monitoring devices (e.g. HOBO data loggers) indicate that temperatures can exceed 38º C (100º F) several days between late May and early October (J. McGraw, unpublished data). Hot summer temperatures likely combine with the season drought to influence the structure and species composition of sandhills plant communities.

Fog

The sandhills are likely influenced by coastal fog characteristic of the maritime climate of the region (Figure A.9). Though the sandhills habitat patches nearest the coast are still approximately 6 km inland, summer fog can frequently be found in the pre-dawn hours. In addition, the early summer months (June and July) can see extended periods of fog and low clouds (e.g. 1-2 weeks) in which fog persists into the mid to late afternoon hours, resulting in daily temperatures much below normal (J. McGraw, unpublished data).

Fog not only reduces daily high temperatures and therefore evapotranspiration rates and desiccation stress, but likely provides plants and animals with water during the dry season. Research in other communities in central coastal California has shown that plants derive a significant portion of their water during the summer from fog (Azvedo and Morgan 1974, Dawson 1998). In addition to reducing radiant energy, the dense hairs on the surfaces of many sandhills species may be an adaptation to collecting fog water, which collects on many plants during the summer months (Figure A.10). Vegetation patterns in sandhills habitat may reflect differential availability of this soil moisture due to fog patterns, though this has not been examined empirically.

2.5 Importance of Sandhills Habitat for the Water Supply

In addition to its extraordinary biotic value, intact sandhills habitat plays an important role in providing water to the community Characteristics of the sandhills geology, soils, and climate interact to render sandhills habitat an important part of the regional water supply system. First, the region receives a fairly high amount of rainfall (40-60 inches annually). When this precipitation lands on intact sandhills habitat (as opposed to hard surfaces associated with development), it readily percolates through the coarse sand Zayante soils, rather than running off directly into streams. There it permeates the porous Santa Margarita sandstone, which acts as an aquifer—an underground water bearing formation (J. Mueller, pers. comm. 2004).

The Santa Margarita aquifer does not hold water for long periods of time. Instead, water is readily cycled through the aquifer, as inputs from precipitation often exceed the aquifer's capacity. Excess water moves underground until it reaches streams including Bean Creek, Zayante Creek, and Newell Creek, among others, where it plays an important part of stream system (J. Mueller, pers. comm. 2004).

Though small in terms of geographic area, the Santa Margarita aquifer contains readily extractable water resources that are an important component of the water supply of the region. The San Lorenzo Valley Water District (SLVWD), which provides water to communities of Boulder Creek, Ben Lomond, Zayante, and parts of Scotts Valley, estimates that an average of 50% the water supply it provides each year comes from the groundwater extracted from wells in the Santa Margarita formation (J. Mueller, pers comm.).

Given the importance of the Santa Margarita aquifer, the SLVWD is understandably very concerned about the persistence sandhills habitat. Development of sandhills habitat that increases the area of impermeable surfaces (e.g. roofs, roads) results in increased run off directly to streams, and thus reduced percolation into the aquifer. Though the SLVWD owns a large tract of sandhills habitat which it managers for its value to the aquifer, land use on private property containing sandhills habitat has the ability to significantly impact the aquifer as well. (J. Mueller, pers. comm. 2004). Non-destructive uses of sandhills habitat are also of concern for aquifer management. Because the sand soils are so porous, chemicals including pesticides have the potential to readily enter the aquifer and thus contaminate the region's water supply. This has important implications for the use of herbicides to control and eradicate exotic plants in the sandhills (Section 9.3).

CHAPTER 3

SANDHILLS BIOLOGY

INTRODUCTION

Due to their unique physical environment, the sandhills support biological communities that are found nowhere else in the world. Sandhills species are adapted to the conditions present in the sandhills, and understanding the constraints and opportunities they face is essential to management to enhance their persistence.

Effective management of the sandhills requires understanding not only of the differences between sandhills and non-sandhills habitat, but also the variability *within* sandhills habitat. Small scale variability in physical conditions results in a patch mosaic of different assemblages of plants and animals. In addition, the complex disturbance regime of the sandhills adds to both spatial and temporal variability in the composition of sandhills communities.

This chapter provides an overview of the general biology and ecology of the sandhills communities. It provides background and essential context for many of the specific management strategies, and provides information that can be used in research and education. Sandhills animals affect plant growth directly and indirectly; however, it is most convenient to build a picture of sandhills ecology from the "bottom up"—that is, by examining plant species and assemblages then the animals for which they provide habitat.

3.1 THE SANDHILLS FLORA

Conditions for plant growth in the sandhills are striking different from those on the adjacent loam soils in central Santa Cruz County (Chapter 2). As a result, the sandhills flora (plant species) is unique. Even though sandhills habitat persists as often small biological 'islands' surrounded by mesic (moist) vegetation, the sandhills flora contains surprising few species found in the mixed evergreen, riparian, and redwood forests. Instead, the diverse sandhills flora contains many species unique to the sandhills within the region (Marangio and Morgan 1987).

The sandhills flora has been described by Morgan (1983), Marangio (1985), and Marangio and Morgan (1987), with a species list provided in Lee (1994). The following description draws heavily from these sources, acknowledging the significance of their contributions.

Native Plant Species

The sandhills flora contains a wealth species that are native to the sandhills—meaning their occurrence in the sandhills predates colonization by the Spanish in the 1700s and is therefore presumed to be natural (Appendix B). In addition, there are 90 species have been called "sand specialty plants"—primarily herbaceous species unique to the area based on *one or more* of the following criteria (Marangio and Morgan 1987):

- Endemic species
- Undescribed ecotypes
- Disjunct populations
- Coastal relicts

- Threatened, endangered, or rare species
- "Locally unique" species
- Species occurring more frequently in the sandhills than other plant communities of the region

The following is a brief description of each of these seven classifications for sand specialty plants based on the work of botanist Randall Morgan (1983). Specific information on the uniqueness and status of individual species in the sandhills flora is provided in Appendix B.

Endemic Species

Presently, there are four plant species in the sandhills that are found nowhere else in the world. That is, these species only naturally occur on the Zayante soils in Santa Cruz County. They are the Ben Lomond spineflower (*Chorizanthe pungens* var. *hartwegiana*; Figure A.11), Ben Lomond buckwheat (*Eriogonum nudum* var. *decurrens*, Figure A.12), Santa Cruz wallflower (*Erysimum teretifolium*, Figure A.13), and the Bonnie Doon or silverleaf manzanita (*Arctostaphylos silvicola*, Figure A.14).

Undescribed Ecotypes

In addition to the four known endemic species, there are numerous undescribed ecotypes of otherwise more widespread species in the sandhills (Morgan 1983, Marangio and Morgan 1987). These species have morphologic differences that suggest they are genetically distinct. Determining whether observed variation is due to genetic differentiation and/or phenotypic expression of a similar genotype (i.e. the plants look different due to their different growth conditions) requires a common garden and/or transplantation experiment. Such as study was conducted for the sandhills poppy (*Eschscholzia californica*) and showed that the morphological variation of the plant is indeed due to genetic differences, leading the authors to conclude that it is a unique ecotype (Espeland and Myatt 2001). Through future taxonomic work, many sandhills plant species like the sandhills poppy will likely be deemed endemic (Morgan 1983).

Disjunct Populations

Populations of several plant species in the sandhills represent highly disjunct distributions for the species, as sandhills populations are more than 50 miles from the nearest non-sandhills populations. Prime examples of these are the ponderosa pine (*Pinus ponderosa*; Figure A.15) and pussy paws (*Calyptridium umbellatum*), both of which are primarily inland, montane species found above 1000 m elevation, yet also occur in the sandhills at approximately 200 m elevation (Griffin 1964). Like the undescribed ecotypes, the geographic isolation of these populations suggests strong potential for genetic differentiation and parapatric speciation—formation of new species as a result of the geographic isolation of populations.

Coastal Relicts

The sandhills support populations of plant species primarily found in the coastal strand communities, including dunes, back dunes, and bluffs in California. This is not surprising, given their similar soil (sand), climate (maritime Mediterranean), and thus conditions for plant growth. Coastal relicts include sea thrift (*Armeria maritima* ssp. *californica*), mock heather (*Ericameria ericoides*), and beach sagewort (*Artemesia pycnocephala*), among others (Morgan 1983). As with the undescribed ecotypes and disjunct populations, the geographic isolation of these relicts from coastal populations creates conditions conducive to speciation.

Locally Unique

Three sandhills plant species have been classified as locally unique by the Santa Cruz General Plan Santa Cruz (Morgan 1980). They are clarkia (*Clarkia rubicunda*), Santa Cruz monkeyflower (*Mimulus rattanii* ssp. *decurtatus*), and curly leaved monardella (*Monardella undulata*).

Rare, Threatened or Endangered Species

Rare, threatened, or endangered species are those that are listed on the California Native Plant Societies Rare and Endangered Species Lists (Skinner and Pavlik 1994), which is the most comprehensive list of rare species for the region. Three of the endangered sandhills species are also on the Federal Endangered Species list, with two of these listed as endangered on the California State Endangered Species list (Section 3.6, Appendix B).

More Frequent in Sandhills than non-Sandhills Communities in the Region

Finally, there are several plants found more frequently in the sandhills than in non-sandhills communities in the Santa Cruz County region. Most of these species area also classified as one of the other six types of sand specialty plant above, though some are simply more abundant or widely distributed in the sandhills than in adjacent communities where they are also found.

As mentioned above, these classifications are not mutually exclusive; rather, most sand specialty plants can be characterized by more than one category (Appendix B). For example, most disjunct populations and coastal relicts are likely unique ecotypes and subspecies, owing to the geographic isolation which allows for parapatric speciation (i.e. speciation that occurs when two populations are geographically separated). Meanwhile, the endemic species are all rare, threatened, or endangered, due to their small geographic range, narrow habitat specificity (Rabinowitz 1981), and habitat destruction and degradation (Skinner and Pavlik 1994, USFWS 1998).

Non-Native Plant Species

Despite ecological theory suggesting that unfavorable soil conditions in the sandhills should render them resistant to biological invasion, exotic plant species have successfully colonized the sandhills (McGraw 2004). Primarily originating in the Mediterranean region, these species are termed "exotic" because they were not present in the region prior to the arrival of Spanish colonists in the 1700s and therefore most likely are present in the sandhills because of humans.

European annual grasses and forbs are the most abundant and diverse group of exotic plant species in the sandhills (e.g. *Vulpia myuros, Hypochaeris glabra, Bromus diandrus*; Figure A.36). In some sandhills sites, large exotic grasses (*Cortaderia* jubata; Figure A. 38), invasive shrubs including brooms (*Cytisus multiflorus, C. scoparius, Genesta monspessulana*) and trees (*Acacia decurrens*. *Eucalyptus globules*; Figure A. 37) have also become established. Unfortunately, ongoing introductions and rapid spread of exotic plant species in the region will likely result in future exotic plant invasions to the sandhills flora.

In addition, the sandhills are also being invaded by plant species native to California but *not* to the sandhills (i.e. *Lupinus arboreus*, *Heterotheca grandiflora*). Such species can reduce the abundance and distribution of sand specialty plant populations and therefore degrade sandhills habitat. The threats of exotic plant species are examined in Section 4.3. More information about their distribution and abundances is provided in the chapter 8, which addresses exotic plant management.

3.2 Plant Adaptations

Sandhills plants and plant communities provide fascinating lessons in evolution, biogeography, physiology, morphology, and ecology. Understanding these lessons can facilitate preservation of the rare species and communities. Toward this end, research in the sandhills has examined floristics (Marangio and Morgan 1987, Lee 1994), plant morphology (Espeland and Myatt 2001), and plant ecology (MCGraw 2004; Section 12.2). In addition, a wide array of documents prepared by consultants have provided insights into the sandhills communities and species (e.g. (Davilla 1980, Morgan 1983, Stanley 1983). This section synthesizes current knowledge of sandhills plants and assemblages.

Limitations to Plant Growth

The hot, dry summers combine with the droughty, low nutrient sand soils to create unfavorable conditions for plant growth in the sandhills. Two inhospitable conditions plants must confront are desiccation stress and low nutrient availability.

Desiccation Stress

High levels of radiant energy reflect off the sparsely vegetated white sand soil, creating conditions that result in large amounts of water loss through transpiration in plants. Due to the low water holding capacity of the Zayante soils (Section 2.3), and the marked dry season in the sandhills (Section 2.4), there is often no detectable soil moisture in the top layer of sandhills soils (McGraw 2004).

Low Nutrient Availability

As evidenced by their light coloration, sandhills soils are also are poorly developed and have low organic matter and thus generally low nutrient availability (Section 2.3; Figure A.6). In addition, the high permeability of sandhills soils combines with high rainfall to result in leaching of nutrients from sandhills soils. Finally, the low pH of sandhills soils renders important nutrients like phosphorus less available (Brady and Weil 1996).

Plant Adaptations

Sandhills plants exhibit a wide variety of adaptations to cope with the desiccation stress and nutrient limitations they face. Characteristics of plant life histories, phenologies, and morphologies have evolved to enhance plant performance in the harsh environment. In addition, plants have evolved important mutualisms—mutually beneficial symbiotic relationships with other organisms that can facilitate plant growth in the sandhills including fungus (mycorrhizae) and nitrogen fixing bacteria. Many plants in the sandhills exhibit more than one of the adaptations, which are summarized in Table 3.1.

Table 3.1: Plant adaptations to two main stresses to growth in the sandhills

Stress	Adaptation	Description	Examples
Desiccation	*Life history:* Annual plants	Live only during wet season	*Chorizanthe, Gilia, Vulpia*
	Phenology: Dormancy	Excise aboveground tissue and survive dry season via underground storage organs	*Dichelostemma, Calochortus*
	Phenology: Drought deciduousness	Excise leaves during dry season to reduce transpiration surfaces	*Lotus scoparius*
	Morphological: Reduce radiant energy	pubescences, light coloration, small leaves	*Arctostaphylos silvicola, Lupinus albifrons, Adenostoma*
	Morphological: Reduce water loss	succulence, leathery leaves, waxy coatings	*Dudleya, Ceanothus*
	Morphological: Increase water uptake	high root to shoot ratio, deep roots, taproots,	*Pinus, Lupinus, Erysimum, Bromus*
	Mutualism: Mycorrhizae	Fungal hyphae on plant roots enhance water absorption	*Pinus*
Nutrient Limitations	*Morphological:* increase nutrient uptake	High root to shoot ratio, fibrous roots	*Bromus,*
	Mutualism: Mycorrhizae	Fungal hyphae on plant roots enhance nutrient absorption (esp. phosphorus)	*Pinus*
	Mutualism: Biological nitrogen fixation	Bacteria on or near plant roots increase plant available nitrogen	*Lupinus, Lotus, Ceanothus*

3.3 Plant Distributions

Plant distribution patterns oftentimes reveal species adaptations to specific conditions for growth. Plant distributions can also be influenced by interactions between other species, including competition and herbivory, thus it is not appropriate to interpret distribution patterns as an indication of optimal plant growth conditions. However, cautious examination of sandhills plants distribution patterns at several spatial scales can reveal important aspects of sandhills plant ecology.

Regional Distribution

First, some plants are found primarily or exclusively in the sandhills and not in communities on adjacent, non-Zayante soils. Understanding the nature of this endemism can be important for managing sandhills habitat for their persistence. Though one might hypothesize that sandhills endemics and plants found only in the sandhills within the region (Section 3.3) require some aspect of the physical environment to complete their life cycles, the unfavorable conditions for plant growth in the sandhills suggest it is more likely that biotic conditions of non-sandhills environment are unsuitable and thus exclude sandhills species. That is, sandhills plants might prefer to grow in the high nutrient, moister soils of the adjacent Nisene-Aptos complex soils yet are excluded by competition in these densely vegetated areas (Baskin and Baskin 1988) or pathogens inhabiting these soils (Tadros 1957).

An experiment was conducted to test these hypotheses for the endemic Ben Lomond spineflower (*Chorizanthe pungens* var. *hartwegiana*), which is found only in plant communities on Zayante soils (the sandhills). Spineflowers grown in the soils of the adjacent plant communities (redwood forest, oak woodland) grew larger and had greater reproductive success in non-sandhills soils than those grown in sandhills soils, suggesting the plant does not require some aspect of the sandhills soils to persist. However, spineflowers performed poorly under shade treatments simulating redwood and oak forests, suggesting that the sandhills endemic is a poor competitor for light and restricted to the sandhills because it cannot tolerate the low light availability in the forests that occur on adjacent soils (McGraw and Levin 1998).

Distribution within the Sandhills

Plant distribution patterns *within* the sandhills may similarly reveal aspects of plant ecology important for conservation. Small-scale variability in soils, topography, and climate, among other factors, creates a high degree of heterogeneity in conditions for plant growth within the sandhills. Most plant species in the sandhills are preferentially found in certain microhabitats. In many cases, these specialized distributions reveal their adaptation to specific growth conditions.

Similar responses among different plant species to environmental variability contribute to the different plant communities in the sandhills (Section 3.4). For example, some sandhills plants are preferentially found in areas characterized by dominance of silverleaf manzanita (e.g. silverleaf manzanita chaparral), while others are found only in areas lacking this dominant plant and instead supporting sparse tree cover and herbaceous plants (e.g. sand parkland). The assemblages that result reflect different conditions provided in these areas, though the factors influencing such different communities is poorly understood.

Distributions within a Plant Community

Sandhills plants also exhibit a wide range of differences in distributions within a given community or assemblage within the sandhills. Within the sand parkland community, some plant species are found almost exclusively under trees (e.g. *Phacelia ramosissima*), on north aspects (*Castilleja affinis*), , at the base of washes (*Mimulus rattanii* ssp. *decurtatus*), along trails or on slides (*Monardella undulata*), or in other specialized locations (McGraw 2004). Understanding these distributions as important adaptations to life in the sandhills is important to managing populations of rare species and points to the importance of maintaining habitat heterogeneity in order to preserve native biodiversity in the sandhills.

3.4 Plant Communities

Preserving biodiversity in the sandhills requires an understanding of the ecology of the plant communities, as well as the individual species. Beginning with a brief background on plant community classification, the following section describes past and current efforts to describe the plant associations in the sandhills, with recommendations for how future research can facilitate conservation efforts.

Background

A **community** is the set of organisms of all types living in the same place at the same time. The term **assemblage** is used to describe groups of related organisms in a community, for example the plants within a community are the "plant assemblage". Though plant assemblage is more appropriate, the term "plant community" is commonly used to refer to the plant species in a given place at a given time. It differs from the "vegetation" which refers to the physiognomy or physical structure of the plants in a given area (i.e. chaparral, forest, grassland) without reference to the species composition. However, names for vegetation such as "silverleaf manzanita mixed chaparral" or "maritime coast range ponderosa pine forest," describe the physiognomy of the community as well as the dominant species present, where dominance is typically determined by visual dominance (typically the physically largest taxa), and not necessarily the most abundant or frequent.

Though plant species respond individually to the abiotic and biotic conditions of the environment and are thus distributed individualistically, species exhibit common responses to environmental conditions and thus co-occur. It is this common occurrence of plant species that plant community classifications address. Efforts to classify communities are often difficult and rife with controversy due to the variation in species composition that results from the independent distributions of plant species. However, edaphic communities—unique plant assemblages associated with unusual soil conditions—often provide the most clear cut examples of plant communities. Where the unique soil conditions (e.g. serpentine, vernal pools, lava flows, sandhills) are discrete, abrupt discontinuities in plant community composition typically occur, allowing ready discernment of distinct communities.

Like other edaphic communities, the sandhills communities can readily be distinguished from communities on non-Zayante soils due to marked dissimilarities in species composition. In most cases, sandhills habitat can be diagnosed and differentiated from non-sandhills habitat based on the plant species composition. The main exception to this is where apparent gradients (rather than abrupt discontinuities) in environmental conditions cause sandhills species to co-occur with non-sandhills species, typically those of the mixed evergreen forest. Such gradients may result from transitional soils—soils intermediate in nature between Zayante series and other soil types—and/or fire suppression, which allows encroachment of non-sandhills species into sandhills communities. These gradual transitions, or ecotones, have been shown to provide important habitat for plants and animals in many systems.

Plant community variation also occurs *within* sandhills habitat where spatial variability in species distributions results from spatial variation in a variety of interacting biotic and abiotic factors (soils, microclimate, disturbance history, etc.). Just as species of the sandhills flora co-occur in the sandhills due to their common responses to environmental conditions, assemblages occur within the sandhills as plant species respond to existing habitat heterogeneity. The result is fine scale variation in plant community structure and composition that can be recognized by biologists familiar with sandhills communities. Understanding the sandhills associations is important to an essential component of conservation efforts.

Sandhills Community Classifications

History

The sandhills plant communities have not been formally classified and described in the Manual of California Vegetation ((Sawyer and Keeler-Wolf 1995), nor elsewhere in the published literature (but see Marangio and Morgan 1987 for a brief description). The nomenclature and descriptions for the sandhills plant communities used in previous published and unpublished documents has therefore varied greatly, as different authors have utilized different classification schemes. The result is that different names have been ascribed to the same associations, causing confusion amongst sandhills biologists, planners, and managers.

The vast majority of sandhills documents have categorized sandhills communities using plant community classifications created for the entire State of California (Critchfiled 1971, Cheatham and Haller 1975, Holland 1977, Holland 1986, Sawyer and Keeler-Wolf 1995). Due to the large geographic areas covered, such treatments inevitably do not include highly localized communities such as the sandhills; much less provide ways to distinguish between associations *within* the sandhills. As a result, vegetation descriptions in many sandhills documents have ‘lumped’ sandhills associations with more common vegetation based on the presences of a few widespread species (e.g. *Arctostaphylos tomentosa*). Such efforts ignore the unique species composition of sandhills plant communities.

Frustrated by these early descriptions of sandhills communities, Morgan (1983) devised a classification for the endemic sandhills plant communities. Based on his extensive observations and species lists from a wide range of sandhills sites, Morgan’s classification defined four plant communities: sand parkland 1a, sand parkland 1b, ponderosa pine forest, and sand chaparral.

Lee (1994) expanded on Morgan's classification, using species cover data obtained from nested quadrats using relevé sampling (Braun-Blanquet 1932) at 20 sandhills sites. Lee employed semi-quantitative methods to derive his classification, as abundances and frequencies amongst plots were examined visually and used as quantitative criteria for his five sandhills community types. Lee found sufficient variation in the species composition in Morgan's 'sand chaparral' to split it into two communities: "pure sand chaparral" or stands dominated by *A. silvicola,* and "mixed sand chaparral" communities with greater abundance of other shrubs.

McGraw used multivariate statistical analyses to derive a quantitative plant community classification for the sandhills habitat of the Quail Hollow Quarry in Ben Lomond (J. McGraw, unpublished data). Plant species cover estimates obtained from 104 randomly located 25 m^2 plots were examined using cluster analysis, indicator species analysis, and nonmetric multidimensional scaling (McCune and Grace 2002). Results were used to create a classification of sandhills vegetation for the 104-acre conservation areas (i.e. South Ridge, West Ridge, North Ridge, and Azalea Dell), which recognized 8 associations unique to the sandhills. The small-scale sampling (i.e. 5m x 5m quadrats) resulted in classification useful for examining the patch mosaic of assemblages that exist within the broad community types which are typically ascribed to large areas (several acres). While such a quantitative, repeatable classification is valuable for mangers who will be planning and implementing management to maintain a patch mosaic at such a fine spatial scale within a site (i.e. Quail Hollow Quarry), scaling up the results of this classification to describe large stands of vegetation is more difficult. In addition, caution should be used when applying such a classification to sandhills sites not sampled in the study, as it is based on species composition data which can vary greatly between sandhills sites.

Based on the results of these previous efforts, the following classification is recommended for use for regional plant community description until a plant community classification based on quantitative analysis of species composition data sampled from randomly located sites *throughout the sandhills ecoregion* is developed. This nomenclature will be used throughout this document in discussions of broad scale patterns in vegetation with respect to, for example, fire, exotic plants, and rare species.

<u>Proposed Classification</u>

Sandhills habitat can be defined by the presence of at least one of two indicator species: ponderosa pine (*Pinus ponderosa*, Figure A.15*)* and silverleaf manzanita (*Arctostaphylos silvicola*; Figure A.14). This is because all intact sandhills habitat has one or both of these two species. Ponderosa pine is primarily a montane species of the intermountain west that is most abundant within California in the Cascade and Sierra Nevada Mountain ranges at elevations between 1500 m – 2500 m. Highly disjunct coast range populations are found in the Mount Hamilton Range (Santa Clara County) and the Santa Lucia Range (Monterey and San Louis Obispo Counties) at 800 – 1200 m elevations (Hickman 1993). Disjunct stands of ponderosa pine in the Santa Cruz Mountains are found in the sandhills (i.e. on Zayante soils) at elevations of 150-280 m (Griffin 1964).

Silverleaf manzanita is endemic to the sandhills, meaning that it is *only* found in the sandhills. Within the sandhills it is fairly ubiquitous, though its abundance varies greatly within different community types. Natural communities within Santa Cruz County which include naturally occurring individuals of one or both of these two indicator species should be considered "sandhills". Diagnosing whether a highly modified area (e.g. quarry, former building site) is or is not sandhills habitat should be based on vegetation prior to alterations using historical aerial photographs that readily can be interpreted for the presence of the two indicators.

Within habitat characterized as "sandhills", there are various distinct assemblages (J. McGraw, unpublished data). Species composition differs greatly between assemblages that oftentimes occur at small spatial scales, creating a complex patch mosaic. Boundaries between communities can be abrupt, reflecting known or potential discontinuities in environmental conditions (e.g. aspect, soil consolidation, soil moisture availability, etc), or they can occur over a gradient, resulting in gradual transitions that are more difficult to discern. These variations in plant species composition are correlated with the distribution and abundance of the sensitive plant species, and represent different habitat conditions for animals, including the two endangered insects. Therefore, site specific management efforts should develop an empirical understanding of the plant assemblages at the site, as established in the conservation areas of the Quail Hollow Quarry (J. McGraw, unpublished data).

In the absence of a regional analysis of plant community composition in the sandhills, efforts to classify plant communities here will focus on the generalities observed at several sites at the regional scale.

In terms of their associates, plant communities supporting just ponderosa pine are differentiated from those supporting silverleaf manzanita alone. For these reasons, plant communities within the sandhills could be defined with reference to the frequency and abundance of these indicators, as in the following key.

1. Silverleaf manzanita more than 25% cover (*sandhills chaparral communities*)
    2. ponderosa pine sparsely distributed in stand…. *silverleaf manzanita chaparral with ponderosa pine*
    2'. Ponderosa pine not present or only very rarely
        3. Silverleaf manzanita more than 75% cover ……………………………..…...*sand chaparral*
        3'. Silverleaf manzanita less than 50% cover………………*silverleaf manzanita mixed chaparral*

1'. Silverleaf manzanita not present as more than 25% cover (*ponderosa pine dominated communities*)
    4. shrubs, mixed evergreen forest trees, dense throughout pine stands…….*ponderosa pine forest*
    4'. Shrubs, trees other than ponderosa pine and live oak uncommon (*sand parkland*)
        5. tree cover <30%, herbs more abundant than subshrubs…......................*open sand parkland*
        5'. tree cover >30%, subshrubs nearly equally herbs in abundance……....*dense sand parkland*

Sandhills Chaparral Communities

The majority of sandhills habitat currently supports communities dominated by silverleaf manzanita and other shrubs. These communities can be distinguished based on the presences of ponderosa pine and, subsequently, by the whether silverleaf manzanita dominates the cover. These communities constitute a type of Northern Maritime Chaparral, which is a sensitive community as listed by the California Natural Diversity Database (CNDDB).

Silverleaf manzanita chaparral with ponderosa pine: In some areas of chaparral, there are widely scattered ponderosa pine trees (Figure A.16). Shrub cover is often dominated by silverleaf manzanita, with *Ceanothus cuneatus,* other *Actostaphylos* spp., and *Adenostoma fasiculatum* less abundant individually, though their total cover can match that of silverleaf manzanita. The presence of ponderosa pine is the distinguishing feature of this community. Though there have been no efforts to quantify abundance, examination of aerial photographs suggests that pine cover is approximately 5-10%. It is not know if or how the other associates in this community (e.g. herbs, shrubs) differ from the other two types of chaparral; however, the presence of ponderosa pine is significant as it is likely an indicator of different habitat conditions for animals, including the Mount Hermon June beetle (Section 5.6).

Silverleaf manzanita mixed chaparral: Mixed stands of chaparral lacking ponderosa pine often occur in the sandhills. These stands include at mix of shrubs (*A. silvicola, C. cuneatus, A.. tomentosa*, *Adenostoma fasiculatum*) as well as shrub-sized oaks (*Quercus agr*ifolia and *Q. wislizinii*), in relatively similar abundance (Figure A.17). The name "silverleaf manzanita mixed chaparral" has been used to describe the sand chaparral community (Davilla 1980, Marangio 1985), and originated from the more general term "California Mixed Chaparral" which reflects the mixed nature of many sandhills stands (Marangio 1985).

Sand chaparral: Many stands of chaparral in the sandhills are dominated by silverleaf manzanita, with other shrubs and oaks in much lower abundance (Figure A.18). In the conservation areas of the Quail Hollow Quarry, the herbaceous species found in gaps between shrubs further distinguish sand chaparral from silverleaf manzanita mixed chaparral. While the latter supports a mix of herbs, the former tends to contain a much lower diversity and is dominated a few species: *Chorizanthe pungens* var. *hartwegiana*, *Mimulus rattanii*, and *Minuartia califonica* (J. McGraw, unpublished data). Soil conditions, primarily the degree of compaction, may contribute to the differences between silverleaf manzanita mixed chaparral and sand chaparral, though this has not yet been investigated.

Ponderosa pine dominated communities

Communities lacking substantial cover of silverleaf manzanita are dominated instead by ponderosa pine. These communities are distinguished by their physiognomy (forest vs. savanna) and subsequently by the cover of woody vegetation and species composition of the herbaceous assemblage. "Maritime coast range ponderosa pine forest" is the designation used by the CNDDB to indicate *all* sandhills plant communities with ponderosa pine present (including the silverleaf manzanita chaparral with ponderosa pine" above).

Ponderosa pine forest: The sandhills contain communities with a high density of trees including ponderosa pines, coast live oaks, and mixed evergreen forest trees including madrone (*Arbutus menziesii*) and as well as shrubs more widely distributed in the region including coffee berry (*Rhamnus californicus*), poison oak (*Toxicodendron diversiloba*), and woolly manzanita (*Arctostaphylos tomentosa* ssp. *crinita*; Figure A.19). They have been termed "ponderosa pine forest" (Morgan 1983), "coast range ponderosa pine forest" (Marangio 1985), and "maritime coast range ponderosa pine forest" (Lee 1994). Gaps between woody vegetation contain sparse assemblages of herbs, dominated by European annual grasses and forbs, and suffrutescents (sub shrubs) including *Lupinus albifrons* and *Lotus scoparius.*

This community is dissimilar from other patches of coast range ponderosa pine forest found at higher elevations in the Hamilton Range and Santa Lucia Mountains (Griffin 1964), and the forests of the Sierra Nevada and Cascade Ranges (Sawyer and Keeler-Wolf 1995), which have only minimal overlap in species composition.

<u>Sand parkland:</u> Sand parkland is the term used to describe the sparse stands of ponderosa pine associated with a diverse and well-developed 'understory' of herbaceous plants, many of which are unique to the sandhills in the region. Primarily comprised of annual and (to a lesser extent) perennial herbs unique to the sandhills, the ground layer of sand parkland also includes a variety of suffrutescents or subshrubs (Figure A.20). Sand parkland typically lacks a shrub component, though isolated shrubs including silverleaf manzanita, sticky monkey flower (*Mimulus aurantiacus*) and mock heather (*Ericameria ericoides*) are found in sand parkland.

Sand parkland communities with a higher density of ponderosa pine, coast live oak (*Quercus agrifolia*), shrubs, and subshrubs have been referred to as "sand parkland 1b", distinguishing them from the "sand parkland 1a" which has lower cover of woody vegetation and higher diversity and abundance of sand specialty annual and perennial herbs (Morgan 1983, Lee 1994, McGraw 2004). Sand parkland 1a is typically associated with hotter, drier south (and west) facing slopes, while sand parkland 1b is found primarily on cooler north (and east) slopes. Specific composition of the herbaceous layer also differs dramatically between these two assemblages (J. McGraw, unpublished data). The term "open parkland" will be used throughout this document to refer to previously describe parkland 1a, while "dense parkland" used to describe the parkland 1b (Figure A.20).

Table 3.2: Comparison of the plant community classification to previous descriptions.

Dominant species	SCMP Community	Morgan 1983	Lee 1994	California Natural Diversity Database
Silverleaf manzanita	**Silverleaf manzanita mixed chaparral**	Sand chaparral	Mixed sand chaparral	Northern maritime chaparral
	Sand chaparral	Sand chaparral	Pure sand chaparral	Northern maritime chaparral
	Silverleaf manzanita chaparral with ponderosa pine	Sand chaparral	Mixed sand chaparral; pure sand chaparral	Northern maritime chaparral and Maritime coast range ponderosa pine forest
Ponderosa pine	**Ponderosa pine forest**	Ponderosa pine forest	Ponderosa pine forest	Maritime coast range ponderosa pine forest
	Open sand parkland	Sand parkland 1a	Sand parkland 1a	Maritime coast range ponderosa pine forest
	Dense sand parkland	Sand parkland 1b	Sand parkland 1b	Maritime coast range ponderosa pine forest

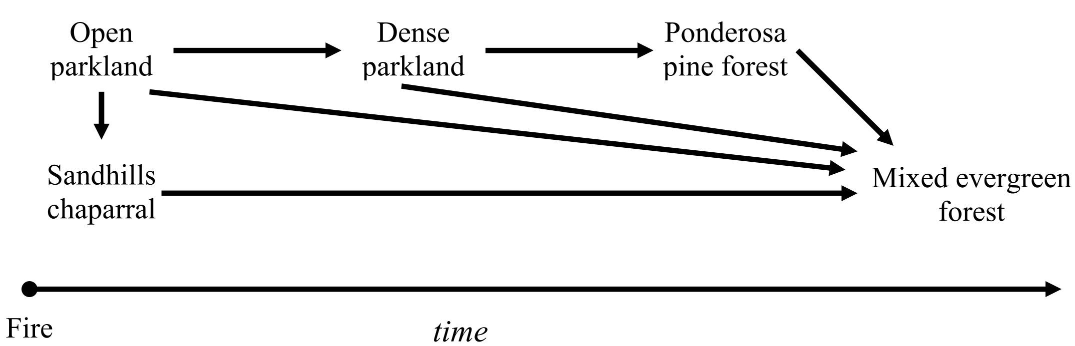
3.5 Successional Relationships Among Sandhills Communities

Succession is the process by which species composition in an area changes as a result of changing mortality and establishment rates through time. Succession can be influenced by interactions between species (e.g. competition, facilitation) and changes in the abiotic environment (e.g. soil development, microclimate) following disturbance. Successional trajectories are best examined with data collected via monitoring of communities following disturbance (e.g. fire; Van Dyke et al. 2001). In the absence of long term data, hypotheses about successional relationships between communities are often developed through analysis of community composition in areas of different 'ages', or time since disturbance in a process known as chronosequencing (Watt 1947).

Chronosequences can be misleading, especially in systems such as the sandhills where a variety of factors (e.g. subsurface geology, topography, and soil conditions), not simply time, influence species composition. Even if data were available to establish a successional trajectory in one sandhills site, such relationships cannot be generalized to other sites. Unfortunately, species composition data are not available for sandhills communities prior to the mid 1970's when Randall Morgan began examining the flora of different sandhills sites. Along with his description of the sandhills flora and communities, Morgan cautiously postulated successional relationships between sandhills communities (Morgan 1983).

Changes in plant community structure observed through examination of historical aerial photographs dating to 1943 can be combined with Morgan's hypotheses to suggest a set of successional trajectories that may influence sandhills communities through time (Figure 3.1). These should be treated as hypotheses to be tested through quantitative analysis. Moreover, just as the plant community classification proposed here understates the variability in plant community structure in the sandhills, this hypothetical successional scheme oversimplifies the natural system and is meant only to illustrate the types of changes that can occur in community composition through time.

Figure 3.1: Hypothesized successional relationships between sandhills communities. Trajectories are described in text.



Examination of historical aerial photographs for several sandhills sites before (1943) and after (1963) the 1954 "dump fire" that burned sandhills habitat in the Quail Hollow area south of the Ben Lomond landfill revealed that patches of sandhills habitat that supported sandhills chaparral communities prior to the fire regenerated as such, while habitat that supported parkland, dense parkland, and some patches of mixed evergreen forest adjacent to sandhills habitat regenerated as open sand parkland (McGraw 2004). Based on this, it is hypothesized that fire will result in two main communities establishing: open sand parkland and sandhills chaparral. While variation in shrub species composition may exist, it is not readily discerned through aerial photographs, such that all sandhills chaparral communities are grouped together presently.

<u>Succession of Open Sand Parkland</u>

Aerial photographs reveal that open sand parkland experiences several different types of changes. The rate and nature of these changes likely depend on several factors including soil conditions, adjacent vegetation, and microclimate, however they appear most likely to be correlated with slope aspect. Each of the hypothesized trajectories is described below.

Open Sand Parkland persists: On dry, south-facing slopes, open sand parkland vegetation appears persistent in some habitat patches, as the density of ponderosa pines, oaks, and isolated shrubs has increased only very slowly during the period of record (McGraw 2004; Figure A.31 south aspect).

Open Sand Parkland to Dense Sand Parkland: On the somewhat cooler east and west facing-slopes (relative to south aspects), the density of both trees (ponderosa pines and oaks) and shrubs (silverleaf manzanita, chamise) have increased (Figure A.31-north aspect).

Dense Sand Parkland to Ponderosa Pine forest: On some of the coolest north-facing slopes, the dense parkland appears to be transitional to ponderosa pines forest via increased density of trees as well as establishment of a variety of shrubs in the understory. It is important to note that ponderosa pine forest and dense parkland, for that matter, may establish readily on cool slopes following disturbance (Figure A.32).

Ponderosa Pine forest→ Mixed Evergreen Forest: Though this has not occurred during the period of record (60 years), it is possible the patches of mixed evergreen forest that have isolated, old ponderosa pines in them were once ponderosa pine forest (Figure A.32 and Figure A.31 north aspect).

Open Sand parkland to Mixed Evergreen Forest: In a few habitat patches on steep, cool north facing slopes, trees typical of mixed evergreen forests including tan oaks, madrones, and Douglas fir have established even without first becoming dense parkland or ponderosa pine forest. This rapid succession of open north slope parkland communities to mixed evergreen forest has occurred in the South Ridge and North Ridge conservation areas of Quail Hollow Quarry following the dump fire in 1954 (Figure A,31 north aspect).

Open Sand Parkland to Sandhills Chaparral: The extent to which open parkland succeeds to sandhills chaparral is unclear. Where they are adjacent, sand parkland and sandhills chaparral exhibit either abrupt boundaries or intergrade, depending on the site. Both communities feature open sand habitat that support herbaceous plant species; however, the composition of herbs differs dramatically in these communities, despite the apparent similarity in abiotic conditions and close proximity. Because it is not possible to discern herbaceous plant species composition from historic aerial photographs, it is difficult to say whether open areas following fire are parkland that is succeeded by sandhills chaparral, or open gaps in sandhills chaparral colonized by shrubs.

Isolated shrubs that dominate sandhills chaparral communities including *A. silvicola, A. fasiculatum,* and *C. cuneatus* occur in open sand parkland. Despite the abundance of adjacent open habitat, however, these shrubs do not spread. Instead, seedling and juvenile shrubs are uncommon in open sand parkland. This suggests that the sand parkland community may have some resistance to shrub encroachment. Various people have hypothesized that perhaps the subsurface geology (sandstone substrate, indurated sand dollar facies) that gives rise to the ridges in sand parkland may limit large shrub establishment (D. Hillyard, pers. comm. 1997, B. Davilla, pers. comm.2002). Though this has not been systematically examined, the lack of ready conversion of open sand parkland to sandhills chaparral despite the presence of shrubs suggests that there is some barrier may restrict conversion of sand parkland to sandhills chaparral.

Succession of Sandhills Chaparral

As described previously, sandhills chaparral communities vary greatly in species composition including in both the dominant trees and shrubs, and in the herbaceous assemblage found in open areas. This variation is not readily discernable in historical aerial photographs, rendering it difficult to examine successional relationships amongst the different sandhills chaparral communities. Colormetric analysis of historical aerial photographs may be used to examine such relationships as part of a future quantitative study of historical aerial photographs. For purpose of this plan, sandhills chaparral communities are grouped and hypothesized to follow one main successional trajectory, though this admittedly represents an oversimplification.

In the absence of disturbance, sandhills chaparral increases in cover of trees common in mixed evergreen forests. *Quercus agr*ifolia, *Q. wislizenii,* and *Arbutus menziesii,* observed within the interior of sandhills chaparral patches are long-lived and taller statured than sandhills chaparral shrubs. Through time, these trees may overtop and outcompete sandhills shrubs. Mixed evergreen forest trees appear to spread into sandhills chaparral communities at their boundary. These ecotones presently include tall statured trees including not only *Quercus* spp. and *Arbutus*, but also *Lithocarpus densiflorus* and *Pseudotsuga menziesii* which overtop spindly sandhills chaparral shrubs, suggesting succession of sandhills chaparral to mixed evergreen forest. This pattern is detectable in examination of historical aerial photographs, which indicate a contraction in the area of sandhills chaparral due to expansion of surrounding mixed evergreen forest at several sites (Figure A.30).

Chaparral communities are often an intermediate sere in succession in California forests. Montane chaparral establishes following forest fires in mixed coniferous forests of the Sierra

Nevada and Cascade ranges (Rundel et al. 1977, Holland and Keil 1995). Closer to the sandhills, a type of non-sandhills chaparral (e.g. knob cone chaparral *sensu* Morgan 1983) may establish following fire or clear cutting of redwood and mixed evergreen forests in the region.

However, sandhills chaparral communities do not likely succeed to any type of ponderosa pine forest communities. *Pinus ponderosa* is a very poor competitors for light (Cooper 1961, Griffin 1964). Thus, rather than being facilitated by early successional shrubs, *P. ponderosa* is likely inhibited from establishing under the canopy of chaparral shrubs. Scattered ponderosa pines that occur in the silverleaf manzanita chaparral survive the fire or establish following fire which removes shrub cover.

<u>Implications of Succession for Management</u>

The hypothesized successional trajectories can have important consequences for the persistence of biodiversity in the sandhills. As was observed by Morgan (1983), succession reduces the amount of sand parkland and sandhills chaparral communities over time, as no trajectories *create* sandhills habitat that can therefore be referred to as early successional. In areas where inimical soil conditions exclude non-sandhills species, perhaps indefinitely, sandhills plant will eventually senesce and, in the absence of fire to remove dead standing vegetation, limit subsequent recruitment. These and other likely consequences fire exclusion for plant and animal species are examined in detail in Chapter 8.

Plant Community Protection

Sensitive plant communities are afforded protection by the California Environmental Quality Act (CEQA) through their designation within the California Department of Fish and Game (CDFG) Natural Diversity Data Base (NDDB) list of rare communities. Because the vegetation of sandhills has not been formally described, sandhills communities are afforded protection as part of one of two communities: "maritime coast range ponderosa pine forest" and "northern maritime chaparral". Until the sandhills plant communities are described and integrated within the Manual of California Vegetation (Sawyer and Keeler-Wolf 1995) and thus the NDDB lists, such designations should continue to be used to provide this unique habitat protection. When describing habitat for purposes of management, however, attempts should be made to more specifically identify the assemblage, perhaps using the above 6 designations to avoid confusion.

3.6 Sandhills Fauna

The unusual combination of soils and climate in sandhills create unique conditions for animal life both directly, as a result of the sand soil, topography, and patchy distribution, and indirectly, by influencing the structure and composition of the plant communities, which in turn vary in the habitat conditions for animal species. This section provides an overview of the unique animal species, while the biology of three rare sandhills animals is provided in Chapter 5.

Vertebrates

The sandhills historically supported several unique vertebrate species. However, widespread habitat destruction and degradation have resulted in several known population extirpations (Marangio and Morgan 1987, Bean 2003). In addition, the frequency of observation of many other species is decreasing, suggesting that they may be in decline.

Found primarily in the desert southwest and dry areas of the central valley, populations of road runners (*Geococcyx californicus*) were historically found in the Santa Cruz sandhills. However, habitat loss and increased populations of subsidized predators (e.g. domestic cats) which predate on the ground dwelling birds likely caused the extirpation of these populations, which have not been observed since 1964 (Marangio and Morgan 1987).

The sandhills also historically supported disjunct populations of the Santa Cruz kangaroo rat (*Dipodomys venustus venustus,* Figure A.22). Like the road runner, the Santa Cruz kangaroo populations have declined due to habitat loss and fragmentation, and presently are known to occur in only a single sandhills site (Bean 2003). The distribution, biology, and threats to this rare animal are described in detail in section 5.7 of this plan.

Two lizard species similarly have highly disjunct populations within the sandhills. They are the western whiptail lizard (*Cnemidophorus tigris*; Figure A.23) and the coast horned lizard (*Phynosoma coronatum*; Figure A.24). Like other disjunct populations of vertebrates in the sandhills, these two lizards otherwise occur primarily in dry, rocky exposed inland habitats in California. Found in only a few sandhills sites in the Quail Hollow area, the western whiptail populations of the sandhills are the only known populations in Santa Cruz County (Marangio 1985). The coast horned lizard populations of the sandhills are also disjunct (Stebbins 1985). Sightings of this rare animal were reported to be decreasingly frequent in the late 1980s (Marangio and Morgan 1987), and the author only observed this rare animal once during the course of eight years of field research conducted at the South Ridge, one of the only sites where it is known to occur (J. McGraw, pers obs.). Like its congeners, the coast horned lizard may be threatened by local domestic cats and invading Argentine ants (Suarez et al. 1998, Suarez et al. 2000).

Other extant unique vertebrates species in the sandhills include: the night snake (*Hypsiglena torquata)*; the black tailed hare (*Lepus californicus*), which is "locally rare" in Santa Cruz County where it is primarily found in the sandhills (Marangio 1985); and the pocket mouse (*Chaetodipus californicus*) and Merriam chipmunk (*Eutamias merriami*) which are associated with the sandhills (Marangio 1985, Bean 2003). Mammal species with more widespread distributions found in the sandhills include mule deer (*Odocoileus hemionus*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), brush rabbit (*Sylvilagus bachmani*), valley pocket gopher (*Thomomys bottae*), dusky-footed woodrat (*Neotoma fuscipes*), deer mouse (*Peromyscus maniculatus*), California mouse (*Peromyscus californicus*), pinyon mouse (*Peromyscus truei*), and California meadow vole (*Microtus californicus*)(Bean 2003, J. McGraw, pers. obs.).

Reptile species with more widespread distributions that occur in the sandhills include the western rattlesnake (*Crotalus viridis*), gopher snake (*Pituouphis melanleucus),* and western fence lizard *(Sceloporus occidentalis*). Sandhills birds vary between sites, depending in large part on the adjacent habitat, but commonly include Red Tail Hawk, American Kestrel, California Quail, Mourning Dove, Anna's Hummingbird, Allen's Hummingbird, Northern Flicker, Acorn Woodpecker, Tree Swallow, Common Raven, Scrub Jay, Chestnut-Backed Chickadee, White-Breasted Nuthatch, California Towhee, and Dark-Eyed Junco (J. McGraw, pers obs.)

Invertebrates

Little is known about the insect fauna of the sandhills, though knowledge is accumulating as research continues. Based on the high level of plant endemism, the unique biotic and abiotic conditions, and the geographic isolation of the sandhills, however, there are likely to be many endemic insects in the sandhills (Rubinoff 2002). Currently, there are two known endemic insects in the sandhills: the Mount Hermon June Beetle (*Polyphylla barbata*; Figure A.25, Section 5.5) and the Zayante Band-winged grasshopper *(Trimerotropis infantalis*; Figure A.26, Section 5.6). Other potentially unique insects include are the Antioch dune wasp (*Philanthus nasalis*), an undescribed robber fly (*Stenopogon sp. nov*.), an undescribed melittid bee (*Hesperapis sp. nov*), and an undescribed flesh flies (*Senotaenia sp. nov. and Metopia sp. nov*; R. Morgan, pers. comm. 2002). The sandhills also support populations of the Santa Cruz rainbeetle (*Plecoma conjugens conjugens*), a rare insect that was proposed for federal listing but denied status due to its more widespread distribution.

3.6 Sandhills Sensitive Species

Due to their extraordinary rarity, several species in the sandhills have been recognized as rare and endangered and receive some protection within the regulations provided by the State and Federal Endangered Species Acts, the California Environmental Quality Act, and Sensitive Habitat Protection ordinance of Santa Cruz County. In addition, there are several undescribed species which would likely qualify as 'endangered' (R. Morgan, pers. comm. 2002). Finally, there are several locally unique species. The sensitive animals are listed in Table 3.4, and the sensitive plant species are listed in Table 3.5.

Table 3.4. Sensitive animal species of the sandhills.

Common Name	Species	Status
Zayante band winged grasshopper	*Trimerotropis infantilis*	FE
Mound Hermon June beetle	*Polyphylla barbata*	FE
Santa Cruz kangaroo rat	*Dipoodomys venustus venustus*	
coast horned lizard	*Phrynosoma coronatum frontale*	FSC, CSC
California whiptail lizard	*Cnemidophorus tigris mundus*	
night snake	*Hypsiglena torquata*	
Antioch sphecid wasp	*Philanthus nasalis*	
Santa Cruz rain beetle	*Pleocoma conjugens conjugens*	
sandhills robberfly	*Stenopogon sp. Nov.*	
sandhills flesh-flies	*Senotaenia sp. nov. and Metopia sp. nov.*	
sandhills melittid bee	*Hesperapis sp. Nov.*	

FE = Federally Endangered; FSC= Federal Species of Special Concern; CSC= CA Species of Special Concern

Table 3.5. Sensitive plant species of the sandhills.

Common Name	Species	Status
Santa Cruz wallflower	*Erysimum teretifolium*	CE, FE, IB
Santa Cruz cypress	*Cupressus abramsiana*	CE, FE, IB
Ben Lomond spineflower	*Chorizanthe pungens* var. *hartwegiana*	FE, IB
silverleaf Manzanita	*Arctostaphylos silvicola*	1B
Ben Lomond buckwheat	*Eriogonum nudum* var. *decurrens*	1B
Santa Cruz monkeyflower	*Mimulus rattanii* ssp. *decurtatus*	4
curly-leaved Monardella	*Monardella undulata*	4
dnapdragon	*Antirrhinum multiflorum*	
sea thrift	*Armeria maritime*	
beach sagewort	*Artemesia pycnocephala*	
pussy paws	*Calyptridium umbellatum*	
harebell	*Campanula angustifolia*	
sandcarpet	*Cardionema ramosissimum*	
pineflower	*Chorizanthe diffusa*	
white Chinese houses	*Collinsia bartsiifolia*	
larkspur	*Delphinium parryi* spp. *parryi*	
mock-heather	*Ericameria ericoides* (ssp. *blakei*)	
California poppy	*Eschscholzia californica*	
slender flowered gilia	*Gilia tenuiflora* spp?	
everlasting	*Gnaphalium* undescribed	
golden-aster	*Hetertheca sessiliflora* var. *camphorata*	
“tipless” tidy tips	*Layia platyglossa*	
linanthus	*Linanthus parviflorus*	
loeflingia	*Loeflingia squarrosa* var. *squarrosa*	
woolly dandelion	*Malacothrix floccifera*	
poppy	*Meconella linearis*	
monkeyflower	*Mimulus androsaceus*	
sandwort	*Minuaritia californica*	
muilla	*Muilla maritime*	
navarretia	*Navarretia hamata* ssp. *parviloba*	
winged pectocarya	*Pectocarya pencillata*	
phacelia	*Phacelia ramosissima* (var. *ramosissima*?)	
ponderosa pine	*Pinus ponderosa* (*P. benthamiana*)	
popcorn flower	*Plagiobothrys tenellus*	
campion	*Silene verecunda* ssp. *platyota*	
nest straw	*Stylocline gnaphalioides*	
fescue	*Vulpia octoflora*	

FE = Federally Endangered; CE = California Endangered, IB = CNPS List 1B: Rare, Threatened, or Endangered in California and Elsewhere; 4 = CNPS List 4: Plants of Limited Distributions, “A Watch List”

3.8 SANDHILLS DISTURBANCE ECOLOGY

Understanding the ecology of sandhills species and communities is integral to virtually all aspects of sandhills conservation efforts from planning and management to research and education. Of particular importance is the disturbance ecology of the sandhills, which can influence species diversity, persistence of sensitive species, consequences of human uses, and the outcomes of management efforts.

Sandhills disturbance ecology is examined throughout the plan, including in discussions of fire management (chapter 8), recreation (chapter 10), research (chapter 12) and education (chapter 13). Indeed, because of the importance of disturbance ecology in the sandhills, Sections 7.4, "Management strategies: The role of disturbances", is devoted entirely to examining how specific aspects of disturbance interact in complex ways to influence disturbance impacts on species and communities. Many readers will find Section 7.4 provides context for these other sections of the plan.

What are Disturbances?

Disturbances are events that remove biomass by killing animals and killing or damaging plants (Sousa 1984b). Natural components of most ecosystems, disturbances play a vital role in the structure and function of communities. Disturbances remove dominant species, free up resources, and allow persistence of competitively inferior species (Sousa 1980, Sousa 1984b, Lesica and Cooper 1999).

Many types of disturbance occur patchily within the landscape, and thereby create a patch mosaic of different successional conditions which provide different habitat for plants and animals (Sousa 1984a, Pickett and White 1985, Forman and Gordon 1986). In systems characterized by recurring disturbances, plant an animal species are typically adapted to disturbance, with many actually requiring some aspect of the disturbance to persist (Denslow 1980, Pavlovic 1994). As a result, natural disturbances enhance and maintain biodiversity in disturbance-adapted systems (Connell 1978, Petraitis et al. 1989), and disruption of natural disturbances has important consequences for diversity and the persistence of disturbance-dependent species (Collins 1987, Wootton et al. 1996).

Natural Disturbances in the Sandhills

The sandhills communities and species experience natural disturbances of two main types: fire and soil disturbances (McGraw 2004). Various human activities, including most notably recreation, but also various land clearing activities, also create disturbance. These anthropogenic disturbances are discussed in subsequent sections of the plant (Section 7.4, Chapter 10).

<u>Fire</u>

The sandhills communities are fire adapted. Though research has not yet determined the natural fire regime of the sandhills, the climate, vegetation, analysis of historical aerial photographs, and the known fire history of the region, all strongly suggests that fire occurred in sandhills communities until the middle of the last century (Langenheim and Greenlee 1983, Greenlee and Langenheim 1990). Efforts to assemble aspects of the sandhills fire regime are reported in Chapter 8.

Based on evidence suggesting the role of fire in the sandhills, McGraw (2004) examined the effects of reintroducing surface fire in sand parkland using small-scale manipulations of fire. To minimize the potential negative impacts of fire and safely contain the burns, which were ignited during the likely burn season (September), burn treatments were conducted in burn boxes—bottomless, galvanized metal 2m x 2m boxes (Pavlik et al. 1993). Scattered throughout sand parkland habitat including on west, north, and south aspects at three sites in the Quail Hollow sandhills area, the burns were designed to test the direct effects of fire on the rare plant community and species, as well as their indirect effects due to their impacts on exotic plant species.

These experimental trials showed that fire enhanced survivorship of the Ben Lomond spineflower and germination and survivorship of the Santa Cruz wallflower, as well as the richness and cover of native herbaceous plants. Examination of the mechanisms showed that fire facilitated native plants directly by removing accumulated leaf litter on the soil surface which otherwise inhibits germination and early seedling survival, and indirectly by reducing the abundance and therefore competitive effects of European annual plants (McGraw 2004).

Soil Disturbances

In addition to fire, the natural disturbance regime in the sandhills includes a variety of soil disturbances that influence the distribution and abundance of many plant species, and thus alter habitat for animals. These include slides, wildlife trails, and gopher mounds.

Slides result from the aboveground movement of water, and to a lesser extent wind and gravity, which removes plant cover and creates soil conditions which deter recolonization by the dominant plant species (Figure A.27). Primarily occurring on steep slopes, slides are most common in the sand parkland community where sparse vegetation primarily composed of shallow rooted herbaceous plans does not adequately protect that soil surface from the erosive forces. These slides vary greatly in size and cover an estimated 16% of the soil surface in sand parkland (McGraw 2004).

Wildlife trails form readily in the loose soil of the sandhills (Figure A.28). Large mammals including deer, bobcat, and coyote, among others, traverse sandhills habitat via a network of trails. Though trails averaged less an 50cm in width, trails were estimated to cover 9% of the soil surface in sand parkland (McGraw 2004).

Finally, mounds created by burrowing gophers (*Thomomys bottae*) are found throughout sand parkland habitat (Figure A.29). Created throughout the year, clusters of mounds create bare ground on the soil surface just as slides and trails do, and cover an estimated 11% of the soil surface in sand parkland (McGraw 2004).

In a sampling study quantifying rare plant distributions with respect to these disturbances, McGraw (2004) found that the two federally endangered plants (*Chorizanthe* and *Erysimum*) were more abundant on slides and trails than on immediately adjacent undisturbed habitat. The disturbances also supported higher cover and higher diversity of native herbaceous plants. At the same time, all three types of soil disturbance had much lower cover of leaf litter and European annual plants that are otherwise ubiquitous in sand parkland.

In experimental research examining the effects of these soil disturbances in sand parkland of the Quail Hollow sandhills, McGraw (2004) found that soil disturbances enhanced the endangered plants demographic performance, increasing germination and survivorship as well as growth and fecundity. Gopher mounds had the greatest effect on the rare plants, perhaps due to increased nutrient availability on the mounds. Again, soil disturbances also facilitated the native species richness and cover of other plants in sand parkland. Examination of the mechanisms indicated that soil disturbances facilitated native plants by removing accumulated leaf litter on the soil surface, which otherwise restricts native herbaceous plant establishment, as well as reducing competition from European annual plants (McGraw 2004).

This research indicates that the natural soil disturbances, especially wildlife trails and slides, enhance populations of the endangered herbaceous plants as well as a larger suite of diminutive native plants in sand parkland. Management of disturbances including fire and soil disturbances must carefully consider the aspects of the disturbance regime to ensure that the disturbances mimic the beneficial effects of disturbance. This topic along with the other important considerations for disturbance management is discussed in detail in Section 7.4 of the plan.

CHAPTER 4

SANDHILLS THREATS

INTRODUCTION

Due to their small geographic range (Santa Cruz County) and narrow habitat specificity (Zayante soils), the endemic species and communities of the sandhills are naturally rare (Rabinowitz 1981). Moreover, human activities that impact sandhills habitat directly and indirectly threaten the persistence of biodiversity in the sandhills at the community (or ecosystem), species, population, and genetic levels. This chapter describes the impacts of human activities on sandhills biodiversity to provide context for discussion of preservation and management strategies. The specific threats due to the three most prominent causes of habitat degradation—fire exclusion, exotic plant invasion, and recreation—are described in greater detail in the chapters provide specific management strategies to confront these threats (Chapter 8-10).

Human impacts on sandhills habitat can be broadly characterized into one or more of the following four categories: 1) habitat destruction, 2) habitat fragmentation, 3) habitat degradation, and 4) genetic erosion (Primack 2002). In turn, these impacts can reduce biodiversity at one or more levels, from the genetic level to the community level.

4.1 HABITAT DESTRUCTION

Also known as "habitat conversion" or "habitat loss", habitat destruction is the process by which land supporting natural communities is dramatically altered by humans such that it can no longer support natural communities (Spellerberg 1996, Primack 2002). Generally speaking, habitat destruction is permanent because the impacts of use prevent the area from supporting the original community of plants and animals that would naturally occurred at the site. Habitat destruction is not synonymous with "environmental destruction" or other terms meant to describe entire loss of value of land. Rather, destruction is with regards to the habitat—the place where organisms naturally occur.

Portions of sandhills habitat have been converted throughout its range. No studies have quantified the acreages of sandhills habitat that has been lost. Examination of historical and current aerial photographs indicated that the greatest losses have been due to sand quarrying and urban development, with conversion for agriculture and landfill creation also contributing to habitat loss (J. McGraw, pers obs; Figure A.33).

Causes

Sand Quarrying

Since its inception during the first half of the 20th century, sand quarrying in the sandhills has occurred in six separate quarries. Three of these operations were completed decades ago, prior to the inaction of the Surface Mining Reclamation Act (SMARA) in 1975, and thus were not revegetated. They are the Scotts Valley Quarry (on Scotts Valley Drive), the Old Geyer Quarry (at the end of Geyer Road near Scotts Valley), and the old Kaiser quarry that is part of the present day Olympia Wellfield managed by the San Lorenzo Valley Water District. Of the three current quarry operations, two are nearing completion: Kaiser's Felton Sand Plant and

RMC's Olympia Quarry. The third, Graniterock's Quail Hollow Quarry, acquired a permit in 1998 to quarry an area that the company anticipates will take 15 years to 50 years to complete (R. Atkins, pers. comm.. 2004).

The marine deposits of the Santa Margarita formation that give rise to the unique sandhills communities also provide sand that is a highly valued commercial product for several reasons. First, the sand deposits extractable from the sandhills are very deep (Section 2.3). Second, unlike cemented sandstones, the Santa Margarita formation is loosely consolidated and thus readily quarried. Third, the action of ocean currents millions of years ago sorted the particles of sand according to their size, rendering the material well sorted for its various uses. The coarse sand is valuable for construction, as it well worn (rounded) and therefore less abrasive to machinery and cause less friction when creating concrete. Unlike beach sand, sandhills sand has a neutral pH that renders it useful for burying utility cables that would otherwise be corroded by the basic pH of high salinity beach sands. These coarse sands are also used is golf courses. In some areas, the fine sand has a relatively high percentage of aluminum making it desirable for manufacturing glass products, including fiberglass (B. Licari pers. comm, R. Atkins pers. comm. 2004).

Quarry operations in the sandhills remove vegetation, soils, parent material, and bedrock, typically to within 20 feet of the high water table (B. Licari, pers. comm. 2004). Upon completion of quarrying, steep walls remain between the adjacent property or non-sandhills habitat (soils), with the resulting landscape creating what is oftentimes referred to as a "bowl" or "pit" (Figure A.34). Reclamation via revegetation of quarried slopes is used to establish plant cover and thus reduce erosion (Chapter 11). Despite extensive effort to prove otherwise (Sproul 1988), it is not possible to recreate sandhills habitat once the geologic formation and topsoil are removed. This is likely because sandhills soils and subsurface geology (Section 2.3) play a large role in plant growth and thus vegetation, which in turn, influences sandhills animals. Though a plan was developed to restore sand parkland following mining at the Olympia Quarry, the success criteria used to define restoration were not attained. As a result of this failure, it is generally considered impossible to recreate sandhills habitat (B. Davilla, pers. comm. 2002).

<u>Agriculture</u>

Though sandhills soils are unsuitable for most types of agriculture, vineyards have been established on Zayante soils in the areas of Bonny Doon and Ben Lomond. Loss due to agriculture likely represents a small fraction of the habitat lost. However, given the relatively small amount of sandhills habitat overall, even such proportionally small losses can have substantial impacts.

<u>Urban Development</u>

Development of sandhills habitat for housing and to a lesser extent, commercial use, has converted sandhills habitat (Figure A.35). In addition to the loss of habitat due to buildings and associated infrastructure (hard surfaces such as roads, driveways, etc.), surrounding habitat is often converted for landscaping, pools, and livestock husbandry. Through both rural lot development and subdivisions, housing has greatly reduced the amount of sandhills habitat, as revealed through analysis of aerial photographs.

Impacts

Community Diversity

Habitat destruction reduces native biodiversity at the community level—that is, the diversity of assemblages of plant, animals, and other organisms that naturally occur within a given area. Examination of historic aerial photographs indicates that many sandhills habitat patches naturally supported a diversity of communities, likely due to variation in geology, soils, and microclimate, among other factors. Habitat destruction, especially large-scale destruction such as through quarrying and residential development, has in many cases removed entire communities (J. McGraw, pers. obs.).

Species Diversity

The irreversible conversion of sandhills habitat can reduce the diversity of species that occupy sandhills habitat by causing extirpations—the loss of populations within an area. As a result of their island-like distribution and variability in size and physical environment, sandhills habitat patches differ in species composition. Several sandhills species, including the Santa Cruz kangaroo rat, coast horned lizard, and coastal sagewort, are presently only found in a handful of remaining sites. Loss of habitat in these sites can therefore reduce the overall diversity of sandhills habitat.

Sensitive Species

Loss of habitat is the leading threat to the persistence of the federally endangered plants (USFWS 1994a) and insects (USFWS 1997) in the sandhills. Indeed, habitat destruction the leading threat to endangered species persistence (Wilcove et al. 1998), and can be especially problematical for edaphic endemic species and communities, given their natural rarity (Skinner and Pavlik 1994). Lack of comprehensive data on the populations prior to habitat destruction prevents assessment of the impacts of habitat conversion on populations of sensitive species. However, there is little doubt that habitat conversion has reduced the number of populations of sensitive species, several of which are extremely rare (e.g. Zayante band-winged grasshopper, Santa Cruz wallflower).

Genetic Diversity

Habitat destruction reduces genetic diversity within a species, which exists at two levels: genetic diversity between populations and diversity between individuals within a population (Silvertown and Doust 1993). Due to their isolated evolution over potentially millions of years, populations of many species within different habitat patches have become genetically differentiated. This is evidenced in the morphological variation of several plant species that is observed at different sites (R. Morgan, pers comm. 2002). Many factors can lead to the development of genetic differentiation within different parts of a larger population, including habitat heterogeneity, low mobility, and mating among closely related individuals within small populations. Removing habitat can cause the loss of those unique genotypes and thus reduce genetic diversity within a population.

Even if not all of the individuals are killed, habitat destruction causes a genetic bottleneck in which the genetic diversity of the remaining population is lower than the original population, due to loss of alleles present in some individuals (Primack 2002). These losses of genetic diversity can influence individual fitness, population growth, and species persistence, as described in Section 4.4.

4.2 Habitat Fragmentation

Habitat fragmentation occurs when a single large habitat patch is broken up into two or more spatially isolated, smaller patches.

Causes

Habitat destruction has not only reduced the overall acreage of sandhills habitat, it has also fragmented what remains. Quarries located in the center of sandhills outcrops (e.g. Quail Hollow, Olympia) have left patches of habitat on their perimeter that are separated by non-sandhills habitat including roads, denuded slopes, development, and non-sandhills vegetation (Figure A.33b).

Roads and highways have fragmented sandhills habitat by separating previously contiguous habitat patches. Prominent roads through sandhills include Mount Hermon Road (Scotts Valley to Felton), Graham Hill Road (Santa Cruz to Felton), Martin Road (in Bonny Doon), and Quail Hollow Road (Ben Lomond). Numerous smaller roads innervate sandhills habitat, especially in medium to high density residential developments. Because of the division of habitat into separate parcels, urban development inherently fragments remaining sandhills habitat.

Forces that degrade habitat (Section 4.3) also often fragment remaining habitat. As evidenced by examination of historical aerial photographs, fire exclusion has allowed encroachment of mixed evergreen forest vegetation into sandhills habitat through invaginations that have divided single large pieces of habitat into several, smaller separated patches. This effect of fire exclusion is observed at Henry Cowell State Park, where isolated patches of sandhills habitat were contiguous, as observed in the 1943 aerial photograph of the site.

Recreation in the sandhills often denudes habitat, creating strips or patches of non-habitat that separate otherwise contiguous sandhills habitat. The amount of separation required to effectively fragment habitat depends on the species in question, as does the impacts of fragmentation.

Impacts

Species Diversity

In the absence of studies examining populations before and after habitat fragmentation, little is known about the effects of fragmentation on diversity at the community, species, and genetic level in the sandhills. Research in other systems has indicated that fragmentation can effectively isolate individuals in different patches, thus creating several smaller populations where there was previously one large population (Primack 2002). The extent to which this occurs may depend on the species and characteristics of the intervening non-sandhills habitat in question.

For highly mobile animals including birds, large mammals (e.g. deer, coyote), some small mammal species, and some flying insects, somewhat narrow strips of non-sandhills habitat, especially those comprised of intact, natural vegetation (as opposed to development or other non-habitat), may not present a barrier to individual movement and therefore not fragment habitat. Narrow strips of non-sandhills habitat may similarly not present a complete barrier to plant species with well-dispersed seed. In contrast, even narrow areas of non-sandhills habitat (e.g. trails) may effectively divide populations of low mobility animals and plants lacking seed dispersal mechanisms.

By eliminating or greatly reducing the likelihood of immigration into newly separated habitat patches, fragmentation reduces population size and therefore the likelihood of population persistence. This is because small populations are more susceptible to demographic and environmental stochasticity— chance events in population demography and environmental conditions, respectively, which can reduce population size dramatically. Already small populations of sandhills species are more likely to be extirpated. Assuming dispersal is no longer occurring between patches, there is no potential for a "rescue effect", whereby immigration from an adjacent patch can boost population growth (Primack 2002).

Sensitive Species

Habitat fragmentation is credited with contributing to the extirpation of Santa Cruz kangaroo rat populations at three of four sites sampled in 2000-2001 (Bean 2003). Smaller patch sizes reduce population sizes and increase the potential for negative edge effects from adjacent developments. As a result, populations are more impacted by recreation and feral and domestic cats which prey on small mammals when habitat is fragmented (Section 5.7).

To evaluate impacts of fragmentation due to sand quarrying at Quail Hollow Quarry on Mount Hermon June beetles, male beetles which fly during their brief mating period aboveground were trapped, marked with trap specific identifiers, and then recaptured to determine flight distances and whether movement occurs between habitat patches separated by a quarry access road of approximately 30 feet in width. Less than 5% of the beetles were recapture, yet all (n=9) were found at the same location at which they were trapped, suggesting the potential for short dispersal distances (Arnold 1999a).

Genetic Diversity

Fragmentation also impacts genetic diversity by reducing population size and causing genetic bottlenecks. Small fragmented populations can ultimately suffer from inbreeding depression, as described in Section 4.4.

4.3 Habitat Degradation

Biodiversity in the sandhills is greatly threatened by habitat degradation—the reduction in suitability of habitat for persistence of species and communities due to anthropogenic stresses. Habitat degradation can be differentiated from habitat destruction (conversion) in three main ways: 1) degradation may be reversible, while conversion generally is not reversible, 2) degradation typically occurs incrementally, while conversion is typically a punctuated event, and 3) degraded habitat can often support populations at lower abundance, while converted habitat does not support most species populations at all.

Habitat degradation in the sandhills is occurring due to fire exclusion, the invasion and spread of exotic plants, and recreational use. An overview of these factors outlining their general mechanisms and biodiversity impacts is provided here to provide context for the endangered species biology descriptions (Chapter 5) and the conservation planning project (Chapter 6). Important details about these stresses that should be used to inform management strategies to reverse impacts from degradation are provided as part of the management recommendations (Chapters 8-10).

Fire Exclusion

The sandhills communities and species have evolved with a natural regime of fire which removes established vegetation, frees up resources, and allows persistence of competitive inferior species. Suppression of wildfires during the past century due to human habitation in and around sandhills has increased the cover and density of dominant, woody vegetation and the accumulation of litter (McGraw 2004). This unnatural succession has important implications for biodiversity at all levels.

Community Diversity

Like sandhills habitat itself, natural fires in the sandhills were likely patchy, resulting in a mosaic of communities in various stages of succession which enhances community diversity (Sousa 1984b, Pickett and White 1985). Widespread fire exclusion has homogenized the landscape and reduced community diversity by facilitating late successional communities throughout most habitat patches (Figure 3.1, Section 8.1, Section 3.4).

Species Diversity

Because different successional stages (seres) offer different environmental conditions required by different species, the patch mosaic enhances the overall diversity of species (gamma diversity) that the sandhills support. Fire exclusion thus reduces species diversity by reducing community diversity.

Fire suppression also reduces species diversity at the local scale. Within a community such as sand chaparral, disturbance maintains diversity by preventing late-successional species from out competing early successional species (Petraitis et al. 1989, Huston 1994, Lessica and Cooper 1999). By allowing late succession species to dominate, fire exclusion may lead to the extirpation of species adapted to both fire and post-fire conditions (Keeley 1984, Huston 1994). Many plant species in fire adapted systems have seedbanks (dormant populations of seed) that can germinate following fire. This allows them to wait out the inter-fire interval. However, seed viability can decline over many years and reduce likelihood of establishment following unnaturally long intervals between fire.

Sensitive Species

Studies strongly suggest that the exclusion of fire from sandhills communities is causing decline in the distribution and abundance of sensitive sandhills species. Fire suppression in silverleaf manzanita chaparral is credited with contributing to the extirpation of Santa Cruz kangaroo rat populations at three sites during the past 20 years (Bean 2003). Santa Cruz wallflower populations, which require early successional conditions, are in decline due to fire exclusion (McGraw 2004). At the Bonny Doon Ecological Reserve, wallflower populations have been below 100 aboveground individuals during the past 10 years and are in danger of extirpation (CDFG 2002). Several other sensitive sandhills species similarly require early successional conditions to persist, including the Zayante band-winged grasshopper, Santa Cruz monkey flower, curly leaved monardella, and Ben Lomond spineflower, and are likely experiencing population declines and extirpations, especially in silverleaf manzanita chaparral.

Genetic Diversity

Populations declines due to fire exclusion can cause bottlenecks which reduce genetic diversity (Section 4.4). If declines are followed by extirpations, as in the Santa Cruz kangaroo rat and potentially the Santa Cruz wallflower at the Bonny Doon Ecological Reserve, the unique genetic diversity contained in that population is lost forever.

If areas where populations are extirpated are subsequently recolonized, for example following the reintroduction of fire or other disturbance treatments (e.g. vegetation management) which returns habitat to favorable conditions, the new population is often established by just one or a few individuals. As a result, this new population will have lower genetic diversity than the previous large population. Such a “founder effect” can create further problems for individual fitness and population growth as inbreeding depression among closely related individuals can reduce likelihood of the founder population persisting. In some plant species, seed banks may allow a larger, more genetically diverse population to establish following fire or management, provided the interval between fires has not reduced seed viability (as described above). However, animal species in the sandhills do not have such a mechanism for preserving genetic diversity following extirpations due to habitat degradation.

Exotic Plants

The invasion and spread of exotic species is a type of habitat degradation commonly credited with threatening the persistence of endangered species (Wilcove et al. 1998), including those in the sandhills (USFWS 1994a, USFWS 1997, USFWS 1998). Abundant exotic plants reduce the ability of habitat to support populations of native species both directly, through competition (Carlsen et al. 2000), and indirectly, by altering habitat conditions so that they are no longer suitable (D'Antonio and Vitousek 1992, Levine et al. 2003).

Community Diversity

By forming virtual monocultures in more than one habitat within the landscape, dominant exotic species can reduce community heterogeneity. Exotic plants including nitrogen fixing shrubs and tree can also degrade habitat quality, ironically enough, by adding nitrogen to the soil. This apparent improvement can facilitate the invasion and spread of non-sandhills plants that would otherwise be inhibited from the sandhills by inimical soil conditions.

Species Diversity

European annual grasses and forbs compete with native species for scarce soil moisture resources and reduce the diversity of native plant species in the sand parkland community (McGraw 2004). Monocultures of exotic brooms and acacia similarly have lower diversity of native sandhills species, though their indirect effects via nitrogen fixation have not been explored.

Sensitive Species

Exotic plants the population growth of the two federally listed plants, and the distribution and abundance of many other sensitive native herbaceous plants in the sandhills (McGraw 2004). Studies showing that the Zayante band winged grasshopper is found primarily in open, loose sand areas without dense European annual cover also implicate exotic species as a source of habitat degradation (Arnold 1999a, Chu 2002).

Genetic Diversity

By reducing or eliminating native populations, exotic plants can reduce genetic diversity by eliminating locally adapted gene complexes, causing population bottlenecks, resulting in inbreeding depression, and creating founder effects during recolonization following extirpation.

Recreational Use

Due to the friability of sandhills soils, recreational use can greatly impact sandhills communities by removing established vegetation, causing soil erosion, and introducing exotic plant species, all of which degrade habitat for many sandhill native species. Though only five sandhills sites have authorized recreational trails, pedestrians (hikers), equestrians, mountain bicyclists, and off highway vehicle (OHV) riders use most sandhills sites for *de facto* recreation.

Impacts

The impacts of recreation depend on complex interactions between the frequency, intensity, and seasonality of the use and the vegetation and soil conditions of the sandhills habitat in which it occurs (Chapter 10). The three most intense uses—equestrian, mountain bike, and OHVs—have degraded habitat and reduced species diversity in many sites by removing established plant in open areas where recreation typically occurs, thereby likely reducing populations of sensitive plants (J. McGraw, unpublished data). By denuding the area of vegetation, recreation reduces food availability for sandhills animals including the Zayante band-winged grasshopper (Chu 2002) and the Santa Cruz kangaroo rat (Bean 2003).

Recreation also contributes to soil erosion, which deters plant recolonization following disturbance and thus reduces habitat available for both native plants and animals. Various forms of recreation also have been shown to promote the invasion and spread of exotic plant species in other systems (Crealock and O'Malley 2002), and observations suggest that recreators may similarly vector exotic plants and/or facilitate their establishment in the sandhills (J. McGraw, pers. obs.).

4.4 Genetic Erosion

Genetic erosion is the loss of unique genetic material (alleles, genes, genotypes) from sandhills populations. Genetic erosion results from habitat destruction, fragmentation, and degradation, which reduce or extirpate populations, and create the potential for population bottlenecks, founder effects, and inbreeding depression, as described above.

Genetic erosion also results from introgression of genetic material that occurs when non-sandhills genotypes are deliberately or accidentally introduced into sandhills populations. Such contamination can occur if non-sandhills plant material is used to revegetate sandhills habitat or if landowners adjacent to sandhills habitat plant cultivars, wildflower seed purchased from generic seed sources, or other plant materials not originally from the site. Cross-pollination and immigration into the sandhills populations due to seed dispersal dilute natural genetic diversity of the sandhills.

Impacts

Genetic erosion due to population extirpations reduces overall diversity and can threaten species persistence. Genetic diversity between many sandhills populations is likely to exist due to the natural patchiness of sandhills habitat, which has isolated populations for millions of years. Even adjacent patches of sandhills habitat may have been isolated for long periods of time, perhaps since their origin (Figure A.1). For example, within the Quail Hollow sandhills, the sand parkland habitat at Quail Hollow Ranch County Park is less than 300 m from the sand parkland on the North Ridge of Quail Hollow Quarry. Separating these ridges is a creek flanked by riparian forests, seasonally inundated grasslands, and mixed evergreen forest, all of which occur on non-sandhills soils. These habitat patches have likely been geographically isolated for millions or years, and sandhills plant populations at each site may have never been adjacent. Though animals and potentially wind may vector genetic material (i.e. pollen or seed) between sites, the geographic isolation between even adjacent sandhills sites sets the stage for genetic differentiation.

Such differentiation is observed in the form of different morphologies being more prevalent or exclusively found at different sandhills sites. Examples of these include *Malacothrix floccifera* (Figure A.49) and *Meconella linearis*, both of which have all yellow flower morphs found at certain sites with yellow and white morphs found at others (R. Morgan, pers. comm. 2002). Similarly, while some populations of *Linanthus parviflorus* in the sandhills include three flower morphs (white, yellow, and purple), others include only the all yellow morph (J. McGraw, pers. obs.).

Loss of genetic diversity can cause reduced individual fitness and lower population growth rates, and thus threaten persistence of populations and species. By disrupting the co-adapted gene complexes that occur in the sandhills, genetic contamination can reduce individual performance and population growth. A high proportion of the plant populations (Section 3.1) and several animal species (Section 3.5) in the sandhills are highly disjunct or geographically isolated from other populations. Combined with often dramatic differences in edaphic, climatic, and biotic conditions, this geographic isolation fosters genetic differentiation between sandhills and non-sandhills populations. This differentiation enhances biodiversity at the genetic level and is the basis for speciation. That is, current sandhills endemics began as disjunct populations of more widespread ancestors from which they differentiated over evolutionary time, such that today we refer to them as different species, subspecies, or varieties.

The current classifications of populations in the sandhills as distinct and therefore endemic, different but not distinct and therefore ecotypes, or just morphological variants of the most widespread populations represents the judgments of systematists and taxonomists. While such experts do not always agree on the taxonomy, most acknowledge that the variation that they observe represents a snapshot in a long evolutionary trajectory and that both the raw materials of evolution (the genes) and the evolutionary processes (isolation, ecological interactions, etc.) merit conservation. In her paper describing the “Saga of the Santa Cruz spineflower”, Dr. Barbara Ertter describes how she and a panel convened to determine the taxonomy of the *Chorizanthe* (spineflowers) in the Monterey Bay area concluded that the striking morphological differences yet persistent similarities between the four putative species result because they were ‘catching evolution in the act’. The panel concluded that all members of the complex should be protected via federal listing on the endangered species act because “…diversity is diversity, whether it is sharply delimited or part of a spectrum” (Ertter 1996).

As a result of the genetic diversity that exists *between* sandhills sites, the loss of populations at individual sites reduces genetic diversity in the sandhills. Moreover, anthropogenic introduction or exchange of genetic material between sandhills sites can result in introgression and reduce genetic diversity. As a result, seemingly strict guidelines for plant procurement, propagation, and planting are needed to prevent genetic erosion in sandhills restoration and revegetation projects (Section 11.3).

Table 4.1 Causes and biodiversity consequences of anthropogenic stresses in the sandhills

Stress	Causes	Impacts			
		Community Diversity	Species Diversity	Sensitive Species	Genetic Diversity
Habitat destruction	Quarrying, residential development, agriculture, landfill	sand parkland assemblages often lost	sensitive species populations reduced, esp. in parkland	ZBWG, SCW, and SCKR imperiled; other populations reduced and persistence threatened	Genetic bottlenecks and loss of site-specific genotypes
Habitat fragmentation	Quarrying, development, agriculture, habitat degradation	Small fragments support fewer assemblages	Populations reduced or extirpated, habitat too small for species with larger home ranges	impacted by increased edge effects	Bottlenecks, founder effects, inbreeding depression
Habitat degradation	Fire exclusion, exotic plants, recreation	Early successional communities lost	Early successional species extirpated or reduced,	Smaller populations more likely to be extirpated; reduce species persistence	Extirpations lose site-specific genotypes,
Genetic erosion	Genetic contamination with non-sandhills ecotypes		Contamination may reduce population viability by disrupting locally adapted gene complexes	Site-specific genetic diversity lost due to translocation; reduce persistence.	Local genetic complexes lost, diversity reduced

ZBWG- Zayante band winged grasshopper
SCW- Santa Cruz wallflower
SCKR-Santa Cruz kangaroo rat

CHAPTER 5

SANDHILLS ENDANGERED SPECIES

INTRODUCTION

As described in chapter 3, the sandhills support many unique and uncommon plant and animal species. Of these, six are endemic to the sandhills and found nowhere else in the world. They are:

- Santa Cruz wallflower (*Erysimum teretifolium*; Figure A.13)
- Ben Lomond spineflower (*Chorizanthe pungens* var. *hartwegiana*; Figure A.11)
- Ben Lomond buckwheat (*Eriogonum nudum* var. *decurrensi;* Figure A.12)
- silverleaf manzanita (*Arctostaphylos silvicola*; Figure A.14)
- Zayante band-winged grasshopper (*Trimerotropis infantilis*; Figure A.26)
- Mount Hermon June beetle (*Polyphylla barbata*, Figure A.25)

In addition, the Santa Cruz kangaroo rat (*Dipodomys venustus venustus*; Figure A.22) is a very rare animal that occurs in disjunct populations in the sandhills, which are considered evolutionary significant units (Bean 2003).

This chapter synthesizes the known information about each of these seven species, including their conservation status, available research, and all known aspects of their biology (morphology, life history, phenology, habitat preferences, population biology, etc.). This information can aid managers and policy makers in efforts to avoid impacts to sensitive species and guide conservation strategies to recover these endangered species.

5.1 SANTA CRUZ WALLFLOWER (*ERYSIMUM TERETIFOLIUM* BRASSICACEAE EASTW.)

Conservation Status

The Santa Cruz wallflower (*Erysimum teretifolium* Brassicaceae Eastw.) is on both the State of California (State) and United States (Federal) List of Endangered Species (USFWS 1994a). In addition, it is on the California Native Plant Society list of most threatened and endangered plants (List IB; (Skinner and Pavlik 1994).

Available Information

In 1998, the United States Fish and Wildlife Service summarized the unpublished studies on the wallflower in its recovery plan for the endangered plant (USFWS 1998). The author completed a dissertation examining the ecological factors affecting the population persistence of the Santa Cruz wallflower and the Ben Lomond spineflower (McGraw 2004). This research focused on examining the interacting effects of fire, soil disturbances, and exotic plant species, but also examined other topics including the effects of interannual variability in fall rainfall, spring rainfall, and the mid winter drought; the effects of deer herbivory on plant survivorship and fecundity; the effects of gopher herbivory on population demography, and the role of seed dormancy in population persistence.

Distribution

As a sandhills endemic plant, the Santa Cruz wallflower is found only on outcrops of Zayante soils in Santa Cruz County near the towns of Ben Lomond, Olympia, Scotts Valley, Felton, Bonny Doon, and Zayante. As of 1998, there were 16 isolated populations Santa Cruz wallflower (USFWS 1998).

Biology

Morphology

The Santa Cruz wallflower is an herbaceous plant in the mustard family (Brassicaceae; Figure A.13). As a seedling and juvenile (plants greater than one year old but not reproductive), the wallflower consists of a basal rosette of narrowly linear (less than 3 mm wide) basal leaves that are finely toothed, covered with thin hairs, and range from 3-17 cm long (Hickman 1993). When the plants bolt (begin to flower), the basal leaves wither and the plant produces cauline leaves on the inflorescence stalk— a raceme of yellow flowers with four, 15-25mm petals. Wallflower fruits are siliques, or long (4-15cm), narrow capsules which dehisce and release seeds born on both sides of a central wall (septum). The seeds are small (1.5-2.5mm long), flat, ovate to round, and yellow-orange to brown when fully developed (Hickman 1993).

Life History and Phenology

Though described as a monocarpic biennial or short-lived perennial (Hickman 1993), Santa Cruz wallflower exhibits variation in longevity. Seeds germinate with the first hard rain in fall that usually occurs between mid-October and mid-November. Seedlings form a basal rosette of leaves over the winter and spring of their first year. Wallflower growth ceases and plants actually lose leaves during the long summer drought that typically occurs from June to October. Plants resume growth at the onset of the rainy season and form a large basal rosette of leaves over the second winter. Many second year plants bolt (produce an inflorescence stalk) between February and March, flower April to May, develop fruits in June, set seed (i.e. fruits dehisce) in July, and die by early August (McGraw 2004). However, smaller plants frequently do not reproduce in their second year. Rather, they retain the basal rosette of leaves for another year then reproduce and die, as described above, in their third year. As has been observed with *Erysimum menziesii* (Berg 1987), a closely related congener, Santa Cruz wallflowers growing in shaded, excessively dry, or otherwise less optimum conditions for growth may take more than three years to reproduce. In contrast, a small proportion (likely less than 1%) of individuals complete their entire life cycle in a year (i.e. as an annual plant; McGraw 2004).

Though the majority of Santa Cruz wallflower plants are monocarpic (reproduce only once), a small proportion of individuals retain, rather than reabsorb, their basal rosette of leaves upon flowering then survive to flower again. This life history is rare, however, and may be due to stresses the plant experiences during reproduction. Observations suggest that the majority of these iteroparous individuals were browsed by deer during their first reproductive effort (J. McGraw, pers. obs.).

The distribution of spring rainfall greatly influences the phenology of the Santa Cruz wallflower. Infrequent storms and below average rainfall in spring result in earlier flowering (mid-February) and earlier seed set (mid-May). In contrast, the occurrence of significant rainfall in spring (March-June) increases growth, delays the onset of flower production, and extends the flowering period of the Santa Cruz wallflower into late July (J. McGraw, unpublished data).

Ecology

Distribution and Habitat Preference

The Santa Cruz wallflower is endemic to the sandhills of Santa Cruz County. Within the sandhills, the distribution of the Santa Cruz wallflower is restricted primarily to open areas away from dense woody vegetation (McGraw 2004). In the sand chaparral community, which is dominated by shrubs (*Arctostaphylos silvicola, Ceanothus cuneatus,* and *Adenostoma fasiculatum*) and oak trees (*Quercus agrifolia* and *Q.wislizenii*), small patches of Santa Cruz wallflower are found along trails and in other gaps in the shrub canopy. However, the largest populations of Santa Cruz wallflower are found in the sand parkland community (McGraw 2004), which is characterized by a sparse tree canopy, minimal shrub cover, and a diverse assemblage of herbaceous plant species (Section 3.4).

Within the sand parkland, the distribution of the Santa Cruz wallflower is primarily restricted to open areas away from trees and shrubs. An experiment examining the mechanism by which trees restrict the distribution of wallflowers showed that, while shade may have reduced plant growth and delayed reproduction, moderate shade characteristic of ponderosa pine trees enhanced plant survivorship to reproduction and therefore facilitated the endangered plant. However, the dense litter that accumulates beneath both ponderosa pine and oak trees in sand parkland inhibited the germination and establishment of wallflower seedlings and restricts the distribution of this rare plant (McGraw 2004).

In its preferred habitat away from woody vegetation, Santa Cruz wallflower populations are restricted by dense non-native annual plants. Rat-tail fescue (*Vulpia myuros*), smooth cat's ears (*Hypochaeris glabra*), rip-gut brome (*Bromus diandrus*), and other European annual grasses and forbs are widespread in the sandhills and patchily abundant in the sand parkland community. A sampling study revealed that Santa Cruz wallflower abundance is negatively correlated with the density of exotic annual plants. Experiments manipulating the presence of exotic plants have shown that they greatly reduce the growth and survivorship of the wallflower (McGraw 2004). As a result, exotic plants are undoubtedly responsible for declining wallflower populations in many sites.

Within sand parkland, the Santa Cruz wallflower is preferentially found on small-scale soil disturbances including slides and trails. Slides, which result from the erosion (gravity, wind, water) of loose soil on steep slopes (>30%) are common in sand parkland and comprise more than 16% of the habitat (Section 3.7). Santa Cruz wallflower density and cover is higher on slides than on the adjacent, undisturbed habitat. Covering an average of 9% of the sand parkland habitat, wildlife trails similarly enhance populations of the Santa Cruz wallflower. Density and cover of the wallflower is much higher on and immediately adjacent to trails than on adjacent, undisturbed areas. An experiment designed to test the mechanism by which trails and slides affect the distribution of wallflower showed that the removal of leaf litter and reduction of exotic plant cover increases wallflower germination and survivorship on disturbances. Gopher mounds, which cover an estimated 11% of the sand parkland habitat, similarly facilitated wallflower demography (McGraw 2004). Experimental manipulations showed that gopher mounds had higher concentrations of nitrate and therefore enhanced wallflower performance beyond simply removing litter and reducing exotic plant cover (J. McGraw, unpublished data).

Mating System

Santa Cruz wallflowers are monoeicous and produce bisexual flowers (each with both pistil and stamens). As with all members of the *Erysimum capitatum* alliance, Santa Cruz wallflowers are self-incompatible (i.e. obligate outcrossers), meaning that seed cannot be produced from fertilization of the ovule by pollen from the same plant. Flowers may be protandrous, producing mature stamens prior to the maturity of the pistil to prevent self-fertilization (Price 1986, Feliner 1990).

Pollination Biology

There have been no reported studies on the pollination biology of the Santa Cruz wallflower. However, numerous insects have been observed visiting flowers and may be pollinators. Chalcedon checkerspot butterflies (*Euphydryas chalcedona)* are frequently observed on flowers between March and June (J. McGraw, pers. obs.). Though they frequently visit wallflowers, they are not specialist pollinators and instead also visit other yellow-flowered plants in the sandhills including the California poppy (*Eschscholzia* californica) and wooly dandelion (*Malacothrix floccifera*), among others. Other insects observed on the flowers of the Santa Cruz wallflower include ants, European honeybees, and bumble bees (McGraw 2004).

Flower, Fruit and Seed Production

Results from a three-year study examining the reproduction of Santa Cruz wallflowers indicate that flower production is strongly positively correlated with the size (diameter) of the basal rosette of leaves prior to bolting. Development of the inflorescence is determinant, with basal flowers developing first and flowers at the tip of the inflorescence developing last. Frequently, buds at the terminus do not mature and even if they do, do not produce a fruit. Fruit production by unbrowsed plants ranged from 10-107 with an average of 38 fruits per plant. The number of seeds in a fruit is strongly positively correlated with fruit length. Fruits varied between 9 and 15 cm and produced 5 to 65 seeds (J. McGraw, unpublished data).

Herbivory

Observations and research indicate that a variety of invertebrate and vertebrate herbivores eat Santa Cruz wallflowers. Lepidopteran larva (e.g. caterpillars) have been observed on the basal rosettes and inflorescences of wallflowers; however, their impact on plant growth, survivorship, and fecundity is unknown. Aphid infestations on wallflowers inflorescences in bud and in flower have prevented successful reproduction and caused mortality (McGraw 2004).

Herbivory by small mammals (e.g. rabbits) has resulted in defoliation of juvenile rosettes and can cause delayed reproduction and occasionally, mortality. Such herbivory has been primarily observed adjacent to shrubs and trees and on north-facing slopes in sand parkland (J. McGraw, pers. obs.).

Deer consume the buds and recently flowered inflorescences of wallflowers. A three-year study examining the impact of deer herbivory on wallflowers found that 38% of adult plants were browsed in 2001 and 40% of plants were browsed in 2002. By removing apical dominance, deer herbivory increased the mean number of inflorescences produced from 1.3 to 3.4. However, fruits of browsed plants were shorter and therefore contained fewer seeds than those of unbrowsed plants. Research is ongoing to quantify the effects of deer herbivory on fecundity (seed production) of the Santa Cruz wallflower (J. McGraw, unpublished data).

Pocket gophers predate upon Santa Cruz wallflower juveniles and adults. A recent study found that nearly 8% of rosettes marked in November were eaten by gophers prior to seed set in the following July, and therefore did not reproduce (J. McGraw, unpublished data).

Seed Dispersal

As fruits of the Santa Cruz wallflower dry between July and August, they split open and release the seeds inside. While a small proportion of seeds adhere to the fruit wall and remain on the dead plant until the onset of rains or significant winds, most seeds fall upon dehiscence. Lacking adaptations for wind dispersal, wallflower seeds typically fall directly below the parent plant. Dense patches of seedlings at the base of parent plants suggest that secondary seed dispersal is limited (J. McGraw, pers. obs.). While it is possible that granivores may provide secondary dispersal for wallflowers, this has not been observed to date.

Germination

Germination trials under laboratory conditions indicate that Santa Cruz wallflower seed viability is very high (McGraw 2004). Santa Cruz wallflower seeds likely require the high ambient temperatures of the summer months to break dormancy and germinate in the fall, however (C. Baskin, pers. comm. 2000). Indeed, seeds buried under soil or litter only infrequently germinated (McGraw 2004). An experiment to examine germination under simulations of early and late fall rains found no difference in the percent germination of the Santa Cruz wallflower (J. McGraw, unpublished data).

Seed Bank

The Santa Cruz wallflower exhibits seed dormancy and therefore has a seed bank. In a series of field experiments over five years, percent germination of wallfower seed in the first year after sowing ranged from 20-50% on average. Though germination rates were much reduced, seed germinated four years following sowing, indicating seed storage occurs in this species (McGraw 2004). In an unpublished study conducted on the South Ridge of Quail Hollow Quarry in 1997, soil cores obtained within patches of adult wallflower contained 38-731 viable seeds per square meter (Brunette 1997).

Establishment

The establishment of Santa Cruz wallflower seedlings is influenced by many factors. Litter accumulation either from trees or dense exotic plants inhibits seedling emergence. In the series of experiments conducted between 1997 and 2002, the highest rates of establishment were observed in open sand conditions away from litter, shrubs, and trees, including trails and gopher mounds. An experiment manipulating the presence of exotic plants showed that exotic plants reduced wallflower seedling establishment (McGraw 2004).

Seedling Survival

Results of numerous experimental studies indicate that wallflower survivorship is the most important factor influencing population growth and persistence. These studies also consistently show that competition from exotic plant species greatly reduces survivorship of wallflower seedlings. In the absence of exotic plants, seedling mortality is low through the winter and spring. Mortality increases greatly due to moisture stress over the long summer drought (June-October), however, and often exceeds 90%. Plants that survive the summer to the onset of rains typically experience high survivorship through the following winter (McGraw 2004).

Exotic plants greatly exacerbate the mortality caused by drought stress during the dry season. Less than 1% of wallflower germinants grown in undisturbed areas away from shrubs and trees survived through the summer. Exotic plants compete with wallflowers for scarce water resources and, by mid-spring, wallflower mortality rapidly increases, with most germinants dying before summer (McGraw 2004).

Spring rainfall has an important effect on Santa Cruz wallflower mortality. An experiment manipulating spring rainfall found that survivorship of wallflower seedlings was greatly increased when rain continued into early June, as it does in many high rainfall years (e.g. El Niño years). In contrast, seedling mortality was 100% in treatments simulating a low rainfall spring (J. McGraw, unpublished data). These results are consistent with observations indicating adult wallflowers density greatly increased following the El Niño year in 1998 (J. McGraw, pers obs.). Increased seedling survivorship over the summer due to the late rains in spring 1998 resulted in increased number of adults observed in spring 1999 (J. McGraw, unpublished data).

Juvenile Survival

Juvenile wallflowers (non-reproductive plants greater than one year old) experience higher survivorship than seedlings. Juveniles have likely developed deep and/or extensive roots and are therefore less prone to desiccation stress. As a consequence, second year or older rosettes that do *not* flower in the spring experience higher survivorship throughout the year, including the summer drought, with the exception of mortality caused by gopher predation described above (McGraw 2004).

Threats

The persistence of Santa Cruz wallflowers, as a species, has been threatened by habitat destruction (Section 4.1). Many populations that historically were known to have occurred have been extirpated (R. Morgan, pers. comm. 2002) such that presently, there are only 12 known populations of Santa Cruz wallflower remaining. Experimental research indicates that wallflower populations may be in decline, even within protected reserves. Fire exclusion is reducing the area of open sandy habitat away from woody vegetation and tree leaf litter that this plant requires. In open areas away from shrubs and trees, competitive European annual grasses and forbs greatly reduce plant establishment and survivorship. Many remaining populations are restricted to persistent soil disturbances (slides and trails) within sand parkland habitat. The areal extent of these microhabitats is very limited. Recreation reduces the size of remaining populations. Wallflowers are preferentially found in open areas frequently used for recreation, which often tramples or uproots seedlings and juveniles, killing them before they can reproduce.

This rare plant is threatened with extinction. Low rates of establishment and survival measured in even the largest populations suggest that populations of this species will not persist in the absence of active management to ameliorate the impacts of habitat degradation (McGraw 2004). Preservation and management strategies throughout this plant reflect the special threats confronting this endemic plant.

5.2 BEN LOMOND SPINEFLOWER

Conservation Status

The Ben Lomond spineflower (*Chorizanthe pungens* var. *hartwegiana* Polygonaceae Rev. & Hardham) is on both the State and Federal list of Endangered Species, as well as the CNPS list of most threatened and endangered plants (List 1B; Skinner and Pavlik 1994).

Available Information

The United States Fish and Wildlife Service has published a recovery plan for the Ben Lomond spineflower (USFWS 1998). Two experimental studies examining the habitat requirements have been published (McGraw and Levin 1998, Kluse and Doak 1998). The author completed a dissertation examining the ecological factors affecting the population persistence of the Ben Lomond spineflower and Santa Cruz wallflower (McGraw 2004). This research focused on examining the interacting effects of fire, soil disturbances, and exotic plant species, but also examined other topics including the effects of interannual variability in fall rainfall, spring rainfall, and the mid winter drought; and the seed bank of the annual plant.

Distribution

As a sandhills endemic, the Ben Lomond spineflower is restricted to the Zayante soils of Santa Cruz County near the towns of Ben Lomond, Olympia, Scotts Valley, Felton, Bonny Doon, Zayante, and Boulder Creek.

Biology

<u>Habitat</u>

The Ben Lomond spineflower is endemic to the sandhills of Santa Cruz County. Experimental research has implicated shade intolerance as the primary cause for the restriction of the Ben Lomond spineflower to the sandhills. Though the spineflower can grow and reproduce in soils of the adjacent oak woodland and redwood forest, plants grew poorly and had much reduced fecundity under low light levels characteristics of this vegetation (McGraw and Levin 1998).

Even within the sandhills, the distribution of the Ben Lomond spineflower is restricted due to light competition. Plants are found in most areas lacking overstory vegetation in both silverleaf manzanita chaparral and sand parkland communities. In silverleaf manzanita chaparral, which is dominated by shrubs (*Arctostaphylos silvicola, Ceanothus cuneatus,* and *Adenostoma fasiculatum*) and oak trees (*Quercus agrifolia, Q.wislizenii*), the Ben Lomond spineflower is found along trails and in other gaps in shrub canopy (J. McGraw, unpublished data).

The sand parkland community (Section 3.4) supports the largest populations of Ben Lomond spineflower. The spineflower is abundant in the herbaceous layer except under trees and shrubs. Experiments examining the mechanism for this restricted distribution confirmed the effect of shade in reducing growth and fecundity, but also showed that tree litter on the soil surface almost completely prevented plant establishment and therefore has an over-riding negative effect on Ben Lomond spineflower population growth (McGraw 2004).

In their preferred habitat away from trees and shrubs, populations of the Ben Lomond spineflower are reduced by dense non-native annual plants. Rat-tail fescue (*Vulpia myuros*), smooth cat's ears (*Hypochaeris glabra*), rip-gut brome (*Bromus diandrus*), and other European annual grasses and forbs are widespread in the sandhills and patchily abundant in the sand parkland community. A sampling study revealed that Ben Lomond spineflower abundance is negatively correlated with the density of exotic annual plants, while an experiment showed that exotic plants reduce the survivorship and fecundity of the spineflower (McGraw 2004).

In habitat lacking overstory vegetation, the Ben Lomond spineflower is preferentially found on soil disturbances in the sandhills including slides, trails, and gopher mounds. Slides or washes, which result from the erosion (gravity, wind, water) of loose soil on steep slopes (>35%) are common in sand parkland and comprise more than 16% of the habitat (Section 3.7). Ben Lomond spineflower density and cover is higher on slides than on the adjacent, undisturbed habitat. An experiment showed that slides increased the demographic performance of the Ben Lomond spineflower by removing accumulated leaf litter and reducing exotic plant competition (McGraw 2004).

Covering an average of 9% of the sand parkland habitat, wildlife trails similarly enhance populations of the Ben Lomond spineflower. Plant size and total cover of Ben Lomond spineflower is greater on and immediately adjacent to trails than on the adjacent, undisturbed area. Experimental manipulations of trails revealed that it is the removal of leaf litter and reduction of exotic plant density that increases spineflower performance on trails (McGraw 2004).

Gopher mounds, which cover an estimated 11% of the sand parkland habitat, similarly facilitated Ben Lomond spineflower demography. Interestingly, experimental manipulations showed that gopher mounds enhanced spineflower not only by removing litter and reducing exotic plant competition, but also by enhancing nutrient availability (McGraw 2004).

Morphology and Phenology

The Ben Lomond spineflower is a small, herbaceous winter-spring annual plant (Figure A.11). Seeds germinate with the first hard rain in fall that usually occurs between mid-October and mid-November. Seedlings form a basal rosette of spatulate leaves over the winter (November to February). Plant growth accelerates in March as larger, oblanceolate leaves are created. In late March, typically three inflorescence branches emerge from the basal rosette. White to pale pink flowers borne on branches in dense clusters (heads) are visible between April and June. Each flower is surrounded by a cylindrical, pink to purple involucre. This spiny bract encases the fruit, an achene, which contains a single seed. Seeds typically fall from the plant, still encased within the involucre, after development in June-July (Hickman 1993, McGraw 2004).

The Ben Lomond spineflower exhibits considerable variability in morphology and phenology depending on habitat and microclimate. Plants growing in full sun (i.e. away from trees and shrubs) without dense European annual exotic plants are prostrate and often very large. Basal leaves can exceed 5cm and flowering stem branches can exceed 20 cm in length. In contrast, plants growing in competition for light are much smaller and erect, with a 3-10cm stem that subtends the leaves. Flowing stem branches are much shorter and, as a consequence, flower production is reduced (McGraw and Levin 1998, McGraw 2004).

The distribution of spring rainfall greatly influences the phenology of the Ben Lomond spineflower. Infrequent storms and below average rainfall in spring result in earlier flowering (mid-March) and earlier seed set (mid-May). In contrast, the occurrence of significant rainfall in spring (March-June) increases growth, delays the onset of flower production, and extends the flowering period of the Ben Lomond spineflower into late June (J. McGraw, unpublished data).

Life Cycle

Mating System

Ben Lomond spineflowers are monoeicous and produce bisexual flowers (each with both pistil and stamens). No specific study has been conducted on the mating system of the Ben Lomond spineflower. However, other spineflowers with nine stamens exhibit a combination of outcrossing and selfing (self-fertilization). Flowers may initially keep the stigma elevated above the stamens so as to increase the chance that pollen from another flower will reach the stigma; however, when the flowers close at night, the stigma may be pollinated by anthers within the same flower (J. Reveal, pers. comm. 2003*)*.

Pollination Biology and Seed Production

Though no study has yet examined pollination biology of the Ben Lomond spineflower, numerous insects have been observed visiting flowers and are likely pollinators. Small ants (<5mm) are commonly observed crawling in flowers while small flies, bee flies, European honeybees, and bumble bees frequently visit plants (J. McGraw, pers. obs.).

While a maximum of one seed is produced per flower, a study of seed set found that an average of only 48% of flowers produced a seed. Plants on north-facing slopes had slightly lower seed set than plants on south aspects (43% and 50%, respectively). Though observations suggested insect activity is higher near larger plants than on small plants, there was only a slight positive correlation between plant size and seed set (J. McGraw, unpublished data).

Flower Production

The overall number of flowers (and therefore seeds) produced is strongly correlated with plant size which depends strongly on habitat conditions. Plants growing in shade or amidst a high density of plants (exotic plants, native plants, or oftentimes other spineflowers) produce fewer than 20 flowers, with many small individuals producing only a single flower. At the other end of the spectrum, plants growing in full sun and without competitors, as on trails or gopher mounds, can produce over 5,000 flowers. Because spineflowers frequently grow in dense herbaceous plant competition, however, plants likely produce less than 100 flowers on average (McGraw 2004).

Seed Dispersal

Spines on the involucre containing the seed cause it to adhere to fur. Mule deer (*Oidocoileus hemionus*), coyote (*Canis latrans*), rabbits (*Sylvilagus* spp.), and a variety of small mammals that contact plants in late June and July when seeds are easily dislodged from the flower stems may disperse seeds. Those not removed typically fall to the soil surface by late summer. Large ants have been observed carrying the involucres to their colonies (J. McGraw, pers. obs.). They, and perhaps other insects, provide secondary dispersal of seeds. However, dense patches of seedlings frequently found below the parent plants suggest that many seeds are not dispersed far from the parent plant (J. McGraw, pers. obs.).

Germination

Germination trials under laboratory conditions indicate that Ben Lomond spineflower seed viability is very high. Seeds likely require high ambient temperatures of the summer months to break dormancy and germinate in the fall (C. Baskin, *pers comm*.). Indeed, seeds buried under soil or litter only infrequently germinate (McGraw 2004). An experiment to examine germination under simulations of early and late fall rains found no difference in the percent germination of the Ben Lomond spineflower (J. McGraw, unpublished data).

Seed Bank

There is little empirical evidence for significant seed storage in natural populations of the Ben Lomond spineflower. Though seeds can be viable one year after production, percent germination of seeds is very low (less than 0.01%). In addition, soil cores taken from high-density populations contained minimal germinable seed (McGraw 2004). Unfortunately, metabolic activity of Ben Lomond spineflower seeds cannot be assess using the tetrazolium test, making it difficult to determine whether any seed that remains is viable (McGraw 2004).

Observations of large populations or Ben Lomond spineflower following disturbances that remove established vegetation (e.g. ground clearing) have suggested to some observers that Ben Lomond spineflowers readily colonize disturbances from a seed bank. Such high density populations of Ben Lomond spineflower may result instead high population growth rates in initially small populations of individuals which were unobserved prior owing to their small size. Following disturbance which remove competing vegetation, these small populations can increase rapidly owing to dramatically increased plant growth and reproduction rates (J. McGraw, pers. obs).

Establishment

Seedling establishment in the Ben Lomond spineflower is influenced by many factors. Litter accumulation either from trees or dense exotic plants inhibits seedling emergence. The highest rates of establishment were observed in open sand conditions including those found on trails and gopher mounds. An experiment manipulating the presence of exotic plant species found that the establishment of seedlings immediately following germination is reduced by the presence of exotic plants (McGraw 2004).

Survival

Seedling survival over the winter to reproduce in spring is most strongly impacted by the presence of exotic plant species. Depending on their density and the year, exotic plants reduced survivorship of the Ben Lomond spineflower by up to 50% (McGraw 2004). The availability of soil moisture strongly influences the ability of seedlings to withstand competition. Mortality of seedlings is highest in years with a prominent mid-winter drought—a two to six-week period with unseasonably high temperatures and minimal or no rainfall between December and February (J. McGraw, unpublished data).

Fungal attacks by rust as evidenced by dark purple to black spots on leaves have been shown to cause seedling mortality, especially in winters with above-average rainfall. More commonly, fungal attack kills leaves and reduces plant growth, however seedlings survive (J. McGraw, pers. obs.)

Herbivory of the Ben Lomond spineflower is minimal. Occasionally, Lepidopteran larva (e.g. caterpillars) are observed on spineflower rosettes. Mammalian herbivory, likely by rabbits, has been observed on seedlings found adjacent to shrubs and trees (J. McGraw, pers obs.)

Despite these factors, survivorship of seedlings is remarkably high. Even under poor habitat conditions, seedlings of the Ben Lomond spineflower frequently survive. Growth and consequently reproduction are often reduced, however, as described above.

Threats

As a narrowly endemic species, Ben Lomond spineflower persistence is threatened by loss of sandhills habitat. Within preserved sandhills habitat, fire exclusion has greatly reduced the area of open habitat required by the spineflower in both sandhills chaparral communities and sand parkland. Competition from exotic species reduces the population size of spineflowers within remaining open sandy habitat. In these areas, disturbance caused by recreation can remove all plant cover and further threatens spineflower populations.

5.3 BEN LOMOND BUCKWHEAT

Conservation Status

The Ben Lomond buckwheat (Polygonaceae *Eriogonum nudum* Dougl. Ex Benth. var. *decurrens* (S. Stokes) M. L. Bowerman) is on the CNPS list of most threatened and endangered plant species (List 1B; Skinner and Pavlik 1994).

Available Information

With the exception of the monograph for *Eriogonum* in California (Reveal 1989), there is no published literature on the Ben Lomond buckwheat. There are also no unpublished studies available on the ecology of the Ben Lomond buckwheat. During the course of an extensive research program examining the ecological factors affecting the population persistence of the Santa Cruz wallflower and the Ben Lomond spineflower, the author collected information on the biology of the Ben Lomond buckwheat, which co-occurs with the two federally endangered species in the sandhills (McGraw 2004).

Distribution

The Ben Lomond buckwheat is endemic sandhills of Santa Cruz County near the towns of Boulder Creek, Ben Lomond, Olympia, Zayante, Felton, Scotts Valley, Glenwood, and Bonny Doon. The published account of the Ben Lomond buckwheat in the Jepson Manual which states that the plant occurs in near Mount Diablo in Contra Costa County (Hickman 1993) was in error, according to Dr. Barbara Ertter, Curator of the Western North America Flora at the University and Jepson Herbaria (UC Berkeley), expert in the Polygonaceae, and author of the "Flora of Mount Diablo" (B. Ertter, pers. comm. 1998). Instead, there is wide agreement that the Ben Lomond buckwheat is endemic to the inland sand soils of Santa Cruz County.

Biology

<u>Morphology</u>

The Ben Lomond buckwheat is a perennial herb or occasionally a suffrutescent (subshrub) with a woody, persistent stem. Including inflorescences, plants range from 30-200 cm tall (Hickman 1993; Figure A.12), though most plants do not exceed 150 cm in height (J. McGraw pers obs). The 10-30 mm long, ovate, cauline leaves with wavy margins are decurrent, or have an extension below the stem where the leaves appear to attach, lending to the infraspecific epithet "decurrens" (Hickman 1993). The green leaves frequently have orange to red pigment and are thick. Though many wither and shrink during the summer, most are persistent. Leaves have dense white hairs coating the underside of leaves, an apparent adaptation to desiccation stress resulting from the high amount of radiant energy that reflects off the white sand soils (J. McGraw, pers. obs.)

The very small (3-4 mm), radial, white flowers of Ben Lomond buckwheat are in dense, head-like, spherical inflorescences at the end of long gray-green, hairy peduncles, (inflorescent stalks) which give the inflorescence an open appearance. The peduncles are frequently taller than the stem itself, such that the height of the plant more than doubles when in flower (J. McGraw, pers obs). The fruits are 1.5-3.5 mm long achenes that remain enclosed in the orange to red-brown dried perianth (petals) following development (Hickman 1993).

Phenology

There is no published information about the life history or phenology of the Ben Lomond buckwheat. However, observations and data collected during plot-based experiments in the sand parkland between 1997-2003 provide some information about the life history of this species (McGraw 2004). Germination occurs with the first hard rains in fall (October-December). The small, green to red spatulate leaves of germinants have been observed as early as two weeks following germinating rains. Seedlings develop a basal rosette of leaves over the first year, with stem elongation and cauline leaves developing in the second growing season following germination (J. McGraw, unpublished data).

Plants typically flower during their third spring following germination. However, perhaps in good conditions for growth (e.g. high soil moisture, low competition, etc.), plants flower in their second year (J. McGraw, unpublished data). Plants bolt, or produce the elongated inflorescence stalk beginning in May, while nascent inflorescences emerge by June. Plants typically flower between June and August, though open corollas have be observed through early fall. Seed set occurs in late summer-early fall, after which the dried inflorescence stalks persist, often until the following spring when barring excessive biomass loss, adult plants typically flower again (J. McGraw, unpublished data).

Ecology

<u>Distribution and Habitat Preference</u>

Ben Lomond buckwheat is endemic to the sandhills of Santa Cruz County. Within the sandhills, the Ben Lomond buckwheat is found in both the sand parkland and sandhills chaparral communities. In sand parkland, Ben Lomond buckwheat is found in areas adjacent to trees and shrubs and in open areas away from woody vegetation. Ben Lomond buckwheat is also found underneath the canopy of ponderosa pine (*Pinus ponderosa)*. Indeed, it is preferentially found near the canopy edge of trees, perhaps because trees facilitate survivorship of the perennial plant through the hot dry summers (McGraw 2004).

Unlike most herbaceous sand parkland species, which are preferentially found either on north or south aspects, but not both, Ben Lomond buckwheat is found on slopes of all aspects. The main factor restricting the distribution of the Ben Lomond buckwheat in sand parkland is the canopy of oaks (*Quercus agrifolia*) and shrubs including *Arctostaphylos silvicola, Ceanothus cuneatus*, and *Adenostoma fasiculatum* (McGraw 2004).

Oaks and shrubs similarly restrict the distribution of the Ben Lomond buckwheat in the sand chaparral community, which is characterized by dense shrub cover with minimal understory species except in gaps between the shrub canopy. Ben Lomond buckwheat is frequently found in the gaps in chaparral, including those created by trails (J. McGraw, unpublished data).

Pollination Biology

There have been no studies on the mating system or pollination biology of the Ben Lomond buckwheat. Numerous insects including European honeybees and bumble bees have been observed visiting flowers and may be pollinators of the Ben Lomond buckwheat. Research showing high outcrossing rates in another endangered *Eriogonum* endemic to limestone outcrops in southern California suggests that pollinators play an important role in maintaining populations of the rare congener (Neel et al. 2001).

Seed Biology

No studies have examined seed biology of this endemic plant. Observations of dense clusters of germinants beneath parent plants suggest that some seed does not disperse far (J. McGraw, pers. obs.). Studies of other *Eriogonum* species in the sandhills vegetation of Florida have found that the plant has no seed bank (Carrington 1999, McConnell and Menges 2002). Research is required to determine dispersal, seed dormancy, and seed bank dynamics in this plant.

Seedling Establishment and Survival

Though Ben Lomond buckwheat can germinate and establish through moderately thick litter associated with areas beneath trees, seedling establishment is facilitated by fire and raking that remove leaf litter on the soil surface (McGraw 2004). Seedlings establish readily in sand parkland during the winter, but suffer high rates of mortality over the long summer drought that typically occurs between May and October. Presumably due to reduced desiccation stress, seedling survival is higher near trees and on north aspects, resulting in greater density of Ben Lomond buckwheat adults in these areas. In contrast, seedling mortality was high in open sandy areas and where the cover of exotic annual species is high (McGraw 2004).

Adult survivorship

Fire removed aboveground biomass of adult Ben Lomond buckwheat individuals; however, most plants successfully resprouted in the winter and flowered in the spring following fire, suggesting this plant is adapted to fire (McGraw 2004(Carrington 1999). Observations of bright orange dots of discoloration in the leaves of adult plants prior to their death suggest a fungal pathogen may reduce survival (J. McGraw, pers. obs.), though as with other aspects of this species biology, research is required to determine the significance of pathogens for plant persistence.

Threats

As a result of its natural rarity, widespread destruction of sandhills habitat threatens the persistence of the Ben Lomond buckwheat. Within protected habitat, encroachment by shrubs and shade-producing oak trees due to fire exclusion further restricts the distribution of this plant. Competition from aggressive exotic plants reduces population sizes. Recreation which denudes sandhills habitat also likely reduces populations of the Ben Lomond buckwheat. Compared to the Ben Lomond spineflower and Santa Cruz wallflower, Ben Lomond buckwheat may be less threatened, owing to its greater distribution within the sandhills. However, little is known about the specific factors which influence population performance of this endemic plant, leaving additional threats to this species persistence unknown.

5.4 SILVERLEAF MANZANITA

Conservation Status

Silverleaf manzanita (Ericaceae *Arctostaphylos silvicola* Jepson & Wiesl), which is also known as "Bonnie Doon manzanita" (Hickman 1993) is on the CNPS list of most threatened and endangered species (List 1B; Skinner and Pavlik 1994) and is a Category 2 plant, or candidate for federal listing.

Available Information

With the exception of the species description (Wiesland and Schreiber 1939), there is no published literature on silverleaf manzanita. In addition, there are no unpublished studies available on the ecology of silverleaf manzanita. However, much research has been conducted on other species of *Arctostaphylos* throughout chaparral communities in California, including in maritime chaparral. Results from this research are incorporated in the following description as they may provide useful information for management of silverleaf manzanita.

Distribution

Silverleaf manzanita is restricted to the sandhills of Santa Cruz County near the towns of Boulder Creek, Ben Lomond, Olympia, Zayante, Felton, Scotts Valley, Glenwood, and Bonny Doon.

Biology

Morphology

Silverleaf manzanita is an evergreen tree-like shrub that grows to be 1-6 m tall (Figure A.14). This non-burl forming manzanita has deep, dark red, smooth bark and stems covered with dense, fine, grayish white hairs. The oblong to elliptic leaves are held erectly and range from 1.5-3.5 cm in length. Their dull gray leaf surfaces are covered with dense white hairs in younger leaves, while older leaves are smooth and glaucus, or covered with a white or bluish film (Hickman 1993). The hairs and bluish film give the plant a gray or silver appearance.

The 7-10 mm long, white, urn-shaped, flowers are borne on dense racemes at the ends of branches. The fruits are 6-12 mm wide drupes that consist of a thick, mealy pulp surrounding 2-10 seeds (Hickman 1993).

Phenology

As with other shrubs in California's Mediterranean climate, seeds likely germinate with the onset of the rains between October and December. The age or size required for the onset of reproduction is currently unknown. Silverleaf manzanita flowers between November and February. Though fruits develop in the spring, many remain on the plant (are not dispersed) so are visible throughout the year (J. McGraw, pers obs.).

Ecology

Distribution and Habitat Preference

Silverleaf manzanita is endemic to the sandhills of Santa Cruz County (Hickman 1993). Within the sandhills, silverleaf manzanita is frequently found in areas where the soil is thinner such as areas where the sandstone from which the soil is derived is nearer to the soil surface (Morgan 1983). These areas are primarily found at the base of ridges and are typically dominated by silverleaf manzanita and other chaparral shrubs including *Ceanothus cuneatus, Adenostoma fasiculatum, Mimulus aurantiacus, Ericameria ericoides* and trees including *Quercus agrifolia* and *Q.wislizenii* (Marangio 1985). Isolated individuals and occasionally small patches of silverleaf manzanita are also found in the deeper soils found on ridges of the sand parkland community (McGraw 2004).

Mating System

Jacobson (1994) found that no fruits developed when inflorescences were bagged to prevent pollinator visitation, indicating self fertilization is unlikely and instead, that pollination is required for seed development.

Pollination Biology

Pollinators of silverleaf manzanita include blow flies, hover flies, house flies, solitary bees, Edward's Cuckoo bees, red cuckoo bees, honey bees, bumble bees, sweat bees, leaf cutter bees as well as butterflies and moths (R. Morgan *in* Jacobson 1994). Silverleaf manzanita flowers contain nectary disks at the base of the ovary (Hickman 1993) that provide a reward to pollinators. However, studies have shown that "nectar robbers", including both bumble bees (Irwin and Brody 1999) and humming birds (Machado and Sazima 1995), can obtain access to nectaries without contacting the stamens or pistil and therefore without effecting pollination. In a study of silverleaf manzanita at the Bonny Doon Ecological Reserve, nectar robbery was observed to occur frequently (Jacobson 1994). Three different types of robbery holes were identified, suggesting multiple nectar robbers. Nectar robbery reduced fruit set, and behavior of aggressive nectar robbers including hummingbirds that actively defend silverleaf manzanita shrubs suggest they might deter legitimate pollinators. Given the requirement of pollination for fruit set, the authors concluded that nectar robber can reduce seed production (Jacobson 1994).

Seed Biology

Silver leaf manzanita is an obligate seeding plant (Hickman 1993). That is, it cannot resprout from underground burls ("stump sprout") following moderate to high intensity fires that consume aboveground biomass, so population persistence requires successful germination of seeds. While there is no published information on silverleaf manzanita seeds, much research has been conducted on the biology and ecology of seeds in the chaparral of California, including that of in other manzanita species. The following discussion of seed ecology in silverleaf manzanita integrates results of these previous studies with observations of silverleaf manzanita ecology in the field.

Seed Dispersal

Observations indicate that while many silverleaf manzanita fruits fall and accumulate on the soil surface, some fruits remain on the stem for over a year following development (J. McGraw, pers obs.) In other species of manzanita, studies have found that fruits are consumed by birds, small mammals such as rodents and rabbits, and large mammals including coyote and bear (Keeley and Hays 1976). Coyote, rabbits, deer mice, and kangaroo rats that inhabit the sandhills chaparral communities community may consume and therefore disperse fruits and seeds. However, other studies have found that though rodents are attracted to the fruits, the majority of *Arctostaphylos* are dispersed within the canopy radius (Keeley 1977).

Seed Predation

There is no current information regarding seed predation (granivory) in silverleaf manzanita. However, a study of seed dynamics in two closely related species (*A. glandulosa* and *A. canescens*) in chaparral on Mount Tamalpais in Marin County found that manzanita seeds are subject to high levels of predation, likely by rodents (Kelly and Parker 1990). While deer and coyote may disperse but not kill the seeds if passed through their gut without destroying the seed coat, small mammals such as kangaroo rats and deer mice predate upon the seeds within the fruits, eliminating their viability (Keeley and Hays 1976).

Seed Dormancy

Though no studies have been conducted on the dormancy of silverleaf manzanita seeds, studies of closely related species have found that *Arctostaphylos glandulosa*, *A. patula, A. uva-ursi* and A. *alpina* all exhibit physiological dormancy, meaning that a physiological inhibiting mechanism prevents germination of the seed even in the presence of appropriate environmental conditions. This dormancy is likely overcome by warm and/or cold stratification (Keeley 1977, 1991, Baskin and Baskin 2001). These species are found in different habitats and not surprisingly, require different temperature regimes to break dormancy (Baskin and Baskin 2001).

Seed Germination

Though no studies have been conducted on silverleaf manzanita seed germination, extensive research on other chaparral shrubs has shown that seed germination is dependent on heat from fire for scarification (Keeley 1987). In addition, laboratory trials showed that the germination of *A. glandulosa* and *A. canescens* seeds was stimulated by the presence of charred wood (Keeley 1987). In the field, an experiment comparing the effects of burning to manual shrub removal in maritime chaparral found that *A. purissima* seedling establishment was enhanced by fire but not manual removal of shrubs, suggesting some aspect of fire (e.g. heat or charate) is required for germination (Tyler 1996). Indeed, observations and studies suggest that species of *Arctostaphylos* frequently produce seedlings primarily or exclusively in the first year following fire (Keeley 1991).

Like other obligate seeding species in the genus, silverleaf manzanita may experience increased seed germination following fire. However, even in "refractory seed species", or those such as *Arctostaphylos* species in which germination is triggered by an environmental stimulus, some of the seed crop is non-refractory, meaning it will germinate without the stimulus (Keeley 1991). This could explain the low density of silveleaf manzanita seedlings observed in areas that have not burned in decades (Lee 1994, J. McGraw, pers obs.).

Seed Bank

There is no information about seed bank dynamics of silverleaf manzanita. However, the absence of the germination stimulus (fire) combined with seed dormancy likely results in seed storage in this rare plant (Keeley 1977). A study comparing seed bank density in *Arctostaphylos* species found no change across a 10 year time period in the absence of fire, suggesting that either post-dispersal seed predation and/or seed senescence/decay may reduce seed storage (Keeley 1987). A study of *A. glandulosa* and *A. canescens* found evidence for high seed predation though no loss of seed viability, at least in the year following dispersal (Kelly and Parker 1990). Results of these studies suggest that silverleaf manzanita likely exhibits seed dormancy and, barring excessive predation, senescence, or decay, has a seed bank. Difficulties germinating seeds of silverleaf manzanita render it difficult to determine whether there is indeed germinable seed within the soil.

Seedling Establishment and Survival

Like other species of manzanita and other shrubs in the chaparral of California, silverleaf manzanita is adapted to fire. In addition to potentially requiring fire cues to break seed dormancy (see above), seedlings are likely adapted to the exposed mineral soil and high light characteristic of a post fire environment. In the absence of fire or other disturbances that remove litter and established plant cover, silverleaf manzanita seedlings may be prevented from establishing.

Though seedlings are occasionally observed, aerial photographs suggest that the currently population of silverleaf manzanita at the Quail Hollow sandhills is comprised primarily of adult shrubs that established following the 1954 fire (J. McGraw, pers. obs.). Other studies of fire in maritime chaparral have found no shrub emergence after the first year following fire, perhaps because the seed bank was exhausted by fire induced germination and mortality (Odion 2000, Odion and Davis 2000).

Silverleaf manzanita seedling establishment may also be limited by low soil moisture availability over the long summer drought (May-October). Experiments examining the effects of exotic plants and spring rainfall in the sand parkland community found that seedling survival in many perennial, suffrutescent, shrub, and tree species was greatly reduced or even eliminated by the presence of exotic annual plants. These competitive effects are reduced in simulations of above average rainfall in the spring (J. McGraw, unpublished data). Though presently exotic plant cover is much lower in silverleaf manzanita chaparral than sand parkland (J. McGraw, pers obs.), increased abundance of exotic plants in the post-fire or disturbance environment may reduce silverleaf manzanita seedling establishment and survival.

<u>Adult survivorship</u>

Though there are no studies examining factors affecting survival of silveleaf manzanita, observations suggest that survivorship of adult shrubs is presently high. “Skeletons” or dead standing individuals are infrequent in the sandhills chaparral communities despite the persistence of the dense wood and lack of fire (J. McGraw, pers. obs.) However, skeletons of once large individuals are occasionally found in the sand parkland habitat and may be less conspicuous in silverleaf manzanita chaparral due to adjacent shrub growth that may cover dead plants (J. McGraw, pers. obs.).

Assuming that most shrubs within sandhills chaparral patches are indeed of a similar age (i.e. established following the most recent fire), mortality may increase as the aging population senesces and becomes more susceptible to disease. There is no information on senescence in manzanita, however, though populations of *Ceanothus cuneatus* in the sandhills chaparral communities appear to be declining (J. McGraw, pers obs).

Threats

As a narrowly distributed endemic species, silverleaf manzanita is primarily threatened by habitat destruction. Within protected sandhills habitat, mortality resulting from senescence and/or disease will reduce populations in the absence of concomitant increases in the population resulting from seedling recruitment, which may require fire. Silverleaf manzanita may be negatively impacted by fire which can kill most aboveground individuals and may enhance establishment of exotic plants, which can compete with seedlings. Careful fire management will likely be required to allow persistence of this endangered shrub.

5.5 ZAYANTE BAND WINGED GRASSHOPPER

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Conservation Status

The Zayante Band Winged grasshopper (*Trimerotropis infantilis* Rentz and Weissman 1984) is a federally-listed endangered species (U.S. Fish & Wildlife Service (1997). The California Endangered Species Act, which comprises Sections 2050-2068 of the state's Fish and Game Code (http://ceres.ca.gov/topic/env-law/cesa/stat/) excludes insects from consideration for endangered or threatened status. Thus no insects are currently recognized as endangered or threatened species at the state level. The International Union for the Conservation of Nature (1994) formerly recognized the ZBWG as threatened.

In 1998 a recovery plan was published by the U.S. Fish & Wildlife Service (1998) that treated two endangered insects (Mount Hermon June beetle and ZBWG) and three endangered plants that occur in the Zayante sand hills of Santa Cruz County. Recovery plans describe actions required to adequately protect listed species like the ZBWG, so their populations can be recovered and they no longer require protection pursuant to provisions of the Endangered Species Act of 1973, as amended. This recovery plan described three events necessary to downlist or delist the ZBWG, namely:

a) protection of the 10 known collection sites (consisting of 7 discrete areas) of sand parkland habitat via fee-title acquisition, conservation easement, or Habitat Conservation Plans
b) development and implementation of a management plan for the Quail Hollow Ranch County Park (County of Santa Cruz)
c) attain stable or increasing populations ZBWG

A total of 10,560 acres was designated as critical habitat for the ZBWG by the U.S. Fish & Wildlife Service (2001). This acreage generally lies between Highways 9 and 17 in the Felton-Mount Hermon-Ben Lomond-Scotts Valley area of Santa Cruz County. The critical habitat includes 610 acres of state or county-owned park lands and 9,950 acres of privately-owned lands. However, most of this acreage includes unsuitable habitats or developed and altered lands that do not currently support the ZBWG.

Critical habitat is defined as specific occupied and unoccupied areas that are essential for the conservation of a federally-listed species (see Section 3, definitions, of the Endangered Species Act of 1973; http://endangered.fws.gov/esa.html#Lnk03). These areas may require protection or management to benefit the listed species. It is identified based on the best available scientific and commercial information about the physical and biological needs of the species. These needs may include:

a) space for individual and population growth
b) space for normal behavior; food, water, light, air, minerals, or other nutritional or physiological needs

c) cover and shelter
d) sites for breeding, reproduction, and rearing of offspring
e) habitat that is protected from disturbance or is representative of the historical geographic and ecological distribution of the listed species

The designation of critical habitat is intended to inform the public and other federal agencies about the ZBWG's habitat needs and to highlight areas where recovery actions are likely to be focused. The designation of critical habitat does not affect land ownership or establish a refuge, wilderness, or habitat preserve. It does not allow the government or public access to private lands, nor close areas to access or use. Activities on private lands that do not require federal permits, licenses, or funding are not affected by the designation of critical habitat.

Species Description and Taxonomy

The ZBWG is a member of the family Acrididae (Insecta: Orthoptera) and subfamily Oedopodinae, the band winged grasshoppers (Figure A.26). The genus *Trimerotropis* contains about 45 species in North America (Rentz and Weissman 1980 and 1984; Otte 1984). Species in this genus range from Canada to Chile and Argentina (Otte 1984). Several have limited geographic ranges and a number of the species in this genus are associated with sand-based habitats, such as dunes, deserts, and sandhills.

Trimerotropis infantilis is one of the smaller species in this genus, hence the specific epithet (Rentz and Weissman 1984). Adult males measure about 0.50 to 0.75 inch in length, while females are slightly longer, approximately 0.75 to 0.9 inch. The body and forewings are pale gray to light brown with dark bands on the forewings. Basal areas of the hindwings are pale yellow. A cream-colored, mask-like marking surrounds the eyes. Tibia of the hindlegs are grey-blue like several other members of the genus *Trimerotropis*. This grasshopper has commonly been referred to as the Zayante Band Winged grasshopper because of its association with the Zayante area of Santa Cruz County and the Zayante sands (U.S. Fish & Wildlife Service 1994, 1997, 1998, and 2001).

Distribution

The historical distribution of the ZBWG is not well understood. Rentz and Weissman (1984) described the species using specimens collected in Alma, Santa Cruz, the Santa Cruz Mountains, and from the Olympia Quarry in Felton. The Alma location is especially puzzling because this area apparently did not support the Zayante soils or indigenous plant communities of the Zayante sand hills. Alma was a stop on the railroad line that formerly ran between Los Gatos and Santa Cruz (Kyle et al.1990). Perhaps specimens attributed to the Alma location were accidentally mislabeled. Alma was inundated by the construction of Lexington Reservoir in the early 1950s. Label data on the specimens from Santa Cruz and the Santa Cruz Mountains do not provide more specific locality information. Specimens from Lonestar's (now RMC Pacific) Olympia Quarry were from a portion of the quarry referred to as "Area B" by Santa Cruz botanist Randy Morgan (BUGGY Data Base 2004; Rentz and Weissman 1984).

Arnold (1999a) reviewed museum specimens and other reported records for the grasshopper, plus visited known and potential locations for the ZBWG throughout the Zayante sandhills. These records are stored in the BUGGY Data Base (2004) and have been summarized by U.S. Fish & Wildlife Service (2001). Based on this review, Arnold (1999a) concluded that the ZBWG had historically been observed at about 20 locations within the Zayante sandhills. However, in a few instances different wording on specimen labels or in written accounts that described these sites may have actually referred to the same locations. Bona fide occurrences the ZBWG were found to be restricted to the loose Zayante sand soils (USDA 1980) that occur in the Scotts Valley-Mount Hermon- Felton-Ben Lomond-Santa Cruz area of the Santa Cruz Mountains (i.e. the sandhills).

Three reported potential occurrences of ZBWG by Randy Morgan (BUGGY Data Base 2004) are from Bonny Doon, a ridge west of Boyer Creek, and Canham Road (near Mt. Roberts) areas of Santa Cruz County, but additional specimens need to be examined to verify if these locations actually support the ZBWG. More indurate Zayante sand formations, such as occur at Bonny Doon, may not be favorable for ZBWG which prefers the loose sands for egg-laying (Arnold, personal observation). The reported occurrence of ZBWG in San Mateo County by Otte (1984) in his taxonomic key to species (p. 184) must be erroneous as it is not substantiated by any specimens in museum collections (BUGGY Data Base 2004) or the occurrence of potentially suitable habitat in San Mateo County.

White (1993) surveyed several locations in the sandhills, but found the ZBWG only at only three locations: Quail Hollow Ranch County Park and the North and South Ridges of Quail Hollow Quarry. Hoekstra (1998) identified eight populations of the ZBWG. Between 1990 and 2003, Arnold (unpublished) visited over 200 individual properties in the sandhills to assess habitat conditions or to perform presence-absence surveys for the ZBWG and the Mount Hermon June beetle. During these surveys, Arnold confirmed the occurrence of the ZBWG at three new locations. Subsequently, however, the ZBWG has probably been extirpated from at one of these new locations.

Today the ZBWG is known from five primary locations in the Zayante sand hills (BUGGY Data Base 2004), namely:

1. Weston Road at the head of Ruins Creek (Site 2)
2. Quail Hollow Ranch County Park (Site 30)
3. Quail Hollow Quarry, 4 subsites that may actually represent separate demes (i.e., local interbreeding groups) or populations, including West Ridge, North Ridge, South Ridge, and Buffer Zone (Site 39)
4. Hanson Quarry (Western Perimeter Set Aside) and adjacent Mt. Hermon Cross and Conference Center (Site 14)
5. portions of several properties located north of Mt. Hermon Road and east of East Zayante Road, which may support one metapopulation or separate populations or demes of ZBWG (Sites 19 and 25)

Habitat

The band-wing subfamily exhibits the greatest species diversity in areas with warm, dry, sunny climates, and individual species are generally most abundant in habitats with a sparse cover of shrubs and grasses (Otte 1984). Orthoptera specialist, Dr. David Weissman (cited in Hovore 1996) indicated that narrowly-distributed species of *Trimerotropis* are often limited to specific soil formations (frequently sand formations), may have narrower food preferences, are unable to tolerate habitat disturbance, and have at least one sex with limited flight capability. Species found on sand sheets or dune formations often have limited powers of flight, perhaps so they aren't blown away from suitable habitat by the incessant winds that often characterize such areas. Not surprisingly, the ZBWG also exhibits such tendencies.

The preferred habitat of the ZBWG is barren or sparsely-vegetated, sunlit sand, features of the open sand parkland plant community. This community is characterized by a diverse assemblage of specialty herbs native to the sandhills, including the endangered Santa Cruz wallflower (*Erysimum teretifolium*; Section 5.1). Randy Morgan originally observed that the ZBWG and the wallflower frequently co-occurred (U.S. Fish & Wildlife Service 1994). Thus, it was hypothesized that the ZBWG might feed or otherwise be dependent upon the wallflower. Subsequent investigation has determined that the co-occurrence of these two endemics is not a dependent relationship, but rather a preference for a common soil type and habitat conditions (Arnold, personal observation). The ZBWG has been found open sandy areas impacted by moderate anthropogenic disturbances.

Two other species of *Trimerotropis* occur in the sandhills. *T. thalassica* occurs in the sandhills chaparral communities, while *T. pallidipennis* occurs in the anthropogenically disturbed areas, such as sand mine pits and haul roads. Rentz and Weissman (1980 and 1984) observed that these three *Trimerotropis* taxa can be distinguished by their size, hindwing and hind tibia colors, and crepitations (short crackling sounds created by males).

In the original description of the ZBWG, Rentz and Weissman (1984) noted that the habitat at the type locality [Lonestar's (now RMC's) Olympia Quarry] was "sandy substrate sparsely covered with *Lotus* and grasses at the base of pines above a rock quarry". Hovore (1996) stated that he and Weissman most frequently encountered the ZBWG within ruderal and successional scrub habitats, where the soils were largely exposed, and in open, sunny flats beneath Ponderosa pine.

Arnold (1999a and 1999b) noted the habitat associations and conditions where ZBWG adults were observed along existing trails that traversed a variety of plant communities at the Hanson Aggregates' Felton Quarry, Hanson's mitigation site at the Freeman property, and the North, South, and Western Ridges of Quail Hollow Quarry. The preferred habitat of the ZBWG was found to be the open sand parkland with widely scattered tree and shrub cover, sunlit ground, and extensive areas of bare or sparsely vegetated ground characterized by loose sand and relatively flat relief. ZBWG was also observed in sunlit grassy or barren patches within or at the edges of sandhills chaparral communities or dense sand parkland.

During subsequent capture-recapture studies and season-long counts along these same trails, a much greater proportion of ZBWGs have consistently been captured or observed in more open portions of these trails (Arnold 2000, 2002a, 2002b, and 2004). It is generally seen along lightly used trails and the upper slopes of ridges, at or below the crest, but above the limit of dense shrub or tree cover. It does not occur in sandhill habitats characterized by dense herbaceous, shrub, or tree cover, or heavily utilized areas. Chu (2002) examined microhabitats and food plant preferences of ZBWG at the North and South Ridge areas of Quail Hollow Quarry. She found ZBWG was preferentially found in areas of lower total plant cover comprised of fewer exotic plant species (Chu 2002).

To date, ZBWG has not been observed in revegetated portions of the Quail Hollow, Hansen, or Lonestar quarries (Arnold, unpublished). Many of these revegetated benches and slopes are characterized by consolidated or indurated sands, rather than the loose sandy sols preferred by ZBWG. In areas where soil s were more loose, soil tackifers and other devices have been used to minimize soil erosion, which may discourage ZBWG from colonizing these areas. In addition, some revegetation areas are at least partially shaded during the hours of the day when ZBWG are active, thus potentially reducing their suitability as habitat. However, at the South Ridge conservation area of Quail Hollow Quarry, ZBWG is commonly observed at the edge of and atop of the hydrologically mined portion of the quarry (Arnold 1999b, 2002a, and 2004). Mining activities ceased here approximately 50 years ago (R. Atkins, pers. comm. 2004) Presently, these areas support a sparse assemblage of native forbs and scattered subshrubs similar to that found in open sand parkland (Section 3.4).

Natural History

Arnold (1999a, 1999b, 2000, 2002a, 2002b, and 2004) has been monitoring the ZBWG populations at the Quail Hollow Quarry, Hanson Quarry, and Hanson's Freeman mitigation site since 1999 as part of the habitat preservation and mitigation activities that the respective quarry companies implemented for their habitat conservation plans and were approved under their incidental take permits for the ZBWG and the Mount Hermon June beetle (Section 5.6). At the start of these monitoring programs, there was very little information about the ZBWG's biology or population dynamics, nor had suitable monitoring techniques been developed to evaluate the status of these insects and their responses to habitat management actions. Thus, the "monitoring" efforts became a research program to learn more about the ZBWG's natural history, its habitat associations, to accurately describe its population biology, and to identify appropriate population monitoring methods that provide reliable estimates of population numbers and other parameters of interest for use in the long term monitoring program. Information gained from these respective quarry studies have been pooled to assemble a better information base, however other aspects of the ZBWG's life history and biology remain to be elucidated.

<u>Seasonality</u>

Collection records (BUGGY Data Base 2004), and observations by Weissman (presented in Hovore 1996) and Randy Morgan (personal communication), as well as studies by Arnold (1999a, 1999b, 2000, 2002a, 2002b, and 2004) indicate that the ZBWG is univoltine, meaning it has only one generation per year. This is typical for other species in the genus *Trimerotropis* (Otte 1984).

Life History

Immatures, known as nymphs, look like adults except for the absence of wings. The nymphs are diurnal and are observed as early as May, while the adults become more prevalent beginning in July. Adults are also diurnal and remain active until the first ground-soaking rains, generally in late October or early November (Arnold 2000, 2002a, 2002b, and 2004).

Specific life history information for the ZBWG is unknown, but can be inferred from related species. Grasshoppers undergo an incomplete (i.e., hemimetabolous) metamorphosis, meaning that they develop from an egg to the adult through a sequence of progressively larger nymphal stages, without larval or pupal stages characteristic of insects that have complete (i. holometabolous) metamorphosis. Presumably the entire life cycle (egg, nymph, and adult) is completed within one year. Eggs are laid in the soil and the majority of the life cycle is probably spent as a subterranean egg.

Behavior

Weissman (cited in Hovore 1996) noted that characteristics of the topsoil may be a critical determinant of presence or absence of any particular *Trimerotropis* species. Soil consolidation, texture, grain size, and perhaps also chemistry, all affect the ability of females to oviposit into the substrate. Based on the occurrences of ZBWG in the Zayante sand hills, this species seems to require sandy substrates with loose, relatively fine upper layers (Arnold 1999a and 1999b). The ZBWG has not been observed at locations in the sand hills where the Zayante sands are more indurate, or where fine-grained sand has been removed (Arnold, personal observation).

In her research examining the diet of the ZBWG between June and September, Chu (2002) observed adults feeding on *Heterotheca sessiliflora* and *Lupinus albifrons*. Arnold similarly observed ZBWG feeding on *L.* albifrons (Arnold 2002a). The majority of plant fragments identified in an analysis of ZBWG frass were *Lupinus albifrons* (61%) and *Heterotheca sessiliflora* at (15%), while two grasses *Vulpia myuros* and *Aira caryophllea* combined for 17% and two asters, *Filago californica* and *Hypochaeris glabra*, combined for 8 % (Chu 2002).

Most adult ZBWGs occur on the sandy substrate where their cryptic color and markings offer good camouflage against the background of sand and sparse leaf litter. Less frequently, adults are also observed on vegetation, in particular among the foliage of *Lupinus albifrons*, where the grasshopper's disruptive coloration and the filtered light of the lupine canopy provide good camouflage (Arnold 2002a). Adults may also rest in the canopy of *Lupinus* and use it as part of their thermoregulatory behavior, especially on hot days (R. Arnold, pers. obs.).

When approached by an observer, nymphs and adults of the ZBWG generally rely on their camouflage and will usually remain motionless until nearly stepped upon. Then they make short, usually looping flights that can be difficult to follow. During the later portion of their flight, they often close their wings, which can make it difficult to see where they land on the sand (R. Arnold, pers. obs.). Males crepitate, making a rapid buzzing-like sound for approximately 1 second in duration. The buzz pattern and duration differs from that made by *Trimerotropis thalassica*, which occurs in Silverleaf manzanita and chaparral-dominated portions of the sand hills (Arnold, personal observation).

Chu (2002) observed adult behaviors by following several individuals of ZBWG as long as possible, often noting different behaviors during the period of observation for a particular individual. Observed behaviors included: walking, flying, feeding, cleaning, resting, thermoregulating, courtship, mating, male posturing, and female oviposition. Chu (2002) found that individual ZBWGs spend most of their time resting (46%), or walking, jumping, or flying (45%), while reproductive (4%) and feeding (5%) activities occurred much less frequently.

<u>Population Estimates</u>

Hovore (1996) provided the first estimates of ZBWG abundance based on a single count along three 100-foot long transects established in what was considered preferred ZBWG habitat located on the North, South, and West Ridges of Quail Hollow Quarry. Densities were calculated per 100 $ft.^2$ and ranged from 2-3 individuals for the North Ridge and West Ridge, plus 3.6 individuals for the South Ridge.

Arnold (1999b) calculated ZBWG densities at Quail Hollow Quarry along 1.3 miles of the existing trails. ZBWG densities ranged from 0.0 to 0.65 individuals per100 ft^2 during 3 survey visits (Arnold 1999b). The lower observed densities were attributed to the variation in habitat quality for ZBWG along the transects, rather than all being situated in prime habitat where ZBWG numbers would likely be greater. Similarly, Arnold (1999a) estimated daily densities of ZBWG at the Hanson Quarry and Freeman property. The densities ranged from 0.00 to 0.03 individuals per 100 ft^2. Three transects, collectively measuring about 0.41 miles, and traversing a variety of plant communities were used during 11 survey dates between late August and early November.

Population studies of the ZBWG have been performed as part of the annual monitoring activities that occur at the Hanson Quarry, Freeman property, and Quail Hollow Quarry (Arnold 1999a, 1999b, 2000, 2002a, 2002b, and 2004) as part of the habitat conservation plans (Hanson Aggregates Mid-Pacific Region 1999; Thomas Reid Associates 1997) that were approved for each quarry by the U.S. Fish & Wildlife Service. A variety of techniques have been used to estimate various population parameters, such as population numbers, adult lifespan, and dispersal, plus describe the ZBWG's seasonal population curve to derive an estimate of total seasonal population numbers. As described earlier, additional information on behavior and habitat associations has also accrued during these studies.

During capture-recapture studies, adults were marked upon their initial capture with a permanent marking pen using a dot code that uniquely identified each individual. Only adults were marked because nymphs lose their identifying marks when they molt. On subsequent survey dates, previously marked adults were recaptured or resighted, while new adults were captured and marked. Additional details on survey methods and analytical procedures are described in Arnold's monitoring reports (1999a, 1999b, 2000, 2002a, 2002b, and 2004).

Population densities were estimated using capture-recapture methods during a 65-day study at the Hanson Quarry and Freeman mitigation sites (Arnold 2000). A total of 169 males were marked at the Hanson Quarry, while 163 males were marked at the Freeman mitigation site. Recapture rates were nearly identical, 56.4% at Hanson and 55.8% at Freeman. Estimated daily population numbers (males + females) ranged from 34 to 210 individuals at Hanson and 58 to 250 individuals at Freeman. Seasonal population estimates for both Hanson and Freeman were generated using daily population estimates and survival rates from three capture-recapture statistical models. The seasonal population estimates ranged from 1,264 to 1,966 individuals at Freeman and 1,508 to 1,772 individuals at Hanson. The ZBWG population at the Freeman study site includes portions of the Freeman, Lonestar, and San Lorenzo Valley Water District properties, while the Hanson study site includes portions of the Hanson Quarry and Mount Hermon Conference Center.

Population densities were also estimated for the South Ridge portion of Quail Hollow Quarry (Arnold 2002a). At total of 454 males were marked and 284 (62.6%) were recaptured during a 32-day survey period. Estimated daily population numbers (males + females) were generally between 148 and 294 individuals, but got as high as 629 individuals. The seasonal population estimate ranged between 6,390 to 8,514 individuals.

Population monitoring of the ZBWG in 2002 and 2003 (Arnold 2002b and 2004) utilized counts of adults observed along various trails at the Hanson Quarry, Freeman property, and Quail Hollow Quarry. Counts were performed at approximately weekly intervals to determine the seasonal population curve of the ZBWG, which approximates a lognormal distribution. The population curve was described mathematically, and a statistical model derived. Using this model, estimates of seasonal population numbers, death rate, and emergence rate were calculated (Arnold 2004). Adult numbers of ABWG at the Quail Hollow Quarry during the 91-day adult activity period in 2003 were estimated to range from 26,954 to 32,186. This survey metholody is less time consuming than capture-recapture methods, and non-invasive since ZBWGs do not have to be captured and marked.

Although these population estimates of the ZBWG derived from each of these techniques are small, so are the sizes of the remaining open parkland habitat for grasshopper in the Zayante sand hills. Population studies of other species in the genus *Trimerotropis* have also yielded small numbers. For example, daily population estimates for the glade-inhabiting band wing, *Trimerotropis saxatilis* ranged from 40 to 277 individuals at four glades studied for a four-year period (Gerber and Templeton 1996). Similarly, daily population estimates for *Trimerotropis occidentalis* ranged from 30 to 110 individuals (Weissman and French 1980). Nonetheless, the small estimated population numbers of the ZBWG raise questions regarding the long term viability of these populations.

<u>Lifespan</u>

Lifespan data from these capture-recapture studies of the ZBWG suggest that adults live several weeks to a few months (Arnold 2000 and 2002a). One male was observed during a 58-day period, while a second male was observed throughout a 65-day period. Seventeen of 183 recaptured individuals lived at least 42 days. Adults of the related band wing, *Trimerotropis occidentalis,* were found to live as long as 156 days, with an average lifespan of about 70 days (Weissman and French 1980). Despite the high recapture rates (56% to 63%), the estimates of longevity for the ZBWG may underestimate actual adult lifespan, especially since the capture-recapture study periods were shorter than the full adult season (Arnold 2000 and 2002a).

<u>Dispersal</u>

When flushed in the field, adults of ZBWG generally move rather short distances (ca. 1-25 feet). Dispersal data from capture-recapture studies confirmed that most adult males are quite sedentary, with home ranges of no more than a few acres. When sampled at approximately weekly intervals, 29% to 40% of recaptures occurred in the same trail interval or study subsite (i.e. bare areas or grassy areas within the overall study site) as the prior handling or sighting event. The average dispersal distance at Hanson Quarry was 91 feet, while at the Freeman property it was 123 feet (Arnold 2000). At Quail Hollow Quarry the average dispersal distance was 105 feet and the longest observed dispersal distance was 930 feet (Arnold 2002a). These studies were not designed to find adults that may have dispersed longer distances between different demes or populations of the ZBWG. Arnold (2002c) observed two ZBWG adults at the former Geyer Quarry, which does not currently support a resident population of the grasshopper.

Movements of a related species, *Trimerotropis saxatilis*, were studied by Gerber and Templeton (1996) in the Ozark Mountains of Missouri, where it inhabits lichen-covered rocks in glade habitats that are separated by dense stands of trees and shrubs. *T. saxatilis* moved freely within a particular glade, but dispersal between even adjacent glades was rarely observed, even when the distance between adjacent glades was less than the observed within-glade movements. The researchers speculate that the dense tree cover growing between glades limits dispersal of this grasshopper.

In the sandhills, dense tree cover may also limit dispersal of the ZBWG. Arnold (1999, 2000, 2002a, 2002b, and 2004) observed daily and seasonal shifts in the use of suitable habitats at the Hanson Quarry, Freeman mitigation site, and Quail Hollow Quarry based on daily and seasonal changes in the position of the sun and corresponding changes in the locations of sunlit bare ground at these study sites. Thus, between deme dispersal of the ZBWG may require sunlit openings or corridors in the surrounding forest or chaparral with sunlit barren or sparsely-vegetated loose sandy soils to facilitate movement of the grasshopper.

Threats

The ZBWG was recognized as an endangered species by the U.S. Fish & Wildlife Service (1997) in 1997 because of historical loss of habitat and several actual or potential future actions that could further reduce the amount of suitable habitat that supports the grasshopper.

Throughout most of its range, the primary threats to the grasshopper are loss of habitat via sand mining and urbanization, plus habitat degradation due to invasive plants and unnatural succession. Other land uses including agricultural conversion, recreation (hikers, horseback riders, mountain bikers and off-road vehicles) have resulted in loss or degradation of habitat. Because of the small sizes of existing habitat remnants known to support the ZBWG, herbicide or insecticide use, as well as insect collectors could potentially damage the ZBWG or its habitat (U.S. Fish & Wildlife Service 1997, 1998, and 2001).

Future loss of habitat from sand mining is unlikely unless a new quarry opens in the Zayante sand hills. Several former sand quarries have closed and the Olympia Quarry and Hanson Quarry are near closure. Remaining habitat that supports the ZBWG at the Hanson Quarry and Quail Hollow Quarry was protected as part of their respective Habitat Conservation Plans and associated incidental take permits (Hanson Aggregates Mid-Pacific Region 1999; Thomas Reid Associates 1997).

Like the endangered Santa Cruz Wallflower, the ZBWG occurs primarily in the open sand parkland plant community of the sandhills. Today, this habitat is limited in acreage and highly fragmented, resulting in overall small patches of habitat which supports small populations of the ZBWG. Natural disturbances such as fire and erosion, including sand blow outs and land slides retard succession and create sunlit openings with sparse herbaceous vegetation cover or bare sand that is favored by the ZBWG. Although several areas within the sandhills have been protected from further loss of habitat, the suppression of fire and other natural disturbances has allowed the cover of herbs, shrubs, and trees to increase, which degrade habitat quality for the ZBWG by reducing the amount of barren or sparsely-vegetated loose sands, and by shading the ground. Also, various exotic plants compete with native plants upon which the ZBWG depends upon for food and shelter, colonize patches of bare sand, and shade the ground. The distances between remaining populations of the ZBWG may be greater than adults normally disperse. Habitats between existing populations may not be suitable for ZBWG. As a result, dispersal and genetic exchange between remaining populations may be limited.

Management

Management activities at protected habitat locations need to focus not only on maintaining the currently known sites where ZBWG occurs, but also managing the vegetation to create new areas of habitat with sunlit, bare or sparsely-vegetated loose sands to benefit the ZBWG, creating suitable patch mosaics assemblages of early and later successional stages of the open sand parkland, and creating corridors that facilitate the dispersal of ZBWG between locations that harbor existing and future populations. Even within the remaining open sand parkland, populations of the ZBWG are very patchily distributed and are highly fragmented. Greater numbers of ZBWG adults are observed where barren, sunlit, loose sandy soils occur. Suppression of natural disturbance factors, such as fire, allow leaf litter to accumulate and successional changes to occur that usurp the bare, sandy soils and block the sunlight at ground level that is favored by the ZBWG. For similar reasons, exotic plants need to be eradicated where feasible and otherwise controlled to protect existing populations and to expand habitat for the grasshopper.

The relationship between the seasonality of natural fire events and the life history of the ZBWG needs to be investigated and further elucidated. Adults of ZBWG are active during the late summer and fall months when natural fires most frequently occur. Because of their apparent limited mobility, the ZBWG may be more vulnerable to short term losses and population declines due to direct or indirect effects of fire and smoke, even though in the long term the grasshopper should benefit from this management action to increase the area of suitable habitat.

Thus management activities at protected habitat locations will need to focus not only on maintaining the sites where ZBWG occurs, but also managing the vegetation to create new areas of habitat with sunlit, bare or sparsely-vegetated loose sands to benefit the ZBWG.

SECTION 5.6 MOUNT HERMON JUNE BEETLE

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Conservation Status

The Mount Hermon June beetle (MHJB; *Polyphylla barbata* Cazier 1938) is a federally-listed endangered species (U.S. Fish & Wildlife Service 1997). The California Endangered Species Act, which comprises Sections 2050-2068 of the state's Fish and Game Code (http://ceres.ca.gov/topic/env-law/cesa/stat/) excludes insects from consideration for endangered or threatened status. Thus no insects are currently recognized as endangered or threatened species at the state level. The International Union for the Conservation of Nature (1994) formerly recognized the MHJB as threatened.

In 1998 a recovery plan was published by the U.S. Fish & Wildlife Service (1998) that treated two endangered insects (Zayante Band Wing grasshopper and MHJB) and three endangered plants that occur in the Zayante sand hills of Santa Cruz County. Recovery plans describe actions required to adequately protect listed species like the MHJB, so their populations can be recovered and they no longer require protection pursuant to provisions of the Endangered Species Act of 1973, as amended. This recovery plan described three actions necessary to downlist or delist the ZBWG, namely:

a) protection of the 28 known (as of 1998) collection sites (consisting of 7 discrete areas) of sand parkland habitat via fee-title acquisition, conservation easement, or Habitat Conservation Plans
b) development and implementation of a management plan for the Quail Hollow Ranch County Park (County of Santa Cruz)
c) attain stable or increasing populations of MHJB

Critical habitat for the MHJB has not yet been proposed by the U.S. Fish & Wildlife Service. However, designated critical habitat for the endangered Zayante Band Wing grasshopper (U.S. Fish & Wildlife Service 2001) includes most of the known geographic range of the MHJB.

Species Description and Taxonomy

The Mount Hermon June beetle is a member of the family Scarabaeidae (Insecta: Coleoptera) and subfamily Melolonthinae (Figure A.25). The genus *Polyphylla* contains 31 species in North America (Young 1988; Arnett et. al 2002) that are commonly referred to as May or June beetles, since the adult flight season often includes one or both of these months. However, additional species in this genus also occur throughout much of Mexico and Central America (Young 1988). A few species of *Polyphylla* are considered economic pests of gardens, orchards, turf grass, and nursery plants (Arnett 2000).

Adult males of the MHJB measure about 0.75 inch in length, while females are slightly longer but exhibit a smaller antennal club than males. The adult male has a black head and dark brown elytra (leathery forewings) that are covered with brown setae (i.e., hairs). The specific epithet, *barbata*, means covered with setae or giving the appearance of a beard. The elytra also have stripes that are broken and irregular rather than continuous and well-defined as in related species of June beetles. Larvae are grub-shaped (scarabaeiform) and vary in color from cream to pale yellow for the body segments and darker brown for the head.

Females of about a dozen species of *Polyphylla* are unknown (Young 1988), perhaps because they don't fly. Until recently, the female of the MHJB was known from only a single specimen, but Arnold (personal observation) has subsequently seen numerous females during the past five years while performing presence-absence and other studies of the MHJB.

Cazier (1938) described the beetle from specimens collected at Mount Hermon, Santa Cruz County, California. Although the scientific name *Polyphylla barbata* has been used since its original description, the beetle has commonly been referred to as the Mount Hermon June beetle or the Barbate June beetle (U.S. Fish & Wildlife Service 1994, 1997, and 1998).

Distribution

Of the 31 North American species of *Polyphylla*, 20 have restricted ranges, with 15 being endemic to isolated sand deposits (Arnett *et al*. 2002; Young 1988). Widespread species of Polyphylla are not confined to particular soils types and have females that actively fly. In contrast, the narrowly-distributed species are often associated with specific soil types (usually sand formations) and often have flightless females. Not surprisingly, the MHJB is restricted to the Zayante sandy soils (USDA 1980) derived from Miocene sand deposits, known as the Santa Margarita formation (Marangio and Morgan 1987) and which are found in the Scotts Valley-Mount Hermon- Felton-Ben Lomond-Santa Cruz area of the Santa Cruz Mountains. Historically, MHJB localities were referred to as sand hills (Cazier 1938; Young 1988), but more recently this area has been called the Zayante Sand Hills (U.S. Fish & Wildlife Service 1998).

Although collection records and observations by entomologists initially suggested that the MHJB occurred only in Mt. Hermon, subsequent surveys have determined that the beetle is more widely distributed in the sand hills of Santa Cruz County. As detailed by Cazier (1938), the type series was collected at Mt. Hermon on June 25, 1937 (n = 11) and July 7, 1922 (n = 2). A series of 139 specimens was also collected at Mt. Hermon in 1938 (Cazier 1940). William Hazeltine grew up on Pine Ave. in Mt. Hermon during the late 1940's and early 1950's and became familiar with the species (Hazeltine 1993). Between June 14 and July 8, 1993 he collected the MHJB at 13 locations in the sandhills. In 1996, Hovore (1996) conducted surveys at the present day Quail Hollow Quarry.

Arnold (1999a and 1999b) reviewed museum specimens and other reported records for the beetle and determined that it had been observed at about 70 locations within the sandhills. Between 1990 and 2003 Arnold (unpublished) visited over 200 individual properties in the sandhills to assess habitat conditions or to perform presence-absence surveys for the MHJB and Zayante Band Wing grasshopper. As a result of these more recent field surveys, the MHJB is now known from approximately 150 locations in the sandhills (Arnold, personal observation; BUGGY Data Base 2003).

Interestingly, surveys of outlying deposits of Zayante sands, such as several locations in Boulder Creek, Bonny Doon, and on Weston Road in Scotts Valley have failed to find the MHJB (Arnold, unpublished). A few locations where the MHJB was not observed, such as Bonny Doon, are characterized by more indurate Zayante sand formations, which may not be favorable for adults and larvae of the MHJB that burrow into the sand. Other outlier sand deposits may be too far from the nearest MHJB locations (i.e., too far for a flightless female to disperse), they are separated by inhospitable habitat(s), or they lack the larval food plant(s).

Habitat

Several species of *Polyphylla* are associated with sand-based habitats, such as sand dunes, riverine sand deposits, deserts, and sand hills, and have flightless females. The flightless condition of MHJB females may be an evolutionary adaptation to avoid being blown away from suitable habitat by the incessant winds that often characterize sand-based habitats.

The results of intensive surveys of the MHJB (Arnold, unpublished, 1999a, 1999b, 2000, 2001, 2003a, and 2003b) indicate that the preferred habitats of the MHJB are silverleaf manzanita chaparral with Ponderosa pine, Ponderosa pine forest, dense sand parkland, and open sand parkland (Section 3.4). Additionally, adults of MHJB have been found in mixed Deciduous-Evergreen Forest when this plant community occurs adjacent to one or more of the aforementioned plant communities and when Ponderosa pine is present (Arnold, unpublished). Adult MHJBs have also been found in disturbed sandy areas where remnants of these habitats still occur (Arnold, unpublished).

Young (1988) presented historical records that three other species of *Polyphylla* co-occur with the MHJB in the sandhills, namely: *P. crinita*, *P. nigra*, and *P. decemlineata*. More recently, Arnold's various distribution and population surveys have confirmed the presence of these three taxa in sandhills. Although the four species of *Polyphylla* co-occur in the same geographic area, adult males appear to be active at different times of the night, a behavioral isolating mechanism to minimize the chance of accidental interbreeding. Also, their initial and peak flight periods differ between the four species (Arnold, unpublished).

Natural History

Arnold (1999a, 1999b, 2000, 2001, 2003a, and 2003b) has been monitoring the MHJB populations at the Quail Hollow Quarry, Hanson Quarry, and Freeman mitigation site since 1999 as part of the habitat preservation and mitigation activities that the respective quarry companies implemented for their habitat conservation plans and were approved under their incidental take permits for the beetle and Zayante Band Wing grasshopper. At the start of this monitoring program, very little information existed about the MHJB's biology or population dynamics, so suitable monitoring techniques could not be prescribed to provide accurate information needed to evaluate the status of these insects and their responses to habitat management actions. Thus, the "monitoring" efforts became a research program to learn more about the MHJB's natural history, its habitat associations, to accurately describe its population biology, and to identify appropriate population monitoring methods that provide reliable estimates of population numbers and other parameters of interest for use in the long term monitoring program. Information gained from these respective quarry studies have been pooled to assemble a better information base, however other aspects of the MHJB's life history and biology remain to be elucidated.

Seasonality

The Mount Hermon June beetle is univoltine (i.e. has only one generation per year). As its common name suggests, adult emergence and seasonal activity often begins in June. Historical collection records (Young 1988; BUGGY Data Base 2003) indicate that adult males have been observed in the months of June, July, August, and September. Season-long trapping studies by Arnold (2003a and 2003b) indicate that the MHJB flight season but can begin as early as mid-May, and continues through about mid-August and that the total season extends about 80 to 92 days in length (Arnold 2003a and 2003b). Considerable year-to-year variation exists in the start, peak, and end of the flight season, with differences of 2 to 3 weeks observed just within the past five year period (Arnold 1999a, 1999b, 2000, 2001, 2003a, and 2003b).

Behavior

Adults are nocturnal. More specifically, they are crepuscular, being active between about 7:00 pm and 10:00 pm, with peak activity usually between 8:45 and 9:30 pm. At dusk, adult males emerge from the sandy soils. As they fly up through herbaceous vegetation and shrubs, they make a characteristic crackling-type noise. Once they reach the tops of the vegetation, they actively fly low to the ground in search of females, which emerge from the soil but remain on the surface of the ground. Flight activity can be affected by temperature and wind. Flight activity generally was very minimal below 57^{o} F, or when wind speed exceeded 9 mph (Arnold 1999a, 1999b, 2000, 2001, 2003a, and 2003b). Activity of some nocturnal insects may be affected by full moon conditions, but no diminished activity of MHJB has been observed under such conditions.

Based on behavior observed in the field (Arnold, unpublished), the female presumably emits an as yet unidentified pheromone that enables the males to find her. Swarms of numerous males, with their lamellate antennal branches extended apart (where the pheromone receptors are presumably located) have frequently been observed flying and landing around mating pairs on the ground (Arnold, unpublished). Males have also been observed on the soil where females subsequently emerged, which suggests that the female may emit her pheromone before emerging from the soil. To demonstrate that a pheromone is used for mate location, Arnold (unpublished) moved calling females and observed males following and swarming around the female, even while in transit from one subsite to another subsite within a particular study site. Even after placing the female in a new location on the ground, males landed on his hand that was used to transport the calling female. Copulation is fairly brief, approximately 5 minutes in duration, and occurs on the sandy soil. Upon the conclusion of copulation, the female burrowed into the sand (Arnold, unpublished).

Life History

Specific life history information for the MHJB is unknown, but can be inferred from related species (Lilly and Shorthouse 1971; Van Steenwyk and Rough 1989; Kard and Hain 1990; Buckhorn and Orr 1961; Downes and Andison 1941). Presumably the entire life cycle (egg, larva, pupa, and adult) takes two to three years to complete. The majority of the life cycle is spent as a subterranean larval stage that feeds on plant roots.

Larval Food Plants

Larval food plants of other species in the genus Polyphylla include a number of conifers, deciduous trees, shrubs, herbs, and grasses (Young 1988; Furniss and Carolin 1977; Van Steenwyk and Rough 1989; Downes and Andison 1941). Rachel O'Malley and her students at San Jose State University are investigating potential food plants of the MHJB. O'Malley and Taylor (2003) observed larvae, presumed to be MHJB based on the presence of a decapitated female, in the ground beneath ferns and a Ponderosa pine at the Quail Hollow Quarry. Arnold (unpublished) has monitored various excavation and vegetation removal projects in the sand hills and observed larvae, presumed to be MHJB, in association with roots of Ponderosa pines.

Although the MHJB's larval food plant has not been confirmed by rearing, and it is unknown whether the larvae are monophagous or polyphagous, distributional studies by Arnold (unpublished) is at least one of the food plants utilized by MHJB larvae. Presence-absence surveys have been conducted at approximately 200 properties in the sandhills, and MHJB has been found only at sites where Ponderosa pine are present or within a few hundred feet. During these same surveys, MHJB has not been observed at locations where Ponderosa pine was absent. Arnold has observed numerous calling females of the MHJB, all within close proximity to Ponderosa pines. Males and females of MHJB have been observed at a few sites where all above-ground vegetation except ponderosa pine or coast live oak had been removed. Similarly, males and females of MHJB have been observed emerging from the soil at properties where ponderosa pine was the only remaining native plant, as well as in mixed deciduous-evergreen forest with widely scattered Ponderosa pines.

Population Biology

Hazeltine (1993) reported numbers of MHJB that were attracted to a portable black light from various locations that were briefly sampled. Because the amount of time spent at each location varied, the tallies are not directly comparable. Hovore (1996) provided the first estimates of MHJB abundance based on black light trap counts. A total of 177 males were captured at 20 trap locations within the Quail Hollow Quarry during a three-night survey in June 1996. In 1999, Arnold (1999a) tallied 190 males during a three-night survey at 13 trap locations at the Quail Hollow Quarry.

Population studies of the MHJB have been performed as part of the annual monitoring activities that occur at the Hanson Quarry, Freeman property, and Quail Hollow Quarry (Arnold 1999a, 1999b, 2000, 2001, 2003a, and 2003b) as part of the habitat conservation plans (Hanson Aggregates Mid-Pacific Region 1999; Thomas Reid Associates 1997) that were approved for each quarry by the U.S. Fish & Wildlife Service. A variety of techniques have been used to estimate various population parameters, such as population numbers, adult lifespan, and dispersal. Also, the MHJB's seasonal population curve has been described to derive an estimate of total seasonal population numbers. As described earlier, additional information on behavior and habitat associations has also accrued during these studies.

During the capture-recapture studies, adult males of the MHJB were uniquely marked, to enable individual recognition, upon their initial capture with a dot code that was applied either with fingernail paint or an acrylic paint pen. On subsequent survey dates, previously marked males were recaptured, while new males were captured and marked. Additional details on the survey methods and analytical procedures are described in Arnold's (1999a, 1999b, 2000, 2001) monitoring reports.

Lifespan data from two brief capture-recapture studies, extending 5 and 9 nights, suggest that most adult males live no longer than one week (Arnold 2000 and 2001). A handful of individuals were observed to live as long as 5 to 8 days between capture and recapture events, but the average estimated lifespan for most individuals was no more than 1 or 2 days. These values may slightly underestimate actual lifespan of the MHJB since the capture-recapture studies were not of a longer duration; nonetheless, the capture histories of recaptured individuals indicate that the lifespan of adult males is brief. At this time there are no estimates of lifespan for adult females of the MHJB.

Dispersal data from the same capture-recapture studies indicate that most adult males are quite sedentary, with home ranges of no more than a few acres. At Quail Hollow Quarry, MHJB males moved between 121 to 923 feet, with an average dispersal distance of 305 feet (Arnold 2000). Only six of 72 individuals that were recaptured moved over 400 feet. Similar trends in dispersal frequency and distances were observed at the Hanson Quarry and Freeman property (Arnold 2001). Given the brief crepuscular flight period and short lifespan of males, the limited dispersal of males is not surprising. Dispersal of females may be limited to burrowing through the sands since they do not appear to fly.

In 2000, nightly population estimates for MHJB males ranged from 136 to 801 individuals depending on the capture-recapture model used to make the population estimates. These estimates were generated for a 5-night capture-recapture study at the Quail Hollow Quarry (Arnold 2000) and should be doubled to include females, assuming that there is a 1:1 sex ratio. A total of 294 males were captured and marked during the 5-night survey and 72 (24.5%) were recaptured at least once.

During 2001, concurrent capture-recapture studies were performed during a 9-night period at both the Hanson Quarry and Freeman mitigation site. Nightly population estimates at Hanson ranged from 104 to 6,604 males, and 96 to 5,005 males depending upon the statistical model used for analysis (Arnold 2001). These estimates should be doubled to include females. A total of 1,206 males were captured and marked during the 9-night survey at Hanson Quarry and 327 (27.1%) were recaptured at least once. A total of 935 males were captured and marked during the same 9-night period at the Freeman property, and 251 (26.8%) were recaptured at least once.

During 2002 and 2003, population estimates of the MHJB were generated for the Quail Hollow Quarry (Arnold 2003a) plus the Hanson Quarry and Freeman property (Arnold 2003b) by using trap counts at fixed locations throughout the full adult activity period. The traps were operated at approximately weekly intervals to describe the seasonal population curve of the MHJB and to derive a new statistical model for estimating seasonal population numbers. Information from the earlier capture-recapture studies was also utilized. Using this model, estimates of seasonal population numbers, death rate, and emergence rates were calculated (Arnold 2003a and 2003b). The catchment area of each light trap was estimated, with considerable variation in size due to differences in vegetation and topography that limited the spread of light. This survey methodology is less time consuming than capture-recapture methods, and less invasive since MHJB do not have to be handled and marked. Using this new model, the seasonal population estimate for the MHJB at Quail Hollow Quarry ranged from 311,285 to 337,317 males (Arnold 2003a).

The new model was refined in 2003 by additional studies at the Hanson Quarry and Freeman property to estimate the detectability function of a solitary light trap (Arnold 2003b). Males were released at distances ranging from 10 to 160 feet to compile recapture frequencies for each release distance and to estimate the overall detectability function of a light trap. Using this refined model, the 2003 population estimates ranged from 1,241,251 to 1,337,651 at Hanson and from 1,029,266 to 1,109,203 at Freeman. At both study sites the MHJB habitat extended onto neighboring properties and the population estimates include these off-site lands. Also, these population estimates are just for males, so assuming a 1:1 sex ration, they need to be doubled to include females.

Threats

The MHJB was recognized as an endangered species by the U.S. Fish & Wildlife Service (1997) in 1997 because of historical loss of habitat and several actual or potential future actions that could further reduce the amount of suitable habitat that supports the beetle. Throughout most of its range, the primary threats to the beetle are loss of habitat via sand mining and urbanization, plus habitat degradation due to invasive plants and unnatural succession. In a few instances, other land uses including agricultural conversion, recreation (hiking, equestrians, mountain biking, and off-road vehicle riding) have resulted in loss or degradation of habitat. Herbicide or insecticide use, as well as insect collectors have also been mentioned as potentially harmful to the MHJB or its habitat (U.S. Fish & Wildlife Service 1994, 1997, and 1998).

Compared to the endangered Zayante Band Wing grasshopper, the MHJB occurs more widely throughout much of the Zayante sandhills because it occurs in association with more plant communities than the ZBWG. Indeed, it has even managed to persist in several residential areas and other degraded portions of the sandhills. However, given the extensive destruction and degradation of sandhill habitats, it is likely that population numbers of the MHJB have declined. Unfortunately, there are no early population estimates, making it impossible to make meaningful comparisons to current population estimates.

Residential neighborhoods in Scotts Valley, Felton, Mt. Hermon, and Ben Lomond collectively constitute a significant portion of the MHJB's geographic range in the Zayante sandhills. These neighborhoods support populations of the MHJB and provide habitat corridors to facilitate dispersal and genetic exchange between MHJB populations that occur in surrounding protected habitat. Although residential areas cannot be restored to pristine habitat, the quality of these degraded habitats for the MHJB can still be improved to benefit the beetle. Residential neighborhoods that are currently occupied by the MHJB are generally characterized by mature native trees that were retained as part of the landscaping when new homes were built on these properties. Installed landscaping at many residential lots has emphasized introduced, ornamental plants rather than plants native to the sandhills. As a result, young seedlings and saplings of ponderosa pine, as well as other native trees and shrubs occur infrequently in these managed environments. As mature trees and shrubs eventually die, population numbers of the MHJB will presumably decline.

Management

In landscaping developed sandhills habitat, effort should be made to both protect and actively plant native trees, shrubs, and herbs indigenous to the sandhill plant communities. In protected habitat areas, fire should be used to convert areas of mixed evergreen forest to sandhill habitats dominated by ponderosa pine, silverleaf manzanita and their associated plant assemblages. This will benefit MHJB by expanding and creating new areas of habitat and reducing gaps between existing populations of the MHJB. Similarly, exotic plants should be eradicated where feasible and otherwise controlled to avoid competition with larval foodplant(s) and to minimize degradation of habitat quality.

5.7 SANTA CRUZ KANGAROO RAT

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Conservation Status

The Santa Cruz kangaroo rat (*D. v. venustus*), a five-toed, narrow-faced rodent in the family Heteromyidae, is known primarily from the Santa Cruz Mountains in the central coast of California (Best 1992; Figure A.22). *D. v. venustus* is not currently legally protected although it is identified by CDFG as a "Species of Special Concern" in an unpublished draft update to this list. This designation applies to animals that are not listed under either the State (CESA) or Federal Endangered Species Act (FESA), but which nonetheless 1) are declining at a rate that could result in listing, or 2) historically occurred at low numbers and known threats to their persistence currently exist. Recent studies suggest that this species meets the criteria for protection pursuant to both CESA and FESA (Bean 2003).

Distribution

D. v. venustus at one time occurred as far north as Belmont in San Mateo County (Grinnell 1922) (Figure 5.1). Grinnell (1922) collected *D. v. venustus* specimens for his comprehensive taxonomic analysis from the nearby Jasper Ridge Biological Preserve, owned and operated by Stanford University. Additionally, Grinnell references specimens collected in Saratoga, south of the Preserve. Due to extensive land use change, fragmentation, and fire suppression throughout the Bay Area it is unlikely that *D. v. venustus* survives anywhere in this portion of the historic range.

The southern-most collections of this subspecies are from Fremont Peak in San Benito County. Although land use change in this area is not as extensive as it is in the Bay Area, Price et al. (1995) demonstrate that fire suppression has negative impacts on Stephen's kangaroo rat (*D. stephensi*), and it is likely that fire suppression has had a negative effect on persistence of this *D. venustus* in this portion of the range. In addition, there is some question as to the identification of these specimens. These records are in close proximity to two records of *D. v. elephantinus* (a subspecies of *D. venustus* that could be easily mistaken for *D. v. venustus*). One of the *D. v. elephantinus* records is within 630 m of a *D. v. venustus* record. Additional work will be necessary to determine if any of these specimens have been mislabeled. If they are confirmed to be *D. v. elephantinus*, the historic range map for *D. v. venustus* would be more limited than previously thought.

D. v. venustus specimens housed at the Museum of Vertebrate Zoology at the University of California at Berkeley (MVZ) were collected mostly during the 1930's and 1940's. The majority of these specimens were collected from the Zayante sand hills ecosystem in Santa Cruz County. Many of the locations where the subspecies was historically documented have been irrevocably altered and no longer provide suitable habitat (Table 1).

Santa Cruz kangaroo rat has been documented at five different sites in Santa Cruz County since the 1950's. However, based on recent live- trapping efforts, *D. v. venustus* may only persist at only one site, referred to as the Save-the-Redwoods League (SRL) parcel (Bean 2003). This site is located in the sand hills ecosystem near Felton in Santa Cruz County. The SRL Parcel represents one of the largest undisturbed parcels of sand-related habitats (124 ha) remaining in Santa Cruz County. The site is bordered on the south by Henry Cowell Redwoods State Park, on the east by Graham Hill Road, on the west by the Southern Pacific Railroad Tracks and on the north by Roaring Camp Railroad. The site supports a variety of habitats including northern maritime chaparral, silver-leaf manzanita chaparral with a scattered ponderosa pine/ knobcone pine canopy, sand parkland, mixed evergreen forest, and redwood forest. The silverleaf manzanita habitat patch covers approximately 54 ha.

Biology

Kangaroo rats are more closely related to the gophers (geomyids) than they are to rats (murids). Members of this rodent family have fur lined cheek pouches that they use to transport the seeds they collect to areas where they cache them. All members of the genus *Dipodomys* have hind legs that are well adapted to jumping locomotion.

Additionally, members of the genus *Dipodomy*s are nocturnal, granivorous and adapted to living in relatively arid environments (Ingles 1965, Schmidly et al. 1993, Reichman and Price 1993). They are very different from murid rodents in that they are relatively long lived (4 to 5 years) and they have small litters of 2 to 3 pups at most. The number of litters produced per year is low. Some females may occasionally produce 3 litters in a season however; more commonly they produce only 1 or 2 (Brown and Harvey 1993). Seasonality of reproductive activity varies, the number and timing of litters is flexible and depends on the suitability of environmental conditions. In extremely dry years there may be no reproduction at all (Brown and Harvey 1993). Generally, the reproductive period begins after the rainy season ends. They have a long gestation period of approximately 30 days and they provide care to their young for up to 30 days. These strategies emphasize the survival of adults through stressful droughts.

Burrows are typified by a main runway, and a few blind side branches, including a nest and food caches. In the one study in which *D. v. venustus* burrow structure was investigated, one burrow was documented as having a length of 2.4 m with a 1.4 m side branch, five caches and a nest (Hawbecker 1940). Burrow openings are often located under shrubs, presumably to take advantage of the structural support provided by the shrub's root system. However, burrows have been observed in open, unvegetated areas as well (Bean 2003). The main burrow openings are usually plugged during the day. Burrows are generally located 5-50 cm below the ground surface (Hawbecker 1940) making them quite vulnerable to destruction from recreational uses such as hiking, mountain biking, and horseback riding..

Based on this same study, diet of *D. v. venustus* is made up almost entirely of seeds of annuals (Hawbecker 1940). Kangaroo rats collect seeds in their cheek pouches during the summer and fall as seeds ripen. The seeds are stored in surface caches that are generally 10 cm deep and 5 cm in diameter (Hawbecker 1940). Typical seed observed in caches at a historic *D. v. venustus* site (near agricultural property) in Corralitos included, *Heterotheca grandiflora*, *Bromus rigidus*, *Medicago hispida*, *Anagallis arvensis* and *Rumex acetosella* (Hawbecker 1940).

These are all weedy annual species and do not likely provide forage at the SRL site. Some green material is also used for food based on observations made by Hawbecker (1940).

In the desert, kangaroo rats are considered "keystone species." Keystone species are species whose physical activities and interspecific interactions have disproportionately large influences on the structure and composition of the communities in which they live. In a long-term study conducted in the Chihuahuan Desert, Brown and Heske (1990) found that their removal caused a conversion of desert shrub habitat to grassland, supporting the idea that they are indeed function as keystone species in that ecosystem. Goldingay et al (1997) have proposed that members of this genus are indicators of sensitive habitat. This is certainly the case in the sandhills ecosystem.

Taxonomy

There are three subspecies of *Dipodomys venustus*: *D. v. venustus* (Santa Cruz kangaroo rat), *D. v. sanctiluciae* (Santa Lucia kangaroo rat), and *D. v. elephantinus* (Big-eared kangaroo rat) (Williams et al. 1993, Patton 1993). *D. v. sanctiluciae* is known primarily from the Santa Lucia Mountains, the coast range that defines the Big Sur coast. This subspecies has been collected from as far north as the Hasting Natural History Reservation in Carmel Valley, Monterey County, and as far south as the vicinity of Santa Margarita in San Luis Obispo County. *D. v. sanctiluciae* is not provided any type of legal or administrative protection.

Dipodomys v. elephantinus is distributed on the western flank of the Gabilan Range of San Benito and eastern Monterey counties, based on known localities from museum collections. There has been no recent survey of its range, however, and it is likely that this taxon is largely limited to the Pinnacles National Monument region. Grinnell (1922) regarded *D. v. elephantinus* as a species distinct from *D. venustus*. However, the most recent compilation of the taxonomy of heteromyid rodents (Patton in press) places *D.* v. *elephantinus* as a subspecies of *D. venustus*. Best (1986) regarded *D. v. elephantinus* as rare and CDFG currently lists it as a State "Species of Special Concern," both views based on its small geographic range.

Demography

To effectively evaluate the risk of extirpation of the only known population of the Santa Cruz kangaroo rat, Bean (2003) estimated demographic parameters, including growth rate, sex ratio, fecundity, survival rate, annual population growth rate (λ), population size, density, and mean distances moved. In order to calculate these estimates live-trapping was conducted from April to September 2001 and May to September 2002 and mark-recapture techniques were used to analyze the data. For a complete summary of these data see Bean (2003)

Sex ratio

Of the 73 kangaroo rats trapped at the SRL site between 2001 and 2002, 34 were adult males and 20 were adult females, making the overall adult population sex ratio 1.7 males to every one female (1.7:1). The sex ratio of the juveniles captured (12 males to 7 females) was also 1.7:1. The male bias in the sex ratio is not unexpected. Price and Kelly (1994) found that live trapping *D. stephensi* generally results in a male bias. This bias could be due to the fact that the males are likely to have larger home ranges than females during the breeding season (Price and Kelly 1994). This means that instead of reflecting the true sex ratio, it might be possible that more males entered the traps than females due to the fact that the males range more widely than females during the breeding season. However, genetic drift is minimized when the sex ratio is 1:1 (Caughley and Gunn 1996). If the observed sex ratio accurately reflects that of the population, this skew towards males may reduce effective population size.

Survival rates

Survival rates were obtained by using the computer program MARK (White and Burnham 1999). The most parsimonious model indicated that survival varied as a function of both age and gender. Female adult survival rate was the highest (0.953) followed by male adult survival rate (0.945). As can be expected, juvenile survival was much lower with 0.749 estimated for males and 0.694 estimated for females.

Population Growth Rate

Bean's (2003) estimates of *D. v. venustus* demographic rates led to a high growth rate estimate (λ=1.29). However, kangaroo rats can be subject to dramatic population fluctuations and thus wide swings in population growth rates (Goldingay et al. 1997). High population growth rates can be commensurate with recovery from a decline, and environmental and demographic variability might result in very different growth rate estimates over time. In fact, Goldingay et al. (1997) suggests that conservation of the *Dipodomys* genus be elevated in priority for several reasons including the fact that their populations exhibit extremely variable demographics.

Data on precipitation in Santa Cruz in the years 2000 and 2001 show that annual rainfall was less than average (76 % of normal in 2000 and 90 % of normal in 2001). Since rainfall can be expected to be a major environmental factor affecting population growth rates of kangaroo rats (Price and Kelly 1994), this population may be recovering from a low rainfall/low population growth year.

In addition, some of the model assumptions were undoubtedly violated by the SRL data set. For instance, due to the fact that the data were collected over a two-year period, the population may have experienced immigration and emigration, thereby violating the assumption of a closed population. However, the limited extent of available habitat in concert with strong site fidelity and limited female movement suggests that this violation would only marginally influence overall population growth within the area trapped. Whether or not the model violated other assumptions, such as lack of density-dependence, is harder to judge.

It is impossible to know with certainty why this population experienced such a significant growth rate between 2001 and 2002, and whether it would continue to do so into the future in the face of a changing environment. Limited gene diversity of this population suggests that it has experienced extreme fluctuations in the past. Assumptions about the relative viability of this small population that may experience dramatic fluctuations would be highly inaccurate based on this model and therefore should not be attempted.

Density estimates

To obtain density estimates, the total area sampled on each of two permanent trap-lines placed at the SRL site, was estimated (1.08 ha). Area was calculated by determining the size of the linear trapping grid (10 m by 240 m and a 15 m buffer was added to account for average distances moved). Density estimates within the trap line grids ranged from 12 ind/ha to 20 ind/ha with a combined mean density of 12 ind/ha on Line 1 and 16 ind/ha on Line 2.

Based on field observations, the silverleaf manzanita chaparral habitat at the SRL site is heterogeneous. Therefore, the density of individuals is expected to vary within the mosaic of intermingled high and low quality habitat and extrapolation of these densities to larger areas would not be justified. Specifically, the trap lines were located in areas where the highest density of burrows was observed. These density estimates are likely higher than would be observed elsewhere on the site.

Distances moved

Male Santa Cruz kangaroo rats move a greater distances on average than females, mirroring observations by Price et al. (1994) for Stephen's kangaroo rat. Price and Kelly (1994) found that the majority of *D. stephensi* individuals maintained an average home range corresponding to a circle with a radius of 20 m. Although data obtained at SRL was not sufficient to allow for home range size estimates, average distance moved between traps of *D. v. venustus* suggests a similar pattern to that observed by Price et al. (1994). Most individuals were recaptured within 10 m of their first point of capture. The longest distance movement within a trap-line by a male Santa Cruz kangaroo rat was 100 m, whereas the furthest distance moved by a female was 50 m. However, one juvenile female moved from trap-line 1 to line 2: a distance of ca. 300 m.

Habitat

The Santa Cruz kangaroo rat generally occurs in association with a unique assemblage of northern maritime chaparral plant species that are distributed on inland marine sand deposits (Roest 1988). This plant community, referred to as "silverleaf manzanita mixed chaparral" (Marangio and Morgan 1987), is one of two plant communities endemic to Santa Cruz County that comprise the Zayante sand hills ecosystem (Federal Register 1997). These communities – silverleaf manzanita mixed chaparral and maritime coast range ponderosa pine– are considered local indicators of the Zayante soil series (Marangio and Morgan 1987). The Zayante soil series is typified by soft, well-drained sand that provides an ideal substrate for digging burrows, a critical habitat component for *D. v. venustus* (Hawbecker 1940, Rudd 1948).

Typical woody plant species in areas where *D. v. venustus* has been documented include, silverleaf and brittleleaf manzanita (*Arctostaphylos silvicola* and *A. tomentosa*), chamise (*Adenostoma fasciculatum*), coyote bush (*Baccharis pilularis*), ponderosa pine (*Pinus* *ponderosa*), knobcone pine (*Pinus attenuata*), wild lilac (*Ceonothus cuneatus*), poison oak (*Toxicodendron diversiloba*), monkey flower (*Mimulus aurantiacus*), and yerba santa (*Eriodictyon californicum*). Common animals include coyote (*Canis latrans*), Merriam's chipmunk (*Tamias merriami*), Botta's pocket gopher (*Thomomys bottae*), pinyon mouse (*Peromyscus truei*), western scrub jay (*Aphelocoma californica*), California thrasher (*Toxostema redivivum*), northern flicker (*Colaptes auratus*), brown towhee (*Pipilo fuscus*), dark-eyed junco (*Junco hyemalis*), and wrentit (*Chamaea fasciata*).

Threats and Reasons for Decline

Habitat loss and habitat fragmentation have been identified as leading causes of the loss of biodiversity and species endangerment (Primack 1993). Reflecting this trend, the range of *D. v. venustus* has been severely reduced by land use change, fragmentation, and likely by fire suppression. This species has not persisted at 4 of the 5 sites where it had been documented in the past 5 decades (Bean 2003).

Four sites were sampled in a distribution study conducted by Bean (2003). These sites included the SRL parcel on Graham Hill Rd; the Old Olympia Quarry owned by the San Lorenzo Water District located on Zayante Road; Wilder Ranch State Park adjacent to Smith Grade Road in Bonny Doon; and the Bonny Doon Ecoreserve on Martin Road. These sites were selected because the subspecies has been documented on them more recently than anywhere else in the County. In addition, three of the sites are owned by public agencies and the SRL property is in the process of being transferred to a public agency, facilitating access. Each of these sites is separated from others by relatively large stands of mixed evergreen forest.

In addition to the 4 sites identified above, D. *v. venustus* had been documented on a parcel owned by the Kaiser Quarry, adjacent to Lockewood Lane (Biosearch 1996, Roest 1988). However, habitat at this site has since been destroyed by quarry expansion activities and therefore, was not included in the study.

At each site, small mammals were captured using Sherman live traps (model XLK, H. B. Sherman Traps, Inc.) between May and September 2001; some additional trapping occurred on several of the sites (for additional details see Bean 2003). No kangaroo rats were captured at the Old Olympia Quarry, Wilder Ranch, and Bonny Doon Ecological Reserve. Of the most recently documented locations of *D. v. venustus* in Santa Cruz County, the SRL site supports the only population known today.

Urbanization has accounted for much of the loss of the historic range of this subspecies. The entire San Francisco Bay Area portion of the historic range for *D. v. venustus* can be considered irrevocably altered. The historical locations within areas underlain with Zayante soils in Santa Cruz County have also been impacted by urbanization, fragmentation, and edge effects such as predation by feral and domestic cats. A large portion of the once intact sandhills ecosystem has been directly destroyed by sand mining operations.

One of the sites on which *D. v. venustus* was documented in the 1980's is the old Olympia quarry. The fact that the subspecies has not persisted there is not surprising, given the destruction of the silverleaf chaparral community by the historic mine at that site and the adjacent active mine. The quarry was closed in 1962 after clearing and mining ca. 25 ha of habitat. It is likely that the *D. v. venustus* population documented in 1984 (Roest 1988) on the old Olympia quarry site was dependent on an extensive patch of intact silverleaf manzanita chaparral on the adjacent parcel that was cleared by neighboring mining operations in 1986.

Less obvious, is why this subspecies may be extirpated from the Wilder Ranch site, where it had been observed as recently as 1990 (Axtell 1990). There have been no major changes in land use at this site other than fire suppression. If a higher burn frequency allowed the subspecies to persist on this site, then the loss of the subspecies on this site may indicate niche requirements that only occur under a regular fire regime (Price et al. 1995).

In support of this explanation, Price and Waser (1984) found that *D. agilis* was consistently more abundant in burned than in unburned sites. Price et al. (1995) reported that population growth of *D. agilis* on burned sites was twice as rapid as on control sites. In addition, population size of *D. agilis* declined steadily at unburned sites. Their results suggest that in coastal sage scrub communities *D. agilis* is actually maintained by periodic fires that create ephemeral patches of open habitat (Price and Waser 1984). The long-term benefit of fire to kangaroo rats is likely to occur through an increase in bare ground with a minimal effect on forbs (Price et al. 1995). As a member of the agilis-group (Grinnell 1922), it is possible that *D. v. venustus* has similar habitat requirements.

In addition, it is likely that *D. v. venustus* is vulnerable to extirpation once a patch of suitable habitat is reduced below a certain threshold area. The causes of this type of threat could be direct, as in the land clearing that occurred adjacent to the old Olympia Quarry, or they could be indirect such as the loss of suitable habitat through fire suppression. Price and Endo (1989) estimated that a minimum reserve size of 100 ha would be necessary for Stephen's kangaroo rat to persist. However, more research would be necessary to estimate the threshold for a minimum patch size for the Santa Cruz kangaroo rat.

In a long-term study conducted at the Hastings Natural History Reservation in Carmel Valley, Heske et al. (1997) found that *D. v. sanctiluciae* presence was strongly associated with the interior of large patches of chaparral. Based on this, they suggest this taxon is more sensitive to area and isolation effects caused by fragmentation than are other small mammals trapped in this habitat type.

The apparent extirpation of *D. v. venustus* from the Wilder Ranch site highlights the potential significance to the fate of this subspecies of demographic stochasticity—the uncertainty resulting from the effects of random events on the survival and reproduction of an individual. The dynamics of small populations can be governed by this type of uncertainty. For instance, random variation in the number of individuals born male or female, or in the number that happen to die or reproduce in a given year can hold great influence over the fate of a population once it has been reduced to a limited number of individuals (Begon et al 1996).

In addition, habitat fragmentation and the isolation of suitable habitat poses a problem. Based on the natural patchiness of suitable habitat and historic observations, it is likely that at one time, *D. v. venustus* populations functioned as a metapopulation, with patches of occupied habitat "interconnected" by some level of long-distance dispersal sufficient for "re-inoculation" in the event of local extirpation. The combination of patch size reduction and limitations to dispersal connections that this taxon has suffered, increase the likelihood of extirpation by demographic stochasticity and eliminates the possibility of recolonization. Therefore, it is critical that the last known population of *D. v. venustus* be managed carefully to prevent chance extirpation.

The size of the historic population at the SRL site is not known. It is possible that the population observed today may be on a downward trajectory as was likely the case on Wilder Ranch in 1990. Threats to the species at the SRL site include recreational uses, edge effects from urbanization, and fire suppression. Even though the site has not burned since sometime before 1943 (based on a review of historic aerial photos) there are portions of the site where the silverleaf manzanita chaparral habitat is open and high densities of burrows were observed. This is a qualitative observation and additional research will be necessary to determine specific microhabitat affinities of this subspecies. This type of information is critical to developing future recovery goals and management plans for *D. v. venustus.*

In addition to the threats listed above, the single, extant population of *D. v. venustus* has less genetic diversity (as measured by mtDNA haplotypes) than do single population samples of either *D. v. santaluciae* or *D. v. elephantinus* (Bean 2003). This difference is more marked given the substantially larger sample size of *D. v. venustus* (22) relative to those of the others (5 and 8, respectively). The low haplotype diversity observed in the *D. v. venustus* population sampled may indicate small population size, population instability, and/or a limited degree of gene flow between adjacent populations (Avise 2000). Lowered genetic diversity can limit the ability of a population to respond to environmental change, be it global climate change or new pathogens. These data further support the finding that *D. v. venustus* is at risk of endangerment.

Future Research Topics

Additional research examining the following topics is needed. A morphometric analysis is recommended to determine whether conspecifics can be differentiated. Additional genetic analysis of specimens from areas of question would increase understanding of the historical distribution, while ongoing surveys in historic habitat should be used to determine whether there are other extant populations.

Further monitoring of population can facilitate development of demographic models to examine the dynamics and viability of the remaining population.

Research should be conducted to determine *D. v. venustus* microhabitat affinities within the sandhills to determine habitat specificity and the types of conditions that managers should create to enhance populations. Research should also investigate the impacts of burning or manually clearing woody vegetation on the distribution and abundance of this rare mammal.

Table 5.1. All known historic locations of *D. v. venustus*.

Year	County	Locality	Source	Habitat Still Available?
1904	San Mateo	Belmont	Grinnell	No
1941, 1907	Santa Clara	Stanford University, Jasper Ridge	MVZ, CAS	No
1922, 1892	Santa Clara	Mt Hamilton Rd. "toward summit"	MVZ, CAS	Specimen misidentified?
1930	Santa Cruz	Doyle (Rodeo) Gulch, 9 mi. NE Santa Cruz	MVZ	Unlikely due to fire suppression and fragmentation. Small patch of maritime chaparral occurs on private property.
1931, 1935, 1941, 1960	Santa Cruz	Head of Doyle (Rodeo) Gulch	MVZ, CAS	See above
1931	Santa Cruz	1 mi. NE Bonny Doon	MVZ	Trapped in 2001: not found
1937	Santa Cruz	1mi. NNE Bonny Doon	MVZ	See above
1938	Santa Clara	2 mi. SW Saratoga	MVZ	No
1942	Santa Cruz	Berglund Ranch, 2 mi. NW Corralitos	MVZ, Rudd	No
1940	San Benito	Fremont Peak Rd. 7 mi. S San Juan	MVZ	Specimen misidentified?
1940	Santa Cruz	Bean Creek Rd., 1.8 mi. E Mt. Hermon	MVZ, Rudd	No
1940, 1961, 1995	Santa Cruz	Zayante Rd., 2.1 mi, E Ben Lomond (@Quail Hollow)	MVZ/CAS, Rudd	Trapped in 1995 by Biosearch Wildlife Surveys; not found
1984	Santa Cruz	Old Olympia Quarry, Zayante Road	Roest	Trapped in 2001; not found
1940, 1941	Santa Cruz	Graham Hill Rd., 1.1 mi. From Felton Station	MVZ/CAS	Yes. This is the SRL parcel
1937, 1939	Santa Cruz	J. Enos Ranch, 1 mi. NW Corralitos	MVZ	No
1936	Santa Cruz	Bear Creek Rd., 2 mi. NE Boulder Creek	MVZ	No
1940	Santa Cruz	Mt Hermon Rd, 1.3 mi. E Mt Hermon	MVZ	No
1958	San Benito	4.25 mi S and 4.75 mi. E San Juan Batista (Fremont Peak)	MVZ	Specimen misidentified?
1933	San Mateo	Redwood City	CAS	No
1948	Santa Cruz	1 mi from the summit of Hecker Pass	Rudd	Specimen misidentified?
1947	Santa Cruz	1.7 mi. SSE Loam Prieta	SJSU	Specimen misidentified?
1984, 1996	Santa Cruz	Kaiser Quarry, Lockewood Lane	Roest, Laabs	No, mined.
1990	Santa Cruz	Grey Whale State Park	Axtell	Trapped in 2001; not found

MVZ=Museum of Vertebrate Zoology at Univ. of Calif. At Berkeley, CAS= Calif. Academy of Sciences, SJSU = San Jose State University

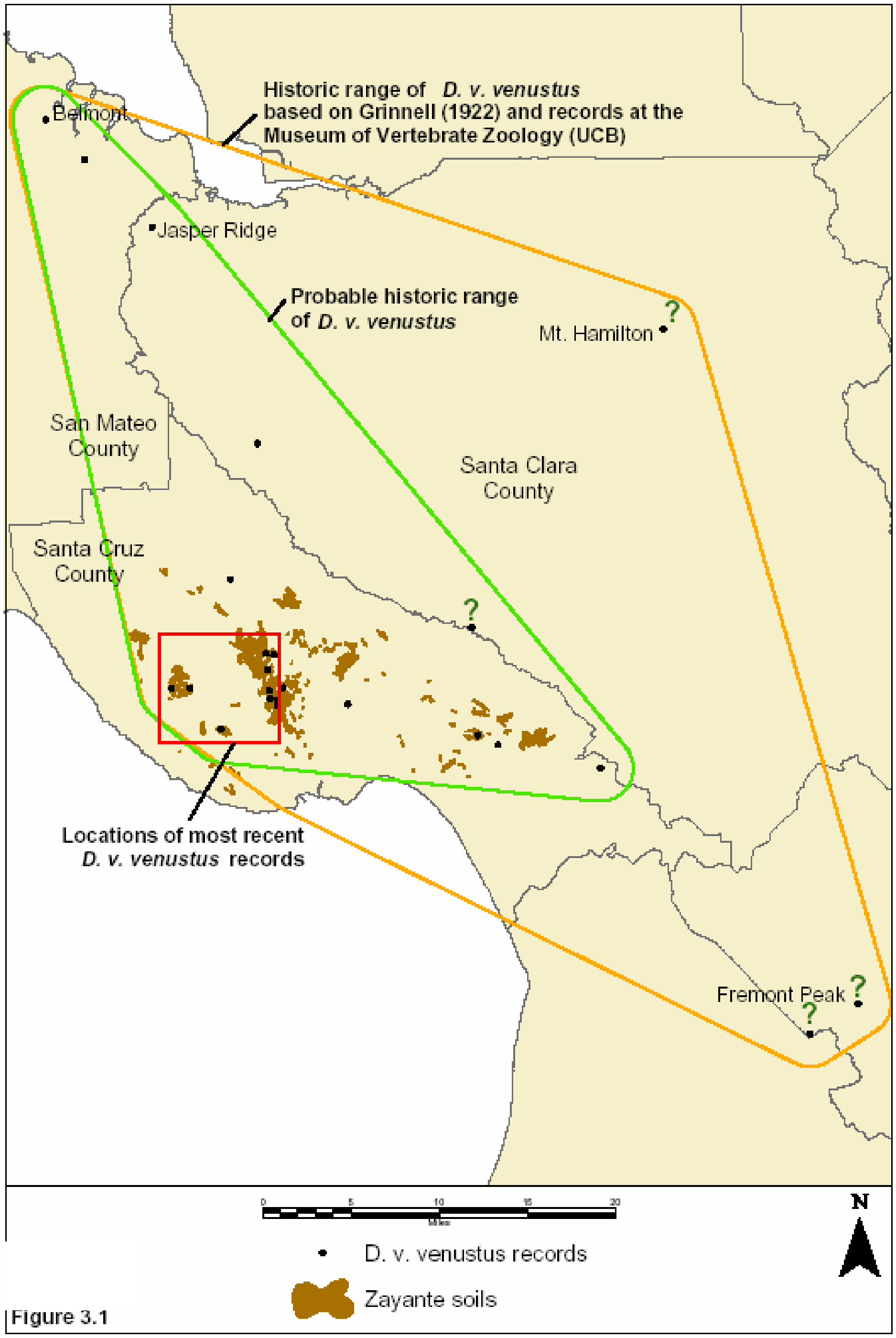
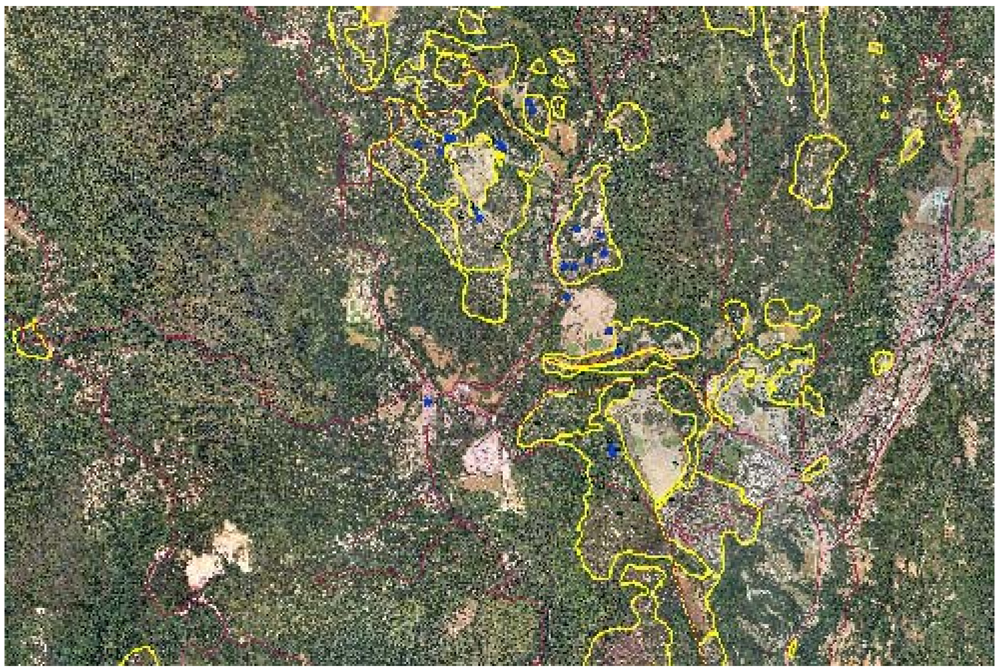


Figure 5.1: Historic and current known location of *D. v. venustus*.

CHAPTER 6

SANDHILLS CONSERVATION PLANNING PROJECT



Prepared by Jodi McGraw and Matt Freeman

INTRODUCTION

Efforts to preserve sandhill habitat will be essential to long-term conservation of sandhills species and communities. Sandhills habitat has been irreparably destroyed and demand for land used in quarrying and development continues. Due to the extraordinary rarity of the sandhills and the negative impacts of habitat loss on sensitive species and native biodiversity (Section 4.1), conservation efforts must endeavor to protect as much sandhills habitat as possible.

Acknowledging the crucial role of habitat preservation, the Sandhills Conservation and Management Plan project endeavored to identify priorities for land preservation through a conservation planning project. While the extreme rarity of sandhills habitat has rendered *all* remaining habitat a priority for conservation, land preservation funds are limited. This project uses available information about remaining habitat patches to prioritize these opportunities according to their conservation value.

Management of sandhills habitat will be crucial to maintaining native biodiversity in protected sandhills preserves. As with land acquisition, funds for management are often limited, necessitating prioritization of management concerns. This project outlines critical management needs within all sandhills sites, and provides specific recommendations for the highest-ranking sites identified in the analysis.

6.1 PROJECT GOALS

At the time this project was initiated, regional land conservancies, conservation organizations, government agencies, and concerned individuals lacked crucial information to identify habitat preservation opportunities for the sandhills. Questions posed included: *Where should preservation efforts be directed? Which sites would most benefit from limited management funds? How can we prioritize conservation, given the overwhelming need?*

These and other related questions were addressed in this project, which was designed to identify and prioritize conservation opportunities in the sandhills through the following objectives:

1. Locate all sandhills habitat
2. Compile available information on each site (preservation status, biological attributes, management needs, etc.)
3. Rank sites according to their overall conservation potential
4. Recommend preservation and management strategies for top sites
5. Prioritize unprotected habitat for preservation
6. Identify key management opportunities

6.2 PROJECT METHODS

The conservation planning project prioritized sandhills habitat for conservation through the following sequence of steps: 1) define sandhills habitat for inclusion in the project, 2) locate all known sandhills habitat, 3) ascribe landscape and biological attributes to sites, and 4) rank sites according to their conservation priority. This section provides details of, and the rationale for, methods so users of this plan can understand the nature of the information, including its strengths and limitations.

Defining Sandhills Habitat

The task of defining habitat for inclusion in this project was not as straightforward as it might seem, as there is no clear definition of what constitutes sandhills habitat. This section describes how sandhills habitat was defined for purposes of inclusion in this study.

Soils

The sandhills are unique communities of plants and animals found exclusively on soils of the Zayante series in Santa Cruz County, central coastal California. As a result of the soil mapping methodology used to map the soils of Santa Cruz County, not all habitat that occurs on soils mapped as Zayante is sandhills, and some patches of sandhills habitat are located areas that are not mapped as having Zayante soils (Section 2.1). Therefore, it was not possible to simply use the distribution of the Zayante soils to define site inclusion.

Communities

As in previous planning projects for the sandhills (Marangio 1985, Lee 1994), this project attempted to identify sandhills habitat using plant communities (i.e. vegetation types), which are both conspicuous and generally predictive of animal distributions. Efforts to classify communities can be difficult, as species composition varies spatially as a result of the individual nature of species responses to ecological factors (Section 3.4). However, like other edaphic communities whose occurrence is tied to unique soil conditions, sandhills communities differ greatly in species composition from non-sandhills communities (Section 3.1). In many cases, the outcrops have fairly distinct boundaries, resulting in abrupt discontinuities in vegetation that are easily diagnosed both on the ground and from aerial photographs in the region.

In some cases, however, distinguishing sandhills habitat is not straightforward. Variation in soil characteristics, subsurface geology, disturbance history, and microclimate, among other factors, interact in complex ways to influence species distributions, resulting in variation in community composition and thus some difficulty in classifying sandhills habitat (Section 3.4). For example, communities comprised of a mix of sandhills species and non-sandhills species occur on soils which appear transitional between Zayante and other soil types, perhaps due to different effects of parent material, age, climate, or vegetation (D. Hillyard, pers. comm. 1997). In addition, succession gradually transforms community composition, such that communities classified as sandhills (e.g. ponderosa pine forest) can become non-sandhills (e.g. mixed evergreen forest) following decades of fire exclusion (Section 3.4, Section 8.1). It is essential to acknowledge this variability in species composition in order to best accomplish the goals of this plan.

Indicator Species

Despite its variability, Zayante soils support two endemic communities that can be readily diagnosed based on the presence of two dominant species: silverleaf manzanita and ponderosa pine. These two species act as reliable indicators of sandhills habitat for two reasons: 1) they are unique to the sandhills in the region, and 2) they are long-lived. Within Santa Cruz County, ponderosa pine and silverleaf manzanita are found only on Zayante soils, rendering them good indicators of the presence of sandhill soils. These species are both relatively long-lived species, and persist in habitat presently dominated by non-sandhills species (e.g. coast live oak, madrone) due to succession.

As a result, this project used the following criteria to delineate sandhills habitat for inclusion in this plan:

1. presence of silverleaf manzanita, *Arctostaphylos silvicola* (Figure A.14) and/or
2. presence of native stands of ponderosa pine, *Pinus ponderosa* (Figure A.15)

Consequences of Indicator Species-Based Criteria

Application of these criteria resulted in inclusion of some areas that have not historically been regarded as sandhills habitat. On the fringes of its range, silverleaf manzanita occurs in associations that differ from typical sandhills communities (Section 3.4). In the area known as "Bracken Brae", along the Boulder Creek drainage approximately five miles west of the town of Boulder Creek on Highway 236, Zayante soils occur along with other soils types to support remnant stands of Santa Cruz cypress (*Cupressus abramsiana*) and what appear to be hybrids of the silverleaf manzanita (*A. silvicola X A. tomentosa*). These communities do not support ponderosa pine, nor are they thought to support many of the herbaceous and suffrutescent plants associated with sandhills communities. As a result, many would not consider these areas to be part of the sandhills. However, these communities were incorporated into this plan through consistent application of the above criteria for inclusion. Though they are fascinating ecologically and essential to conservation of the endangered Santa Cruz cypress, organizations concerned strictly with conserving the endemic species and communities of the sandhills can simply exclude them from their consideration.

Silverleaf manzanita also occurs in association with other non-sandhills chaparral species found on mudstone deposits and the Maymen soils in the region, such as south-facing slopes near Loch Lomond. These areas were not identified prior to the analyses and thus were not included in this project. Additional examination of these areas may increase understanding of how sandhills communities intergrade with non-sandhills communities and the range of this endemic plant; however, they are unlikely to represent important conservation priorities as they do not support the diverse assemblage of characteristics of sandhills communities on Zayante soils (Chapter 3).

Locating Sandhills Habitat

The following methods were used to locate sandhills habitat: consultation with experts, examination of current aerial photographs, and examination of historical aerial photographs.

Experts

Biologists, consultants, planners, and agency representatives, and other individuals familiar with sandhills habitat, were asked to share their knowledge of existing sandhills sites for this project. At a meeting held September 25, 2002, we provided experts with an overview of the project, then asked them to note the location of sandhills on aerial photographs which showed major streets for reference.

Current Aerial Imagery

High-resolution digital photographs (two foot pixels) from flights in September 2002 were examined to locate additional sandhills habitat. Additional patches of sandhills habitat were identified by searching the region for the sandhills vegetation, based on the 'signature' of known sandhills habitat. Sites with public road access were visited to confirm the presence of sandhills habitat. Sites that could not be accessed were defined as "check sites"—those requiring ground truthing to confirm the presence of sandhills habitat.

Historic Aerial Photographs

Obtained from the University of California Santa Cruz Science and Engineering Library, aerial photographs of the region dating to 1943 were examined to determine the existence of sites that may have historically supported sandhills vegetation but currently do not have such a signature due to succession in the absence of fire.

Defining Sandhills Sites

Sandhills habitat is spatially very patchily distributed within the landscape, owing to a variety of natural and anthropogenic factors. While some areas support large tracts of sandhills habitat, in many areas, small patches of habitat exist as islands within a sea of non-sandhills communities. Determining where to draw boundaries around individual sites was important, because the site is the unit of analysis in this study. Attributes of sandhills habitat, including habitat size, integrity, and biology, clearly depend on the boundaries of the site. Therefore, a consistent, operational definition for "sandhills site" was essential.

In this project, a ***sandhills site*** *is an extant, contiguous patch of sandhills habitat or a series of adjacent patches of habitat interspersed by no more than 100 feet of development or 500 feet of non-sandhills habitat.* As an important exception, areas of moderate to high density development were split off from areas of low density development and undeveloped sandhills habitat, even if they would have been considered as a single sandhills sites by the definition above. This broke up single, large, heterogeneous areas, thus facilitating ascription of site attributes and subsequent analyses.

Delineating Sandhills Sites

Sandhills sites were determined by drawing a polygon circumscribing contiguous sandhills habitat. There was no minimum mapping unit: all known sandhills habitat was included. In determining whether to include developed or otherwise highly modified areas in the analysis, we adhered to the definition of sandhills habitat described above. Therefore, residential developments in which ponderosa pine or silverleaf manzanita are found were mapped as sandhills habitat in this study. Developed areas which lacked these species, including sand quarries, were excluded.

The precision with which the boundaries of sites were mapped varied, depending on the adjacent habitat. Where abrupt boundaries occur, as where sandhills habitat abuts large roads, quarried pits, or natural features including riparian vegetation, boundaries are likely fairly precise and accurate. In areas where sandhills habitat intergrades with non-sandhills habitat more seamlessly, the boundaries are less precise. The precision of site outlines is appropriate for the landscape-level analyses of this project; however, ground truthing would be required to accurately delimit habitat within individual sites.

Delineating Sand Parkland

To determine the location and acreage of remaining sand parkland habitat, this project delimited the boundaries of this unique community, which is characterized by sparsely distributed trees and a dense and diverse herbaceous plant assemblage which supports the highest diversity and density of sandhills species (Section 3.4). Two separate data layers were created: total sand parkland, which includes both open and dense sand parkland sites, and open sand parkland alone (Section 3.4).

The signature of sand parkland habitat was readily distinguished through aerial photograph interpretation by Jodi McGraw, who has examined most of these sites on the ground as well. Delineation of sand parkland by GPS based surveys on the ground would increase the precision of the acreage estimates for this rare habitat.

Sandhills habitat that was not mapped as sand parkland could be characterized as ponderosa pine forest or one of the three sandhills chaparral communities. Though highly recommended to aid future planning, research, and conservation efforts, vegetation mapping of all habitat within the project area was beyond the scope of this project.

Attributes of Sandhills Sites

Data on the attributes of sandhills sites were compiled for use in the analyses to prioritize sites for conservation. To obtain comparable, site-specific information on a wide variety of habitat characteristics that influence conservation value and management needs, sandhills experts were asked to provide their knowledge about sandhills sites by completing a data sheet. This two-page sheet covered various aspects of sandhills habitat including: soils and geology; current development, mining, and recreation; the presence of woody exotic plants and other stresses; the presence of sensitive species; and the presence of sandhills indicator species— plants and animals that typically indicate specific sandhills community types and environmental conditions within sandhills habitat (Appendix C).

Data compilation revealed that comprehensive information about sandhills sites is not available. Though recent research combined with surveys required by the Santa Cruz County Planning Department provided detailed information on a few sites, there was little or no information available about many sites. The most comprehensive information resulted from species lists for many sandhills sites created by Randall Morgan in the late 1970's and early 1980's. Owing to changes in land use and ongoing impacts of habitat degradation, this information may not accurately reflect the biological attributes of the sites. An ecoregional survey of sandhills sites in which consistent methods are used to catalogue site conditions via a standardized data sheet could be used to collect the comprehensive data required for the analyses originally proposed for this project. Such a survey was beyond the scope of this project.

Ranking Sandhills Sites

Within this project, we had hoped to use separate quantitative analyses to prioritize sandhills sites (contiguous areas of sandhills habitat) and subsequently, rank parcels within sites. However, comprehensive parcel level data were not available, nor were there any reliable surrogates quantitatively describing parcel quality. As a result, we did not attempt to prioritize parcels. Instead, potential parcels were identified within high priority sites, which were analyzed based on three attributes: 1) size, 2) integrity, and 3) biology. The following sections describe and provide a rationale for how these characteristics were included in the analysis.

<u>Size</u>

To assign scores based on site size, the GIS was used to calculate acreage for each site. Natural breaks in the frequency distribution of sizes were used to delimit five size classes. While the rule "bigger is better" applied in conservation planning and reserve design is certainly true in sandhills conservation, even small patches of sandhills habitat can represent high conservation value. Sandhills habitat is naturally patchy and variable in size, as outcrops of Zayante soils range from less than 1 acre to over 2,000 acres. Unlike populations of large mammals that are often the subject of conservation planning, many sandhills species, including the sensitive plants and insects, are likely adapted to persist in small habitat patches. In addition, fragments of sandhills habitat created from habitat destruction of once larger patches have, thus far, continued to support populations of sandhills species. Finally, plants and animal populations on isolated patches likely contain important genotypes that increase genetic diversity and may facilitate long term species persistence.

As a result, naturally small sites, as well as small habitat fragments, are regarded as important parts of the conservation strategy for the sandhills. While higher size scores are provided for larger sites, the relationship between size and size score is not linear (Table 6.1). In addition, biological attribute scores were given greater weight than size scores in the analyses, as described below.

Table 6.1: Scores awarded based on size

Size Range (acres)	Size Score
<2	0
2-10	1
11-60	2
61-150	3
>150	4

<u>Integrity</u>

The integrity score quantifies the degree to which the habitat is intact, without development or degradation that can reduce the ability of the site to continue to support species and communities. Development and roads within habitat reduce integrity as they reduce the likelihood of long-term persistence of sandhills populations and communities. In addition, adjacent land use can influence integrity, as development, quarrying, recreation, and other activities on adjacent land can impact sandhills habitat. Table 6.2 describes the criteria for integrity scores given to sandhills sites.

Table 6.2: Criteria for integrity scores assigned at the site level

Integrity Description	Score
High density development (<1 acre parcels) within site	0
Low density development (>1 acre parcels) within site; perimeter primarily composed of developed areas	1
Low density development (> 1 acre parcels); perimeter primarily composed of undeveloped areas	2
Habitat largely intact; however roads and development are present and/or the perimeter of the site includes a high proportion of development.	3
Habitat intact with little to no development within the site; perimeter surrounded primarily by intact natural areas.	4

<u>Biology</u>

In the absence of comprehensive information about species distributions and community diversity, relative scores for the biological value of each site were based on the likely presence of sensitive species and indicator species based on information from sandhills experts, using the criteria outlined in Table 3. These relative biology scores were attributed by the lead author, who has extensive experience in sandhills biology and ecology.

Sites for which there was no available biological information did not receive biology scores and are referred to as ‘check sites’.

Table 6.3: Criteria for biology scores assigned at the site level. Special status and indicator species listed in the site data sheet and information form (Appendix C).

Biology Description	Score
One or two special status species; few indicator species	1
Low proportion of special status and indicator species	2
Moderate proportion of special status and indicator species	3
High proportion of special status species and indicator species	4
Exceptionally high proportion of special status species and indicator species	5

Analysis

Designed to reflect their overall conservation value, scores were calculated as a function of site size, integrity, and biology scores. Because conservation in the sandhills is focused on preserving sensitive species and communities, rather than open space, biology scores reflecting the relative diversity of each site were weighted by a factor of three using the simple equation:

total site score = size + integrity + 3 (biology)

Lacking biology scores, check sites were not assigned final scores or further considered in the analysis of conservation priorities.

6.3 PROJECT PRODUCTS AND RESULTS

GIS Database

A comprehensive geographic information system (GIS) database was compiled for this project, the layers of which are shown in Table 6.4. In addition, this project created four new layers: total sand parkland, sand parkland, sandhills sites, and priority parcels. These layers will be made available to partner agencies upon completion of this project. Individuals and organizations interested in more information about the data used in the SCMP GIS database should contact the lead author (Appendix E).

Table 6.4 Components of the planning project geographic information system (GIS).

LAYER	SOURCE	DISCRIPTION
Base Map		
County Boundary	TIGER	
City Boundaries	TIGER	
Digital Elevation Model, 10 meter res.	USGS	To derive slope, aspect, proximity
Digital Orthophoto, effective to 1:2000 scale	Airphoto USA	Aerial image rectified to base map
Digital Raster Graphic of USGS Felton Quad	USGS	High res. scan of USGS Felton quad
Land Use as per County General Plan	County	
Parcels, developed and undeveloped	USFWS	
Roads, Major and Local	County	
Streams	USGS	
Topography, 40' Contour Interval	USGS	
Zoning as per County General Plan	County	
Protected Lands		
CDFG Ecological Reserves	CDFG	
County Parks	County	
Protected Lands, State/Fed	USFWS	
Soils		
Soils	NRCS	
Zayante Soils	NRCS	
Biotic		
Mt. Hermon June Beetle occurrences	Dr. R. Arnold	BUGGY database as of March 2004
Zayante band-winged grasshopper occurrences	Dr. R. Arnold	BUGGY database as of March 2004
ZBWG Critical Habitat Boundary	USFWS	BUGGY database as of March 2004
Biotic Resources as per 1994 General Plan	County	Areas defined as sensitive habitat
CA Natural Diversity Database	CDFG	sensitive species occurrences
Geyer Propety Biotic Resources	SAND	From 05/18/02 Survey
TNC Superlative Sites	TNC	Conservation priorities from TNC
SCMP Products		
sandhills sites	SCMP (various)	From site data sheets and aerial photo interpretation
total sand parkland	Jodi McGraw	based on aerial photo interpretation
open sand parkland	Jodi McGraw	based on aerial photo interpretation
priorities for conservation	Jodi McGraw	assessment of parcel level priorities

Sandhills Habitat

Sandhills habitat was located in an approximately 60-square mile area in the central part of Santa Cruz County, from Bonny Doon in the west to the northeastern edge of Scotts Valley (Canham Rd) in the east, and just south of Smith Grade near Bonny Doon in the south to Bracken Brae, northwest of Boulder Creek in the north (Figure 6.1).

A total of 3,960 acres of habitat fitting the definition of "sandhills" (Section 6.2) was identified in 54 sites. It is important to note that this figure includes areas of moderate to high density residential development. An additional 309 acres of potential habitat was identified in 10 check sites, which require further analysis to determine whether they are sandhills (Table 6.5).

This project did not attempt to calculate the original acreage of sandhills habitat or quantify the proportion that has been lost. A previous study to quantify historical and contemporary habitat acreages using aerial photographs estimated that there was originally a total of 6,265 acres of sandhills habitat, 600 of which was sand parkland. In 1992, the study indicated that 3,608 acres of sandhills habitat remained, 193 acres of which was sand parkland. These figures suggest a 40% reduction in total habitat and a 68% reduction in sand parkland by 1992 (Lee 1994). While these measures highlight the extent to which habitat conversion has removed habitat, they provide little information to inform efforts to conserve populations of sensitive species and functioning communities. For these purposes, biologists and planners must integrate knowledge of the population and community ecology of the rare systems with information about the total habitat remaining, the size of remaining patches, the extent of fragmentation, and the biology of remaining habitat patches.

<u>Sandhills Sites</u>

The 54 known sandhills sites differed greatly in size, integrity, and biology. The frequency distribution of total site scores revealed natural breaks in total habitat scores that were used to classify sites into three tiers (Figure 6.2). These tiers reflect the relative conservation value of the sandhills sites. The following narrative describes general development and biotic conditions within sites of each of the three tiers. Table 6.5 provides the mean and range of the size, integrity, and biology scores for sites within each tier, as well as example sites in each.

Tier 1: Eighteen sites were in the top tier. These excellent sites have high value for sandhills conservation, owing to their relatively large size, high landscape integrity, and high biological value. Two of the Tier 1 sites received moderate biology scores (i.e. three) because they lacked the diversity of sandhills species; however, these sites are exceptionally large and provide opportunities for management which may enhance their biological value.

Tier 2: Twenty-one intermediate sites were classified. These good sites also have high conservation value, yet typically lack the high level of biological diversity of Tier 1 sites. In addition, some of these sites have intermediate density development and/or are located adjacent to high-density development.

Table 6.5: Characteristics of sandhills site tiers resulting from analysis of site size, integrity, and biology (described in text).

Sites	Number of Sites	Total Acreage	Mean and (Range) Size (acres)	Mean and (Range) Scores[1]				Example Sites
				Size	Integrity	Biology	Total	
Tier 1	18	2531	140.6 (24-532)	3.0 (2-4)	2.8 (1-4)	4.2 (3-5)	18.5 (17-21)	Martin Road (50), Quail Hollow Quarry (39), Weston Road (2), Marion (36), Mt Hermon/SRL (14), Henry Cowell (13), Mt. Hermon Rd-North (19), Olympia Wellfield (25)
Tier 2	22	659	30.0 (1-79)	1.6 (0-3)	2.5 (0-4)	2.8 (2-4)	12.6 (10-15)	Mt. Hermon Rd-S (18), South Hihn Rd (41), Hidden Valley (37), Lockhardt Gulch East (22), Smith Grade South (44), Montevalle (23), Bonny Doon (49), Maymac South (27)
Tier 3	14	770	55.0 (6-201)	2.9 (1-4)	1.4 (0-4)	1.1 (1-2)	7.0 (5-9)	Whispering Pines (15), Mt. Hermon Residential (16), West Park (46), Hihn Rd. (40), Glen Arbor East (42), Graham Hill South (12), Bean Creek (24), Canham (7)
All Known sandhills	54	3,960	73.3 (1-532)	2.3 (1-4)	2.4 (0-4)	2.9 (1-5)	13.1 (5-21)	
Check	10	309	30.9 (3-86)	1.9 (1-3)	3.8 (2-4)	NA	NA	Mackenzie Cr (C-5), Smith Grade (C-6), Bracken Brae N of 236 I (C-10), Maymac central (C-7), Nelson Rd (C-4)

Tier 3: Fourteen sites were included in the third tier. These fair sites represent either moderate to large areas of sandhills habitat with high density residential development, or small sandhills sites that have either been degraded or developed such that they support a low diversity of sandhills species. Despite the high level of habitat fragmentation associated with housing or roads, these sites provide habitat for sandhills species and represent important opportunities for sandhills conservation.

Section 6.5 describes each of the Tier 1 sites, including their location, ownership, zoning and land use, landscape and communities, sensitive species, stresses, and preservation and management opportunities. The current known attributes of all sandhills sites are provided in Appendix D.

Sand Parkland

Total Sand Parkland

Only 208 acres of sand parkland habitat remain (Table 6.6). This highly fragmented habitat occurs in 27 isolated patches found at 12 different Tier 1 sandhills sites from Martin Road (i.e. the Bonny Doon Ecological Reserve) in the west to the Mt. Hermon Road North Site in the east (Figure 6.1). Analysis of aerial photographs from 1943 indicate that there was more than 1000 acres of sand parkland habitat originally. Remaining remnant patches range between 0.6 and 27 acres in size, but average only 8 acres (Table 6.6).

Though ground inspection could more precisely delimit the boundaries of sand parkland sites, these acreage estimates are likely very close approximates of the actual acreage. This is because sand parkland habitat is easily distinguished from other community types via aerial photograph interpretation and the lead author has examined most of these sites on the ground. Moreover, it is unlikely that additional sand parkland habitat exists that has yet to be documented. It is more likely that this calculation over-estimates the acreage of this unique community, since it includes patches exhibiting transitional community structure including sand parkland that appears to be succeeding into ponderosa pine forest (Mount Hermon) and parkland that is a mosaic with sandhills chaparral (Landfill).

Of the remaining sand parkland habitat, only 111 acres receive some form of protection from development, as in reserves, parks, watershed land, open space preserves, or public land. The remaining 97 acres are privately held and have no known protective status.

Open Sand Parkland

Only 57 acres of sandhills habitat supports open sand parkland—the unique assemblage of plants and animals that occur in open canopy, bare soil areas that support the highest diversity of native sandhills species and largest populations of many of the sensitive species (Section 3.4), including the Zayante band winged grasshopper and Santa Cruz wallflower (Chapter 5). Found at only 7 sandhills sites, only 14 patches of this habitat were identified. Though patches range in size from 0.25 – 16.5 acres, nine patches are less than 3 acres and all patches together average a mere 4 acres (Table 6.7). Only approximately 10 acres of open sand parkland habitat occur on north aspects, which support a unique assemblage of plants and animals adapted to the cooler, more mesic conditions found in these areas (Section 3.4; McGraw 2004).

Of the remaining open sand parkland habitat, only 37 acres receives some form of protection. The average size of these protected patches of habitat is exceptionally small: a mere 4 acres. The remaining 20 acres of open sand parkland are in private ownership, and presents important opportunities for land preservation.

Table 6.6: Area of total and protected sand parkland habitat (dense and open) in 27 isolated patches (details described in text).

Patch	Site Name	Site #	Approx. Size (acres)	
			Total	Protected
Eagle Creek	Mt Hermon/SRL	14	5.2	5.2
Mount Hermon	Mt Hermon/SRL	14	26.6	22.5
Ponderosa camp	Mt Hermon/SRL	14	0.8	0.8
Dumas parkland	Mount Hermon Rd North	19	12.9	0
Dumas-OP	Mount Hermon Rd North	19	6.8	0
Ocean Pacific	Mount Hermon Rd North	19	3.5	0
Olympia Wellfield	Olympia Wellfield	25	11.4	9.7
Olympia	Olympia Wellfield	25	8.2	0
Zayante Fire House	Olympia Wellfield	25	3.2	0.5
Zayante RR-South	Olympia Wellfield	25	5.0	0
Zayante RR-North	Olympia Wellfield	25	3.4	0
Camp May-Mac-West	Maymac-South	27	2.0	0
Quail Hollow CP-Main	Quail Hollow CP-East Ridges	30	5.1	5.1
Quail Hollow CP-North West	Quail Hollow CP-East Ridges	30	1.1	1.1
Lompico parkland	West Lompico	32	1.2	0
Quail Hollow CP-West	Quail Hollow CP-Northwest	34	0.9	0.9
Quail Hollow CP-Dense	Quail Hollow CP-Northwest	34	2.5	2.5
Vista Robles	Vista Robles, Marion	35,36	10.2	0
South Ridge	Quail Hollow	39	25.2	21.4
South Ridge-NE	Quail Hollow	39	1.2	1.2
South Ridge-North	Quail Hollow	39	0.6	0.6
North Ridge	Quail Hollow	39	15.2	15.2
Schnell Parkland	Quail Hollow	39	6.4	0
West ridge	Quail Hollow	39	12.0	10.2
Landfill	Landfill Heights	43	22.1	0
Bonny Doon-North	Martin Road	50	14.1	13.4
Bonn Doon-South	Martin Road	50	1.1	1.1
	Total acreage		**207.9**	**111.4**
	Mean patch size		**7.7**	**7.0**

Table 6.7: Area of total and protected open sand parkland habitat in 14 isolated patches.

Patch	Site Name	Site #	Size (acres.) Total	Protected
Mount Hermon	Mt Hermon/SRL	14	1.8	1.8
Dumas	Mount Hermon Rd North	19	6.7	0
Olympia-south	Mount Hermon Rd North	19	2.8	0
Olympia Wellfield	Olympia Wellfield	25	11.7	5.1
Zayante RR-North	Olympia Wellfield	25	2.4	0
QHR-main	Quail Hollow CP-East Ridges	30	4.1	4.1
QHR -northwest	Quail Hollow CP-East Ridges	30	0.5	0.5
Vista Robles	Vista Robles, Marion	35,36	0.5	0
South Ridge-NE	Quail Hollow	39	0.4	0.4
South Ridge	Quail Hollow	39	16.5	16.5
North Ridge-main	Quail Hollow	39	5.8	5.8
North Ridge-west	Quail Hollow	39	0.2	0.2
West Ridge	Quail Hollow	39	2.3	2.3
Schnell	Quail Hollow	39	1.2	0
		Total acreage	**57.0**	**36.7**
		Mean patch size	**4.7**	**4.1**

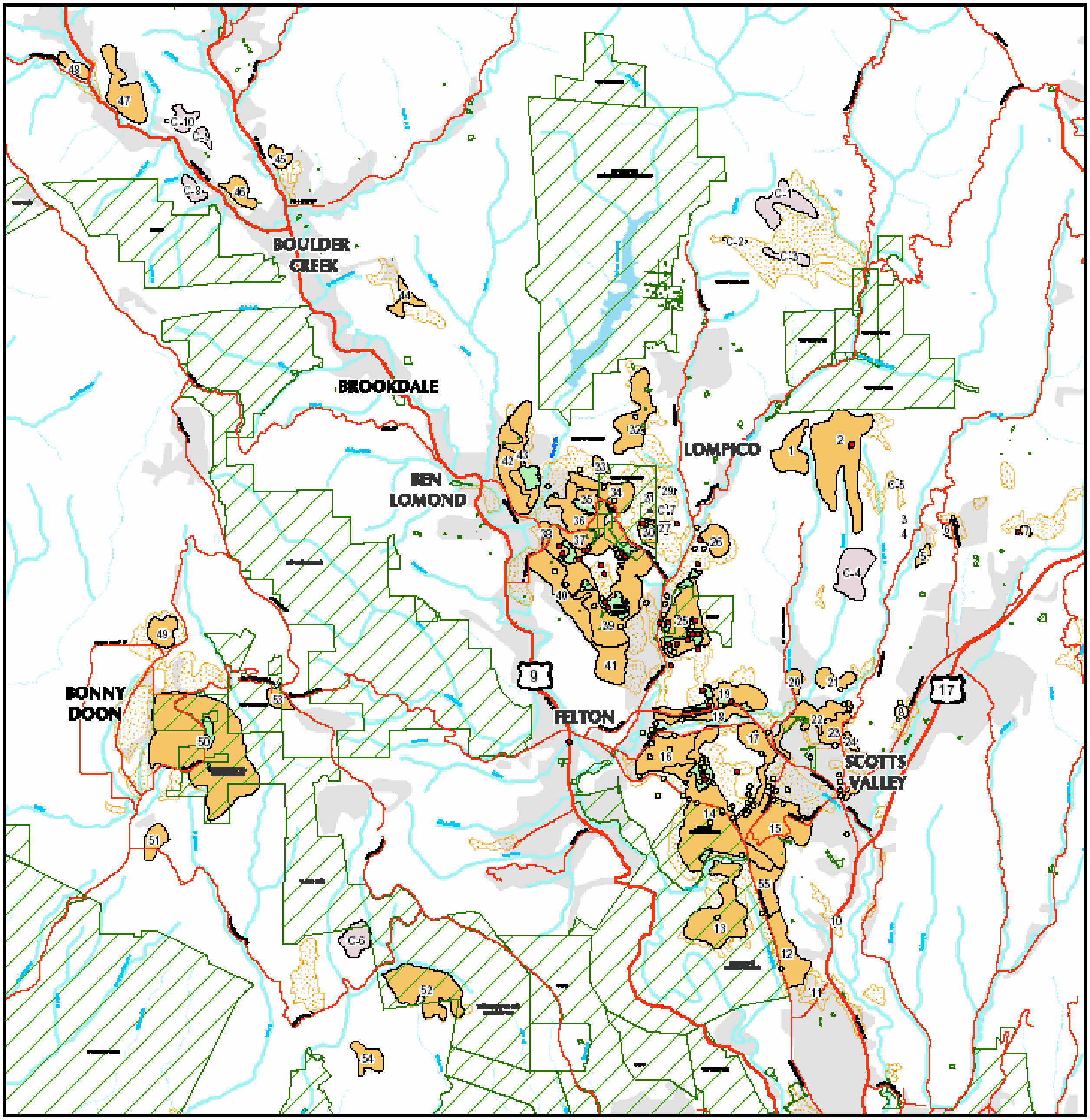
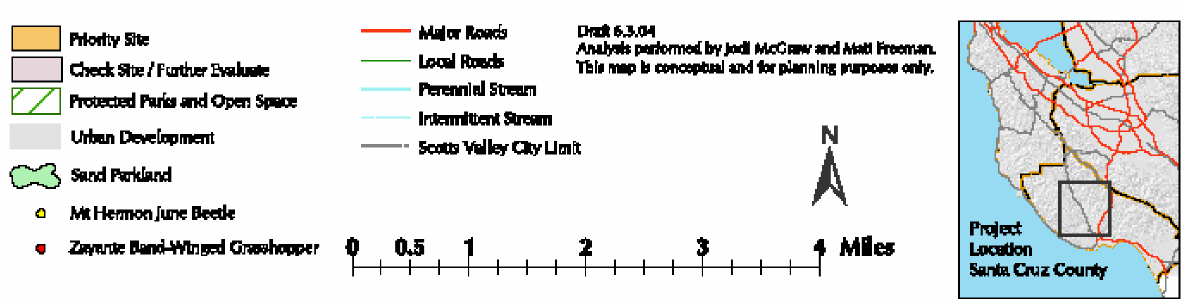


Figure 6.1 Sandhills Habitat Conservation Management Plan: Biological Resources



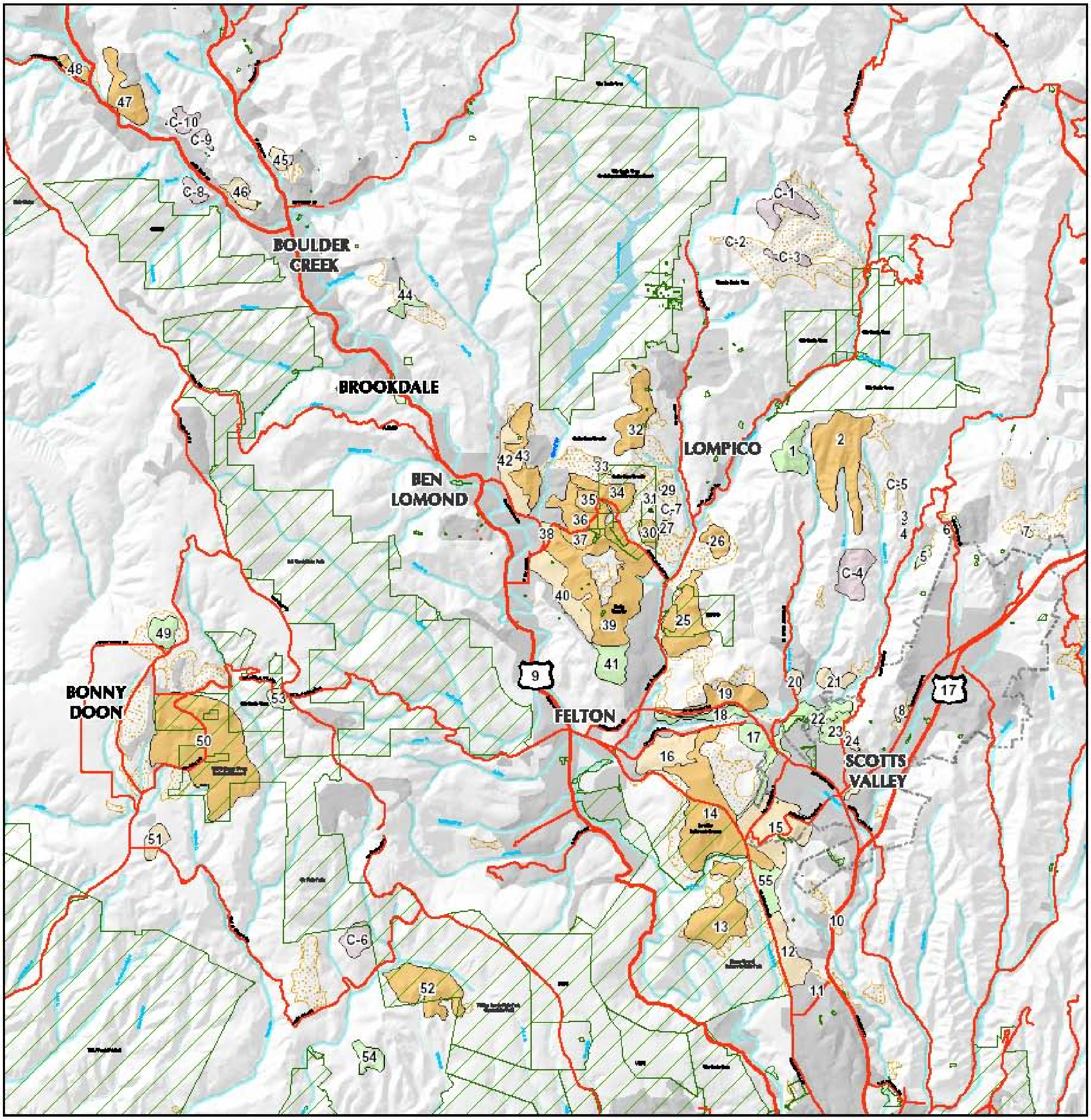
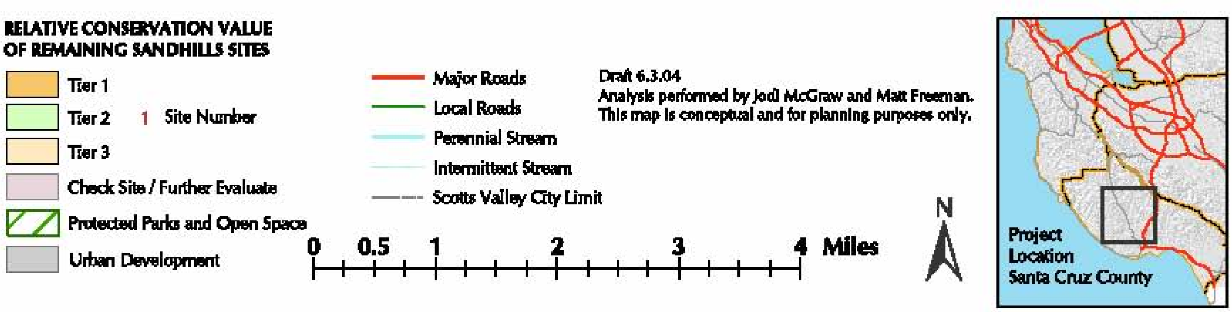


Figure 6.2 Priority Sites for Sandhills Habitat Conservation and Management



6.4 GENERAL RECOMMENDATIONS

Land Preservation

Analyses in this project confirm what has been understood for several decades: the unique communities of plants and animals in the sandhills are extraordinarily rare. With less than 4,000 acres of sandhills habitat remaining, a large proportion of which is developed, land preservation is a crucial step in sandhills conservation. Sandhills habitat preservation efforts during the past three decades have succeeded in preserving large tracts of sandhills habitat in many of the Tier 1 sites. However, several Tier 1 sites have little or no preserved habitat and represent important opportunities for preservation efforts to increase both the distribution and acreage of preserved sandhills habitat.

Of particular concern is the preservation of sand parkland habitat—only 200 acres of which persists worldwide (Table 6.6). Recognizing the exceptional rarity of this unique and diverse system, organizations conducting sandhills conservation during the past two decades have necessarily focused on this rare habitat and have been successful in preserving more than 50 acres of sand parkland habitat, including approximately 25 acres of open sand parkland.

Our analysis indicates that there are several opportunities to preserve additional sand parkland (Tables 6.6 and 6.7). Eleven sand parkland patches receive no form of protection and merit consideration for preservation, especially as many support populations of the sensitive species. Increasing the distribution and overall acreage of preserved habitat can increase the likelihood that multiple populations of these endangered species will persist. Increasing the size of protected sand parkland patches by preserving habitat adjacent to already protected habitat can also facilitate conservation, as many of the habitat patches are small and would benefit from protection of additional acreage.

Though less rare than sand parkland, the sandhills chaparral communities are still globally very rare. For reference, sandhills chaparral communities, which cover approximately 3,000 acres, can be compared to the coast redwood forests, a community of limited distribution and important biodiversity, which covers 2 million acres. All sandhills habitat is extraordinarily rare. Land preservation efforts should focus on preserving many of the large tracts of undeveloped sandhills chaparral habitat that remains.

Though time constraints limited detailed analysis of preservation and management opportunities to the eighteen Tier 1 sites, the remaining 36 sites total more than 1,400 acres of sandhills habitat. A large portion of these sites includes moderate to high density residential development. Within these sites, however, there are several undeveloped parcels supporting patches of intact habitat. In addition, highly modified areas oftentimes support populations of sensitive species, including the Mount Hermon June beetle (Section 5.6, Appendix D). These sites are oftentimes located adjacent to sandhills habitat preserves, and thus can greatly influence the ecology of the protected habitat. Further decline of the habitat and sensitive species populations within these sites would represent a loss to overall conservation efforts, and the value of these areas for conservation should not be discounted. Many management techniques described in the following chapters can be applied to moderate and highly developed areas. The landscaping around developments may influence persistence of sensitive species (Section 11.5) in these sites.

Efforts to preserve sandhills habitat should be coordinated amongst individual land conservancies, conservation organizations, and government agencies of all types that are involved in habitat preservation. Different organizations can provide different resources, including programs, information, and funding, that are required to preserve habitat (Section 14.3). Indeed, previous preservation successes, such as the preservation of the South Ridge of Quail Hollow, have resulted from such coordinated efforts.

Various mechanisms exist to protect sandhills habitat from destruction. These include landowner education and outreach, fee title acquisition, conservation easements, transfer of development rights, lot line adjustments, habitat conservation plans, and land use regulations. Each of these mechanisms should be critically evaluated for its role in preserving remaining sandhills habitat.

Management

Though habitat preservation is an essential first step to conserving sandhills biodiversity, recent extirpations within "protected" habitat suggest that habitat preservation alone cannot conserve sandhills species and communities. As discussed through this plan, fire exclusion, exotic species proliferation, and intensifying recreation degrade habitat, reducing its ability to support sensitive species (Chapter 4). These stresses are negatively impacting a large proportion of privately owned sandhills habitat as well as habitat within sandhills preserves. Preservation efforts must incorporate methods for managing habitat, as described in chapters 7-10 of this plan.

Recommended Next Steps

Many preservation efforts will focus on preserving individual parcels or groups of parcels within a site, rather than entire sites. Comprehensive and current information about key sandhills habitat attributes (e.g. sensitive species distributions) would greatly facilitate these conservation efforts. Though most parcels and some sites are privately owned and have restricted access, many landowners are interested in learning more about the sandhills. As part of a larger community effort to increase awareness, perhaps access could be obtained for many of the sites for which currently there is little or no information. Provided a more comprehensive database of sandhills sites is developed, quantitative analyses should be used to re-assess the conservation value of sandhills sites and parcels. Though not implemented within this plan, the methodology for these analyses has been developed by the authors and could be readily employed once data are available.

Regional habitat preservation efforts could be greatly aided by a series of integrated studies to quantify the distribution and abundance of sensitive species populations and their associations with various community types within sandhills habitat. First, a study should be conducted to examine the variability in plant community structure and species composition in remaining sandhills habitat. This study could be used to determine the habitat associations of sensitive plant species. The plant community types in remaining sandhills habitat could then be mapped via a combination of aerial photograph interpretation and field reconnaissance. Following establishment of such a sandhills vegetation map, targeted surveys should be used to examine the distribution and abundance of sensitive animal species within the different community types. These coordinated studies would allow community types to be used as a surrogate for species composition and biodiversity patterns at broader spatial scales, strengthen our knowledge of the habitat requirements of sensitive species, and provide an important baseline for determining the success of the conservation measures (habitat preservation and management).

6.5 Tier 1 Site Descriptions and Recommendations

This section provides a description of the 18 Tier 1 sites, which represent some of the most important conservation opportunities for the sandhills. Within this project, time did not allow similar descriptions of Tier 2 and Tier 3 sites to be developed. These sites will also play an important role in sandhills conservation, and it is recommended that they be examined in greater detail during a subsequent effort.

Location

The number used to indicate the site on the maps (Figure 6.1 and Figure 6.2) and a brief written description of the geographic location of the site is provided.

Ownership

A summary of the ownership status of the parcels located within the sites is provided, with emphasis on identifying habitat in public ownership.

Land Use and Zoning

A description of the general types of current land use occurring in habitat within the site is provided, along with the codes that correspond to the zoning of the parcels within the site.

Landscape and Communities

The characteristic of the natural landscape is described in terms of its integrity and overall development patterns. In addition, this section lists the sandhills community types found within the site.

Sensitive Species

Sensitive species found within the site are listed. There may be some inaccuracies in this information, as with other of the site attributes catalogued in Appendix D, owing to the lack of current, comprehensive survey information on all of the sites.

Stresses

The factors that are degrading sandhills habitat (reduce its ability to support sandhills species populations) are noted in this section. This information also may not be comprehensive, but indicates the factors likely to be impacting sandhills habitat within the site. Additional information about the impacts of several of the factors noted including fire exclusion, exotic plants, and recreation, is provided in the text of the plan including Chapters 4,8,9, and 10.

Preservation Opportunities

Unprotected habitat that is of high value for conservation of sandhills communities and species is described. Due to the sensitive nature of this information, the location of habitat is not provided in this document, but has been made available to partner agencies and organizations in support of the plan. Individuals and organizations interested in more specific information about sandhills preservation opportunities should contact the lead author (Appendix E).

Management Opportunities

Based on current knowledge of the factors that are impacting habitat at the site, an outline of management priorities for each site is provided. The management chapters of this project (Chapter 7-10) provide greater details about management techniques. It was beyond the scope of this plant to provide detailed management strategies for each site. Individuals and organizations interested in obtaining more information about the management opportunities at a site should contact the lead author (Appendix E).

Site Name	**Site Number**	**Approximate Acreage**
Martin Road	50	532

Location
This site straddles either side of Martin Road south of Ice Cream Grade near Bonny Doon.

Ownership
The majority of the site is located within the Bonny Doon Ecological Reserve (BDER), which is managed by the California Department of Fish and Game. The City of Santa Cruz owns a small portion of the northeast corner of the site. The remainder of the site is in private ownership, and distributed among 17 private parcels adjacent to the BDER and 5 additional smaller (±1 acre) parcels to the west.

Zoning and land use
This site is in a rural area with low density development. Land within the site is zoned PR, RA, or RR

Landscape and Communities
This site represents the largest contiguous patch of sandhills habitat remaining. Though rural development is imbedded within the site, the BDER has protected a large patch of habitat that includes a patch of dense parkland, and *the* largest acreage of sandhills chaparral communities including an extensive patch of sand chaparral. These communities differ somewhat from the Ben Lomond sandhills in species composition, perhaps owing to their higher elevation and geographic isolation.

Sensitive Species
This site supports relatively large populations of silverleaf manzanita and Santa Cruz cypress, moderate populations of Ben Lomond spineflower, and a small and imperiled population of Santa Cruz wallflower. Santa Cruz monkeyflower is also known to occur at the site. Surveys are needed to determine whether the two listed insects are found at the site. Given their distance from the Ben Lomond sandhills, populations at this site are likely genetically dissimilar and therefore represent an important component of overall genetic diversity in the sandhills.

Stresses
Fire exclusion, exotic plants, and recreation impact this site. Fire exclusion has reduced the acreage of open sand soil and thus threatens persistence of species requiring this open habitat, including the Santa Cruz kangaroo rat, which surveys indicate may have been extirpated, and the Santa Cruz wallflower, which is in decline. Exotic plants including *Acacia, Eucalyptus, Genista monsepssulana*, *Cortaderia jubata,* reduce open habitat within the site. *Vulpia myuros, Hypochaeris glabra,*and *Briza maxima* compete with native herbs in the parkland. Recreation by equestrians and hikers maintains gaps in chaparral, but disturbance is too frequent and intense to support gap specialist herbs and may reduce populations of sensitive species that line the trails.

Preservation Opportunities
Excellent opportunities to protect additional high quality habitat exist through habitat preservation in 13 parcels within the site.

Management Opportunities
CDFG should implement management as outlined in the BDER management plan completed in 2003, which addresses many of the stresses to this site. Efforts to develop a vegetation management plan (VMP) to address impacts of fire exclusion are essential to managing biodiversity in the long term. Private landowners should be encouraged to manage their sandhills habitat in ways that will support efforts in the adjacent BDER. Interpretation and education efforts should continue at this site in order to enhance appreciation of the sandhills.

Site Name	Site Number	Approximate Acreage
Mount Hermon/SRL	14	347

Location
The site is located between the Mount Hermon and Henry Cowell State Park. It straddles Graham Hill Road and is bounded to the south and west by the Henry Cowell State Park; to the northwest by Roaring Camp (an historic railroad theme park); to the north by the community of Mt. Hermon; to the northeast east by the Hanson Quarry; and to the southeast by the Lockewood Lane and Whispering Pines neighborhood.

Ownership
The southern half of the site encompasses a property owned by the Save the Redwoods League, which intends to deed it to State Parks. The northern half of the site includes large private parcels owned by the Mt. Hermon Association, the County of Santa Cruz, Hanson Aggregates Company, and Kaiser Sand and Gravel Company. Sections of the thin strip of sandhills habitat east of Graham Hill Road are owned by the County, the City of Scotts Valley, and an individual private landowner.

Zoning and land use
This site is largely undeveloped and is *de facto* open space. Zoning includes: SU, PR, and PR-O

Landscape and Communities
This site supports a diverse mosaic of all sandhills plant communities. The Mt. Hermon and County parcels support dense and open parkland. The County parcel supports ponderosa pine forest as well. The Hanson parcels support primarily chaparral communities. The SRL parcel supports a diverse mosaic of communities and contains the second largest contiguous, undeveloped patch of sandhills habitat remaining.

Sensitive Species
This site supports all 6 endemic sandhills species, as well as moderate diversity of sandhills indicator species. In addition, it contains the last known population of the Santa Cruz kangaroo rat (Bean 2003).

Stresses
Biodiversity at this site is threatened by fire exclusion, exotic plants, and recreation. Fire exclusion is causing type conversion of sandhills habitat and increasing woody vegetation which restricts the distribution of many sensitive species. The parkland is infested by woody brooms as well as dense European annuals. Recreation by mountain bikes and to a lesser extent, horses, has trampled and eroded habitat at the SRL and Mt. Hermon parcels and threatens the last known population of Santa Cruz kangaroo rat. OHVs occasionally trespass into this site.

Preservation Opportunities
If and when the large parcel south of Graham Hill Road is transferred to State Parks, it should be designated and managed as a Natural Preserve—a distinct area of outstanding natural or scientific significance established within the boundaries of other state park system units. According to State of California guidelines, the purpose of natural preserves is to preserve rare and endangered species, representative examples of plant or animal communities existing in California prior to the impact of civilization, geological features illustrative of geological processes, significant fossil occurrences or geological features of cultural or economic interest, or topographic features representative of unique biogeographical patterns. Remarkably, this site meets each and every one of these criteria.

Two private parcels supporting ponderosa pine forest and sandhills chaparral communities have been identified as opportunities to preserve sandhills habitat adjacent to otherwise undeveloped habitat within this site.

Management Opportunities

This site presents many important management opportunities that can enhance regional sandhills conservation. Two of the site's landowners, SRL and Mt. Hermon Assoc., are actively working to confront stresses to sandhills habitat. Mt. Hermon has controlled recreation access, repaired erosion caused by recreation, removed exotic brooms, and mimicked the beneficial effects of fire in sand parkland by raking litter. These efforts are should be continued and supported. SRL is attempting to address the unlawful recreation degrading their site. Given the large amount and importance of habitat in their parcel, SRL should develop a management plan for the site to address the stresses. The site represents a great opportunity for fire management, given its need and isolation from development and adjacency to the State Park. Sandhills habitat owned by the County and City of Scotts Valley presents important conservation opportunities. These government agencies should examine the parcels and plan and implement management that confront the degradation caused by exotic brooms and recreation.

Site Name	Site Number	Approximate Acreage
Mt. Hermon Road North	19	103

Location
This site is located north of Mt. Hermon Road between Scotts Valley and Felton.

Ownership
The site encompasses 18 private parcels and nearly 5000 feet within the County right of way along Mt. Hermon Rd.

Zoning and land use
The site contains a former quarry and some development and is zoned SU, RA, and M-3.

Landscape and Communities
Though there are patches of sandhills chaparral communities, this site primarily supports sand parkland habitat. Unfortunately, a large quarried pit fragments much of the habitat to the east of the site. The western portion is intact, though degraded by unlawful recreation as described below.

Sensitive Species
With its intact sand parkland habitat, this site supports all 6 endemic sandhills species as well as *Monardella undulata, Mimulus rattanii* ssp. *decurtatus,* and a diverse assemblage of indicator species including Santa Cruz rain beetle and *Calyptridium umbellatum*.

Stresses
This site has been greatly degraded by recreation use. Used by OHVs for both arena style and trail use, the vegetative cover has been denuded not only in the former mine area, but also within intact habitat on the west end of the site. This removes habitat for sandhills species and causes erosion and sedimentation into Bean Creek, a steelhead stream. Fire suppression has reduced habitat on the north end of the site. Exotic brooms threaten species in sand parkland.

Preservation Opportunities
None of the habitat within this site is currently preserved. Given its high biological value and adjacency, it represents one of the top priorities for sandhills habitat preservation. Eleven parcels containing sand parkland are identified as priority parcels, with those at the west of the site topping the list. The conservation value of this habitat has decreased during the past five years due to degradation caused by OHVs, which may be difficult to reverse. Rapid preservation is highly recommended.

Management Opportunities
Private landowners should be educated about the extremely high habitat value of their properties and the degradation that occurs. Destructive recreation should be excluded through fencing and patrols. Active restoration will be required to prevent ongoing damage caused by erosion on steep slopes, especially in sand parkland, where sandhills species can recolonize following cessation of disturbance. Small infestations of French broom should be eradicated before they can spread. Due to its relative distance from development and its adjacency to roads, quarries, and other fuel breaks, this site presents an opportunity to use prescription burning to remove litter, reduce exotic plant cover, enhance populations of native herbaceous plants, and restore habitat for Zayante band winged grasshoppers. Though highly altered owing to road creation, the habitat within the County right of way should be managed to increase populations of sensitive sandhills plants and create a better buffer to prevent abundant exotic plants from invading the adjacent high quality parkland.

Site Name	**Site Number**	**Approximate Acreage**
Quail Hollow Quarry	39	375

Location

This site is located in the center of Quail Hollow, on a ridge that separates the San Lorenzo and Zayante watersheds. It is contiguous with four other sites: Hidden Valley site (37) to the north, Glen Arbor (38) to the northwest, Hihn Road (40) to the west, and South Hihn Road (41) to the south. It is separated from these sites due to its much lower density development.

Ownership

This large site is comprised of more than 40 parcels owned by a variety of landowners including the Granite Rock Corporation, the County of Santa Cruz, and many individual landowners.

Zoning and land use

Land within this site is zoned SU or RA. The site encompasses parcels that range widely in size and land use. Several parcels, ranging from 1 acre to over 50 acres, have single home sites on them. One hundred and four acres of this site comprise the conservation areas of the Quail Hollow Quarry, which are being managed as part of Graniterock's HCP. A few parcels are undeveloped, including one 45-acre parcel. The site was drawn to exclude past, current, and some future mining areas that have been permitted.

Landscape and Communities

This site is doughnut shaped as it surrounds the Quail Hollow Quarry which, upon completion will cover approximately 200 acres. There is potential is to maintain contiguous habitat surrounding the quarry pit. Presently, this habitat consists of a mosaic of primarily sandhills communities including the largest remaining patch of large patches and diverse and intact patches of sandhills chaparral communities including sand chaparral.

Sensitive Species

With its intact sand parkland habitat and sandhills chaparral communities, this site supports all 6 endemic sandhills species, curly leaved monardella, Santa Cruz monkeyflower, and the most diverse assemblage of indicator species. Indeed, it has the highest biological value of any sandhills site.

Stresses

Fire exclusion, exotic plants, and recreation have impacted this site. Fire exclusion is reducing habitat for gap specialist species in sandhills chaparral, causing type conversion on north slope sand parkland to mixed evergreen forest, and accumulation of leaf litter on south slope sand parkland. European annual grasses and forbs outcompete native sandhills herbaceous plants and degrade habitat for Zayante band-winged grasshopper in sand parkland and dense infestations of French broom threaten to invade north aspect parkland. Recreation use historically by OHVs, equestrians, hikers, denuded large tracts of sandhills habitat and caused extensive erosion on the steep slopes in both parkland and chaparral.

Preservation Opportunities

Due to the minimal development on the large parcels within this site, and high biological value of habitat in this area, twenty-eight parcels containing sandhills habitat have been identified as preservation priorities in this site alone. All parcels contain large acreages of intact sandhills chaparral habitat, and a few exceptional parcels also contain sand parkland. Land preservation focused in this area can enhance sandhills conservation by adding to the habitat already conserved by the County of Santa Cruz and Graniterock through conservation easements to the County that encircle the Quail Hollow Quarry.

Management Opportunities
Due to the extraordinary high biodiversity, large populations of sensitive species, and various threats to sandhills habitat in this site, management of sandhills habitat will be essential to attaining regional sandhills conservation goals, including perhaps the persistence of sensitive species such as the Zayante band winged grasshopper and Santa Cruz wallflower. As part of their HCP, Graniterock has agreed to actively manage 104 acres of preserved habitat encircling their quarry operation as described in their Long Term Management and Maintenance Plan which was drafted in 2003, but has not yet been finalized. Management should address the impacts of fire exclusion, exotic species, and recreation on populations of sensitive species and communities within their habitat.

Other private landowners in this site should be informed of the high value of sandhills habitat and encouraged to consider habitat management on their properties. Adjacent landowners should be educated about the role of sandhills habitat in this site and encouraged to support Graniterock's management efforts, including necessary policies restricting recreational access within the sandhills habitat preserves.

Site Name	**Site Number**	**Approximate Acreage**
Olympia Wellfield	25	154

Location
This site is located east of East Zayante Road, north of the Olympia Quarry, and south of the Zayante School Road neighborhood.

Ownership
The site is comprised of sandhills habitat located in 17 parcels. The majority of the site is owned by the San Lorenzo Valley Water District (SLVWD). However, Lonestar California Inc. and Hanson Aggregates own large parcels in the southern portion of the site, and parcels in the north and west are held by a variety of individual private landowners.

Zoning and land use
Property within the site held by SLVWD is managed for water supply protection. The site is zoned SU and PR.

Landscape and Communities
This site supports intact sand parkland and sandhills chaparral communities within a matrix of other vegetation (riparian, mixed evergreen forest) and non-habitat including an abandoned quarry. Though not adjacent to them, this site may provide biological connectivity between sites to the east of East Zayante Road and the Mount Hermon Road North site.

Sensitive Species
The intact sand parkland at this site supports populations of all 6 endemic sandhills species, as well as a diverse assemblage of sandhills indicator species. Though not actively revegetated, the abandoned quarry supports populations of Zayante band-winged grasshopper, Mount Hermon June beetle, Ben Lomond spineflower, and Ben Lomond buckwheat.

Stresses
This site is primarily threatened by recreation use and exotic plant species. OHVs use the abandoned mine as well as the intact sand parkland habitat for both arena and trail riding, and connect to the Mt Hermon Rd north site via a trail to the east and south. Owing to the presence of an equestrian center adjacent to the property and the railroad tracks that function as a trail corridor, equestrians frequently use the site as well. Finally, the quarry pit provides an arena for paint ball wars and shooting. These uses have denuded sandhills habitat and, on steep slopes in sand parkland, resulted in erosion that further degrades habitat. Exotic plant species also degrade habitat. Woody exotic species including *Acacia* and *Eucalyptus* are found in and adjacent to the intact habitat and have proliferated in the abandoned quarry. European annuals compete aggressively with native plants and reduce habitat quality within the sand parkland. Fire exclusion is increasing the density of woody vegetation and leading to type conversion of sand parkland.

Preservation Opportunities
Five parcels held by private landowners have been identified as priorities for preservation within this site. Protection of habitat within these parcels can enhance conservation due to their adjacency with habitat protected by the SLVWD.

Management Opportunities
Because of the importance of this site for the local water supply as well as biotic diversity, it can provide great opportunities for outreach and education regarding the role of sandhills in the larger environment and community. Recreation management is essential for this site. SLVWD should continue its work to reduce habitat degradation caused by recreation and work with adjacent landowners who may be able to assist their efforts. The sand parkland habitat should be protected from recreational use. Efforts to eradicate exotic trees at the site initiated by SLVWD should continue and be expanded to include habitat of adjacent landowners to avoid re-infestation. Due to its lack of adjacent development, the dense parkland habitat in this site would be good candidate for fire management to reduce woody plant density, remove accumulated leaf litter, reduce European annuals, and thereby enhance sensitive species populations.

Site Name	Site Number	Approximate Acreage
Quail Hollow Ranch County Park: East Ridges	30	28

Location
This site is located on the eastern border of Quail Hollow Ranch County Park.

Ownership
The site is owned by the California Department of Fish and Game which manages the site through a cooperative agreement with the Santa Cruz County Department of Parks and Recreation.

Zoning and land use
As part of the park, the site is zoned PR-L and PR. The site is currently only used for education and research; however, trespassing by recreationists at the park occurs.

Landscape and Communities
This site consists of two outcrops of sandhills habitat that are separated by mixed oak woodland vegetation, each of which supports sand parkland habitat on the ridge top and sandhills chaparral communities on the lower slopes. The larger outcrop also supports ponderosa pine forest on its southern edge.

Sensitive Species
The intact sand parkland at the site supports populations of all 6 endemic sandhills species, as well as a diverse assemblage of sandhills indicator species. It is a historic location of Santa Cruz kangaroo rat, though it may not still support this species.

Stresses
Fire exclusion, exotic plants, and recreation impact this site. Suppression of fire has reduced the amount of habitat at the site by increasing woody plant density and facilitating type conversion of the chaparral to dense oak woodland. This has also fragmented the sandhills habitat on the two ridges, which was connected as recently as 1943. Exotic plants at the site primarily consist of dense European annual grasses and forbs which compete aggressively with sandhills herbs and reduce habitat quality for Zayante band-winged grasshoppers. Though beginning in 2000 the County Park has attempted to restrict recreational access to the site, ongoing recreational use continues and has removed rare plant patches and caused erosion.

Preservation Opportunities
This site is already owned and managed for biodiversity, so conservation requires only proper management.

Management Opportunities
This site requires management in order to preserve biodiversity. Indeed, the recovery plan for the federally listed sandhills species indicates that a management plan for this site is an important step required for recovery. A management plan should be developed to addresses the ongoing stresses and protect the sensitive species at the site. A fence should be erected at the southern entrance to the site, with a gate installed to allow access for education purposes. Erosion control measures should be implemented on the trails which are beginning to fail.
Fire management or fire surrogates should be used to reduce woody vegetation, litter, and exotic plants and enhance native plant and animal populations within parkland.

Site Name	Site Number	Approximate Acreage
Weston Road	2	251

Location
This remote site is located towards the northernmost terminus of Lockhart Gulch Road, about one mile east of the community of Lompico. The site straddles three ridges that divide Bean Creek and Lockhart Gulch.

Ownership
The site is comprised of approximately forty private parcels approximately 5-10 acres in size.

Zoning and land use
This area is primarily used for low-density residences and is zoned SU.

Landscape and Communities
This site contains three adjacent ridges or outcrops of sandhills habitat. Though examination of historical aerial photographs suggest that these ridges supported sandhills chaparral communities throughout much of their area, the site currently supports sandhills habitat primarily on the ridges and immediate slopes, with other vegetation and uses in the intervening draws. Though there are scattered ponderosa pines, the site is primarily comprised of sandhills chaparral communities.

Sensitive Species
Though information about this site is incomplete, the site is known to support the four endemic plants and the Mount Hermon June beetle, and thought to house the Zayante band-winged grasshopper. In addition, the site contains populations of several sandhills indicator species including *Monardella undulata* and *Artemesia pycnocephala*.

Stresses
This site has been greatly altered by fire exclusion and alterations associated with rural development including exotic plants and recreation. Fire exclusion has increased density of woody vegetation and, based on aerial photo analysis, caused type conversion to non-sandhills habitat in much of the site. Roads and housing as well as recreation also likely reduce the populations of sensitive species, though little is known about this site.

Preservation Opportunities
Five parcels in the center of the site were identified as potential priorities. This assessment was based on aerial photograph analysis and requires a resource assessment to determine biological value. Due to its location in the northeastern edge of the sandhills range and geographic isolation, this site can provide important genetic diversity.

Management Opportunities
Landowners at this site should be informed of the high biological value of their property to encourage preservation of habitat around their development. Specific management recommendations require greater knowledge of the site. However, the threat of wildfire resulting from the high fuel vegetation in the area likely necessitates vegetation management. Such efforts should carefully consider the biologies of the sensitive species.

Site Name	Site Number	Approximate Acreage
Henry Cowell	13	169

Location
This site is in the northeastern portion of Henry Cowell State Park, located west of Graham Hill Road.

Ownership
The California Department of Parks and Recreation owns this site.

Zoning and land use
This site is managed as a park and recreation area and is zoned PR.

Landscape and Communities
This site contains large patches of sandhills habitat interspersed by mixed evergreen forest. The sandhills habitat is comprised primarily of silverleaf manzanita chaparral with ponderosa pine. Despite its location within a State Park, there is surprisingly little information available on the habitat as no studies have occurred at this site.

Sensitive Species
This site contains large stands of silverleaf manzanita and scattered stands of ponderosa pine. It is thought to support Ben Lomond spineflower and Mount Hermon June beetle, though this is not confirmed at the time of this report.

Stresses
This site is primarily impacted by fire exclusion and recreation. Examination of historical aerial photographs suggests that sandhills chaparral communities have been encroached upon by non-sandhills trees (e.g. madrones, tan oaks), while shrub cover has reduced the areal extent of open sand habitat. Restricted only to trails, recreation impacts at this site are relatively small, given the overall acreage of the site. However, high intensity recreation including mountain bike and equestrian use remove cover and cause erosion on slopes (e.g. Ridge Fire road trail) within the sandhills portion of the park.

Preservation Opportunities
This site is owned and managed for recreation and natural resource protection. Sandhills conservation requires an adequate balance between these uses.

Management Opportunities
Management in this site would benefit from a survey of the sandhills habitat patches within the site to determine the distribution and abundance of sensitive sandhills species. Owing to its location away from development, this site provides opportunities for fire management in the high fuel load communities of the sandhills (chaparral and ponderosa pine forest). State Parks Resource Ecologists began vegetation management in February 2003 by burning a patch of habitat just south of the campground. They intend to burn other patches of habitat. Such management should be conducted and monitored using a research framework so that information about the responses of sandhills species and communities can be obtained from these important first efforts to reintroduce fire. Recreation management at this site should focus on reducing erosion and associated impacts on trails located within the sandhills portion of the park. Due to the erosive nature of sandhills soils, this will require restricting high intensity uses and/or relocating or redesigning trails to reduce impacts.

Site Name	**Site Number**	**Approximate Acreage**
Hilton Drive	47	100

Location
This site is located north of the intersection between Highway 236 and Jamison Creek Road approx. 1.5 miles northwest of Boulder Creek. The northern third of the site straddles east Hilton Road.

Ownership
The site is primarily comprised of five private parcels under two ownerships.

Zoning and land use
The site is largely undeveloped and zoned TP and SU.

Landscape and Communities
This site is one of two Tier 1 sites (the other being Jamison Creek) that support unique communities that differ in composition from those found in other sandhills areas. While they support silverleaf manzanita, the associates in these chaparral communities are likely different from that of the sandhills chaparral communities described in this plan. These patches of habitat represent the northwest most part of the ecoregion.

Sensitive Species
Though there is little specific information available regarding their species composition, owing to the private ownership, this site is known to support silverleaf manzanita and Santa Cruz cypress. More information is needed about the habitat in this site.

Stresses
Little is known about this site, making it difficult to address the stresses.

Preservation Opportunities
Because they support two endangered endemic plants and unique communities found only in this area, known as "Bracken Brae", the five large undeveloped parcels at this site each represent important conservation opportunities. More information about the biological characteristics of this site based on ground surveys is required to fully evaluate their value to the conservation of sandhills species and communities. If they are found to support other sensitive species populations, parcels in this site would be especially important, due to their size and distance from other patches.

Management Opportunities
In the absence of specific biological information about these sites, it is not possible to describe management. Fire management may be important to reduce density of woody vegetation and facilitate persistence of Santa Cruz cypress.

Site Name	**Site Number**	**Approximate Acreage**
Sunset Ridge	33	13

Location
This site is located to the east of Newell Creek Road and the Rancho Rio neighborhood near the community of Ben Lomond.

Ownership
The site is located on the intersection of three parcels, one owned by Santa Cruz County as part of the Quail Hollow Ranch County Park, and the two are in private ownership.

Zoning and land use
This site is used for open space and currently a single rural residential development and is zoned SU and PR.

Landscape and Communities
Currently located in a matrix of mixed evergreen forest and non-sandhills chaparral, this site is presently isolated from the QHR Northwest Ridges site to the south by non-sandhills vegetation, and the West Lompico site to the north by a residential development and non-sandhills vegetation. Aerial photo analysis indicates it primarily supports silverleaf manzanita chaparral with ponderosa pine, though a small parkland site may exist in the southeast corner.

Sensitive Species
Though incomplete, current records indicate that the site supports populations of silverleaf manzanita, Ben Lomond buckwheat, and Ben Lomond spineflower. The presence of ponderosa pines suggest it may support Mount Hermon June Beetle, though it has not been examined. If parkland habitat is present, this site would likely also support other sensitive species.

Stresses
This site appears to be impacted only by fire exclusion. Aerial photographs indicate the site was previously connected to sandhills sites to the north east and south, though succession has isolated these. Within the site, the fire exclusion has reduced amount of open sandy habitat. Residential development (2 units) has occurred on either side of the habitat but separated by non-sandhills habitat. A single access road (driveway) bisects the site.

Preservation Opportunities
The two privately owned parcels within this site represent important opportunities for protection, owing to their known biology, high integrity, and adjacency to already protected habitat.

Management Opportunities
More information about the biological characteristics of the site should be obtained in order to develop management opportunities for the County Parks portion of the site, as well as to share with adjacent landowners who may be interested in preserving habitat in the undeveloped portions of their parcels.

Site Name	Site Number	Approximate Acreage
Quail Hollow Ranch CP: North West Ridge	34	73

Location
This site is located on and adjacent to the north western part of Quail Hollow Ranch County Park

Ownership
This site includes four privately owned parcels and two parcels owned by the Santa Cruz County Department of Parks and Recreation.

Zoning and land use
This site is primarily used for recreation as part of the QHR County Park, but also contains entirely or partially undeveloped privately owned parcels. This size is zoned PR-L, PR, and RA.

Landscape and Communities
The site is bisected by Quail Hollow Road, with the majority of habitat on the north and east side of the road. It contains a mix of intact non-sandhills vegetation (oak woodland, mixed evergreen forest, non-sandhills chaparral) in a mosaic with patches of sandhills communities including sand chaparral, silverleaf manzanita mixed chaparral, a small patch of sand parkland, a small patch of ponderosa pine forest, and a large area of previously sandhills habitat that is recovering naturally from use as an orchard.

Sensitive Species
This site is known to contain silverleaf manzanita, Ben Lomond spineflower, Ben Lomond buckwheat, and Mount Hermon June beetle, and thought to contain Santa Cruz wallflower. It also contains a small patch of dense sand parkland which supports a relatively low diversity of sandhills specialty species.

Stresses
This site has been negatively impacted by fire exclusion, exotic species, recreation, and agriculture. Fire exclusion has greatly reduced sandhills habitat by facilitating type conversion to non-sandhills communities. It has also fragmented remaining sandhills habitat, and reduced the amount of open habitat required by sandhills species. The eastern half of the site (i.e. in the Park) has been highly impacted by exotic plants. *Eucalypus globulus* located on the south end of the sand parkland patch have reduced habitat and create shade and dense leaf litter in remaining habitat. European annual grasses and forbs are abundant in ponderosa pine forest and the former orchard which otherwise supports a low density and diversity of sandhills species, including the Ben Lomond spineflower. Recreation has caused erosion and trampling of sandhills plants in the sandhills chaparral communities located on the western edge of the site and along the sunset trail in QHR County Park. An orchard formerly located in the large central grassy area west of the QHR County Park parking lot may have degraded habitat at the site, though the orchard was present at the time of the first available aerial photographs in 1940.

Preservation Opportunities
The site contains three contiguous large parcels (20-24 acres) that contain sandhills habitat and represent important opportunities for conservation. These include a 22 acre undeveloped site that supports intact sandhills chaparral communities, a 24 acre site that has a single home site but approximately 15 acres of adjacent intact sandhills chaparral, and a 24 acre site that includes a single home site but approximately 5 acres of sandhills chaparral located in this site and 5 acres of intact habitat in the Sunset Ridge site. Together, the habitat in these sites comprises a large area adjacent to the already protected habitat in the Quail Hollow Ranch County Park.

Management Opportunities

Habitat contained within the County Park presents several important management opportunities for sandhills habitat. Fire or other vegetation management should be used to reverse succession that has converted patches of sandhills chaparral to mixed evergreen forest. Intact sandhills chaparral should be managed to increase open sandy areas that support gap specialist herbs. The sand parkland would greatly benefit from removal of the several large *Eucalyptus*. Populations of Ben Lomond spineflower and perhaps other sandhills herbaceous plants can benefit from efforts to reduce European annual grasses and forbs in the former orchard area. Raking litter or fire in the small patch of ponderosa pine forest may enhance diversity in this site which presently supports only dense European exotics. Owners of the privately owned parcels should be informed of the uniqueness and rarity of the habitat, and encouraged to manage their sites.

Site Name	Site Number	Approximate Acreage
Vista Robles	35	28

Location
This site encompasses the rural Vista Robles neighborhood, located just north of Quail Hollow Road. It is contiguous with the two other sites: QHR Northwest Ridges is northeast (34), and Marion is southwest (36). This site is separated due to its higher–density development.

Ownership
The site includes 18 privately owned parcels.

Zoning and land use
The site supports moderate density residential development on 1 to 5 acres parcels that are zoned RA. All but 2 parcels are developed with a single home site.

Landscape and Communities
This site is comprised of a sand parkland ridge. The development has occurred primarily on the ridge top and the north east facing slope, leaving the south-west facing slope supporting patches of open sand parkland. This habitat is contiguous with part of the Marion Site, which also features some development. The northeast-facing slope historically supported open, north slope sand parkland. Presently, only the coast live oaks and a few scattered pines remain in the center of the site; however, the northeastern edge adjacent to the QHR Northwest Ridges site supports sandhills chaparral.

Sensitive Species
Despite development, this former sand parkland site is known to support a remnant Santa Cruz wallflower population as well as Ben Lomond spineflower, Ben Lomond buckwheat, and silverleaf manzanita. It is not known whether the site supports the two endangered insects, but surveys are highly encouraged given the open parkland habitat and the ponderosa pines. This site also supports a population of western whiptail lizard, known from only 2 other sandhills sites.

Stresses
This site is primarily impacted by the development that has occurred and by ongoing uses associated with development. These include recreation (trails) and road (driveway) creation and maintenance, as well as landscaping, which has recently reduced patches of sandhills habitat. Exotic annuals are abundant in the remnant patch of open sand parkland.

Preservation Opportunities
Six privately owned, residential parcels within this site were identified as important opportunities for habitat protection. Four are 2-3 acres and feature relatively intact habitat adjacent to homes. Two parcels are 5 and 10 acres, respectively, and thus have greater acreage of habitat adjacent to the home site. These latter two straddle the Marion and Vista Robles sites.

Management Opportunities
Landowners at this site should be informed of the high biological value of their property and encouraged to preserve habitat around their development. Specific management that landowners can implement to reduce impacts on intact habitat include: minimizing non-sandhills landscaping, minimizing road and trail creation, protecting Santa Cruz wallflower populations on the site, raking or other management of sand parkland to reduce litter and European annuals, and reducing subsidized predation of whiptail lizards by domestic cats.

Site Name	Site Number	Approximate Acreage
West Lompico	32	109

Location
This remote site is located on a steep ridge between Loch Lomond Reservoir and the community of Lompico.

Ownership
This site is known to include 8 large parcels, though a single large parcel may have recently been split. All parcels are privately owned except a single parcel in the south west portion of the site owned by the County of Santa Cruz which includes approximately 10 percent of the site area.

Zoning and land use
There are just two known residences at this site, which also features two separate well sites managed by the San Lorenzo Valley Water District. The site is zoned: SU and PR. The area to the north, west, and south of the site is largely undeveloped. Many small developed parcels are located in the forested community of Lompico to the east of the site.

Landscape and Communities
This site supports a mosaic of non-sandhills communities and sandhills communities including sand chaparral, silverleaf manzanita chaparral with ponderosa pine, silverleaf manzanita mixed chaparral, and a small patch of dense sand parkland on a ridge that previously may have supported a large area of open sand parkland. This site is separated from the Sunset Ridge and QHR East Ridges sites by mixed evergreen forest and non-sandhills chaparral.

Sensitive Species
Though incomplete, current records indicate that the site supports populations of silverleaf manzanita, Ben Lomond buckwheat, Ben Lomond spineflower, and Mount Hermon June Beetle. Gap specialist species are found in disturbed areas including road cuts. There is no information available about the species supported on the dense sand parkland patch.

Stresses
This site is primarily impacted by fire suppression and exotic species. Fire suppression has reduced the acreage of sandhills chaparral communities due to type conversion, fragmented remaining habitat, and reduced the open area needed for herbaceous plants in remaining chaparral stands. Exotic brooms are found along roads in the site.

Preservation Opportunities
This site represents the northern limits of sandhills habitat in the Ben Lomond region. Four large parcels containing undeveloped sandhills habitat have been identified as priorities for conservation. The parcel boundaries used in this analysis may not be accurate, however, due to recent splits.

Management Opportunities
Landowners at this site should be informed of the high biological value of their property and encouraged to preserve habitat around their development. Specific management needed at the site includes fire or other vegetation management to increase open sand areas within sandhills chaparral and the dense sand parkland, and removal of exotic broom (*G. monspessulana*) infestations along roads that could invade intact habitat. European annuals could also be reduced in the open habitat near the wells that currently supports a moderately diverse assemblage of herbaceous plants.

Site Name	Site Number	Approximate Acreage
Jamison Creek Road	48	24

Location
This site is located northwest of the town of Boulder Creek just north of the intersection between Highway 236 and Jamison Creek Road.

Ownership
This site includes five private parcels.

Zoning and land use
This area is characterized by low-density rural residential housing and is zoned SU and R-1-15. The site contains only one structure which is located adjacent to a row of developed parcels that line Jameson Creek Road.

Landscape and Communities
Like Hilton Road (site 47), and other sites in this region, this site supports unique communities that differ in composition from more widespread sandhills chaparral communities described in this plan. More information is needed to describe these communities and understand how they differ from sandhills chaparral.

Sensitive Species
Though incomplete, current records indicate that the site supports populations of silverleaf manzanita and Santa Cruz cypress, and according to the CNDDB, may support Ben Lomond spineflower, though this has not been confirmed.

Stresses
Little is known about this site, making it difficult to address the stresses.

Preservation Opportunities
Because they support two endangered endemic plants and unique communities found only in this area, three large undeveloped parcels at this site represent important conservation opportunities. More information about the biological characteristics of this site based on ground surveys is required to fully evaluate their value to the conservation of sandhills species and communities. If they are found to support other sensitive species populations, these parcels would have high value due to their size and distance from other patches.

Management Opportunities
In the absence of specific biological information about these sites, it is not possible to describe management. Fire management may be important to reduce density of woody vegetation and facilitate persistence of Santa Cruz cypress.

Site Name	Site Number	Approximate Acreage
Gray Whale Ranch	52	167

Location
This site is located west of Empire Grade Road and the upper UCSC Reserve, and to the south of Smith Grade Road.

Ownership
The large site contains only two large parcels: one owned by the California Department of Parks and Recreation (CDPR), and the other private.

Zoning and land use
The parcel owned by CDPR is within Gray Whale Ranch, a unit of Wilder Ranch State Park, and is managed for recreation and resource protection. The private parcel to the south is largely undeveloped. The site is zoned TP and CA-O.

Landscape and Communities
This site supports silverleaf manzanita mixed chaparral with some patches of non-sandhills vegetation including mixed evergreen forest. Bisected by one known trail and one access road, this site is surrounded by open space including large tracts of mixed evergreen and redwood forests.

Sensitive Species
This site supports silverleaf manzanita. It also supports Ben Lomond spineflower populations, which due to genetic differences and/or environmental conditions exhibit different morphologies than those at BDER and in the Ben Lomond sandhills. Though the habitat contains a sparse population of ponderosa pine, it is not known whether it supports Mount Hermon June Beetle. Recent surveys by CDPR biologists indicate that Ben Lomond buckwheat, Santa Cruz wallflower, Zayante band-winged grasshopper, and Santa Cruz kangaroo rat do not occur at this site.

Stresses
Though large and relatively unimpacted by development, the habitat in this site has been degraded by fire suppression and recreation. Fire exclusion has likely reduced the area of open habitat. This site exhibited minimal bare ground even in 1943 aerial photographs, suggesting it is long unburned. This site has also been degraded by high intensity recreational use which causes erosion and may directly or indirectly impact Ben Lomond spineflower populations on the north edge of the habitat (i.e. the Woodcutters trail).

Preservation Opportunities
The majority (approx. 80%) of the sandhills habitat at the site is within the CDPR property. The remainder includes late successional habitat with mixed evergreen forest, which buffers the sandhills habitat and may provide additional habitat under appropriate management.

Management Opportunities
This site can contribute to regional sandhills conservation through the implementation of fire or other vegetation management which can increase the area of open canopy conditions and potentially facilitate sensitive species at the site. The site is an excellent candidate for experimental burning owing to its need for fire, the expertise of CDPR staff in fire management, and its relative isolation. Such experimental burns can inform future fire management in other sites provided they are implemented and monitored using methods that allow quantitative assessment of their impacts. Management should minimize the negative impacts of higher intensity recreation (mountain biking and equestrian use) which can reduce spineflower populations that occur in trail corridors and cause excessive erosion.

Site Name	Site Number	Approximate Acreage
Marion	36	95

Location
This site is located along Marion Road and Quail Hollow Road in Ben Lomond. Contiguous with Vista Robles (site 35) and Hidden Valley (site 37), it is separated from them due to its lower density of development.

Ownership
The eastern edge of this site includes a parcel owned by the County of Santa Cruz and a parcel owned by the State of California, which total approximately 15% of the site. The remainder is composed of approximately 40 privately owned parcels.

Zoning and land use
This rural residential area includes parcels ranging from 1 to 30 acres, with many undeveloped. It is zoned: SU, RA, PR, R1, R-1-15

Landscape and Communities
The site has variable development within it and is adjacent to an elementary school and a moderate density neighborhood. Habitat on the site is composed of a mosaic of communities that are not unique to the sandhills, including oak woodland, mixed evergreen forest, and knob cone chaparral, amidst sandhills habitat supporting sand chaparral, silverleaf manzanita mixed chaparral, and sand parkland.

Sensitive Species
Though incomplete, current records indicate that the site supports populations of silverleaf manzanita, Ben Lomond spineflower, Ben Lomond buckwheat, and Mount Hermon June beetle. It contains a patch of degraded sand parkland which may support Zayante band-winged grasshopper and Santa Cruz wallflower. Like the adjacent Vista Robles site, this site likely also supports western whiptail lizards.

Stresses
Fire exclusion has likely impacted sensitive species populations on the eastern edge of this site. The remainder is primarily impacted by development and associated land uses including recreation. There are a variety of *de facto* trails through sandhills chaparral communities within the site, especially near the Quail Hollow School. A mine or other large scale disturbance has degraded otherwise undeveloped parcels east of Marion, where ongoing OHV use further erodes and degrades the habitat, threatening sensitive species located at the site.

Preservation Opportunities
Owing to their biological value and location near other protected habitat, six privately owned parcels within this site were identified as important opportunities for habitat preservation. They range from 5-30 acres and have relatively large tracts of intact habitat adjacent to the home sites.

Management Opportunities
Landowners at this site should be informed of the high biological value of their property and encouraged to preserve habitat around their residences by primarily avoiding additional disturbance of intact vegetation, (e.g. new roads, destructive recreation), minimizing non-sandhills landscaping, and minimizing predation by domestic cats.

Site Name	Site Number	Approximate Acreage
Landfill Heights	43	95

Location

This site is located east of Newell Creek Road and west of Glen Arbor Road, adjacent to the Santa Cruz County Landfill in Ben Lomond. Though contiguous with remnant sandhills habitat within the Glen Arbor site, the habitat of this site was distinguished because of its reduced residential development.

Ownership

This site contains approximately 27 parcels. Five adjacent parcels on the east end are owned by Santa Cruz County as part of their landfill, while approximately 22 privately owned parcels border the landfill to the west and south.

Zoning and land use

Parcels within the site range from 2-45 acres and primarily have low-density residential development.

Landscape and Communities

This site supports oak woodland habitat on the eastern border, but otherwise is comprised entirely of sandhills chaparral communities including sand chaparral, silverleaf manzanita mixed chaparral, and silverleaf manzanita with ponderosa pine. Though the adjacent landscape is either destroyed (landfill) or moderately densely developed (Glen Arbor Site), this swath of habitat in between is relatively intact.

Sensitive Species

Though likely incomplete, current records indicate that this site supports high-density populations of silverleaf manzanita and Ben Lomond buckwheat. The site likely also supports Ben Lomond spineflower, and based on the presence of ponderosa pines, may support Mount Hermon June beetle.

Stresses

Little is known about the ecology of this site. It may be impacted by fire exclusion, which has reduced some of the open habitat amidst the chaparral shrub canopy, though not to as great an extent as in other sandhills chaparral sites. This could be because the site burned in 1954. The site may be impacted by recreation from adjacent neighborhoods, though this is unknown.

Preservation Opportunities

One important conservation opportunity lies in the habitat adjacent to the landfill owned by the County of Santa Cruz. This intact sandhills chaparral should be preserved, rather than used for additional refuse deposition. In addition, there are 11 privately owned parcels at this site that may provide opportunities for habitat preservation. One 45-acre site is completely undeveloped. A 20-acre site has a single home site on its edge, with the remaining habitat apparently unimpacted by development. An additional 16-acre site similarly supports sandhills chaparral. Four parcels each approximately 5 acres in size similarly have intact habitat adjacent to the home site and contiguous with habitat that could be preserved by the County.

Management Opportunities

Landowners within and adjacent to this site (i.e. Glen Arbor Road) should be informed of the high biological value of the site and encouraged to protect habitat by: avoiding additional disturbance of intact vegetation around their residences, reducing recreation impacts, and minimizing non-sandhills landscaping. Vegetation management may be needed to reduce the risk of wildfire at this site. Such management should follow guidelines in this plan or otherwise take into account the unique ecology of the system.

Site Name	**Site Number**	**Approximate Acreage**
Zayante School Road	26	42

Location
The site straddles either side of Zayante School Road, located east of East Zayante Road north of the intersection with Quail Hollow Road.

Ownership
This site contains 11 privately owned parcels.

Zoning and land use
The site and surrounding areas are characterized by low density, rural residential housing and is zoned SU and RA

Landscape and Communities
This site contains a mix of sandhills communities including a degraded sand parkland site and sandhills chaparral communities, in a matrix of non-sandhills communities including mixed evergreen and redwood forest, and rural development.

Sensitive Species
Though incomplete and potentially outdated, current records indicate that the parkland at the site supports Ben Lomond spineflower, Santa Cruz wallflower, and Ben Lomond buckwheat. Ponderosa pines are present, suggesting the site may support Mount Hermon June beetle. Though present, silverleaf manzanita is not abundant.

Stresses
Fire exclusion and impacts associated with residential development have impacted the habitat at this site. Though the site previously supported open sand parkland, succession by non-sandhills chaparral combined with residential development and associated uses including probably recreation by OHVs has likely degraded the sand parkland habitat at this site. Fire exclusion has allowed encroachment of mixed evergreen forest into the sandhills chaparral communities at the site.

Preservation Opportunities
Incomplete and potentially outdated records for this site render it difficult to evaluate conservation priorities. Pending more information about the sand parkland at the site, however, two parcels supporting degraded sand parkland could represent important opportunities. More information is needed about this important site that, due to proximity to the Olympia Wellfield site (25), can increase overall acreage of protected habitat.

Management Opportunities
Landowners at this site should be informed of the high biological value of the site and encouraged to preserve habitat around their residences by primarily avoiding additional disturbance of intact vegetation, (e.g. new roads, destructive recreation) and minimizing non-sandhills landscaping.

CHAPTER 7

GENERAL APPROACHES TO SANDHILLS MANAGEMENT

INTRODUCTION

Due to the negative impacts of habitat degradation, active management of sandhills species and communities is essential to their persistence, even within protected sandhills preserves. Efforts to manange native biodiversity in the sandhills must confront many challenges presented by the ecological complexity and extreme rarity of the system. Through devising specific strategies for the management of the known threats to sandhills species in protected reserves (Chapter 4), several common management considerations and approaches emerged. Described in terms of their scientific basis and rationale for the sandhills, these general management guidelines provide a background for specific management strategies devised in this plan (Chapters 7-9) and will hopefully assist managers as they continue to confront new threats that may emerge following completion of this plan.

Addressed in the order in which policy makers and managers will approach management, the sections of this chapter discuss the following aspects of management: 1) Need, 2) Planning, 3) Goals, 4) Strategies, and 5) Techniques.

7.1 NEED FOR MANAGEMENT

In order to maintain native biodiversity in protected sandhills habitat, management must be active. While habitat preservation is essential, it will not be sufficient to recover endangered species nor maintain natural community structure within protected reserves. In the long run, this is likely true of most natural systems in California. However, three aspects of sandhills ecology point to their urgent need for active management.

Sandhills are Dynamic

Ecologically speaking, the sandhills are a dynamic system in which natural, recurring disturbances enhance diversity through both space and time by creating a mosaic of habitat conditions (Section 3.7). Ongoing anthropogenic disruption of natural disturbance regimes (e.g. fire exclusion) creates late successional conditions over a large area. Such habitat is unsuitable for the many sandhills species adapted to post-disturbance conditions including the Santa Cruz wallflower, Ben Lomond spineflower, Santa Cruz kangaroo rat, and Zayante band-winged grasshopper. Allowing natural disturbance processes to occur (e.g. wildfire cycle) is not be feasible due to human habitation in and around sandhills habitat. This necessitates active management to mimic disturbance effects and thus maintain conditions required for species and community persistence.

Sandhills have been degraded

Anthropogenic threats to sandhills habitat impact native species even within protected reserves. In addition to fire suppression, exotic plant species have reduced populations of native plants, including the two federally listed species, and altered community structure, including habitat conditions required for the Zayante band-winged grasshopper (Chapter 9; McGraw 2004). Barring active management, the spread of these species and the continual introductions of other exotic species will further threaten native biodiversity in the sandhills. Unregulated recreational use is similarly impacting 'protected' habitat. In the absence of efforts to actively manage use, sandhills habitat will be further degraded and populations of sensitive species reduced and perhaps ultimately lost (Section 4.3).

Extirpations are Occurring

For evidence that active management is urgently needed to address the degradation of sandhills habitat, one need only consider the recent population extirpations (local extinctions) of sandhills endemics in patches of protected, yet unmanaged, sandhills habitat. Populations of the Santa Cruz wallflower and Santa Cruz kangaroo rat have been extirpated, reducing their distributions, overall abundance, and thus likelihood of persistence (Bean 2003, Morgan 2003). Not random or chance events, these extinctions can be linked to loss of habitat quality, and suggest that other unstudied species with similar habitat requirements are also being extirpated. Active management is needed to halt, reverse, and repair the degradation to sandhills habitat before the species are lost.

7.2 MANAGEMENT PLANNING

The rarity, unique ecology, and complex threats in the sandhills necessitate careful management planning. With less than 4,000 acres of habitat remaining (Section 6.3), there is little room for neglect or poor management. The ecology of the sandhills is both unique, and diverse, due to the various species, natural processes, and anthropogenic stresses found at different sites. Management strategies, techniques, and potential impacts must be carefully considered prior to implementation. The incorporation of adaptive management can greatly facilitate long-term success.

Though management is traditionally regarded as a conservation strategy to be implemented by individual organizations, sandhills management should be planned at the regional, site, and ownership levels to maximize conservation benefit.

Regional Planning

Regional planning should be used to develop a unified strategy to sustain biodiversity throughout sandhills habitat by identifying management priorities for individual habitat patches that could maximize regional conservation benefit while meeting site management goals. Though many threats or stresses in sandhills habitat are widespread (Chapter 4), their intensity or degree of impact is not uniformly distributed within sandhills patches and neither is the distribution of community types and sensitive species. By examining the spatial distribution of communities, populations, and stresses throughout remaining sandhills habitat, ecoregional planning should identify site-specific management strategies that could be used to meet ecoregional goals for the maintenance of native biodiversity in protected sandhills habitat.

The multiple entities responsible for sandhills conservation and management render ecoregional planning both essential for long-term persistence yet immensely challenging. No one agency has ultimate responsibility or authority for sandhills habitat. An independent entity, such as the Sandhills Alliance for Natural Diversity (SAND), might coordinate efforts towards ecoregional planning via the development of long-range plan for sandhills management.

Site Planning

Though often used to refer to a contiguous area of land under the same ownership, the term "site" is used here consistent with its definition in the conservation planning process (Section 6.1), to refer to a contiguous area of sandhills habitat irrespective of ownership. Many stresses to sandhills habitat, are contagious (i.e. spatially autocorrelated) and thus typically impact entire sites. For this reason, management planning should occur at the site level. This can be difficult, as most sandhills sites have multiple owners. However, managing habitat at the individual ownership level can be logistically difficult, as in the case of fire management (Chapter 8), or in vain, as in exotic plant management where eradication of an exotic species from a habitat under single ownership will be followed by reinfestation from adjacent, untreated habitat if management is not coordinated at the site level.

Ownership Planning

Despite planning of management strategies at the regional level and coordination of management techniques at the site level, individual landowners, be they agencies, organizations, or private citizens, will likely be ultimately implementing management activities within their own property. A detailed and well developed management plan specific to the site will be crucial to enhancing and maintaining biodiversity in the sandhills. This section outlines the elements and processes of a management plan for the site or ownership level.

Preparation of a Management Plan

From design to implementation to evaluation, management in the sandhills should follow a comprehensive management plan. Acknowledging that individual organizations have their own directives and criteria, the following are recommendations for essential components of sandhills management plans.

<u>Plans should be specific for the area</u>

A management plan should be developed for each area to be managed, be it by a single entity or through a cooperative agreement among landowners. Though plans from other sandhills sites can provide ideas for approaches and techniques, or serve as templates for plan development, sandhills sites differ in ways that should determine essential aspects of the management plan including priorities, specific treatments, and monitoring methods.

<u>Plans should be developed following a detailed site assessment</u>

Plan preparation should begin with a thorough assessment of the site, which can reveal both the opportunities and constraints for management. Using systematic surveys, individuals experienced with sandhills ecology should document important aspects of the sites including the geology, plant communities, sensitive species, and stresses (e.g. fire, exotic plants, erosion, etc.).

The information should be spatially explicit, either via a GIS or hand drawn maps, to facilitate identification of treatment areas and planning monitoring. If designed and executed using appropriate methods, quantitative sampling can allow the inventory to serve as baseline data for post-management monitoring.

Plans should be comprehensive and detailed

Management goals, strategies, and techniques to address the stresses identified through the biological assessment should be evaluated through consideration of the complex interrelationships that make up the ecology of the site. Management activities will, in most cases, have both direct and indirect effects on sandhills species that will propagate through the system. Management strategies should first begin by examining the "big picture", which includes all species, communities, and threats, prior to pursuing any one avenue. The pay off for the upfront commitment of resources to develop a management plan will be greater success in long-term management.

Whether organization staff or consultants complete the plan, sufficient resources should be committed to the plan including time (e.g. for assessment and development), funding, and expertise. The organization should seek peer review from those experienced in sandhills ecology including scientists and managers. Members of the Sandhills Alliance for Natural Diversity (SAND) have experience in sandhills biology, ecology, and management and may be available to review management plants. Management plans should also be submitted for comment to the resource agencies (California Department of Fish and Game, United States Fish and Wildlife Service) as well as local government entities (County of Santa Cruz, City of Scotts Valley).

Management Plan Elements

Though it is beyond the scope of this plan to outline all of the elements of a management plan, the following are recommended contents.

Goals and Objectives: Specific goals and objectives are the cornerstone for management planning and sufficient time should be devoted to their preparation. As described below, separate goals and objectives will be necessary for individual management targets identified, which may include different treatment areas, different projects (fire vs. exotic species), and different time scales (short-term vs. long-term), among others.

Priorities: Because management needs will likely exceed available resources, a management plan should set priorities. A cost-benefit analysis of management should incorporate the cost savings associated with avoiding or minimizing future threats, as well as mitigating current impacts. An objective prioritization should be used to avoid inadvertent biases in determining management activities.

Adaptability: The plan should include mechanisms for evaluating and altering management based on the outcomes of management (Section 7.6). In addition, it should allow for priorities to be shifted or new priorities introduced in the event that new threats or opportunities emerge.

7.3 MANAGEMENT GOALS

What are appropriate goals for sandhills management? How should they be determined? The purpose of this section is to provide an overview of important considerations: targets, spatial scales, and time frames.

Management Targets

Developing management goals requires identification of the components of the system management is designed to enhance. Environmental laws designed to conserve biodiversity at the species level (e.g. endangered species acts) resulted in an emphasis on single species management in the 1970s and 1980s. Concern that single species management efforts harmed larger communities, either due to management actions or simply neglect, combined with the recognition that species protection is often accomplished through ecosystem protection, has shifted attention toward protecting sensitive communities and the species they contain.

In view of the several listed plants and animals that occur in the sandhills, management must consider endangered species. In addition to the listed species, however, the sandhills support unique and diverse assemblages of species (i.e. communities) found no where else in the world. These communities support the wealth of biodiversity that exists at the species as well as genetic level (e.g. undescribed species and ecotypes). As a result, sandhills management goals for maintaining natural community structure should be pursued concurrently with goals for sensitive species.

Single Species Goals

Sandhills management is crucial to maintain populations of rare or unique species, many of which are in decline and threatened by habitat degradation (Chapters 4-5). Management goals for single species can include enhancing population growth, abundance, extent, and individual performance.

Population growth: Increasing rates of population growth, measured simply as population density at one time period divided the density at some time period before (N_{t+1}/N_t), can be an appropriate goal for some sensitive species at a site. This requires periodic monitoring using a standardized sampling regime for evaluation.

Abundance: Increasing density (number of individuals) of a sensitive species within the area of concern can be a goal for management. Natural periodic fluctuations may make it difficult to discern meaningful changes, however, so coupling goals for abundance with other performance goals (e.g. extent, individual performance) can be useful.

Extent: Increasing the area of habitat occupied by a rare species can be an appropriate management goal, as it can reflect changes in habitat suitability due to management. Increasing the areal extent of a species, provided density is not reduced, will likely enhance population persistence.

Individual performance: Goals can be set for increasing the demographic performance of the target population, assuming there is information linking individual success measures to population performance. Fecundity (number of offspring produced), survivorship (number of individuals that survive between two time periods), and individual growth are oftentimes used to measure management success as they can be correlated with population performance.

Community Goals

Natural lands management efforts designed to enhance communities have emphasized the goal of maximizing species diversity, a goal that is often not well defined. First, species diversity varies in how it is calculated. Technically, it is defined as some combination of species richness, the number of species, and evenness, the degree to which each species is equally abundant in the community(Hayek and Buzas 1997). However, in most research and monitoring efforts, diversity is measured solely as species richness. If the goal of management is simply to maintain persisting populations of species, then species richness may be an appropriate target. However, enhancing actual diversity must consider the relative abundance of species as well.

Second, though most managers working to enhance community diversity (or richness) are genuinely concerned with the entire community, management and research oftentimes focus solely on diversity of one group of organisms (e.g. plant diversity, small mammal diversity, arthropod diversity, etc.). This is primarily due to logistical constraints including lack of expertise required to examine diversity at all taxonomic levels, and the extensive effort required to monitor management impacts on all organisms. The implicit assumption is often that higher diversity for one set of organisms (e.g. plants) correlates with greater diversity at all levels.

Third, and perhaps most importantly for management in the sandhills, diversity exists at several spatial scales. Most research and monitoring programs focus on enhancing alpha diversity, or the diversity of species in a given place. Efforts to maximize the number of species measured in a quadrat ignore beta diversity, which is the difference in species composition between areas, and gamma diversity, the sum total of alpha and beta diversity. Though it may be interesting to understand the impacts of management (or a stress) on species diversity within an area, the relevant question for management should be: how does this treatment (or stress) impact overall community diversity? For example, to evaluate whether fire enhances diversity, one might compare species richness in burned and unburned areas (alpha diversity); however, the real criterion for management should be whether burned and unburned areas, together, have greater diversity than unburned areas alone.

Patch Mosaics: Management in the sandhills to enhance total (landscape level) diversity can be facilitated by designing management strategies that create and maintain a patch mosaic of communities (Borsmann and Likens 1979, Forman and Gordon 1986). In communities with complex disturbance regimes such as the sandhills, disturbances of different types act at varying spatial scales to create patches of disturbed habitat of different sizes, resulting in a landscape that naturally consists of a patchwork of plant communities in various successional stages (Sousa 1984a, Baker 1993). Due to their different abiotic and biotic conditions, patches of different successional age support different species. Thus, a patch mosaic approach to management has strong potential to enhance overall diversity (Petraitis et al. 1989, Huston 1994).

In the sandhills, fire and soil disturbances increased alpha diversity of the herbaceous plant assemblage (Section 3.7). More importantly, as patchy components of the overall landscape, these disturbances enhance *total* diversity (McGraw 2004, McGraw 2004, *in prep.*). Meanwhile, studies of the rare insects and Santa Cruz kangaroo rat suggest a patch mosaic may be important for their persistence (Arnold 1999a, Chu 2002, Bean 2003). Behavioral observations of the Zayante band-winged grasshopper revealed that it requires patchy habitat conditions to persist, using open sand areas dominated by early successional herbaceous plants for basking and feeding, and later successional patches dominated by subshrubs for escaping intense summer heat (Chu 2002). This dependence on the patch mosaic for animal species is likely the rule, rather than the exception; emphasizing the need for even single species focused management efforts to consider the importance of maintaining a patch mosaic.

Managers are often tempted to create *the* habitat conditions thought to be preferred by sensitive species. For example, one might propose to increase the density of ponderosa pine in sand parkland because current evidence suggests it is the host plant for larval Mount Hermon June beetle (Section 5.6). However, ponderosa pines restrict the distribution of many native herbaceous plants unique to sand parkland, including populations of Ben Lomond spineflower and Santa Cruz wallflower (McGraw 2004). Presently, ponderosa pines occur patchily within sand parkland, which provides habitat both for species that require pines and those that do not occur under pines, including the Zayante band-winged grasshopper. Thus, filing in the gaps in pine distributions to enhance populations of Mount Hermon June beetle would reduce overall diversity.

Time frame

Management goals may differ depending on the time frame examined, necessitating both short-term goals and long-term goals. Setting long-range goals and then working back can be an effective means of planning long-term management.

Some management treatments may influence species through complex interactions, thus requiring longer time frames to assess their impacts. For example, prescription burning might be expected to initially reduce populations of a rare plant, such as the Ben Lomond spineflower, by directly negatively impacting seed germination. Over several years, however, these populations would be expected to increase dramatically, as fire would have indirect positive effect by creating open habitat previously unoccupied by the species (McGraw 2004). Evaluating the success of management and determining whether goals are attained requires consideration of these different time scales.

Managers should frequently update goals in terms of the new information available, both as a result of research and evaluation of their own management projects through adaptive management (Section 7.6). Though long-term goals should be used to guide management efforts, they should be adaptable.

7.4 MANAGEMENT STRATEGIES: THE ROLE OF DISTURBANCES

Management strategies to enhance sensitive species populations and maintain or restore natural community composition should address the stresses to the system. Current known stressors in the sandhills are fire exclusion, exotic plants, and recreation (Section 4.3). Managers can utilize natural community functions (disturbance, species interactions) to promote natural community structure (species, community types, and the patch mosaic).

While much attention in sandhills management is given to structure, including maintaining populations of sensitive species and native species diversity, insufficient emphasis is given to the processes that maintain community structure naturally. These processes can provide the integrated, long-term, sustainable approach to maintaining management goals. In the sandhills, a variety of natural disturbances play a crucial role in maintaining sandhills structure (species and communities), and provide powerful tools for alleviating multiple threats of sandhills populations and communities. An overall strategy based on managing disturbances is therefore recommended as a means of attaining management goals for sandhills species and communities.

Defining Disturbance

The term 'disturbance' takes on many meanings even within discourse regarding natural lands management. The term is often used to describe a negative impact caused by humans that disrupt the system or habitat conditions. Managers will often refer to an area that has been mechanically manipulated (e.g. by a vehicle or heavy equipment) as a "disturbance" or "disturbed" area. In this usage, disturbance has a purely negative context.

Ecologists use the term "disturbance" to describe natural events that remove established biomass by killing animals and killing and damaging plants (Sousa 1984b), such as fires, hurricanes, or small mammal diggings, among others. A natural part of most ecological systems, such disturbances remove dominant species, free up resources, allow for the persistence of competitively inferior species, and create habitat conditions required for many animals. As such, natural disturbances typically promote diversity and are essential components of natural systems (Petraitis et al. 1989, Huston 1994).

In this document, the term "disturbance" will be used to describe any event that removes established biomass (Sousa 1984b). The term natural disturbance' will be used to specifically identify natural components of the sandhill disturbance regime, which include fire and soil disturbances. The term 'anthropogenic disturbances' will be used to refer to human caused disturbances, including recreation, road grading, and other manipulations.

Different types of disturbance impact sandhills species and communities by similar mechanisms; however, their consequences depend on complex interactions between characteristics of the disturbance and the characteristics of the habitat (Sousa 1984b). In addition, disturbance processes set in motion a series of direct effects and feedbacks, such that the ultimate impacts of disturbance depend not only on the habitat and the disturbance characteristics, but on the on community components being examined (e.g. June beetle density, native plant diversity, etc.) and the spatial and temporal scale at which it is examined. This complexity makes it essential that sandhills managers and policy makers careful consider the consequences of disturbance to avoid potentially irreparable damage to sensitive sandhills species and communities.

This section outlines how disturbance regime components, habitat characteristics, and aspects of the species biology interact to determine disturbance impacts in the sandhills (Table 7.1), then discusses how direct and indirect effects occurring at a variety of temporal and spatial scales determine the impacts of disturbance for species and communities in the sandhills. It is intended to provide a conceptual background and context for the specific management techniques involving disturbance that are recommended in Chapter 7-9.

Disturbance Characteristics

The characteristics of a given type of disturbance, often referred to as the 'disturbance regime', which greatly influence disturbance impacts are as follows (Sousa 1984b).

Magnitude: The magnitude of disturbance depends on two components: severity and intensity

Intensity: The intensity measures the strength of the disturbing forces (e.g. pressure, sheering).

Severity: The severity of a disturbance is measured by the damage it causes (e.g. amount of biomass removed, number of individuals killed).

Return Interval: The amount of time between disturbances, the return interval is often (incorrectly) referred to as the disturbance frequency, which is actually the number of disturbances that occur in a given time.

Areal Extent: The size of the area impacted by the disturbance.

Shape of Disturbance: The configuration of the disturbed area.

Timing: The timing of disturbance, in terms of the season or time of day, can influence soil conditions, as well as the phenology of plants and animals, and therefore disturbance impacts.

Habitat Characteristics

The characteristics of the habitat can determine disturbance impacts in the sandhills. Topography, soil conditions, and plant community structure are three general aspects of the habitat that will likely influence the consequences of a given type of disturbance in the sandhills.

Topography: The slope of the habitat varies widely in the sandhills, and will influence whether disturbances cause erosion by overland water flow, gravity, and wind. Topography can also influence fire behavior and affects.

Soils: Sandhills soils vary in their degree of thickness (Section 2.3). In most places soils are deep and loose, like beach sand. In some areas, however, soils are thin and perched on consolidated material (sandstone).

Plant Community: Dense ground cover comprised of thick leaf litter and, to a lesser extent dense assemblages of herbaceous plants, can reduce disturbance impacts on soil. The successional status of the community will also influence impact. In late succession habitats, disturbances may make resources available to early successional species that can be excluded in the absence of disturbance. In early successional communities (e.g. after fire), disturbance could cause greater soil erosion due to the lack of vegetation to cushion the disturbing forces.

Table 7.1 Factors influencing disturbance impacts in the sandhills, as described in text.

Disturbance Characteristics	Habitat Factors	Species Biology
Intensity	Topography	Size
Severity	Soils	Life History
Return Interval	Plant Community Structure	Phenology
Areal Extent		Behavior
Shape		Habitat Specificity
Timing		

Characteristics of the Species Being Examined

Further complicating assessments of management impacts, the effects of disturbance will depend on the species being examined, as different species respond differently, owing to aspects of their biology. For example, fire effects will depend on the characteristics of the burn, the community in which it takes place, and the species being examined. Of particular importance for consideration of disturbance management are the size, life history, phenology, behavior, and habitat specificity. (Characteristics of the seven endangered species are provided in Chapter 5.)

Size

The size of an organism can influence the impacts of disturbance. Trampling that would uproot diminutive herbaceous plants would not have the same effects on large statured shrubs and trees. Similarly, activities that would trample and kill small insects such as the Zayante band-winged grasshopper would have little or no effect on large mammals (e.g. deer). For this reason, trampling disturbances can have disproportionate impacts on the many small-statured sandhills species, including six of the seven endangered species (Chapter 5).

Life History

The sequence and timing of events in the life of an organism, known as its life history, will influence the impacts of disturbance. Both plants and animals evolve to persist in a given environment via the specific timing of birth, growth, and reproduction. As previously addressed (Section 3.2), such adaptations are often necessary for many species to persist in the hot, droughty sandhills environment (McGraw 2004). However, the life history of species can also evolve as an adaptation to a particular regime of disturbance (e.g. fire) as well. This has been well illustrated through extensive research in the chaparral communities of California (Keeley 1977, 1987, Keeley and Keeley 1987, Keeley 1991).

Anthropogenic disturbances often do not mimic natural disturbances in terms of seasonality, and thus negatively impact species that are not adapted to the timing (Pavlovic 1994). Managers should carefully consider the life history of the specific species or suites of organisms (e.g. annual plants) in their assessment of management impacts, and be especially cautious when managing disturbances such as wet season fires or high intensity recreation, with which sandhills species have not evolved.

Phenology

Disturbances impacts are also influenced by the organisms phenology, or annual timing of establishment, growth, and reproduction, as it can determine the organisms vulnerability, or perhaps positive response, to disturbance. For example, annual and short-lived perennial plants are often more susceptible to disturbance impacts (e.g. trampling, fire) during early seedling establishment (late fall-early spring); however, disturbance prior to reproduction can impact next year's recruitment by influencing seed set. Managers controlling exotic plant species are familiar with the importance of phenology in determining the success of disturbance-based treatments in reducing the abundance of exotic plants, and often conduct control efforts (grazing, fire) during the time when the undesirable plant is *most* susceptible to disturbance. Many animals are similarly more susceptible to disturbance during different parts of the year, though typically less is known about their phenologies owing to their cryptic behaviors.

Behavior

The behavior of an animal species can influence the impacts of disturbance. Highly mobile animals that can detect and respond rapidly may be able to avoid being directly impacted by the disturbance, while low vagility animals may be casualties of the disturbance. An animals behavior interactions with the various disturbance characteristics to influence impacts. For example a fast moving recreator (OHV, bicycle) would be more likely to kill an animal than a slow moving recreator (pedestrian).

Disturbances that do not kill an animal directly can nonetheless have important impacts for individuals and populations. Animals that must evade chronic disturbance (e.g. recreation) do so at an energy cost, which can influence survivorship and reproduction. Chronic disturbances can also directly influence a species reproduction, by disrupting reproduction events.

Habitat specificity

The habitat specificity of the species in question will determine the impacts of disturbance or management in general. A species restricted to one type of habitat is unlikely to be directly impacted by disturbance or management which occurs in another habitat type. For this reason, managers should become familiar with the specific characteristics of the habitat of the sensitive species of the sandhills (Chapter 6).

More importantly, many sandhills species including several sensitive species are preferentially found in disturbed areas, including gaps in sandhills chaparral communities maintained by wildlife trails or open sand parkland habitat created by fire. While these species are often indirectly facilitated by disturbance, in that disturbance maintains their specific required habitat conditions, they are often directly *negatively* impacted by disturbance events themselves. This disturbance-dependent ecology of many sensitive species in the sandhills should not be used as a reason to avoid disturbance, but instead to emphasize the importance of careful evaluation of the characteristics of the disturbance, habitat, and species life history, as well as the direct, indirect, and net effects, as described below.

Direct, Indirect, and Net Effects of Disturbance in Management

Disturbances, by definition, initially impact plants and animals directly by killing or damaging them. Because of the interconnected relationships among sandhills species and between species and the physical environment, however, this direct effect of disturbance can initiate a chain reaction of *in*direct effects, many of which result in positive feedbacks for sandhills species and communities. The importance of many such complex interactions initiated by disturbance for the persistence of endangered plants has been revealed through experimental research in the sandhills (McGraw 2004). Such indirect feedbacks are likely the rule in the sandhills and may play important roles in determining the outcome of management techniques that incorporate disturbance.

The direct and indirect effects can be difficult to predict, and in some cases, may be in conflict (i.e. one positive, one negative), rendering decisions regarding management techniques difficult. In some cases, the direct and indirect effects of disturbance might have the same outcome. For example, fire in sand parkland benefited some rare plants directly by promoting seed germination, and *indirectly* by reducing exotic species—both effects were positive. However, other strategies may have direct and indirect effects with different consequences. For example, fire may directly negatively impact grasshoppers, kangaroo rats, or other animals by killing individuals and thus reducing population density. The same fires, however, may have an indirect positive effect on sandhills animals by reducing the cover of woody vegetation and thus creating more habitat for future populations to occupy. If the increase in population density through time due to the expansion of the animals' distribution into the newly created habitat overcomes the initial direct mortality caused by the fire, then such a management strategy would have an overriding positive effect and thus be beneficial. Natural systems are complex. Evaluation of potential management techniques should consider direct and indirect effects and, in many cases, *net* effects should be used to guide management decisions.

Predicting the net effect of a particular management technique may be difficult. Small-scale experimental research prior to large-scale implementation and adaptive management can help managers confront this uncertainty (Section 7.5), which can lead managers and policy makers to do nothing for fear of potential negative outcomes. In evaluating management strategies, the potential consequences of proposed techniques should be compared to those of "no management", which oftentimes can have serious negative impacts (Section 4.3).

Disturbance Mimics in Management

In situations where natural disturbances have been excluded (e.g. fire), anthropogenic disturbances can be used to mimic the beneficial effects of natural disturbances (Pavlovic 1994). Tight evolutionary relationship between disturbance-dependent species and the disturbance regimes to which they are adapted require that disturbance mimics match the natural disturbances in all or most aspects of the natural regime including the type, seasonality, intensity, frequency, and areal extent of disturbance. Departures from aspects of the natural regime may not only fail to facilitate the native species, but can cause detrimental effects on rare species.

For example, though the sandhills plants may be adapted to summer fire (the likely fire season in the sandhills), wet season burns might have negative effects on native populations by killing the aboveground individuals and steaming and thus killing seed in the seed bank. As another example, wildlife trails facilitate many native plants by maintaining areas free of woody vegetation, removing litter, and reducing exotic plant abundance (McGraw 2004). Most recreation causes a higher intensity and frequency of use that does not benefit herbaceous plants, which are instead trampled (J. McGraw, unpublished data).

Effective use of disturbance mimics requires a thorough understanding of the ecology of natural disturbance and should only be used as a management technique following experimental trials or through adaptive management using small treatment areas (McGraw 2004).

7.5 Management Techniques: Scientific Approaches to Enhance Success

Within an overall management strategy based on understanding and utilizing natural processes (e.g. disturbance), specific management techniques should be determined and designed using empirical evidence of sandhills communities and species. Research examining the effectiveness of management techniques to enhance rare species populations and community diversity in other systems throughout California has provided abundant information that can be used to generate hypotheses for the potential utility of management techniques in the sandhills. However, the unique ecology of sandhills species and communities requires that research be conducted within the sandhills to test the effectiveness of specific strategies before they are implemented at large spatial scales within sandhills habitat. Moreover, the variability in communities *within* sandhills habitat renders it equally important that strategies be tested within the specific community in which they will ultimately be used. Furthermore, because individual sites differ greatly in various environmental conditions and their species pools, which can interact in complex ways to determine impacts of management efforts, research to examine the effects of potential management should be conducted within the site at which it will be implemented, or ideally, at multiple sites to look for generality of response.

Research

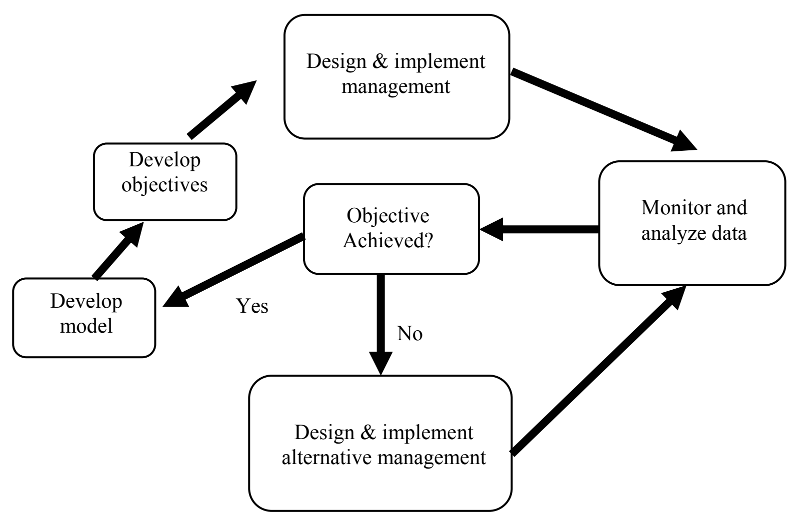
Ideally, research evaluating the impacts of proposed techniques to manage sandhills habitat should precede large-scale management efforts. Carefully designed, implemented, and monitored manipulative experiments can provide insight into sandhills ecology while testing the efficacy of management treatments (Section 12.3). For example, the author used manipulative experiments to examine the direct and indirect effects, via exotic species, of managing sand parkland communities using fire and soil disturbances (McGraw 2004). Given that sandhills species are threatened by the suppression of disturbances with which they have evolved over millions of years, it is not surprising that these treatments increased diversity and enhanced demographic performance of the two endangered plants. Though their common evolution in the disturbance-adapted system suggests other species in the sandhills may similarly benefit from natural disturbances, fire impacts on sandhills animals have not been empirically evaluated.

Management treatments may differ from experimental trials in ways that can influence their effects, including the size, shape, intensity, and other aspects of management treatments. To evaluate the effectiveness of management and increase knowledge of the biology of sandhills species, all management in the sandhills should use an adaptive management approach.

Adaptive Management

Adaptive management is the process by which management activities are monitored using a scientific research design, which allows statistical analysis of changes due to management and therefore management effectiveness (Lee 1999). Following a cycle of activities (Figure 7.1), adaptive management includes six main steps: 1) development of a model of the system and/or species, 2) development of objective that describe the desired conditions, 3) management designed and implemented to meet the objective(s), 4) monitoring of the system, 5) data analysis to determine whether objectives were reached, and 6) change management based on new insights gained if objectives are not met. Greater details about adaptive management, including step by step guidance for the development of adaptive management plans are provided in the literature (Walters and Holling 1990, Nyberg 1998, Lee 1999, Elzinga et al. 2001). This section provides the rationale for using adaptive management in the sandhills.

Figure 7.1: Adaptive management cycle as described in text (from (Elzinga et al. 2001).



Adaptive management can play three crucial roles conserving biodiversity in the sandhills: 1) increase the effectiveness of management, 2) provide additional biological information on sandhills species and communities, and 3) allow management when sufficient knowledge of the system is lacking (Elzinga et al. 2001).

Increase effectiveness of management

Even though previous research may have examined the effects of a specific management technique, for example fire in sand parkland (McGraw 2004), implementing management at different spatial scales, in different sites, or in different years than were previously tested may result in different effects. By conducting management as an experiment, monitoring can be used to inform future management and thus increase success in the long term.

Gain Understanding of Sandhills Ecology

The task of assembling knowledge required to design management strategies to enhance diversity and facilitate population persistence of endangered species has only recently begun. Scientific research in the sandhills plays an essential role in filling data gaps and allowing the development of empirically based management strategies. Collaboration between organizations responsible for sandhills management and professional scientists can provide a cost effective means of filling data gaps necessary for sandhills management prior to implementation (Chapter 12). However, management actions themselves can and should play a vital role in increasing our knowledge of sandhills biology.

By designing management as an experiment, adaptive management facilitates "learning by doing" (Walters and Holling 1990, Nyberg 1998, Lee 1999). For adaptive management to accomplish this, however, it must be designed as a statistically valid manipulative experiment (Chapter 12). Organizations managing sandhills habitat can partner with individuals and organizations experienced with conducting research who can facilitate design of adaptive management plans that can indeed increase knowledge of sandhills biology.

Management in the Absence of Empirical Evidence

Ideally, we would have perfect knowledge of management impacts prior to implementation: however, this is not possible. Adaptive procedures can allow management to occur in the absence of *a priori* knowledge of impacts. Given the potential for unanticipated negative impacts and the relatively small size of remaining sandhill sites, experimental management should be conducted at small spatial scales. Interspersing management treatments throughout the target habitat will not only facilitate experimental analysis of management effects, but also create a patch mosaic within the landscape that can maximally enhance diversity in the sandhills for many management treatments.

These various benefits of adaptive management outweigh the costs associated with the steps necessary to implement management in an adaptive framework. Indeed, given these benefits, failure to use adaptive management truly represents a large opportunity cost for sandhills conservation.

CHAPTER 8

SANDHILLS FIRE MANAGEMENT

INTRODUCTION

In the absence of fire, sandhills community structure has been altered in ways that threaten the persistence of many sensitive species in the sandhills. The different sandhills community types differ in the ways they have been modified. Community characteristics including their sensitive species distributions and fuel loads influence their management needs and appropriate techniques. This chapter provides biological information regarding the effects of fire exclusion, the potential benefits and negative impacts of reintroducing fire or fire surrogates in the sandhills, and recommended strategies for fire management.

Evaluating techniques for fire management requires consideration of the development patterns, as human habitation in and around sandhills communities will influence management decisions. Though complex, fire management will be essential to long-term preservation of sandhills biodiversity, and an important component of efforts to protect property and lives in the this fire-prone region.

8.1 FIRE EXCLUSION

Examination of historical aerial photographs of sandhills sites indicates that the lack of fire during the past 60 years has substantially altered plant community structure in ways that likely influence persistence of sensitive plant and animal species in the sandhills (McGraw 2004; Figures A.30-32). The precise nature of the changes depended on the plant community and the aspect as well as characteristics of the site including soils and adjacent vegetation. Generalizations based on plant community can be drawn however, and the pattern of community change and the consequences for the maintenance of biodiversity are outlined in this section.

Sandhills Chaparral Communities

Patterns

Sandhills chaparral communities have undergone the most dramatic shift in structure due to succession in the absence of fire. Comparison of the vegetation structure of the Martin Road (Bonny Doon Ecological Reserve), Henry Cowell, and Mount Hermon/SRL sites in aerial photographs from 1943 and 2002 reveal large increases in woody vegetation and concomitant reductions in open sand during this time period for which fire has been prevented (Figure A.30 shows the Martin Road site). Similar increases in tree and shrub density have been observed since 1963 in the conservation areas of the Quail Hollow Quarry (South Ridge, West Ridge, North Ridge, and Azalea Dell), which burned in 1954.

In many patches of sandhills chaparral vegetation, canopy closure results from an increase density and coverage of trees including oaks (*Quercus agrifolia, Q. wislizenii*) and to a lesser extent, ponderosa pines and knobcone pines; however, much of the canopy closure in sandhills chaparral is due to increased size (areal coverage) and density of shrubs including *A. silvicola, A. tomentosa*, and *Ceanothus cuneatus,* among others.

<u>Consequences</u>

Canopy closure due to fire exclusion reduces the abundance of open sandy habitat required by diversity of the sand chaparral community by sand chaparral 'gap specialist species'— a diverse assemblage of herbaceous plant species found primarily or exclusively in shrub canopy gaps in sandhills chaparral communities (Table 8.1). Their absence underneath the canopy of shrubs and trees in sand chaparral suggests that these annual and perennial herbs and subshrubs cannot complete their life cycles in the closed canopy environment characterized by dense leaf litter and low light availability.

Table 8.1: Sand chaparral gap specialists plant species and their status

Scientific Name	Common Name	Status
Antirrhinum multiflorum	snapdragon	
Camissonia contorta	suncup	
Camissonia micrantha	suncup	
Chorizanthe pungens var. *hartwegiana*	Ben Lomond spineflower	FE, CNPS List 1B
Dudleya palmeri	dudleya	
Eriophyllum confertifolium	golden-yarrow	
Filago californica	herba impia	
Gnaphalium sp.	everlasting	Undescribed endemic species
Helianthemum scoparium	peak rush-rose	
Horkelia cuneata	horkelia	
Linanthus parviflorus	linanthus	
Mimulus androsaceus	monkeyflower	
Mimulus rattanii ssp. *decurtatus*	Santa Cruz monkeyflower	CNPS List 4
Navarettia atractyloides	navarettia	
Nemophila pedunculata	nemophila	
Plagiobothrys tenellus	popcornflower	
Stylocline gnaphiloides	everlasting nest straw	

In some sites, canopy gaps persist even in the absence of fire (Figure A.30b). These gaps appear to result from one or more of the following independent or interacting causes: altered soil conditions, recent or ongoing disturbance, and shrub mortality. Certain canopy gaps in sandhills chaparral vegetation at the Martin Road, Mt. Hermon/SRL, and Quail Hollow sites have an indurated layer at or near the soil surface. These gaps likely persist because the dominant shrubs cannot establish in these adverse soil conditions. These soil conditions appear to also deter establishment of many of the gap specialist plants as well, as such gaps have low cover (<10%) and density of a select species that can apparently tolerate the soil conditions (e.g. *Mimulus rattanii* ssp. decurtatus, *Stylocline gnaphaloides*; J. McGraw, unpublished data).

Gaps in sandhills chaparral communities lacking thin soil conditions are primarily the result of recent or ongoing disturbance. At many sites, mechanical disturbance (e.g. by bull dozers) to create roads originally removed the established shrub canopy. No longer used by vehicles, these roads are often maintained by recreational use which prevents shrub establishment in the corridor traversed. In addition, recreationalists often prune limbs from adjacent shrubs to maintain trail corridors. The extent to which these canopy gaps support gap specialist plants depends on the type, frequency, and intensity of disturbance (Chapter 10). In general, gaps maintained by recreation do not support gap specialists in the area of ongoing disturbance, as these species are sensitive to direct trampling. The adjacent open habitat which receives intermediate levels of disturbance may support populations of gap species, as has been observed at BDER and SRL (J. McGraw, pers. obs.).

Cessation of disturbance facilitates population growth of gap specialist plants in sand chaparral. In the conservation areas of Quail Hollow Quarry (Quail Hollow site), rapid colonization of canopy gaps by specialists species following recent efforts to reduce illegal trespassing has resulted in a high density (up to 100%) and diversity of native herbaceous plants in the previously disturbed areas. Shrub colonization or lateral growth from adjacent shrubs may eventually result in low light, high litter conditions that render the gaps unsuitable for the herbaceous plants. In areas where recreational trails co-occur with the unique soil conditions that cause persistent canopy gaps, cessation of trail use does not result in rapid colonization as the inimical soil conditions that prevent plant growth persist (J. McGraw, unpublished data).

Gaps in the shrub canopy also occur due to shrub mortality, though these gaps are less common and smaller (typically the diameter of a single adult shrub). While the mortality of the shrub increases light availability below its canopy, litter accumulation on the soil surface may prevent establishment of gap specialist species mechanically, by preventing seedlings from emerging, and perhaps also due to allelopathy, whereby chemicals from decomposing litter inhibit seed germination and/or seedling survivorship (Keeley et al. 1985, Callaway et al. 1991). Lateral growth and colonization from nearby shrubs likely renders these gaps short lived in the absence of fire.

Canopy gaps important for maintaining plant diversity are likely also important for the sandhills fauna, which is impacted by canopy closure due to fire exclusion. Animals may rely on the gaps in the canopy which provide habitat conditions dissimilar from the closed canopy environment including a greater availability of sunlight (e.g. for thermoregulation) and a higher diversity of plants which may provide a variety of food sources not found in the closed canopy (e.g. flowering plants for pollinators, seeds of herbaceous plants for granivores, etc.). Indeed, shrub encroachment due to fire suppression in sandhills chaparral communities is cited as one likely cause for the likely extirpation of the Santa Cruz kangaroo rat from the Bonny Doon Ecological Reserve and Wilder Ranch sandhills sites during the past 20 years (Bean 2003).

Sand Parkland

Patterns

Woody plant density has also increases in the absence of fire in sand parkland; however, the magnitude of alteration depends on the aspect of the site (McGraw 2004). Sand parkland habitat on both the South Ridge and North Ridge of Quail Hollow Quarry has remained unburned since the ‘dump fire’ in 1954. During that time, tree and shrub coverage has increased dramatically on north aspects, resulting in the savanna-like characteristic parkland being replaced by patches of closed canopy forest (Figure A.31 shows North Ridge). This woody vegetation is comprised no only of sand parkland shrubs and trees (e.g. *P. ponderosa, Q. agrifolia*), but also species abundant in the mixed evergreen forests and oak woodlands adjacent to the sandhills including madrone (*Arbutus menziesii*), tan oak (*Litocarpus densiflorus*) bay laurel (*Umbellularia californica*), and Douglas fir (*Pseudostuga menziesii)*. Not surprisingly, understory species in these patches are also characteristic of the oak woodland and mixed evergreen forests (e.g. *Pentagramma triangularis, Monardella villosa, Dryopteris arguta;* McGraw 2004). Several, increasingly small and fragmented patches of open sand parkland habitat are still found at these sites. Such patches may persist due to soil conditions unfavorable to the woody plants; alternatively, tree encroachment on north slopes of sand parkland may continue in the absence of fire and further reduce the remaining acreage of this rare plant community.

The pattern of woody plant encroachment on south aspects in sand parkland is different. During the same fifty-year interval, tree and shrub density on the south slopes of South Ridge and North Ridge has increased more slowly (McGraw 2004; Figure A. 31). In addition, encroachment is limited primarily to the tree and shrub species commonly found in sand parkland (e.g. *P. ponderosa, Q. agrifolia, P. attenuata, A. silvicola,* and *C. cuneatus*). The slower rate of encroachment and absence of species from the more mesic forests suggests that the hotter, drier conditions on south slopes reduce establishment of trees and shrubs and deter the establishment of species not adapted to the more xeric conditions of south slope sand parkland. However, isolated trees on south slopes alter environmental conditions (soils, water availability, microclimate, light availability, etc.) and facilitate establishment of such species, as indicated by the preferential establishment of *A. menziesii* under *P. ponderosa*. While the rate of woody plant encroachment on south aspects is slower, fire suppression may still result in a high density of trees and shrubs. Similar encroachment patterns are observed in the sand parkland found at Olympia Wellfield, the Ocean Pacific Property (McGraw 2004) and Mount Hermon (Figure A. 32).

Consequences

Woody plant density increases in sand parkland may threaten the persistence of sand specialty plants which are only occur in open habitat away from shrubs and trees. The endangered spineflower and wallflower are both inhibited by trees and shrubs. They represent a diverse assemblage of other herbaceous sandhills specialty species including curly leaved monardella (*Monardella undulata*), pussy paws (*Calyptridium umbellatum*), and the undescribed *Gnaphalium*, among others that are similarly restricted to areas away from trees due primarily to the litter that accumulates on the soil surface, but also as a result of low light availability under oak trees (McGraw 2004).

The Zayante band-winged grasshopper actively selects open microhabitats and preferentially forages on herbs and subshrubs found away from trees and large shrubs on ridge tops and south slopes of sand parkland, suggesting that woody plant encroachment into sand parkland may limit habitat for this endangered insect (Chu 2002). Given the high diversity of sensitive species (rare and endangered plants) in sand parkland, many of which only occur in this rare habitat, the increase in woody plant density in sand parkland has important implications for the maintenance of native biodiversity in the sandhills.

Ponderosa Pine Forest

Patterns

Analysis of historical aerial photographs suggest that many areas currently characterized as ponderosa pine forest previously supported dense or open sand parkland habitat (J. McGraw, pers. obs.). These once open stands of ponderosa pines with herbaceous and subshrub understories now support dense sands of trees including knobcone pine as well as mixed evergreen forest trees (Arbutus menziesii, *Pseudotsuga menziesii,* and *Lithocarpus densiflorus)*, and shrubs (*A. silvicola* and *C. cuneatus, Rhamnus californicus, Toxicodendron diversiloba*), which increase in size and density in the absence of fire (Figure A.32).

Consequences

Sandhills specialty herbs are presently found only in infrequent canopy gaps primarily maintained by recreation and mechanical disturbance within these dense forested areas, if they are present at all. Ongoing fire suppression will likely reduce habitat quality for native plants and animals in these communities by allowing unnatural succession of these transitional sandhills communities to non-sandhills habitat unsuitable for many sandhills species.

8.2 Fire Management: Potential Benefits and Negative Impacts

Fire management can be used to enhance community structure and facilitate population growth and persistence of the endangered species in the sandhills, while reducing the threat of wildfire that is posed by the accumulative of fuel in this fire adapted system. Fire management in the sandhills involves the use of prescription burning whereby fires are deliberately ignited, actively monitored and managed, and extinguished following a specific burn plan.

Developed well in advance of a prescription fire, a burn plan details the management goals of the treatment, provides a thorough description of the treatment area, determines the constraints of burn treatments, and provides a detailed plan for the burn including thorough safety information. This plan includes the burn prescription—a specific statement of the desired fire behavior, smoke production, and environmental conditions that are required for safe and effective execution of the treatment.

Burn plans should be developed for specific treatment areas by ecologists, fire practitioners, and vegetation management experts. It is beyond the scope of this plan to provide the specifics for sandhills burn plans. Rather, the purpose of this section is to describe the potential benefits, as well as potential negative impacts, of fire management; to discuss different fire management techniques that can be used in the sandhills, including fire surrogates; and to provide an overview of hypothesized direct and indirect effects of such management in the different sandhills communities. Section 8.4 discusses the potential impacts of fire management for public health and safety.

Potential Ecological Benefits of Fire

Reintroducing fire in the sandhills may benefit sandhills communities and species by reversing the effects of fire exclusion. This assumes, however, that prescription fire treatments mimic the beneficial effects of natural wildfire. Like other natural disturbances, successful fire mimics must match natural disturbance characteristics including frequency, intensity, and seasonality, among others (Section 7.4).

Fires in the sandhills most likely occurred naturally at the end of the summer (i.e. August-October) when fuel moisture is minimal and tropical storms bring lightning to the region and provide the ignition source for wildfire (Langenheim and Greenlee 1983, Greenlee and Langenheim 1990). Experimental tests examining the effects of reintroducing fire using small scale fires in open sand parkland were conducted in September (McGraw 2004). Based on the likely fire regime, the following are known and hypothesized direct effects of fire:

1. remove established vegetation
2. remove litter and woody debris
3. reduce abundance of exotic plant species
4. stimulate seed germination
5. reset succession of sandhills soil
6. volatize chemical compounds (incl. allelochemicals)

Remove Woody Vegetation

By acting as a large-scale disturbance agent, fire removes established vegetation, including trees and shrubs that compete with many of the unique native herbaceous plants in the sandhills (McGraw 2004). By removing woody vegetation, fires would also create open habitat required by sandhills animals including the Zayante band-winged grasshopper (Arnold 1999a, Chu 2002) and the Santa Cruz kangaroo rat (Bean 2003).

Remove Litter and Woody Debris

Fire also removes plant leaf litter and woody debris that otherwise decomposes slowly on the soil surface in the open, often hot and dry sandhills environments. This litter suppresses germination and reduces seedling survivorship for many sandhills herbs, including the two federally listed plant species (McGraw 2004). Based on its current distribution in open sand areas (Arnold 1999a, Chu 2002), the Zayante band-winged grasshopper may similarly benefit from fires which remove leaf litter, though these effects have not been examined empirically.

Reduce Exotic Plant Abundance

In open sand parkland habitat, experimental fires reduced the cover of European annual plants, which dominate open areas away from shrubs and trees where they compete aggressively with native herbaceous plants (McGraw 2004) and reduce the area of loose, sandy soil required by the Zayante band-winged grasshopper (Arnold 1999a, Chu 2002). Fire may also remove woody exotic plant species including trees (*Eucalyptus* and *Acacia*) and shrubs (e.g. *Genista, Cytisus*), though these effects have yet to be evaluated in the sandhills.

<u>Stimulate Seed Germination</u>

In other fire-prone systems, the heat and/or the charate (chemicals from the burned organic matter) has been shown to stimulate germination of plant species adapted to the environmental conditions characteristic of the post-fire, early successional environment (Keeley et al. 1985, Keeley and Keeley 1987, Baskin and Baskin 2001). Experimental fires in sand parkland increased native species richness and cover, perhaps by stimulating seed germination, though this mechanism was not isolated through the research (McGraw 2004).

<u>Reset Soil Succession</u>

Fires can reduce soil nutrients (Christensen 1977, Clark 1989, Johnson et al. 1998), organic matter (Perry 2000), and microorganisms in the soil (Clark 1989). By reducing soil fertility, fire may prevent establishment of aggressive, non-sandhills plants that can colonize sandhills soils rendered more amenable by fire exclusion and outcompete native sandhills species. In doing so, fire in the sandhills may play a crucial role in preventing conversion of sandhills habitat to non-sandhills communities (Section 3.4).

<u>Volatize chemical compounds</u>

Fire volatizes chemical compounds in soils, including those derived from the decomposition of plant litter and root exudates (Clark 1989). Many such compounds, including those from *Arctostaphylos* spp. are hypothesized to be allelochemicals—chemicals that inhibit the germination, establishment and/or growth of other plant species (Keeley et al. 1985). Though the pattern of plant distributions with respect to dominant woody vegetation including *Arctostaphylos* suggest that chemical compounds may restrict plant establishment, careful experiments would be required to implicate allelochemicals as the cause of these patterns.

Potential Negative Ecological Consequences of Fire

Research from other systems and knowledge of sandhills species biology suggest that fire may also have direct and indirect negative consequences for sandhills species and communities. Not restricted to fire alone, these impacts also likely pertain to many fire surrogates or mimics. Fires can have negative impacts if they:

1. Facilitate exotic species
2. Reduce rare species populations
3. Cause soil erosion

<u>Facilitate Exotic Species</u>

Experimental fires reduced the abundance of exotic plant species in open parkland vegetation (McGraw 2004). However, fire in closed canopy sandhills vegetation (i.e. dense parkland, sandhills chaparral, ponderosa pine forest) may facilitate the invasion and spread of exotic plant species by removing the biotic resistance of these communities. Research in other closed canopy vegetation has found that disturbances such as fire can promote the invasion of exotic plants that were excluded prior to disturbance by low light availability (Zedler and Scheid 1988, Hobbs and Huenneke 1992, Haidinger and Keeley 1993). A diverse assemblage of European annuals as well as woody exotic species (Section 9.1) that may be inhibited by low resource availability in late-successional sandhills communities might be able to invade and spread following disturbances which free up light and soil resources.

Reduce rare species populations

Fire will kill individual plants and animals and thus have immediate direct negative effects on many populations, including sensitive species. By create new habitat and enhance habitat conditions as described above, fire's positive effects may outweigh the direct negative effect and result in increased population size and greater likelihood of persistence. Aspects of the prescription burn including its location, size, shape, and severity, as well as aspects of the management regime including season and frequency should be carefully planned to minimize direct negative impacts to sensitive species.

Cause soil erosion

Fire can increase soil erosion by removing established vegetation and other ground cover, including litter (Clark 1989). Water erosion can increase due to reduced root area binding the soil, increased erosive effects of rainfall landing directly on the loose sand soil lacking ground cover, and increased overland flow of water during high rainfall events. In some cases, fire can alter the chemistry of soils rendering them hydrophobic and thus resistant to infiltration, further exacerbating water erosion (Clark 1989). Wind and gravity can also cause erosion in the absence of dense vegetation cover following fire.

Erosion caused by water, wind, and/or gravity can uproot plants, bury plants in soil deposition, and inhibit new plant establishment on thin soils remaining. These effects may be more pronounced on steep slopes, especially those supporting sand parkland. As evidenced by the slides and washes that have formed following recreational use in open sand parkland, this fragile community, which is home to many sensitive species in the sandhills, may be most susceptible to soil erosion following fire.

Erosion impacts in the sandhills are not solely negative, however. Soil disturbances facilitate many rare plant populations by removing leaf litter and reducing dominant vegetation (including exotic plants) and may create and maintain open habitat conditions required by the Zayante Band-winged grasshopper (Section 5.5). Fire similarly removes cover, however. So while soil erosion following fire would not have an added benefit in the short term, patches of eroding soil may prevent establishment of woody vegetation and maintain early successional conditions required for many species. As part of a patch mosaic, chronically disturbed areas located in a matrix of later-successional habitat may play an essential role in maintaining populations of sensitive species and native species diversity (Section 7.4).

8.3 SANDHILLS FIRE MANAGEMENT TECHNIQUES

In designing management techniques using disturbance, it is often advised that disturbances match the natural disturbance regime characteristics as closely as possible (Section 7.4). This is because native species and communities are presumably adapted to characteristics of the natural disturbance regime with which they have evolved over millions of years (Pavlovic 1994). While the natural fire regime of the sandhills has not been determined through research, the climate and vegetation in the sandhills, combined with analysis of historical aerial photographs and the known fire history of several sandhills sites, allows some hypotheses about the seasonality of fire and the type of fires that would burn the area that can be used to design effective management.

In addition to matching the natural disturbance regime, effective strategies should consider the goals of management in determining the specific fire prescription (Johnson and Miyanishi 1995). The goal of using fire in the sandhills is to reverse the negative consequences of fire suppression which include loss of open habitat, accumulation of leaf litter, and soil succession. In some cases, these objectives may be not be achieved by designing fire management strategies that strictly mimic the natural fire regime. In such cases, fire management should be designed to attain the specific objectives of management; however, caution should be used to avoid negative impacts to native species that are not adapted to such processes.

The following assessment of biologically preferred use of fire in the sandhills is based on the goals of fire management, experimental tests of fire reintroduction in the sandhills, and hypotheses about the natural fire regime (McGraw 2004). Additional research is needed to further develop strategies for fire management in the sandhills. As a result, all management should be implemented within an adaptive management framework (Section 7.5).

Fire Characteristics

Seasonality

Fire management in the sandhills communities would ideally occur during the dry season (July to November). Prior to fire suppression, this is likely when fires would naturally have occurred, as the long summer drought combined with high temperatures reduces fuel moisture and increases likelihood of ignition and spread (Langenheim and Greenlee 1983, Greenlee and Langenheim 1990). As a result, summer season fires would have been hot and consume fuels (litter and vegetation), and alter soil conditions.

Areal Extent

Sandhills fire management should focus on creating several small (e.g. 1 acre) patchy disturbances rather than a single large fire. Small fires can reduce negative impacts to sensitive species and increase opportunities for recolonization of burned areas by both plants and animals (Simmons et al. 1995). In addition, two sandhills characteristics suggest that natural fires may have been naturally patchy: island-like occurrences and the heterogeneity in fuel availability.

Sandhills habitat exists as small islands interspersed among non-sandhills habitat including mixed evergreen forest, northern maritime chaparral, and riparian vegetation, among other communities. Fire models developed for the area suggest that fires in the region would not have burned all sandhills sites (Langenheim and Greenlee 1983, Greenlee and Langenheim 1990). This may perhaps be due to the differential flammability of fuels in these different communities.

Sandhills communities also have very different fuel characteristics that suggest fire may have been patchy *within* the sandhills. Sand parkland has a sparse, non-contiguous tree canopy in a matrix of fine fuels (herbaceous cover) while sandhills chaparral communities consist of dense stands of woody vegetation comprised of species, including *Adenostoma fasiculatum,* known for their fire facilitating fuel.

As a result, it is likely that a fire that occurred in one year would not burn all sandhills sites; rather, sites would have different time since they last burned and thus support vegetation at different stages of succession. Moreover, it is conceivable that a fire that burned in sand chaparral might not have burned the entire habitat in adjacent sand parkland communities, further contributing to the patchwork of successional habitat.

Treatment Area Shape

Burning long, narrow areas may reduce direct negative impacts to sensitive species, especially animals with low vagility (Simmons et al. 1995). Treatment areas with greater perimeter to area ratios can be more readily colonized as well.

Fire Class

The class of fire desired for sandhills management depends on both the plant community and the goal of the fire. Surface fires, which burn fuels in contact with the ground, would be appropriate for managing open sand parkland vegetation. Like other savannas, the natural fire regime in sand parkland may have consisted of moderate to low frequency surface fires that removed tree leaf litter on the soil surface as well as some herbaceous and suffrutescent plants. Such leaf litter and abundant herbaceous exotic plants presently threaten native plants in open sand parkland where experimental tests showed that surface fire increased native plant cover and richness as well as the demographic performance of the two federally endangered plants (McGraw 2004).

Dense sand parkland, sandhills chaparral communities, and ponderosa pine forest, on the other hand, would not likely have experienced surface fires alone. The dense cover of trees and shrubs in these communities would probably have ignited directly from lightning strike or following initiation of a surface fire, thus burning the biomass in trees and shrubs above the ground and creating a canopy fire. Such fires often create a clean burn which removes most of the aboveground biomass. This would be the goal of fire management in these communities, where fire exclusion has increased woody vegetation and reduced the amount of habitat required by species adapted to open conditions maintained through recurring fire (McGraw 2004).

Severity

Severity is a measure of the degree of impact of the fire; specifically, the extent to which biomass is removed. To enhance diversity, multiple treatment areas should be designed to have different levels of severity, such that different environmental conditions will result from the burn. Such patchiness can be promoted *within* each treatment area as well, by allowing areas that don't burn to remain unburned (i.e. don't ignite skipped areas) and/or creating patches that won't burn in advance (Simmons et al. 1995).

Fire Management in Sandhills Communities

Based on the above discussion of fire effects and characteristics, knowledge of the sandhills fire regime, and previous experimental tests of fire effects, the following management strategies are proposed for each of the main vegetation types. These recommendations are summarized in Table 8.2.

Open Parkland

Because sand parkland communities differ greatly in structure depending on their aspect, fire management in sand parkland should be designed differently for open parkland, which is found primarily on south, west, and east aspects and on top of ridges, and dense parkland, found primarily on north aspects.

Fire suppression in open parkland has allowed accumulation of leaf litter on the soil surface. A main goal of fire management in open parkland is to remove accumulated leaf litter, which has been shown to prevent germination and seedling survival of many native sandhills herbs, including the Ben Lomond spineflower and Santa Cruz wallflower, while favoring aggressive exotic plants including *Hypochaeris glabra, Bromus diandrus,* and *Bruza maxima* (McGraw 2004). Experimental research examining the impacts of dry season (i.e. September) fires in open sand parkland habitat occurring on south and north slopes found that fire increased native plant cover and richness, both directly by removing litter, and indirectly, by reducing the abundance of exotic plants (McGraw 2004).

Preferred Fire Management: Fire in open sand parkland would consist of patchy (i.e. small and discrete) surface fires conducted during the dry season. Fuel breaks surrounding patches of open sand parkland, including already existing fuel breaks such as open mines, roads, and wide, denuded trails, can be used to contain these fires within the predetermined burn compartments.

Alternative Management: Two alternatives to patchy, dry season fires include wet season fire and raking. Conducted after the first inch of rainfall during the precipitation year (July –June) and before the end of the rainy season (i.e. between approximately November and May), a wet season surface fire could pose less of a risk by dramatically reducing the likelihood that fuels in the adjacent, closed canopy vegetation will ignite, due to their high moisture content during the wet season (T. Hyland, pers. comm. 2003.). However, as discussed previously, such disturbance treatments that do not have the same characteristics of the natural disturbance regime, including the seasonality, may not have beneficial effects and could instead have negative effects on species that are not adapted to their occurrence. The sandhills would not likely burn naturally during the wet season; therefore, sandhills plants and animals may not be adapted to wet season fires which could negatively impact them by killing newly germinated seedlings (e.g. for annual plants), incinerate the new growth of perennial plants, and negatively impact seeds and soil organisms that may be more susceptible to the heat of fire when moist. The effects of wet season burns should be examined using small-scale experimental burns prior to large-scale management using such an approach.

Raking can mimic some of the beneficial effects of fire. As part of the dry season fire experiment, the effects of removing leaf litter from the soil surface using a leaf rake were evaluated to determine impacts on native plant community structure (McGraw 2004). Like fire, raking increased germination and seedling survival of native plants directly, by removing leaf litter, and indirectly, by reducing exotic plant competition. These results suggest that raking (and removing) leaf litter accumulated on the soil surface near and underneath *Ponderosa pine* in sand parkland can have a beneficial effect (McGraw 2004). This experiment did not evaluate treatment impacts on soil conditions; however, raking is unlikely to reverse soil succession (i.e. reducing organic matter and nutrient availability) as fires might.

<u>Dense Parkland, sandhills chaparral communities, and Ponderosa Pine forest</u>

The goal of fire management in dense parkland, ponderosa pine forest, and sandhills chaparral communities is not only to remove litter and herbaceous vegetation, but also to reduce the cover of woody vegetation. In addition to allowing accumulation of leaf litter, fire suppression in some areas of sand parkland habitat, especially on north aspects, has increased the density of trees and shrubs which restrict the distribution of many sandhills species (McGraw 2004). In these areas, surface fires or their surrogates (e.g. raking) which remove litter will not be sufficient to benefit sandhills species; instead, fires must kill trees and shrubs and create open spaces to benefit many species. To date, there has been no research examining the effects of such fires in the sandhills, leaving uncertainty regarding their impacts on the species and communities and necessitating future research and/or adaptive management. However, Resource Ecologists at Henry Cowell State Park burned small patches of ponderosa pine forest in areas supporting silverleaf manzanita in February 2003 (Figure A.47). Monitoring these areas using adaptive management framework would provide insight into the potential effects for sandhills species and communities.

Fire suppression has similarly increased the cover of woody vegetation and caused a decline in open sandy habitat required by many plants and animals in the sandhills chaparral communities. Moreover, in ponderosa pine forest and dense sand parkland, this succession is causing type conversion of sandhills to mixed evergreen forest. One goal of using fire to manage these communities would therefore be to increase the amount of open habitat available to these species by killing trees and shrubs. However, fire has additional beneficial affects beyond simply removing aboveground biomass which include stimulating germination of seeds, reducing the amount of soil organic matter, cycling nutrients, reducing fungal pathogens, volatilizing soil chemicals, and reducing fungal symbionts that may promote succession and type conversion. These 'secondary effects' of fire can be essential to successful sandhills management as removal of woody vegetation alone may not be sufficient to create conditions that support sandhills species adapted to open areas. These aspects of fire have not yet been examined in the sandhills, but have been explored in other fire-adapted systems.

Preferred Fire Management: Patchy, dry season broadcast burns are recommended to maintain open areas lacking dense woody vegetation within sandhills chaparral communities, dense sand parkland, and ponderosa pine forests. Given the large amount of tall fuel in these areas, the fire would burn as a surface and canopy fire that would likely kill shrubs and trees. Analysis of historical aerial photographs taken before and after the 1954 fire that burned three dense sand parkland and several sand chaparral sites in the Quail Hollow sandhills indicate that the wildfire removed most trees and shrubs, though several large ponderosa pines survived this fire (J. McGraw, unpublished data).

Given our lack of knowledge of present day effects of such fires, adaptive management should be used to increase the areal extent of open habitat by removing selected patches of closed canopy vegetation to create a patch mosaic which may maximize diversity while allowing evaluation of fire impacts. Such areas must be large enough to truly open up the habitat and increase light availability, temperature, and reduce or eliminate litter fall within the core of the open habitat. While this minimum size has yet to be determined empirically, an area of at least 20m x 20m is likely necessary. Removing patches of dense woody vegetation adjacent to current open habitat would be a good way of increasing open habitat in dense parkland.

Alternative Management: As an alternative to using broadcast burns, trees and shrubs can be manually removed. As with a broadcast burn, the goal of manual removal is to create open patches of habitat in selected areas of contiguous canopy cover. Therefore, within a treatment area, all woody vegetation should be removed, rather than selectively removing individuals to 'thin the stand'—a treatment that can enhance individual tree or shrub growth but not create open habitat.

Manual removal of woody vegetation should be followed by biomass removal. Three biomass removal techniques recommended for experimental examination or adaptive management are: surface fire, pile burn, and hauling off site.

The biologically preferred method of removing biomass following manual removal is through a surface fire to burn the debris during the dry season. By laying the fuel (i.e. woody debris from trees and shrubs) flat on the soil surface, the risk of igniting a fire in the adjacent vegetation is greatly reduced (T. Hyland, pers. comm. 2003). Burning the fuel would also remove leaf litter on the soil surface and potentially promote the beneficial effects of a fire including stimulating seed germination, removing organic matter from the soil, increasing soil pH, among others (Section 8.2).

If concern regarding burning a larger area is significant, biomass might be heaped into several piles. These piles can then be ignited and monitored successively. Unfortunately, such pile burns cannot create the beneficial effects of fire over large areas as a surface fire can. At best, pile burns will mimic the beneficial effects of fire in a small subset of the treatment area. At worst, the long duration and high intensity of these fires due to heaping biomass onto a small area can cause very negative effects including incinerating seed.

As described above, both surface and pile burns should be conducted during the dry season in order to facilitate the beneficial effects of fire and minimize the negative impacts associated with having a fire crew in the habitat during the growing season. If wet season burns are deemed absolutely necessary to reduce fire danger, extensive monitoring should be conducted on small scale experimental treatments prior to use over larger areas to determine whether such off-season burns are indeed beneficial.

If burning is absolutely deemed impossible, the woody debris of shrubs and trees should be hauled off site. Some woody debris could be left intact in discrete portions of the treatment area to facilitate animal species that require this material for food (e.g. wood-feeding insects) or habitat (e.g. wood dwelling insects, amphibians and reptiles, etc.). However, woody debris should not be distributed throughout the area through chipping or other methods, as such a layer of litter can have strong detrimental effects on several sandhills plants (McGraw 2004) and animals.

8.4 Logistical Aspects of Sandhills Fire Management

Fire is a natural part of sandhills ecology to which sandhills species are adapted. Fire exclusion alters sandhills communities and threatens species persistence. Reintroducing fire can facilitate native biodiversity and endangered species recovery. This section addresses the logistical aspects of sandhills fire management, which include public safety considerations and fire management implementation.

Public Health and Safety

Human habitation in and around sandhills sites necessitates careful consideration of public safety in fire management. Even a small burn executed within a narrowly delimited prescription can escape outside the treatment area. Rather than being used to justify excluding fire, the risk of wildfire in and around sandhills communities should motivate management to reduce fire risk, including prescription burning. Widespread fire suppression is allowing an unnatural accumulation of fuel, creating a risk of catastrophic wildfire in the Santa Cruz Mountains (The Nature Conservancy 2002). Even in the absence of prescription burning or natural ignition (e.g. lightning), inadvertent human ignition can cause a wildfire. This risk is significant for long unburned sandhills chaparral and ponderosa pine forest communities where high conditions are surrounded by human habitation and activity, creating the potential for disaster.

Recognizing this risk, the California Department of Forestry and Fire Protection (CDF) is motivated to work with sandhills land managers to develop and execute fire management. Through its Vegetation Management Program (VMP), a cost-sharing program for fuel management and prescription burning, CDF works to reduce fire threat in private, city, county, and state-owned land (CDF 1995). In response to recent inquiries regarding sandhills

Table 8.2 Fire management considerations for sandhills communities.

Community Type	Effects of Fire Exclusion	Biologically Preferred Management	Alternative Management	Shortcomings of Alternative Management
Open parkland	Leaf litter accumulation Exotic plant spread	Patchy, dry season ground fire to remove litter and reduce exotics; cause secondary fire effects[1]	1. wet season ground fire 2. raking	1. a) negative effects of wet season burn[2]; b) may not be hot enough to burn and/or affect secondary fire effects[1] 2. no secondary fire effects[1]
Dense parkland	Reduction in open habitat; accumulation of leaf litter; invasion by exotics; soil amendments that facilitate non-sandhills species	Dry season broadcast burns in patches to kill shrubs and trees, remove litter, reduce exotics; cause secondary fire effects[1]	1. Tree thinning followed by patchy dry season ground fire 2. Tree thinning followed by patchy, wet season ground fire 3. Tree thinning followed by raking	1. trampling effects[3] 2. a) trampling effects[3], b) negative effects of wet season burn[2]; c) may not be hot enough to affect desired burn effects and/or secondary fire effects[1] 3. a) trampling effects[3]; b) no secondary fire effects[1]
Sandhills chaparral and ponderosa pine forest communities	Reduction in open habitat; accumulation of leaf litter; soil amendments that facilitate non-sandhills species; type-conversion to non-sandhills habitat (transitional communities)	Dry season broadcast burns in patches to kill shrubs and trees, remove litter, reduce exotics; cause secondary fire effects[1]	1. manual shrub/tree removal followed by dry season broadcast burn of small patches 2. manual shrub/tree removal followed by dry season pile burn 3. manual shrub/tree removal with biomass removed from site	1. a) trampling effects[3] 2. a) trampling effects[3], b) unnaturally intense fire on pile may incinerate seeds; c) beneficial effects of burn, if realized, constrained to small areas 3. a) trampling effects[3], b) no secondary fire effects[1]

[1] Secondary fire effects: Effects that fires can have other than incinerating fuel including: stimulating seed germination, reducing soil organic matter, cycling nutrients, removing fungal pathogens, volatilizing soil chemicals, reducing fungal symbionts that may enhance succession, etc.

[2] Negative effects of wet season burns can include: killing of newly germinated seedlings of annuals, incineration of new growth on perennials, steaming of soil which kills soil microorganisms and seeds in the seedbank which may not be adapted to heat during wet conditions.

[3] Trampling associated with manual removal might have negative impacts including: removal of crust, removal of native herbs, excessive erosion

management, vegetation management officials in the San Mateo-Santa Cruz County Unit have expressed their concern about the risk of catastrophic wildfire in sandhills habitat and their interest in partnering with landowners and other agencies in vegetation management programs (M. Gagarin pers. comm. 2004, A. Petersen, pers. comm. 2004ment, vegetation management officials in the San Mateo-Santa Cruz County Unit have expressed their concern about the risk of catastrophic wildfire in sandhills habitat and their interest in partnering with landowners and other agencies in vegetation management programs (M. Gagarin pers. comm. 2004, A. Petersen, pers. comm. 2004).

Implementation

Implementation of fire management in the sandhills can be greatly aided by partnering with CDF through the VMP. With the exception of the California Department of Parks and Recreation, which manages sandhills habitat at Gray Whale Ranch State Park and Henry Cowell State Park, sandhills landowners do not have land management crews with the skills, equipment, and other resources necessary to implement fire management. These landowners can partner with CDF through the VMP to implement fire management.

To do so, sandhills landowners should contact representatives of CDF Vegetation Management (Appendix E) to initiate the process in which CDF will (CDF 2001):

1. Evaluate project feasibility
2. Gather information from other agencies (USFWS, CDFG, water quality agencies, etc.)
3. Design a detailed burn plan (e.g. prescription) for the project
4. Notify the community
5. Implement the burn when prescription conditions are met

Active involvement of sandhills land managers in the development of the burn plan is crucial to a successful partnership. Though CDF personnel involved in the VMP include are actively learning about sandhills vegetation, they cannot possibly be aware of the ecology of the particular site to be managed, including for example, the location of high density populations of sensitive plants, exotic species, or endangered insects. The land manager must be ultimately responsible for seeing that vegetation management as planned by CDF, can meet the management objectives that have been developed for the site. Careful planning and involvement in implementation will be necessary to insure that collaboration of sandhills land managers with CDF will facilitate sandhills conservation management goals as well as CDF vegetation management goals, which most likely will not be identical.

Inappropriate Fire Surrogates for the Sandhills

Though arguably more acute in the sandhills, the detrimental affects of fire exclusion are not unique to the sandhills; rather, disruption of natural fire regimes is altering natural communities and threatening wildfire throughout the western United States. In the state of California, efforts to reduce the risk of wildfire in fire prone communities such as chaparral have focused on developing fire surrogates. Unfortunately, due to the extreme fragility of the sandhills, many such techniques are not appropriate in the sandhills. These include a variety or mechanized removal methods in which large, tractor like vehicles are driven over the vegetation.

Mastication is a mechanized method of large-scale shrub removal designed primarily to reduce the risk of catastrophic wildfires in fire-prone chaparral communities. In mastication, a large, tractor-like vehicle (masticator) shreds all plant cover as it moves through a site. While mastication would open up the shrub canopy as in fire or manual removal, it would not remove the woody debris or mimic the secondary effects of fire (Table 8.2), and could promote water and wind erosion by disrupting the sandhills soils. In addition, the mulch or chipped material left on the site can prevent sensitive sandhills species from utilizing the habitat.

CHAPTER 9

SANDHILLS EXOTIC PLANT MANAGEMENT

INTRODUCTION

Exotic species can endanger the persistence of rare species through a variety of direct and indirect mechanisms. In the sandhills, exotic plant species present many threats to the maintenance of native biodiversity (Section 4.3). Their management will be essential for the persistence of endangered species (USFWS 1998) and natural plant communities in the sandhills (McGraw 2004).

Effective management of exotic plants requires examination of their biology, the ecology of the invaded community, and techniques for their control. This section examines the distribution and impacts of exotic species of different functional groups, discusses essential aspects of exotic plant management planning, and recommends strategies for exotic plant management in the sandhills.

9.1 EXOTIC PLANTS IN THE SANDHILLS: DISTRIBUTIONS AND IMPACTS

Despite ecological theory suggesting that unusual soil conditions in the sandhills should render them resistant to biological invasion, exotic plant species have successfully colonized the sandhills (McGraw 2004). Primarily originating in the Mediterranean region, these species are termed “exotic” because they were not present in the region prior to the arrival of Spanish colonists in the 1700s and therefore are likely present in the sandhills due to direct and indirect effects of humans. As in other sensitive plant communities, exotic plant species in the sandhills threaten the persistence of native plants both directly, through their competition, and indirectly, through the abilities to alter ecosystem structure and function. Their abundance patterns and effects depend on the type of exotic plant and the plant community they have invaded, as described below.

European annuals

Distribution and Abundance

European annual grasses and forbs are the most abundant exotic plant species in the sandhills (McGraw 2004). Their success in relatively inhospitable abiotic conditions within the sandhills can likely be explained by two factors. First, these species are ‘pre-adapted’ to the conditions for growth in the sandhills as most originated in the Mediterranean region of Europe, which has climate and soil conditions similar to the sandhills (Jackson 1985). Second, through their annual life history, these species avoid the seasonal drought and high temperatures of summer that may prevent establishment of exotic perennials.

European annual plants are found throughout the sandhills; however, their abundance and therefore their impacts vary greatly among the different plant communities. Most of these diminutive plants are found only in open areas away from woody vegetation, likely because they are poor competitors for light (i.e. shade intolerant). As a result, European annuals occur in relatively low abundance in sandhills chaparral communities and ponderosa pine forest.

In contrast, European annuals are widespread and abundant in sand parkland, where predominantly open canopy conditions are conducive to their growth. The two main exceptions are in areas of soil disturbances (slides, trails, gopher mounds) and where moss and/or cryptobiotic soil crusts are found on the soil surface (McGraw 2004). In chaparral gaps and in north slope sand parkland where such perennial ground cover is present, European annuals are far less abundant, suggesting these species may afford the sandhills communities some biotic resistance as well.

European annuals exhibit different habitat specificity with respect to aspect in sand parkland. The hotter, drier south-facing slopes are dominated by European *Vulpia* species (*V. myuros* and *V. bromoides*), *Hypochaeris glabra,* and to a lesser extent *Bromus diandrus.* While *H. glabra* is also abundant on north slopes, *V. bromoides* and *V. myuros* are far less abundant and instead another diminutive grass, *Aira caryophyllea* dominates the cooler slopes. Exotic annuals also exhibit distribution patterns with respect to trees in sand parkland. *Briza maxima* is preferentially found underneath pines and to a lesser extent oaks, while the litter from both types of trees greatly reduces the abundance of both *V. bromoides, V. myuros,* and *H. glabra* (McGraw 2004).

Other less abundant annual exotics in the sandhills include *Senecio sylvaticus, Avena fatua, Bromus tectorum,* and *Cynosurous echinatus*. *Senecio sylvaticus* is preferentially found in sandhills chaparral communities and presently is less abundant in sand parkland. *Avena fatua* is found primarily in disturbed areas and underneath pines while *C. echinatus*, a recent invader of the Ben Lomond sandhills, is currently restricted to cooler, moister microsites (i.e under trees and/or on north slopes). Though highly abundant in the arid intermountain west, *Bromus tectorum* is only patchily abundant in the sand parkland. Presently, it is more abundant on north slopes suggesting it may not be able to tolerate the drier, hotter conditions on south aspects where many of the sensitive native species are found. Alternatively, successful populations along trails on south slopes suggest that this plant, like other exotics in the sandhills including the occasional *Erodium botrys*, may have yet to realize its full range in the sandhills (J. McGraw, unpublished data).

Impacts

European annuals exert strong competitive effects on the native herbaceous plants in the sandhills (Figure A.36). Their impacts on native plant species in sand parkland have been studied through a series of removal experiments which quantified the direct effects of exotic plants, and the role they play in altering the effects of natural processes including fire, soil disturbances, and interannual variation in rainfall on native plant populations and community composition (McGraw 2004).

Due to their abundance and similar distribution in areas away from shrubs and trees, *V. bromoides, V. myuros,* and *H. glabra* have the greatest effect on south slopes in sand parkland where many of the sand specialty herbs are found. Exceeding 80% cover in places, exotic *Vulpia* spp. create a mat of fibrous roots that reduce soil moisture and dense stalks that limit light availability during the winter months (McGraw 2004). The tap roots and basal rosettes of *H. glabra* grow rapidly during the winter, allowing this plant to draw down soil moisture, reduce light availability, and physically crowd native seedlings. In cooler and/or wetter microsites or years, *H. glabra* is more abundant than *Vulpia* spp. while the opposite is typically true on the south-facing sand parkland slopes.

Research in sand parkland showed that these abundant exotics reduce both the cover and diversity (species richness) of native herbs. In addition, they reduce the fecundity (seed production) of *C. pungens* var. *hartwegiana* by over 85% and can completely prevent survivorship of *E. teretifolium* seedlings over the hot dry summer (McGraw 2004). European annuals likely reduce native plant performance, abundance, and richness in gaps in chaparral and ponderosa pine forest where they co-occur with native herbaceous plants; however these effects have not been examined.

In sand parkland study plots in which European annuals were removed, the population performance of *Chorizanthe* and *Erysimum* were dramatically improved. In addition, the cover and richness of native annual and perennial herbs increased dramatically over a four year period such that their cumulative cover equaled that of exotic annuals in control plots. This experiment provided a glimpse of plant community composition in sand parkland *prior* to exotic plant invasion. Dense cover of diminutive annuals including *C. pungens* var. *hartwegiana, Stylocline gnaphaloides, Filago californica, Crassula connata, Lotus strigosus,* and *Gilia tenuiflora*, among others, was interspersed by perennial herbs including *Gnaphalium, Eschscholzia californica, Heterotheca sessiliflora, Lessingia filaginifolia,* and the endangered *Eriogonum nudum* var. *decurrens* once competition from European annuals plants was removed. These results indicate that efforts to remove European annual plants at the landscape scale will greatly enhance populations of the endangered herbs and the larger suite of native herbaceous plants (McGraw 2004).

European perennial herbs

<u>Distribution and Abundance</u>

Many aggressive European perennial grasses and forbs found throughout Santa Cruz County have yet to invade the sandhills. Their abundance in more mesic vegetation adjacent to the sandhills suggests that the sandhills may indeed have some abiotic resistance to invasion due to a combination of the hot dry summers and low nutrient conditions. Two exceptions to this trend are *Hypochaeris radicata* and *Rumex acetosella*, which are found in the more mesic microsites in sand parkland. While *H. radicata* is relatively rare, *R. acetosella* is patchily very abundant under trees and on north slopes in sand parkland (McGraw 2004).

A third noteworthy exception to the trend is the recent invasion of *Holcus lanatus* into the sandhills. Well known for its ability to invade and quickly dominate wet grasslands and meadows, this European perennial grass is rapidly becoming one of the most abundant exotic plants in mesic grasslands communities in central and northern California including Santa Cruz County. Like *H. radicata* and *R. acetosella*, it preferentially establishes under trees, on north slopes, and in other moist microsites such as along ephemeral watercourses in the sandhills. Interestingly, *H. lanatus* that invaded sand parkland in the Quail Hollow region during the first two years of the invasion (2000, 2001) essentially functioned as annual plants as they were able to successfully reproduce in spring, yet died during their first summer. However, several second year plants were observed under an oak canopy on the north slope of South Ridge in QHQ in 2002. These observations suggest that *H. lanatus* may become established in the sandhills through wet microsites or years with above average rainfall (J. McGraw, pers obs.).

Impacts

Perennial invaders in the sandhills similarly reduce the cover and richness of native herbs as well as the performance of the two endangered plants; however, their overall impact is not as pronounced as that of the European annuals due to their greatly reduced distribution and abundance (McGraw 2004). In addition to competing for light and soil resources during the growing season, these perennials may also draw down scarce soil moisture during the late spring and early summer, thus further competing with the perennial natives. If allowed to become abundant, aggressive perennial invaders like *H. lanatus* which have large root area and rapid lateral growth may compete with native perennials and subshrubs as well as annuals in the sandhills.

Large Invaders including Shrubs and Trees

Distribution and Abundance

Aggressive shrubs and trees as well as the shrub-sized pampas grass (*Cortaderia jubata;* Figure A. 38) have invaded many sandhills sites. Large exotics including *Acacia dealbata* (Figure A.37), *Eucalyptus* sp., *Cytisus multiflorus*, *C. scoparius,* and *Genista monspessulana,* are often found along roads and have become established on the perimeter of many sandhills habitat patches. These plants have not yet aggressively invaded most open sand parkland habitat patches. This may be due to the hot, dry conditions, combined with perhaps competition from dense European annuals which reduces establishment of native shrubs (McGraw 2004). These exotic plants have also not yet successfully invaded the sandhills chaparral communities, perhaps owing to their closed canopy as well and often thin soils.

Successful invasions by large exotic plants at two sites indicate that resistance may be overcome and the consequences can be highly detrimental for native species. At the Mount Hermon sandhills site, exotic brooms, (*C. multiflorus* and *G. monspessulana*) formed monocultures in the dense sand parkland habitat during the 1980s and 1990s. Extensive efforts have been undertaken to remove adult plants and reduce seedling establishment. However, like other plants in the Fabaceae (pea family), this species has a long-lived seedbank which generates new seedling cohorts annually, necessitating extensive and prolonged efforts to eradicate this invader. *Acacia dealbata* became established and abundant at the old quarry of the Olympia Wellfield. Also in the Fabaceae, this tree not only has a persistent seedbank, but readily ‘stump sprouts’ such that simply cutting the tree at the trunk does not kill the plant, though techniques for eradicating this aggressive invader are being developed (Section 9.3; Horowitz 2003).

Impacts

Observations of heavily invaded sites indicate that these large exotics can have profound effects on native communities in the sandhills. Like abundant annuals, these exotics can compete for soil resources (moisture and nutrients) and light with the magnitude of their competitive effect proportional to their size. These large shrubs and trees can completely shade the soil surface thus rendering sand parkland uninhabitable by the diverse assemblage of native herbs that are poor competitors for light (McGraw and Levin 1998).

In addition to their competitive effects, these invaders have the potential to alter ecosystem properties and processes in dramatic ways that can further degrade sandhills habitat. Several of the large invaders are in the pea family (Fabaceae: *C. multiflorus*, *C. scoparius, G. monspessulana, A. dealbata*). These plants have nodules on their roots containing symbiotic bacteria (*Rhizobium* spp.) that fix atmospheric nitrogen and enhance the concentration of plant available nitrogen in the soil. As a result, these plants likely increase nitrogen availability in the Zayante soils, thus rendering the sandhills more susceptible to invasion by plant species from adjacent communities (e.g. mixed evergreen forest) that may presently be inhibited by low nutrient availability. Restoration efforts in the sandhills may need to also include techniques to reduce nitrogen availability following removal of these exotics (Section 9.3).

Native Invaders

<u>Distribution and Abundance</u>

Plants native to California but not to the sandhills have also invaded sandhills communities. Though naturally occurring in California, these species likely owe their occurrence in the sandhills, at least at their present abundance, to anthropogenic factors. As a result, native sandhills species are not adapted to competition with these species nor the habitat conditions they create.

Unnatural succession due to fire exclusion (Section 8.1) may facilitate such invasion. Native shrubs and trees from the adjacent mixed evergreen forests including *Arbutus menziesii, Lithocarpus densiflorus,* and *Pseudotsuga* menziesii, among others, invade the sandhills communities, likely facilitated by unnatural levels of light, organic matter, nutrients, soil moisture, and perhaps mycorrhizae that develop in the absence of fire. Though coast live oaks (*Quercus agrifolia*) found in sand parkland and sandhills chaparral communities are similarly abundant in the mixed evergreen forests and oak woodlands, these are not 'native invaders' because they occur during early successional conditions in sandhills and are therefore not due to anthropogenic causes (J. McGraw, pers obs.).

Yellow bush lupine (*Lupinus arboreus*) is likely a 'native invader' in the sandhills. Native to coastal bluffs and dunes below 100 m in central California, this plant became naturalized in northern California as a result of deliberate introductions to stabilize dunes (Hickman 1993). Though the native sandhills flora contains many disjunct populations of primarily coastal species (e.g. *Armeria maritima, Artemesia pycnocephala, Dudleya palmeri)*, *L. arboreus* is found at very low density in a small number of sandhills habitat patches, the majority of which have been altered by anthropogenic activities (i.e. mining, other development). This suggests *L. arboreus* occurs in the sandhills as a result of human causes and is not a native sandhills species.

Telegraph weed (*Heterotheca grandiflora*) is another example of a native invader in the sandhills. Though primarily found in highly disturbed areas within the sandhills (e.g. mine spoils, road cuts), this plant has recently become more widespread in the open parkland habitat at the Bonny Doon Ecological Reserve, suggesting it can invade intact sandhills habitat. It produces abundant seed that can be dispersed by wind long distances, potentially enabling it to colonize newly disturbed habitat including recently burned sites or soil disturbances.

Impacts

Like exotic plants, the impacts of native invaders depend on their life history traits and ecologies as well as their abundance and distribution in the sandhills. Trees from the mixed evergreen forest suppress sand specialty herbs through their shade, which reduces growth, and their leaf litter, which prevents establishment. Like native sandhills trees (e.g. *Pinus ponderosa, Quercus agrifolia*), these trees can promote further succession by enhancing soil nutrient availability and thus the ability of Zayante soils to support more light competitive species (McGraw 2004). The medium statured, nitrogen fixing *L. arboreus* may reduce light availability and alter soil nitrogen availability similar to exotic invaders. Finally, telegraph weed is likely to compete with other sandhills specialty native herbs for scarce soil moisture resources.

9.2 Planning Sandhills Exotic Plant Management

The large negative impacts of exotic plants on natural communities and populations of sensitive species call for efforts to reduce exotic plants in the sandhills. Attaining regional goals will require management via detailed site-specific plans (Chapter 7). This is because different exotic species likely have different impacts in different sandhills communities at different sites and will respond differently to the various management efforts, due to interactions between aspects of the species life history, structure of the natural community, characteristics of the individual site, and features of the various techniques. With so many variables, and so many 'unknowns', the management of exotic plant species is complex. Moreover, the stakes for exotic plant management in the sandhills are high. In contrast to management in more widespread communities (e.g. California grasslands), the extreme rarity of sandhills communities and species necessitates precise management.

Collaboration among entities involved in sandhills conservation will be necessary to attain sandhills management goals with regards to exotic plants (Section 7.2). Site-specific strategies should be developed in advance of management implementation and include the following: 1) an exotic plant assessment, 2) a prioritized list of goals, and 3) a plan for action. This section describes important considerations for each of these components.

Exotic Species Assessment

The first step in the development of an exotic plant management plan is to inventory the exotic plants at the site, assess the significance of their impacts, evaluate the feasibility of their control, and use this information to rank exotic species according to the urgency of management. Detailed descriptions of these steps for exotic plant assessment are provided to assist managers.

Inventorying Exotic Plants

An initial, thorough inventory of exotic plant species distributions can aid development of a comprehensive exotic plant management plan. Through a systematic survey of the site, a trained biologist should document the distribution of all exotic species. The occurrence of exotic plants adjacent to the sandhills habitat though not present within the site at the time of the survey should also be recorded. A general description of exotic plant abundances and distribution patterns (Section 9.1) and the plant species list for the sandhills (Appendix B) can facilitate such an inventory. Unfortunately, ongoing exotic plant invasion and spread will render these aids outdated soon after publication, necessitating collaboration between managers and researchers to maintain species lists and other relevant biological information.

The initial site inventory must also determine the abundance of each exotic species in the site. Ideally, a quantitative sampling regime would be used to estimate density or percent cover, as such data could provide the baseline information for determining management treatment effects. However, at a minimum, relative abundance categories should be assigned to facilitate assessment of impact and likelihood of control.

The resulting data on the distribution and abundance of exotic species should be spatially explicit, through notations on maps or, ideally, through the use of a geographic information system (GIS). As with quantitative abundance sampling, spatially explicit baseline information will be crucial to evaluating exotic plant management effectiveness.

Assessing Impact Significance of Exotic Plants

The significance of impact of each exotic species found within the site should be assessed. Determinations of impact should consider current impacts as well as the likelihood the species will have increased impact at a later date (Hiebert and Stubbendieck 1993). Current impact determinations should consider the distribution, abundance, and current or potential effects on species (incl. sensitive species) and ecosystem processes (e.g. succession, nutrient cycling, fire, etc.). Assessment of future impact should consider the species' reproductive ability, dispersal ability, habitat requirements, competitive ability, and known impacts in natural areas that might be similar to the sandhills in ecological characteristics (e.g. soils, climate, vegetation structure, etc.).

Determining Feasibility of Management of Exotic Species

The feasibility of successful management should then be determined for each exotic plant. Specific management goals (prevention, eradication, and control) are discussed in the next section. In general, feasibility would be the function of three main factors: 1) distribution, 2) abundance, and 3) availability and ease of effective treatments.

Distribution: Narrowly distributed plants, including those limited to specific microsites and those that have only recently invaded, will be more feasible to manage than widespread plants.

Abundance: Abundant plants (those that occur with high population densities) may be more difficult to control than those with just a few individuals.

Treatments: Whether a technique for controlling the species is known, and the extent to which that technique is easily executable will greatly determine the extent to which control is feasible. Many exotic plants in the sandhills have been the subjects of research and management efforts in other systems, and several have been examined specifically in the sandhills, as described below (Horowitz 2003, Pollock 2004, McGraw 2004, *in prep.*). A complete review of the literature combined with conversations with experienced land managers (given that the success of many efforts is not published) can facilitate assessment of the extent to which control is feasible. Factors that will influence ease of control include: 1) seedbank presence, 2) vegetative regeneration, 3) type of treatments (physical, biological, chemical), 4) unintended negative impacts of treatments, and 5) the cost of treatments, among other factors (Hiebert and Stubbendieck 1993).

Ranking Exotic Plants for Management

Based on the assessment of impact significance and determination of management feasibility, exotic plant species should be ranked according to the urgency for management. A ranking system based on quantitative assessments of species impact and the management feasibility developed for use in the National Park System (Hiebert and Stubbendieck 1993) could be modified to aid ranking of exotic plants in the sandhills. The purpose of such a system is to separate the disruptive exotic species from those that are more innocuous in areas which have hundreds of exotic species (e.g. large national parks). Given the relatively small number of plant species, managers with extensive experience with the sandhills and exotic species management may be able to determine qualitative ranks that are as or more meaningful. Developing even a pseudo-quantitative ranking system in which relative scores are assigned for impact and feasibility might help avoid the inadvertent interjection of biases by managers.

Exotic Plant Management Goals

Management of exotic plants in the sandhills should follow carefully established goals. These goals should be developed in consideration of the overall site management goals to avoid conflicting management objectives and treatments with regard to recovering sensitive species, enhancing native species diversity, and maintaining a patch mosaic of communities, among other objectives. As with other management efforts, exotic plant management should use adaptive management to enhance effectiveness, avoid negative impacts, and increase knowledge of sandhills species and communities (Section 7.5).

Though a global goal of exotic plant species management within a site might simply be stated as “to lessen the impact of exotic plant species”, several goals, each with its own set of clearly stated objectives, will be necessary in a successful exotic plant management plan. Exotic plant species have different impacts in different sandhills communities, (e.g. parkland, chaparral, etc.), and exotic plant issues are not static problems, but rather dynamic processes. Thus, different objectives may require different management techniques, both of which will need to change through time.

Management of exotic plants in the sandhills should pursue three objectives: prevention, eradication, and control.

Prevention of Exotic Plant Establishment

Given the strong negative impacts of exotic plants on sandhills species and communities, and the large effort required to eradicate and control these species, sandhills management must endeavor to prevent the invasion of new exotic plants. Several patterns and processes suggest that the sandhills will be subject to further invasion. First, while there are 20 exotic species presently found within intact, sandhills habitat, there are 342 known exotic plants species in Santa Cruz County (CalFlora 2004). Second, two exotic species, *H. lanatus* and *C. echinatus,* invaded the sandhills during the last three years (2000-2003). Third, several exotic plant species are found on the perimeter or immediately adjacent to sandhills habitat patches that are *not* presently found within the habitat interior (e.g. *Acacia,* exotic brooms). Meanwhile, aggressive exotic plants continue to invade California and the sandhills region.

There are several steps that managers can take to help prevent new invasions. These include:

1. Remove/reduce exotic plant seed sources near the site
2. Limit introduction of foreign material into the site
3. Conduct education and outreach
4. Establish methods for early detection
5. Plan for early eradication

Removal of exotic plant seed sources

Though transportation and recreation can bring seed from long distances, most dispersal of new exotic plants into sandhills habitat will occur through short distance dispersal from areas adjacent to the habitat. Therefore, reducing the exotic plant seed source adjacent to sandhills habitat can limit new invasions. Many sand quarries in the sandhills are highly invaded by exotic plants such as *Cortaderia jubata* which are not yet found in the adjacent intact habitat. Other sites have exotic species on their perimeter which are not yet found in the interior. For example, the southern portion of the Mount Hermon/SRL site, has *Acacia dealbata* along its perimeter adjacent to Graham Hill Road, yet this aggressive tree is not yet found inside.

Though the current absence of some exotic plants within intact habitat suggests that sandhills communities may be somewhat resistant to invasion by these exotics, apparent resistance is no guarantee against future invasion. Any number of site conditions including climate (e.g. precipitation), disturbances (fire, etc.), or nutrient availability, among others, could change and render the site invadable. Moreover, habitat may not be "resistant" at all; rather, dispersal simply has yet to occur. Either way, efforts to reduce or remove exotic plant species at the perimeter or adjacent to sandhills habitat may greatly facilitate prevention.

Limit introduction of foreign material into sandhills sites

Humans can inadvertently vector exotic plant seed into sandhills habitat through a variety of means, including through construction and restoration projects, transportation, and recreation. Construction and restoration material including gravel, fill, mulch, and straw can harbor exotic plant seed. Fortunately, many suppliers guarantee that their material is 'weed free' (Tu et al. 2001). Projects in and near sandhills sites should use material from these suppliers, when possible, and involve steps to insure that exotic species do not become established at construction or restoration sites.

Vehicles and humans entering sandhills habitat can also disperse exotic seed. Washing cars before and after entering sensitive sandhills sites can help prevent seed transportation. Hikers and equestrians can similarly transport seed from non-sandhills habitat into otherwise uninvaded habitat. Trails should be constructed and maintained to minimize the potential for recreators to disperse exotic plants. Sandhills habitat should not be connected by trails to highly invaded non-sandhills habitat, and exotic plants should be regularly removed from parking lots, staging areas, and trailheads. Equestrians should be encouraged to monitor livestock for weed seed and required to use only weed free hay when recreating in the sandhills.

Education and Outreach

Education and outreach efforts on behalf of the sandhills should inform landowners and recreators of the detrimental impacts of exotic plants and what they can do to help prevent new invasion. Sandhills residential landowners, especially those adjacent to reserves, should be encouraged not to grow invasive species including brooms, pampas grass, and acacias. Broader efforts should encourage nurseries to promote non-invasive alternatives and stop the sale of aggressive exotic plants within the County.

Early Detection

Despite these and other efforts, propagule pressure will result in new exotic plant invasions into the sandhills. However vigilance can prevent new exotic species establishment. Because invasions initiated in one growing season can turn into widespread infestations within just one or a few years, systematic monitoring for new exotic plants should occur annually at all sandhills sites.

Exotic plant invasions can occur at any time. However, certain conditions can promote the invasion and spread of exotic plant species into sandhills habitat, necessitating heightened watchfulness. Disturbances that remove established plant cover and alter soil conditions including fire, road construction, and landslides, can promote the invasion of exotic plants into the closed canopy communities (Hobbs and Huenneke 1992). Because the most likely mechanism of abiotic resistance in the sandhills is the low availability of soil moisture, very wet years (e.g. El Niño) may facilitate establishment of new exotic plants into the sandhills. Addition of nutrients to sandhills soils due to fertilization or, over longer time periods, atmospheric deposition, may similarly enhance invasion and require added vigilance.

Early Eradication

Management of sandhills should include a plan for eradicating newly invaded exotic plant species. Such a plan should include mechanisms for sufficient funds to be available for intensive efforts during the first year that the plant is detected to eradicate the plant.

<u>Eradication of Exotic Plants</u>

Eradication, or complete elimination of the species from the site, is an important goal of sandhills management. Though often regarded as impossible, eradication can occur in small sites and for exotic plants that have recently invaded, are narrowly distributed, and/or occur at low density. Fortunately, many exotic plants in the sandhills fall into one or more of these categories, and can likely be eradicated from many sandhills sites.

Recent invasions: Most invasions begin with one or a few individuals in a single area. Removal efforts focused on such new invasions can be successful, in large part due to the limited geographic area and the low number of individuals requiring treatment. Moreover, recent invasions of species requiring more than one season of growth prior to reproduction (shrubs, trees, and many perennial herbs) can be eradicated if removed before they have the opportunity to reproduce. This can be especially important for species that develop seedbanks (populations of dormant seed) or other belowground dormant structures (e.g. bulbs, tubers) that can be difficult to locate and remove. Two recent invasions into the sandhills should be the focus of eradication efforts (*Cynosorus echinatus* and *Holcus lanatus*) as should the inevitable future invasions.

Narrowly distributed species: All else being equal, species can be more easily eradicated if they occur in a smaller geographic area, where focused treatments are more likely to successfully remove every individual. Several exotic species in the sandhills cannot tolerate the general environmental conditions of the habitat and instead have relatively narrow distributions as a result (e.g. along roads or creeks, near structures, etc.). Such species are good targets for eradication before changes in environmental conditions or other factors potentially facilitate their proliferation.

Less Abundant Species: Small populations oftentimes comprised of just a few, sparsely distributed individuals can be more readily eradicated than large populations. Many sandhills sites presently have exotic plant species that occur at very low abundances and thus that could be readily eradicated. Though highly invasive in other systems, *Genista monspessulana*, *Eucalyptus globulus*, *Acacia dealbata,* and *Cortaderia jubata*, among others, occur in many sandhills sites as small, often narrowly distributed populations. Presumably conditions are not conducive to their widespread establishment; however, rather than allowing them to persist and build up potentially explosive seed reserves, managers should swiftly eradicate these exotic species before conditions change (e.g. fire, drought, wet years, climate change, succession, etc.) and allow them to proliferate.

Eradication should be the goal for the many narrowly distributed and/or less abundant exotic plants that have strong potential to completely alter sandhills community structure and ecosystem processes (e.g. exotic trees, the brooms, pampas grass, etc.). Successful eradication will require preventative maintenance, as propagule pressure resulting from areas near sandhills habitat may result in continued invasions of the same species. Efforts to collaborate with adjacent landowners to remove exotic species can reduce the likelihood of future invasions.

Most exotic plant species in the sandhills presently are widespread, abundant (i.e. densely populating) herbaceous plants that produce copious amounts of seed, have persistent seedbanks, and have been present in the sandhills for many years (if not decades or centuries). These plants are not good targets for eradication; however, their successful control might facilitate the persistence of native biodiversity in the sandhills.

Control of Exotic Plants

The goal of controlling exotic plants is to contain their spread and reduce their abundance (e.g. density), distribution, and/or vigor and thus their deleterious effects on sandhills communities and species. Though preventing establishment and eradicating exotic plant species are the only way to completely avoid their negative impacts, a variety of methods of controlling exotic species have been developed to reduce exotic species effects. Control can proceed using an ecosystem-level approach, or by targeting single species or functional groups of species.

Ecosystem-Level Approaches: Management efforts focused on controlling exotic plant species by addressing ecological processes that influence their distribution, abundance, and population performance may be the most cost-effective strategies for controlling widespread and abundant exotic species over large spatial and temporal scales. Reintroducing fire is one method of controlling exotic plant species in open sand parkland, where the accumulation of leaf litter facilitates exotic species establishment and succession may enhance establishment of non-sandhills species (McGraw 2004). Given that different processes influence their invasibility, different approaches would be necessary in the different sandhills communities.

Functional Group Approaches: Management efforts to control groups of exotic plant species similar in their ecologies and/or impacts in the sandhills may be more effective than focusing on single species. For example, efforts to control all three species of exotic brooms (*G. monspessulana, C. striatus,* and *C. scoparius*) could be more effective (and more logical!) than focusing on a single species. Similarly, strategies could be implemented to reduce the abundance and distribution of many European annuals that co-occur (e.g. in open sand parkland).

Single-species approaches: Though single species management may be highly effective in eradication and prevention, control efforts (i.e. those focused on minimizing populations and impacts) focused on single species may be limited to cases where a species has large impacts and/or a unique ecology which requires specialized treatment. For example, while it may not be possible to completely eradicate Portuguese broom from the parkland at Mount Hermon in the short term, control efforts targeting this exotic are merited because of its large impact on parkland communities and species.

The following section provides an overview of techniques for managing exotic plant species. Some recommendations for applying such techniques based on current knowledge are provided in the section that follows.

9.3 Exotic Plant Management Techniques

Born out of necessity caused by the large-scale habitat degradation wrought by exotic plant species, a seemingly infinite number of techniques have been developed to kill or damage exotic plants. Whereas single techniques are oftentimes effective on their own, savvy managers and researchers have found that two or more techniques used together can often be more effective (Bossard et al. 2000), sometimes synergistically so (Tu et al. 2001). The sheer number of individual techniques, much less their combinations, far exceeds that which can be covered here. Sandhills managers should utilize the wealth of knowledge available through invasive species biologists, weed scientists, land managers specializing in exotic species control, and the numerous texts including "Invasive Plants of California's Wildlands" (Bossard et al. 2000) to identify specific techniques for examination.

Though previous research and management have examined the effectiveness of some of these techniques in the sandhills (Horowitz 2003, Pollock 2004, McGraw 2004, *in prep.*), the vast majority of these methods have not yet been examined in the sandhills. As a result, prior research involving experimental treatments at small spatial scales and adaptive management are necessary prior to large-scale implementation to insure desired effects (Chapter 7.5).

Management techniques have been broadly categorized as physical, biological, or chemical (Hoshovsky and Randall 2000). The following sections examine techniques that might be useful in the sandhills by describing the basic technique, discussing its effectiveness in other systems, then evaluating the benefits and potential negative impacts of its use in the sandhills.

Physical

Potential methods for physically controlling exotic plant species include manual and mechanical removal, fire, mulching, and soil solarization.

<u>Manual and Mechanical Removal</u>

A wide variety of techniques have been developed to remove plants or plant biomass by hand, with our without hand tools (manual removal), or using mechanized tools (mechanical removal). These include various types of cutting and pulling as well as girdling.

Cutting: Cutting exotic plants at their base using saws (manual or chain), machetes, loppers, brush cutters, weed whackers, mowers, and brush hogs (which twist off aboveground biomass) can sometimes effectively kill them. Many exotic species resprout when cut, and therefore require physical treatments, such as stump grinding, or chemical treatment with herbicide.

Girdling: An incision cut into the trunk of a tree around its circumference can sever water and nutrient transport conduits in the trunk, thus killing the tree. While left standing in many systems, girdled trees and shrubs should be removed in the sandhills as a standing dead tree will continue to produce shade and litter and, once it falls, it will negatively impact sandhills plants directly, through crushing, and indirectly, by usurping space as the process of decomposition will be slow, leaving the dead tree on the soil surface for decades.

Pulling: Because cutting often allows plants to resprout, pulling exotic plants out by their roots is often more effective. The loose sand soil conditions of the sandhills render it fairly easy to hand-pull seedlings as well as adults of many species. Pulling large adult shrubs, including brooms (*Genista monspessulanai, Cytisus scoparius* and *C. striatus*) can be aided by Weed Wrenches (The Weed Wrench Company, Eugene, Oregon), which consist of a lever connected to a clamp which, when attached to the base of the plant, allows one to leverage the shrub out of the ground using one's weight.

Fire

Blowtorches and flamethrowers: Flames can be used to kill exotic plant individuals or patches through incineration or heat-girdling. When used during wet weather, risk of fire is greatly reduced (Tu et al. 2001).

Prescribed burning: Broadcast burning removes aboveground individuals, and for many species with dormant seed banks, either kills seeds or induces their germination, after which seedlings can be removed (Bossard et al. 2000). In fire management, aspects of the fire regime including seasonality and intensity of the burn, among other aspects, will influence fire impacts (Chapter 8). Research examining the effects of small-scale burns during the dry season found that burning reduced establishment of European annual grasses and forbs and thus enhanced the abundance and diversity of native species in sand parkland (McGraw 2004). In coastal prairies (grasslands) at Wilder Ranch State Park, spring burns have been conducted just prior to annual seed dispersal to kill the seed crop and reduce the following year's abundance (T. Hyland, pers. comm. 2003). Spring burns might reduce populations of native species in the sandhills, however, and should be carefully evaluated to determine whether the indirect positive effects outweigh such direct negative impacts (Section 7.4).

For some exotic plants, fire stimulates seed germination, while many others are adapted to the open conditions created by fire (Bossard 2000). Thus, burning, especially in closed canopy sandhills communities, could inadvertently benefit exotic species (Section 8.3). Oftentimes a single burn is not sufficient, but several consecutive burns are needed to control exotic plants. For example, an initial burn can be to kill aboveground individuals and stimulate germination from the seedbank, and a second (and sometimes third or fourth) burn used to kill the newly established seedlings. As always, small-scale experiments must be used to test the effectiveness of such treatments prior to large-scale implementation.

Mulching

Litter or other cover on the soil surface that reduces light availability and thus photosynthesis can inhibit populations of many exotic plants. To prevent new seedling establishment or resprouting following removal of adult shrubs and trees, a variety of mulches including straw and hay, sawdust and wood chips, grass or other clippings (Tu et al. 2001). Sandhills native plants are inhibited by mulch (e.g. litter; McGraw 2004), which also reduces habitat quality for Zayante band-winged grasshoppers (Chu 2002). Therefore, mulching should not be used to control exotic plants in intact sandhills habitat.

Mulching may be an effective way to control dense infestations of exotics in highly degraded areas lacking native populations within the sandhills. For example, Horowitz (2003) covered cut stumps of *Acacia dealbata* with black plastic tarps that inhibited re-sprouting and thus killed trees in dense stands within the Olympia Wellfield sandhills, which had been degraded by mining and years of uncontrolled recreation. Such "tarping", as it is called, might be used to remove exotic plants in other degraded sandhills sites, but should not be used as a widespread treatment within intact habitat.

Solarization

Increasing soil temperatures by placing clear plastic sheets over moist soils, causing a greenhouse effect, can kill many seeds and thus prevent their germination. As with mulching and "tarping", this treatment will kill most plant seeds, regardless of whether they are native or exotic, and should therefore only be used in highly degraded areas. As with all experimental treatments in the sandhills, solarization should be implemented through adaptive management examining small scale treatment areas before widespread implementation.

Biological

Biological control methods use natural enemies of exotic plants to reduce their abundance or vigor and thus their negative impacts on native species. Three types of biological control include biocontrol, competition through restoration, and grazing (Bossard 2000).

Biocontrol

Biocontrol is the process by which natural enemies of target species including animals, fungi, and other microbes are released into the wild to predate upon or parasitize exotic plants. Prior to their release, biocontrol agents are rigorously tested to insure that they do not negatively impact native species and must be approved for use by the USDA. This extensive process precludes the use of biocontrol agents on all but a few of the worst pest plants.

Competition through Restoration and Management

Native plants can compete with exotic plant species, thus reducing their performance and ultimately their populations. Typically, exotic plants are problematical because they are strong competitors for resources and thus 'out compete' native plants. Restoration techniques that 'tip the balance' (Corbin et al. 2004) towards native species might enhance native biodiversity in the sandhills. Such techniques can include: propagating and reseeding native species, reducing the availability of nutrients through carbon addition, and facilitating succession.

Propagating and reseeding native species: In general, sowing seeds and planting seedlings or cuttings of native species into intact, preserved sandhills habitat is highly discouraged. The goal of sandhills reserves should be to maintain native biodiversity and natural community structure, and the purpose of management is simply to counteract, where possible, the negative impacts of anthropogenic alterations to habitat, not engineer desired landscapes. Ecological research relies heavily on examination of natural distribution and abundance patterns of species and assemblages within intact sandhills habitat. Planting will preclude the ability of researchers to investigate the ecology of sandhills communities and species in such areas.

In highly degraded habitat where native plant propagule supply is limited, management to control exotic plant species may benefit from sowing or planting native plants following removal or other control techniques. A very conservative protocol for procuring, propagating, and out planting plant material must be adhered to in order to protect the native genetic diversity of the site (Section 11.3).

Reducing soil nutrient availability: Several exotic plant species in the sandhills are nitrogen fixers: plants with symbiotic nitrifying bacteria in and around their roots that increase the availability of plant available nitrogen (i.e. nitrate, ammonium). These plants include those in the pea family (Fabaceae) including the exotic brooms (*Genista monspessulana*, *Cytisus scoparius,* and *C. striatus*) and acacia *(Acacia dealbata*) as well as the native invader, bush lupine (*Lupinus arboreous*). Research in other systems has shown that invasive nitrogen fixers can increase available soil nitrogen and thus facilitate other exotic plants, including annual grasses (Haubensak 2001). Such an effect of nitrogen fixation may have large impacts in the sandhills, where the low nutrient soils likely confer abiotic resistance to some invasion.

Though the sandhills support native nitrogen fixers including a shrub (buck brush: *Ceanothus cuneatus* ssp. *cuneatus*) two subshrubs (silver bush lupine: *Lupinus albifrons* ssp. *albifrons,* and deer weed: *Lotus scoparius*), and two annual herbs (miniature lupine: *Lupinus bicolor,* and *Lotus strigosus*), these native species are sparsely distributed and thus their effects on soil nitrogen are diffuse. Exotic brooms and acacia, in contrast, often form dense, monospecific stands where they can greatly increase soil nitrogen. Following removal, the legacy of increased soil nitrogen can enhance site invisibility by exotic plants that would otherwise be restricted from sandhills habitat by nitrogen limitation. One way to remove additional nitrogen in sandhills soils is to facilitate uptake of nitrogen by soil microbes including bacteria. Adding carbon via sugar (e.g. sucrose) or sawdust has been shown to reduce the amount of plant available soil nitrogen. Such restoration may return the competitive advantage to native sandhills plants which are adapted to the low availability of soil nutrients (Haubensak 2001, Corbin and D'Antonio *in review*).

Succession: Many exotic plants in the sandhills are early successional species. That is, these plants require environmental conditions characteristic of post-disturbance environments which include high availability of light and soil resources and low competition. The natural successional trajectory in dense parkland, sand chaparral, and transitional sandhills communities will tend to render conditions less suitable for these species. This is not the case for open sand parkland where succession is dramatically slower. While succession will reduce suitability of sandhills habitat for the numerous early successional exotic species, it might also render habitat less suitable for many sensitive plants and animals of the sandhills which also require early successional conditions.

<u>Grazing</u>

Recent efforts to decrease exotic plant abundance at large spatial scales in other systems have focused on the role of grazing animals. Livestock including goats, sheep, and cattle as well as chickens have been used to control exotic plants; however, the impacts of grazers on plant communities have been mixed. Grazing has been proven effective in enhancing diversity of native forbs in mesic grasslands (Hayes and Holl 2003); however, grazing has also been shown to facilitate, rather than reduce, populations of some exotic plant species and increase the distribution of exotic plants by vectoring weed seed through animal droppings (Tu et al. 2001).

The unique ecology of sandhills species and communities necessitates a system-specific approach to management. As with all management, techniques that match natural processes to which sandhills species are adapted are more likely to have beneficial effects (Section 7.4). Communities that evolved under a regime of native grazers (e.g. elk, antelope) may benefit from grazing to reduce exotic plants, as the native species are likely adapted to herbivore pressure. However, it is not known whether the sandhills communities experienced grazing from native animals. There is also no known history of livestock grazing in the sandhills.

While grazing has been recommended as a potential treatment to reduce the abundance of European annual grasses and forbs that dominate sand parkland (Lee 1994), grazing may further degrade sandhills habitat by reducing populations of sensitive species, facilitating exotic plant spread, and causing soil erosion. As a result of the strong potential for such negative impacts, grazing is only recommended as a method of removing dense infestations of exotic plants in areas of flat topography for which there is no other conceivable removal method. In these cases, the smallest effective grazers (e.g. sheep and goats, not cattle) should be penned into the designated area and removed immediately following treatment.

Chemical

In chemical control, herbicides are used to kill exotic plants or inhibit their growth. The porous nature of Zayante soils may increase the likelihood that herbicides used in the sandhills will be able to reach groundwater and thus potentially contaminate the public water supply. For this reason, the San Lorenzo Valley Water District prohibits the use of most types of herbicides in their lands (Mueller 2004). Use of herbicides in adjacent sandhills habitat could similarly contaminate the aquifer and harm sandhills animals including the endangered insects. Proposed use of chemicals to control exotic plant species should be carefully evaluated in consultation with experts as well as officials charged with protecting the aquifer (SLVWD) and sandhills animals (USFWS). Like all potential management techniques, chemical control methods can have both positive and negative effects via direct and indirect mechanisms, all of which should be considered in evaluating the potential use of herbicides.

Herbicides vary in their chemical composition, their application method, the species that they impact, the type of damage they cause, their length of persistence in the environment, and their potential impacts on animals, among numerous other important characteristics that should be considered. Given these variables, even an overview of herbicides and their use is beyond the scope of this plan. Sandhills managers can find more information about using herbicides on sandhills weeds in numerous references available including Bossard et al. (2000), the *Weed Control Methods Handbook* (Tu et al. 2001) and the Weed Society of America's *Herbicide Handbook* (Weed Society of America 2002). At the time of preparation of this plan, numerous organizations were sharing their information regarding exotic plant management on the World Wide Web. These include: The Nature Conservancy Wildland Invasive Species Team (http://tncweeds.ucdavis.edu/about.html) and the California Invasive Plant Council (CalIPC.org). Searching the web for "exotic plant control" will bring these as well as well as hundreds of other websites containing invaluable information to help inform exotic plant management in the sandhills including examples of weed control plans and methods of prioritizing exotic plants for control efforts, among others.

9.4 CASE STUDIES IN SANDHILLS EXOTIC PLANT MANAGEMENT

Projects to manage exotic plants in intact sandhills habitat to date have included two projects to remove woody invaders in the sandhills and a series of volunteer efforts to remove non-sandhills plants at the Bonny Doon Ecological Reserve.

Broom Removal at Mount Hermon

Beginning in the 1980's, exotic brooms including French broom (*Genista monspessulana*) and Scotch broom *(Cytisus scoparius*), but primarily Portuguese broom (*Cytisus multiflorus*) invaded the dense parkland community on the top of Mount Hermon. Previously characterized by relatively dense stands of ponderosa pine with a diverse herbaceous understory, a large portion of the site was dominated by the exotic brooms including 2-3 m tall individuals creating dense, monospecific stands. Recognizing the negative impacts of these aggressive exotic species on the unique sand parkland community, naturalists and program director Rick Oliver of the Mount Hermon Outdoor Science School (MHOSS) initiated a program to remove broom in the sandhills as part of their weekly curriculum. As one of the elective courses in which they can participate on Wednesday afternoons, 10-30 students work with a MHOSS naturalist to pull broom seedlings as they learn about the sandhills and the threats this aggressive non-native plant poses at the site.

Recognizing that the nearly six-acre infestation might present a significant challenge to students, MHOSS and the Mount Hermon Christian Conference Center (MHCCC) partnered with the United States Fish and Wildlife Service (USFWS) through the "Partners for Fish and Wildlife Program" to fund a series of coordinated efforts to remove exotic brooms from the dense parkland on Mount Hermon.

Beginning in spring 2002, MHCCC hired the Natural Resources and Employment Program (NREP), a project of the Community Action Board of Santa Cruz County, to remove broom plants greater than 1m in diameter. Naturalists with the MHOSS trained NREP crews and MHCCC staff to identify exotic brooms and to avoid direct and indirect negative impacts to native sandhills species, including the native California broom *(Lotus scoparius*). An NREP crew of six to eight people worked for one week to remove the eight to ten foot tall shrubs by cutting them at the base using chain saws, rather than pulling individuals out of the soil by the roots which had the potential to disturb the soil and negatively impact larva of Mount Hermon June beetles. Fortunately, an estimated 95% of cut individuals died, and those that resprouted the following winter were pulled out of the ground. Left over the summer to dry out, the shrubs were burned on piles in the sandhills habitat or at an off-site location during the winter burn season (D. Pollock, pers. comm. 2004).

Between Spring 2002 and Fall 2003, two to three MHCCC staff worked approximately two days a week to remove remaining broom plants. Beginning with reproductive individuals, these crews pulled large individuals from designated sections of the infested area. MHCCC staff also supplemented the effort of students to hand pull new seedlings that germinated from the seedbank by "flaming"— using a torch to kill seedlings by burning the leaves and stem during the winter and spring.

Staff at MHCCC and MHOSS are continuing to remove broom in an effort to avoid reinfestation by expanding the treatment area to the mixed evergreen forest adjacent to the sand parkland. These efforts are somewhat hampered by the fact that broom is abundant and untreated on the adjacent property owned by the County of Santa Cruz, illustrating the importance of site -level exotic plant management.

For more information about this project, contact Dale Pollock at the MHCCC and Kate Symonds at the USFWS (Appendix E).

Acacia Removal at the Olympia Wellfield

Though primarily found only along road corridors adjacent to sandhills habitat and not within the interior of habitat patches, *Acacia dealbata* became abundant within the sandhills habitat of the Olympia Wellfield where it formed dense monospecific stands that exclude sensitive sandhills species including all six sandhills endemic species. In 2001, the San Lorenzo Valley Water District (SLVWD) partnered with the United States Fish and Wildlife Service (USFWS) through the Partners for Fish and Wildlife Program to remove *Acacia*.

The SLVWD, in turn, contracted with the Natural Resource and Employment Program to have a crew, lead by arborist Matt Horowitz, remove the exotic trees from the center of the habitat. The NREP crew cut the trees using chain saws to no more than 10 cm above the soil surface, burned the cut material, and then experimented with two methods to avoid reprouting: herbicide and tarping. Two separate herbicide treatments were used: a 2% solution of Roundup in 2001, and Garlon 4 ® in 2002. In both cases, the herbicide was applied within 1 minute of cutting directly to the stump in order to reduce potential for spread to non-target species. The tarped stumps were trenched by digging to a depth of 30cm within a 0.6m diameter of the stump, then covered with three layers of 6 mm black plastic tarp for two years (Horowitz 2003).

Horowitz (2003) found that both tarping and Garlon 4 ® provided kill rates of over 95%. The 2% solution of Roundup was not effective, although stronger concentrations may work better. Though there were no untreated stumps for comparison, acacia stumps have been observed to readily resprout following cutting in other sandhills sites including along Graham Hill Road and in Quail Hollow Ranch County Park (J. McGraw, pers. obs.). Given the loose soil of the sandhills which are conducive to trenching an tarp installation, Horowitz suggests that the costs per stump are comparable between the methods, though tarping may be more economical if the costs of a Certified Pest Control Adviser are included. Horowitz suggests these techniques will also likely be effective for removal of *Eucalyptus globulus* in the sandhills (Horowitz 2003). For more information about this project, contact Matt Horowitz or Jim Mueller of the SLVWD (Appendix E).

Non-native plant removal at the Bonny Doon Ecological Reserve

Volunteer groups lead by docent coordinator Valerie Haley have worked on a variety of projects to remove non-native plants from the sandhills habitat in the Bonny Doon Ecological Reserve (BDER) as part of their monthly work parties at the reserve over the past 10 years.

These include: removal of French broom, acacia, telegraph weed, and jubata grass (V. Haley, pers comm.).

Stands of French broom (*Genista monspessulana*) have developed in the BDER, primarily in the mixed evergreen forest, but also in the sandhills communities. In 1994, a group of 20 people worked for one day to remove broom at the BDER as part of the Wildlands Restoration Team, a team of volunteers that works primarily in State Parks to remove exotic plants. Working with weed wrenches, hand saws, and loppers provided by the California Department of Fish and Game, an average of five BDER volunteers and docents work two to three days a year to remove French broom plants in infestations located primarily along Martin Road and in a stand of the rare Santa Cruz cypress on the northwest portion of the reserve (V. Haley, pers comm.).

Between 2001-2003, BDER docents removed 12 *Acacia dealbata* along the border of the reserve with Martin Road. In response to a proliferating telegraph weed (*Heterotheca grandiflora*) population in the open parkland of the BDER, volunteers removed the inflorescences from individuals in a dense patch in September 2003. In February 2004, 2 clumps of jubata grass (*Cortaderia jubata*) located along trails within the BDER were removed (V. Haley, pers. comm. 2004).

9.5 Recommended strategies for Exotic Plant Management

Based on knowledge of the ecology of the exotic species, sensitive species, and communities, the following recommendations are provided for exotic plant management. These recommendations include goals for eradication and control, using ecosystem, functional group, and single-species approaches, which may vary depending on the plant community being managed. These recommendations are summarized in Table 8.1.

Eradication

The limited abundance and distribution of several exotic species makes eradication possible, while their aggressiveness and strong impacts renders such an approach necessary. These include trees (*Eucalyptus globulus*, and *Acacia* spp.), the brooms (*Genista monspessulana* and *Cytisus* spp.), pampas grass (*Cortaderia jubata*), and several herbaceous plants currently found in only low abundance (*Cynosaurus echinatus*, *Holcus lanatus*, and *Erodium cicutarium*). With the exception of a few isolated sandhills patches that have large infestations of these species (which should serve as a motivation for quick eradication at other sites), these species can be eradicated or nearly so through a concerted effort to manage sandhills habitat. Though a few of these species including the grasses may require ongoing removal efforts due to continued propagule supply, the majority of these species can likely be removed from most sites completely through a punctuated effort on behalf of managers.

All new invasions should similarly be dealt with immediately so that they can be eradicated quickly and avoid habitat impacts as well as costs associated with their subsequent control.

Control

Management should attempt to control all other exotic plants currently occurring within the sandhills (Table 9.1). These include herbaceous exotic plants with moderate to widespread distributions that occur at moderate to high density. Control methods can range from spot treatments to ecosystem level management, depending on the distribution of the species. Spot treatment can be used to reduce species with patchy distributions including *Avena* spp., *Briza maxima,* and to a certain extent, *Bromus diandrus,* and *Senecio sylvaticus.* Grass stalks can be easily pulled from the loose sand soils and often without negative impact to native species. Inflorescences can also be removed through cutting prior to seed maturation and dispersal, to reduce the number of seeds available for the following generation and thus population size in these annuals.

Localized treatment might also be used to reduce dense populations of *V. bromoides, V. myuros*, *Hypochaeris glabra, Aira caryopyhyllea,* and *Bromus tectorum.* However, control of these more widespread species might more effectively focus on ecosystem level management techniques that can reduce their abundance over large spatial scales. In sand parkland, fire and soil disturbances (slides, trails, and gopher mounds) reduced exotic plant abundance while removing accumulated leaf litter on the soils surface and, in doing so, enhanced the richness and cover of native herbs and the population performance of two endangered herbaceous plants. Simulating the characteristics of the natural disturbances, disturbance mimics including raking and artificial soil disturbances had similar effects on native and exotic plant species (McGraw 2004). Any attempts to implement these treatments or other disturbance management techniques at a larger spatial scale should be careful to match the characteristics of the natural disturbance regime (Section 7.4). In addition, while experiments have shown the direct and indirect benefits of fire in open sand parkland, fire may increase the abundance and distribution of exotic plants in closed canopy conditions and should be investigated at small scales prior to widespread implementation.

Prevention

One of the most important management objectives for exotic plant species in the sandhills is prevention. Though current exotic plants competitive effects and alterations to natural community structure and function necessitate eradication and control efforts, several sandhills sites remain relatively pristine. For example, the ratio of native plants to exotic plants in terms of both richness and cover is very high in the sandhills chaparral communities. This is presumably because the closed canopy conditions are inhospitable for the growth of many ruderal plants. These conditions are also inappropriate for many native plants, including the gap specialist species which are likely experiencing decreasing populations due to fire suppression (Chapter 8). The conundrum of reintroducing fire into sandhills chaparral communities is an important one for managers to carefully consider in their management planning. Small-scale manipulations of dense canopy communities working from the inside dense woody vegetation may prevent establishment by exotic plants. These and other approaches should always be experimentally evaluated and/or implemented through adaptive management. Other methods of preventing new exotic plant species outlined in Section 8.2 should also be implemented.

Table 9.1 Recommended management goals and techniques for exotic plant species in the sandhills

Species	Distribution	Abundance	Goal	Potential Management Techniques	References
silver wattle (*Acacia dealbata*)	Limited	Low	Eradication	Adults: cut using chain saw, pile burn or remove biomass; tarp or herbicide to prevent stump sprouting Seedlings: hand pull individually or mulch (tarp)	Horowitz 2003
blue gum (*Eucalyptus globulus*)	Limited	Low	Eradication	Adults: cut, pile burn or remove biomass; grind stump or use Triclophyr to prevent stump sprouting	Boyd 2000
pampas grass (*Cortaderia jubata*)	Limited	Low	Eradication	Adults: cut (chain saw/weed eater); remove or burn biomass incl. inflorescences (prior to seed maturation) Seedlings: pulling, shoveling	DiThomaso 2000
Exotic brooms: (*Genista monspessulana*, *Cytisus scoparius*, *C. striatus*)	Limited[1]	Low[1]	Eradication[1]	Seedlings: pulling (by hand), or cutting (weed wacker) during dry season Adults: Physical: pulling (weed wrenches) or cutting in dry season Chemical: basal bark treatment with Garlon ®	Alvarez 2000, Bossard 200a,b; T. Hyland, pers. comm. 2003
Cynosurus echinatus, Holcus lanatus, Erodium cicutarium	Limited	Low	Eradication	Physical: hand pulling incl. collection of inflorescences	Tu et al. 2001
Briza maxima, Bromus diandrus, Avena spp.	moderate	Moderate	Control	Physical: cutting (weed wacker) just before to fruit development (Feb-March) Chemical: spot treatment with Fluazifop-p-Butyl (grass specific herbicide) in dense patches of V. myuros or B. diandrus	Tu et al. 2001
Senecio sylvaticus	moderate	Moderate	Control	Physical: hand pulling or cutting (prior to fruit development in early spring)	Tu et al. 2001
Vulpia myuros, V. bromoides, Hypochaeris glabra, Bromus diandrus, Aira caryophyllea, Bromus tectorum	widespread	high	Control	Physical: prescribed fire during dry season; cutting (weed wacker) just before to fruit development (Feb-March) Chemical: spot treatment with Fluazifop-p-Butyl (grass specific herbicide) in dense patches of V. myuros, B. diandrus, B. tectorum	McGraw 2004, Tu et al. 2001

[1]sand parkland at Mount Hermon has a large infestation; containment and control may be only feasible goals.

CHAPTER 10

SANDHILLS RECREATION MANAGEMENT

INTRODUCTION

Recreational access is a key component of sandhills management plans. Undeveloped sandhills habitat is subject to recreational use, which removes plant cover, causes erosion, and threatens sensitive species populations in many sites. Due to the fragility and rarity of the sandhills species and communities, the impacts of recreation are disproportionately large in the sandhills relative to other systems in the region.

This chapter provides an overview of recreational use, discusses the factors that influence recreation impacts, outlines the potential benefits and negative impacts of different types of recreation in preserved sandhills habitat, then makes recommendations for providing recreation opportunities designed to enhance protection of habitat and persistence of endangered species. Though primarily focused on the recreation management at the ownership and site level (Section 7.2), regional management of recreational access is essential to long-term conservation efforts in the sandhills.

10. 1 SANDHILLS RECREATION OVERVIEW

Like other open space nestled within rural and suburban communities, sandhills habitat has been used for recreation for many decades. Scattered throughout the central part of the County, sandhills habitat is adjacent to many homes, workplaces, stables, and parks (Figure 6.1). It is this proximity that renders sandhills habitat both a destination spot, and habitat through which recreators access other adjacent open space areas.

In addition to parks and the Bonny Doon Ecological Reserve, sand quarries and undeveloped sandhills habitat in private ownership have been used for recreation either as part of official agreements, verbal agreements, or simply *de facto* use. Demand for access has increased due to both an increasing local population and increasing popularity of recreation including mountain biking and off highway vehicle (OHV) riding. As a result, the pressure for recreational use in these areas is very high.

At the same time, growing recognition of the uniqueness, rarity, and fragility of sandhills communities and species has decreased the availability of recreational opportunities during the past five years. The result is an unfortunate clash between agencies and organizations promoting protection of remaining sandhills habitat, and recreators desiring to retain or expand access.

Presently only five sandhills sites have established trails available for public recreational use. These are Henry Cowell State Park, Wilder Ranch State Park, Bonny Doon Ecological Reserve, Quail Hollow Ranch County Park, and Mount Hermon Christian Conference Center (for conference participants only). However, all known sandhills sites receive some level of use for one or more types of recreation including: hiking/walking, horse riding, mountain biking, and off highway vehicle (OHV) riding. In addition, several sandhills habitat patches, especially those featuring rock outcrops, sand parkland ridges, or other promontories, have served as congregation sites for local youths. Finally, abandoned and active sand quarries are used as arenas for parties, paint ball wars, target shooting, and OHV riding.

Individual sandhills sites differ greatly in recreational use, environmental characteristics, and species composition. As a consequence, the impacts of recreation vary among sites. The following section reviews the factors that influence recreation impacts in various types of sandhills habitat. To summarize briefly, recreation impacts sandhills habitat by three main mechanisms: removing biomass (i.e. killing animals, killing or reducing the cover of plants), causing soil erosion, and promoting exotic plant invasion. Each of these impacts initiates a series of direct and indirect effects that can have both negative and positive impacts, depending on the component of the sandhills ecosystem being evaluated and the temporal or spatial scale being addressed. As a result, it is not possible to state '*the* effect' of recreation. Instead, evaluating different types of recreation according to the specific characteristic of the disturbance regime can allow objective assessment of recreation impacts that can inform recreation management. Section 7.4 of this plan examines the aspects of disturbance which influence their impacts on natural communities in greater detail, and can provide the conceptual background for the following discussion of aspects influence recreation impacts.

10.2 CHARACTERISTICS OF RECREATION THAT INFLUENCE IMPACTS

Like all disturbances, recreation impacts sandhills communities and species in various ways which depend on the magnitude (intensity and severity), areal extent, shape, and return interval of use. Though one could certainly find exceptions, the following generalizations are drawn from examination of recreational use at a variety of sandhills sites over the past eight years (J. McGraw, pers. obs.).

Magnitude

The magnitude of the disturbance (biomass removal) depends on two factors: 1) the intensity of the recreation, which measures the strength of the force (pressure, sheering) and 2) the severity of the disturbance, which measures the degree to which biomass is removed. Based on observations of trails used for different types of recreation, the magnitude of disturbance caused by recreation appears to follow the general basic gradient: walking<horse riding = mountain biking < OHV riding.

Trails used solely by wildlife (e.g. large mammals including black tailed deer, coyote, bobcat) are narrow (<50 cm wide) and support populations of herbaceous plants within the disturbance corridor (McGraw 2004; Figure A.28). Trails used infrequently by pedestrians (e.g. researchers, managers, infrequent hikers) are also narrow (<1m wide) and also have plant cover within the disturbance corridor. Sandhills trails receiving use by more intense recreation including horse riding, mountain biking, and OHV riding are greater than 1m wide and typically support minimal plant cover (J. McGraw, pers. obs.; Figure A. 39). While wildlife and pedestrian trails are rarely incised, trails used by equestrians (Figure A.39), mountain bikes (Figure A.40), and OHVs (Figure A.41) are frequently incised where they occur in sloped areas (S. Singer, pers. comm. 2004).

Areal Extent

The area of use influences disturbance impacts. Non-trail recreational use in which patches of habitat are transformed into arenas for gatherings, paintball wars, shooting, and OHV riding result in large areas being denuded. Long, linear trails used for recreation similarly can create a large area when summed across their length. For example, an estimated 1.5 acres of sandhills habitat were disturbed by a network of recreational trails within the intact sandhills habitat of the current conservation areas of the Quail Hollow Quarry. Recent proliferation of trails at the Save-the-Redwoods-League sandhills site has caused a similar area of disturbance.

Wider trails disturb a greater area than narrow trails. Trail width appears to be related to disturbance intensity, as recreation causing greater force loosens more soil and cause greater erosion, which leads to use of the adjacent, previously undisturbed area— thus widening the trial. Single-track trails, as they are referred to by recreation planners, invariably become wider over time if there are no barriers along the trail corridor. This has been observed in trails in many central coast State Parks open to multiple uses (e.g. Wilder Ranch, Nisene Marks, Henry Cowell, among others). Trails in sand parkland readily become wider, as the open vegetation provides no barriers to meandering recreators. Though one might expect that trails located on the spine of parkland ridges might be constrained from widening by the topography, such trails have dramatically widened through years of use for high intensity recreation. For example, a ridge top trail on the South Ridge of Quail Hollow Quarry used by horses and motorcycles as well as hikers widened to more than 10m, flattening what was once a pointed ridge, irreversibly altering the topography of this prominent landmark.

Trails in silverleaf manzanita chaparral and ponderosa pine forest communities used by horses, mountain bikes, and OHVs have also been shown to widen to more than 2 m. In some cases, woody vegetation lining the trails prevents trail widening; however, some recreationists actively create and maintain trails by pruning such vegetation, as evidenced by the cut limbs along even unauthorized trails (J. McGraw, pers. obs.). While wildlife trails in these areas support diverse assemblages of “gap specialists” (Section 8.1), recreational trails are denuded, presumably because diminutive plants cannot withstand the higher intensity disturbances (McGraw 2004).

Shape of Disturbance

The shape or spatial configuration of the disturbed area, specifically the perimeter to area ratio, influences recreation impacts on habitat by affecting recolonization following disturbance. Arenas have a low perimeter to area ratio compared to trails, and wider trails characteristic of higher intensity uses (equestrians, OHVs) have greater perimeter to area ratios than narrow trails. This ratio influences the rate of recolonization following disturbance by determining the disturbance plants (and then animals) must disperse from adjacent, undisturbed habitat.

Seedbanks can facilitate recovery of disturbances; however, ongoing erosion and lack of plant cover on disturbances results in low seed supply in sandhills soils subjected to ongoing recreation. For example, soil seed on the South Ridge trail provided only a small proportion of the seed involved in recolonization. This is likely because the soil with viable seed had been removed by erosion on due to soil ongoing intense recreation (J. McGraw, unpublished data). In contrast, narrow wildlife and low intensity pedestrian trails, have herbaceous plant cover *within* the disturbance corridor and were not observed to have reduced seed availability (McGraw 2004). Meanwhile, these narrower trails also receive seed inputs annually from trailside vegetation.

<u>Return Interval</u>

The time between successive disturbance events (i.e. recreational uses) determines the amount of time the system has to recover from the perturbation and therefore greatly influences the impact of recreation. The same type of trampling will result in greater impacts at higher frequencies (shorter return intervals). If the time between trampling events is sufficiently long, plants can recover or re-establish and soil crusts can reform, such that the next disturbance will not further impact site conditions. Due to the fragile nature of sandhills soils and organisms (plants and crusts), even low frequency denudes trails.

10.3 Habitat Characteristics that Influence Recreation Impacts

Recreation use impacts can vary depending on the habitat conditions where they occur. This is essential to evaluating recreational use in sandhills compared to other non-sandhills communities, as well as assessing recreation impacts in the different communities found *within* the sandhills.

Sandhills Habitat vs. Other Habitats

One of the most important points that must be considered in managing recreation in the sandhills is that the unique geology, soil, and biology of the sandhills, combined with their rarity, renders them especially susceptible to degradation by recreational use. Land managers and policy makers experienced in recreation management in other systems are oftentimes unaware that sandhills communities can be greatly impacted by the same recreational use that would cause less of an impact to other systems (e.g. Redwood forest, Mixed Evergreen Forest).

The inordinate impacts of recreation in the sandhills, when compared to other systems, are due primarily to three main factors: sandhills soils are fragile, sandhills species inhabit open areas where recreation occurs, and sandhills species and communities are extraordinarily rare. These same factors contribute to the differences in recreation impacts *within* sandhills habitat due to the heterogeneity of different communities.

<u>Soil Conditions</u>

The coarse texture of Zayante soils renders them inherently susceptible to erosion when disturbed (Section 2.3). Moreover, sparse plant cover in the sandhills provides minimal root area to bind soil and plant cover aboveground to reduce splash erosion caused by rain drops (Section 3.3). In contrast to grasslands such as the coastal terrace prairies, which are the more widespread herb/grass-dominated vegetation in the region (e.g. Wilder Ranch State Park), herbaceous cover in sand parkland is comprised of sparsely distributed, individual plants, that do not form a contiguous layer of vegetation. The majority are diminutive annual plants that do not grow laterally or propagate vegetatively, nor leave dense litter (or duff) covering the soil surface. As a consequence, the sandhills are naturally more susceptible to erosion (USDA 1980). Direct trampling associated with recreational exacerbates soil erosion by killing herbaceous plants, breaking up soil crusts, and creating channels for stormwater run off, with the magnitude of these effects likely proportional to the intensity of the recreation (Section 10.2).

Similarly, while chaparral communities can provide opportunities for recreation in other systems (e.g. maritime chaparral, hard chaparral), these often occur on gravely or rocky, thin loamy soils which overlay dense sandstones that are less erosive (S. Singer, pers. comm. 2004). In contrast, the deeper, coarse-grained sand soils supporting sandhills chaparral communities are highly susceptible to erosion once sparse plant cover has been removed following recreational use. In some sandhills sites, the soil is thinner and underlain by loosely consolidated sandstone near the surface. Following erosion of the loosened topsoil, which occurs on even gently sloping areas during significant rainfall events, only consolidated material remains. In the absence of soil, these areas cannot support plant life and therefore do not provide habitat. Thus, permanent loss has occurred.

This is the case at many sites throughout the Ben Lomond sandhills, including the southern portion of the Mt. Hermong/SRL site, and the West Ridge of Quail Hollow site, among others. Unlike most consolidated sandstones, however, this material readily erodes as a result of high intensity recreation including horse riding and mountain biking, as this material cannot support the shearing forces (S. Singer, pers. comm. 2004). On steep slopes subject to such recreation, trails have turned into 1-2 m deep gullies (J. McGraw, pers. obs.; Figure A.40). Once trails become incised, they channel runoff which, in turn, causes increased erosion. At several sandhills sites, this positive feedback loop between recreation and erosion has lead to large gullies in trails, which provide neither habitat nor recreation opportunities (S. Singer, pers. comm. 2004).

Sensitive Species Distributions

Recreation more negatively impacts native biodiversity in the sandhills than other systems because recreation occurs in areas supporting many sensitive sandhills species. Understandably, recreators are attracted to the open, park-like setting of sand parkland habitat, which supports the largest remaining populations of many of the sensitive species. Within both sand parkland and chaparral communities, recreation occurs disproportionately in open areas, where five herbaceous sensitive plants (including the three endangered species), the Santa Cruz kangaroo rat, and the Zayante band-winged grasshopper are all preferentially found (Section 3.7, Chapter 5, Section 8.1). This is not to say that recreation has targeted the most vulnerable areas, but that there is an unfortunate coincidence between the areas chosen by recreators and those inhabited by sensitive sandhills species.

Large mammals also preferentially utilize open areas away from shrubs and trees in sand parkland, and between woody vegetation in sandhills chaparral and Ponderosa pine forest. Wildlife trails enhance populations of the native plants including the two endangered plants, by reducing the abundance of European annuals and removing accumulated leaf litter (Section 3.7, McGraw 2004), mechanisms which may similarly facilitate Zayante band-winged grasshoppers (Section 5.5, Arnold 1999a). Santa Cruz kangaroo rats burrows also occur more frequently on wildlife trails than in dense vegetation (Bean 2003).

In the absence of designated recreational trails at most sites, wildlife trails are often utilized for recreation. Following recreational use, these trails no longer support the diverse assemblages of rare plants in the matrix of the disturbance but instead are denuded (J. McGraw, unpublished data; Figure A.39). Santa Cruz Kangaroo rat burrows have been collapsed by trampling associated with recreation (Bean 2003). Meanwhile, observations of Zayante band-winged grasshopper behavior suggest that these animals are susceptible to mortality by directly trampling, especially by fast-moving recreationalists, because they fly only at the last minute and have minimal flight capabilities (Section 5.5).

Extreme Rarity

Recreation has greater consequences for native biodiversity in the sandhills quite simply because the sandhills are extraordinarily rare. Policy makers and land managers accustomed to managing large tracts of land supporting relatively large populations of more widespread species may need to adjust their sense of scale when working on sandhills management. The small populations in these fragmented patches of habitat are extremely vulnerable to extirpation due to disturbances resulting from recreation use (Section 4.3).

In many parks, the negative impacts of recreational use are carefully weighed against resource management objectives to provide public access while protecting the resources for future generation. These parks, most of which contain thousands of acres of more widespread habitats, typically contain one or a few trails. A similar objective approach should be used to weigh recreation impacts in the sandhills communities, which occur on only 4,000 acres in the world.

Habitat Variability *within* the Sandhills

Habitat variability amongst communities within the sandhills also creates differential impacts of recreation, within a given type of recreation (Section 10.2). The main factors influencing these differences are topography and vegetation.

Topography

Following the direct effect of biomass removal, the largest impacts of recreation are due to erosion. Wind, gravity, and, most importantly, water moves the loosened sand particles in the sandhills. During high rainfall events characteristic of winter precipitation in the sandhills region, the permeable soil saturates and water flowers overland, carrying the loosened soil with it. The extent of erosion is in large part a function of the topography of the site. Sandhills habitat ranges in slope from 0-55% (USDA 1980). Not surprisingly, recreation on steep slopes results in greater erosion than that on flat habitat.

Steep slopes enhance erosion by water by allowing overland flow to increase in speed and thus its ability to transport sediment. As speed increases, the ability of water to dislodge and transport soil particles increases exponentially (S. Singer, pers. comm. 2004). The result of such erosion is rilling and gullying of the trail, and deposition of potential deep sediment in alluvial fans where the slope becomes more gradual and water slows and thus infiltrates, leaving the sediment behind. The deposition buries and typically kills herbaceous sandhills plants, creating a disturbance that will be recolonized over time, provided deposition is not ongoing. In the area where the sediment originates, ongoing erosion will prevent new plant establishment and thus continue to erode (Figure A.40).

This link between recreation and erosion is evidenced in several sandhills sites. At the Mt. Hermon Road-North site, OHV trails up the steep slope repeatedly failed and were repeatedly repaired using a small bulldozer. In an intense storm in 2003, however, a fully approximately 4m deep, 3m wide, and 10m long formed at the base of the trail. Failure of this trail resulted in increased unauthorized use of the adjacent, intact sand parkland habitat to the west of the old quarry site, which, like all sand parkland, features steep (<30%), sparsely vegetated slopes that are beginning to suffer greater erosion. Sediment from these trails flows via ephemeral streams through culverts under Mount Hermon Road into Bean Creek, a steelhead stream and tributary to the San Lorenzo River.

Use of a trail ascending the steep (>40%) slopes in sand parkland on the South Ridge of the Quail Hollow site by horses and, historically OHVs, has resulted in a 2.5 m deep incision during the past decade. Efforts to arrest erosion have included installing water bars and straw wattles along the length. The deepness of the trench has caused ongoing, unauthorized equestrians to ascend the sand parkland ridge via another trail, which is also the target of erosion control efforts.

Trail incision similarly began in 2002 in the southern portion of the Mt. Hermon/SRL site due to the dramatic increase in unauthorized recreation. On an old road cut that went directly down the slope, a 5m long, 1m deep gully formed (Figure A.40). Use of the trail by bicycles may have exacerbated the erosion as bicycle tracks create continuous channels in the substrate through which water can flow at increased speeds during high rainfall events, compared to the disturbance caused by foot or hoof prints (CDFG 2002).

In contrast, the relatively gentle topography of the area where trails are located in the Martin Road site has spared sandhills habitat there from erosion. However, even gently sloping areas that lack vegetation can erode if trails become incised and begin to function as channels for water flow. Sheet and rill erosion was observed following grading of an old road on a slope less than 10% at the Bonny Doon Ecological Reserve within this site (S. Singer, pers. comm. 2004)

<u>Vegetation</u>

The vegetation in the sandhills community can interact with soils and topography to similarly influence effects of recreation by determining the degree of biomass removal and subsequent erosion. Cover of plant material including leaf litter and moss as well as dense herbaceous cover can cushion the force caused by low intensity recreation occurring at low to moderate frequency. In areas where leaf litter including pine needles and oak leaf litter covers the ground to near 100%, the deep litter cushions the impact of footsteps on the ground. Equally importantly, these areas typically support a lower diversity of the sensitive plant species within the sandhills communities, as most native sandhills specialty plants are inhibited by litter, and instead support denser assemblages of European annuals. Low intensity, low frequency disturbance characteristic of wildlife trails promotes native plant species persistence (McGraw 2004).

In sandhills chaparral communities, low intensity, low to moderate frequency recreation might similarly benefit native plant community structure by mimicking the natural disturbance regime. While fire suppression reduces the amount of open area required by 'gap specialist' species (Section 8.1), wildlife trails and trails used by researchers and education groups infrequently maintain canopy gaps that support these rare plants. Unfortunately, high intensity associated with equestrians, mountain bikes, and OHVs removes all plant cover and thus do not bring about this beneficial effect.

Though the potential function of recreation as a surrogate for natural disturbances is ecologically interesting, attempts to devise recreation management to enhance plant communities will likely fail for several reasons. First, sandhills communities intergrade in a patch mosaic, such that a given trail will enter communities susceptible to degradation by recreation. For example, while litter covered areas in sand parkland or dense canopy covered areas in sandhills chaparral communities might provide areas where low intensity recreation could have positive impacts, these areas do not form contiguous swaths where trails could be sited. Second, the potential beneficial effects are based on observations of low frequency recreation due to trespassing in currently protected habitat. Increased frequency of use would certainly result in negative effects as discussed previously. For example, more frequent use would displace leaf litter, leaving bare soil conditions that are prone to erosion and associated impacts.

10.4 Potential Benefits of Recreation for Sandhills Conservation

Despite the many known negative impacts of current recreational use on sandhills habitat, a complete assessment of recreation management must consider the benefits of recreation for overall sandhills conservation. Recreation can increase awareness and appreciation of sandhills communities, which can facilitate conservation support and conservation action on behalf of the sandhills. These crucial relationships are described in greater detail as part of a discussion of education and interpretation in the sandhills (Section 13.4). Public support of conservation efforts on behalf of the sandhills (or open space and habitat preservation in general) is crucial to many conservation and management efforts. People are more likely to support conservation efforts if they appreciate the habitat, and this appreciation most often results from personal experience. While many members of the community are active in education, participate in interpretive programs, or attend lectures at museums and public meetings, outdoor recreation provides a mechanism for many others to experience the sandhills. Thus, recreation may provide a way to increase support for the overall goals of conservation.

Policy makers and land managers in many organizations involved in sandhills habitat management may have additional reasons to consider allowing recreation access despite its negative effects on sandhills species and communities. Recreation may be part of their mission statement or mandate. They may simply want to be 'good neighbors' to those who have enjoyed access to habitat historically. Recognizing the value of recreation in the sandhills, the following section provides recommendations for managing sandhills recreation that may provide maximum benefit to the public while reducing negative impacts to sandhills communities and species. Regulations governing endangered species (California and Federal Endangered Species Acts), and environmental impacts (California Environmental Quality Act) may limit the potential for any of the recommended approaches to be implemented (Section 1.3).

10.5 TYPES OF RECREATION MANAGEMENT IN THE SANDHILLS

There are a variety of methods of managing recreation access in the sandhills habitat. The following section describes these methods and, for each, provides a definition, rationale, and example of its application in the sandhills.

No Recreation

Definition

In "no recreation", access for all types of recreation would be prohibited. This would not affect access for research, education, and interpretation.

Rationale

Given the impacts of recreation on sensitive communities and species, the financial costs associated with preventing, monitoring, and repairing damage caused by recreation (e.g. erosion), and the logistical and legal difficulties associated with providing and regulating recreation, providing no recreational access to preserved sandhills habitat is an important option for management. Much of the demonstrated impacts of past recreation on sandhills habitat have resulted from unauthorized use (i.e. trespassing) by a relatively small number of recreationists, while many potential users have been deterred from recreating in sandhills habitat by the illegality of the activity. Sanctioning recreation within sandhills habitat therefore has the large potential to increase usage, and thus negative impacts.

Application

Many patches of preserved sandhills habitat are not open for recreation. These include the conservation areas of the Quail Hollow Quarry located in the Quail Hollow site, and the Quail Hollow Ranch County Park east ridges, as well as several private properties.

Controlled Use

Definition

Controlled use is an approach to recreation in which private landowners provide access to sandhills habitat to individuals for use in recreation on a case by case basis, through specific agreements which stipulate the parameters of the use including allowable types, locations (e.g. appropriate trails), seasonality, weather conditions, timing, and other aspects of the use.

Rationale

The negative impacts of recreation are proportional to the frequency and type of use. Landowners may choose to provide recreational opportunities to a group, either through membership in a ”trails” group or other entity, or by agreement with individuals. Through such agreements, the landowner can stipulate strict parameters for recreational use that can reduce their negative effects including: frequency, type, location, seasonality or climate conditions appropriate for use. Access can be revoked at any time, either for the entire group, if degradation is excessive for example, or for individuals do not abide by agreements.

The benefit of controlled use for sandhills habitat is that group members, based on their incentive to maintain access, can deter unauthorized use and provide a form of self-regulation to recreation that can minimize impacts. Quantitative monitoring conducted annually to determine whether degradation is below a predetermined maximum level can be used to catch damage before it is too late, and provide incentive *within* the group to find ways to keep degradation down. In the case of trail groups, landowners might charge use fees through which they can finance trail maintenance and repair, monitoring trail use and effects, and other costs associated with sanctioning recreation in the sandhills.

Application

Prior to establishment of conservation easements that prohibited recreation, Graniterock allowed a group of equestrians access to sandhills habitat. Habitat degradation due to this use was high in the sand parkland habitat where it was concentrated. Because of the damage, such use was prohibited following establishment of the conservation areas under easement in 1997.

San Lorenzo Valley Water District has similarly implemented controlled use to manage recreation at the Olympia Wellfield. Equestrians affiliated with the Santa Cruz Horseman’s Association have been granted access to specific trails within the site. Sand parkland habitat has been degraded. Meanwhile, unauthorized access by OHVs necessitated security patrols beginning in 2002 (J. Mueller, pers. comm. 2004).

The Mount Hermon Christian Conference Center (MHCCC) restricts recreational use in its sandhills habitat to registered guests and homeowners as pedestrians. As a result of widespread damage to the fragile sand parkland community near the peak of Mount Hermon, MHCCC ceased to hold their annual Easter service at the site in 2001 after which they closed some trails, rerouted and added erosion control devices to other trails, and using low fences to discourage trampling of the sand parkland habitat off trail, before resuming the annual service (D. Pollock, pers. comm. 2004).

Controlled use may be appropriate in other privately owned sandhills habitat where landowners perceive the benefit of access outweighs the negative impacts to sandhills habitat and the responsibility they assume in sanctioning such use on their property. Even controlled use may result in the take of federally endangered species, necessitating permits for compliance with the Endangered Species Act.

Limited Public Use

Definition

Like controlled use, limited public use regulates the parameters of recreational (type, location, seasonality, etc.); the difference being that access is not limited to certain people with whom the landowner has agreements.

Rationale

On public land or private land where the landowner would like to provide recreational opportunities yet wants to avoid habitat degradation associated with unlimited access, recreational opportunities can be provided within narrow parameters designed to protect habitat. Trails can be sited, designed, and created to reduce impacts to sensitive species and communities. The type of use can be restricted to reduce the habitat degradation that results from moderate and high intensity uses. Numerous other aspects of recreational use can be designed based on current knowledge of the system and recreation impacts (Sections 10.2, 10.3)

Application

Currently, the four sandhills sites on public land provide limited recreational use[1]. The two State Parks (Henry Cowell and Wilder Ranch), Quail Hollow Ranch County Park, and the Bonny Doon Ecological Reserve all have designated trails to which use is restricted. These trails were not planned *a priori* to consider impacts on sandhills communities and species (CDFG 2002). Rather, many trails are former roads and fuel breaks that were pushed straight through the habitat, without consideration for the communities traversed or the topography and erosion potential. As a result, many of these trails provide poor recreation opportunities due to high erosion, including the Ridge Fire Road in Henry Cowell S. P., the Woodcutter's Trail in Wilder Ranch S. P., and the Sunset Trail at Quail Hollow Ranch County Park.

All current public lands allowing recreation in intact sandhills habitat also restrict the type of use. Off highway vehicle use is not allowed in any cases. State Parks (Henry Cowell and Wilder Ranch) do not allow mountain bikes on trails, but allow mountain bikes on unpaved "roads" (old fire breaks); thus, mountain bike use is allowed on Powder Mill Road and the Ridge Fire Road (but not the Pine Trail.) Trails in State Parks as well as those in the Quail Hollow Ranch County Park and Bonny Doon Ecological Reserve allow horses and hikers only. Henry Cowell State Park has a history of erosion problems associated with equestrian use of its trails. Although some trails have been repaired and treated to withstand horse use, other trails, such as the Pine Trail north of the Observation Deck, have on-going very severe erosion problems (S. Singer, pers. comm. 2004)

[1] This excludes the South Ridge Conservation Area of Quail Hollow Quarry which, though owned by the County, has a specific legal agreement that prohibits recreational use.

10.6 Recommendations for Recreation Management in the Sandhills

Based on the best available science for sandhills habitat including knowledge of recreational use effects as well as considerations of the potential benefits of recreation, the following recommendations are provided to guide policy makers and managers in their decisions regarding recreational access in intact sandhills habitat. Recommendations are provided for recreation at the site level (or individual ownership level) as well as for regional recreation.

Site-Level Recreation Management

Types of Recreation

Sandhills habitat should not be used for arena type recreation, including OHV riding, paintball games, shooting, partying, or any other similar arena style recreation in which disturbance occurs over a relatively large area with a low perimeter-to-area configuration (Section 10.2). Such uses typically remove the biological value of the habitat completely, and cause extensive erosion that can impact adjacent areas. Alternative areas for these activities should be identified and recreators accustomed to using sandhills habitat in this manner should be educated about the extreme rarity, uniqueness, and fragility of sandhills habitat and recreational opportunities elsewhere. Private landowners that allow such activities to occur should be apprised of the negative consequences of such recreation, including the impacts on listed species.

Sand parkland

No recreational use should be permitted within sand parkland habitat (open or dense). With only 200 acres of sand parkland remaining, the negative impacts of recreation simply create too much potential for complete loss of this unique community and its diversity of sensitive species.

Conservation efforts should endeavor to preserve all sand parkland habitat using conservation easements or through fee title ownership by organizations and agencies that recognize the fragility of this habitat. This habitat should be managed solely for the persistence of the sensitive species and communities it supports. Access for research, education, and interpretation should be permitted within narrow limitations designed to protect biodiversity in this habitat (Chapter 12, Chapter 13). Outreach programs should be developed and implemented to encourage compliance with any newly established rules for protecting sand parkland habitat, and should include: written materials, presentations, and guided walks to illustrate the reasons for closure; interpretive signage posted at prior access points; and information about alternative trails.

Conservation Easements

Conservation easements established for any sandhills habitat should specifically exclude recreation. Such use of sandhills habitat is simply not consistent with the purpose of a conservation easement: to protect sandhills species and communities. Conservation easements on sandhills habitat, regardless of the community type it supports, should include active management (within an adaptive management framework), research, and education programs.

Other Sandhills Habitat

When compared to sand parkland, sandhills chaparral communities and the ponderosa pine forest are more widespread. However, these communities are extremely rare and imperiled. Given that so little is known about these communities, and the documented habitat degradation that results from moderate to high intensity recreational use, these communities should also be closed to moderate to high intensity recreation which have been shown to have both direct and indirect impacts on the sensitive species and communities.

Trail Planning and Management

If access to publicly owned sandhills habitat is unavoidable, it should be carefully managed to avoid the negative impacts that have been proven to occur. The following are recommended guidelines for limited public use. These recommendations incorporate biological understanding of the sandhills outlined in the previous sections of this chapter. They do not take into account potential regulations which govern such uses of sensitive habitat and resulting impacts to endangered species which by policy makers and land managers should examine prior to project inception (Section 1.3).

Trail Location

The route of a trail for recreational should be carefully selected a team of experts including sandhills scientists, soil scientists, erosion control specialists, trail designers, and others experienced in designing, constructing, and managing trails. Most existing trails have serious flaws in one or more areas of design and render them unacceptable (T. Hyland, pers. comm. 2004). Existing trails should not be selected simply because they are already created.

To determine the precise location for the trail, biologists experienced with the sandhills communities and species should thoroughly inspect the site to determine the location of sensitive species and habitats, as well as map more widespread habitats that may occur in the site. If at all possible, the trail should be cited through non-sandhills habitat occurring at the site. If the trail must enter sandhills habitat, the segment within sandhills habitat should be limited in length and avoid any patches of highly sensitive habitat or rare species populations.

Within the area determined by the biologists to be *least* likely to have impacts, the rest of the team should determine the locations that will be less likely to require extensive design and maintenance to control erosion. Zayante sands impose "severe" restrictions on trail development and will likely render this task difficult (USDA 1980).

Trail Design

Following identification of a site, trail designers should draft a plan for a short trail that addresses the limitations of Zayante sands for recreation (USDA 1980). Trail widening and incision present two problems. The trail should be narrowly delimited using low fences to prevent trail widening by users seeking to step on firmer substrate. Artificial substrate might be added to prevent incision; however, such material will likely preclude native sandhills species from using the trial corridor and may introduce exotic plants (Section 9.2), so should be carefully considered.

Interpretation

Trails through the sandhills should educate users about the uniqueness, rarity, and fragility of the sandhills ecosystem to both enhance their experience and promote compliance with the regulations regarding recreational use. Interpretive signs along the path or numbered posts which reference information contained in a brochure available at the trailhead can enhance the recreational experience for many users. Large format interpretive signs or "kiosks" posted at the trial entrance may similarly provide information and increase compliance with rules (Section 13.5).

Monitoring, Maintenance, and Enforcement

According to the Soil Service, trails in the erosive Zayante soils require extensive maintenance to prevent erosion (USDA 1980). If located on flat terrain and designed to incorporate erosion control techniques, maintenance costs and effort to control erosion might be reduced. Erosion is just one component of degradation to sandhills habitat necessitating extensive maintenance to avoid negative impacts. Monitoring should be conducted to detect newly created, unauthorized trails, which should be immediately closed, and exotic plants that establish on the trail corridor, which should be removed to avoid invasion into the intact habitat (Section 9.2). Enforcement will likely be required to gain compliance with trail use restrictions.

Regional Recreation Management in the Sandhills

Like other aspects of sandhills management discussed in this plan, recreational use should be examined at the regional level in order to maximize the conservation efforts on behalf of the sandhills. In previous discussion between recreationists desirous of attaining and maintaining access to sandhills habitat and landowners, regulators, and conservation organizations desiring to protect sandhills communities and species, recreators have indicated that they would like routes through sandhills habitat to access other locations (e.g. parks) where they can recreate. Equestrians wish to avoid moving their horses in trailers, and mountain bicyclists seek to link open space patches where mountain biking is permitted without having to rely extensively on roads. Efforts to identify one or a few regional trails which can be carefully managed may increase the utility of trails through sandhills and reduce current impacts of recreation throughout sandhills sites.

CHAPTER 11

RECLAMATION, RECONSTRUCTION, AND RESTORATION

INTRODUCTION

Throughout its original distribution, portions of sandhills habitat have been destroyed by a variety of human uses (Chapter 4). Sand quarrying, viticulture, and residential development have reduced and fragmented sandhills habitat. Though conversion of habitat is typically permanent, there are in some cases opportunities to rehabilitate land that previously supported sandhills species and communities.

Covering more than 600 acres of former sandhills habitat, sand quarries represent such an opportunity. Following completion of mining, the Surface Mining and Reclamation Act (SMARA) of 1975 requires that "…mined lands be reclaimed to a usable condition which is readily adaptable to alternative uses." Though "alternative uses" can include subsequent development, formerly mined sandhills habitat can be reclaimed in such a way that can enhance conditions in adjacent intact sandhills habitat, increase migration between habitat patches, and in some cases, increase populations of sensitive species. In addition to converting habitat, human uses of sandhills have also greatly degraded some sites.

This chapter discusses efforts to return habitat value to destroyed or degraded sandhills habitat in terms of their role in sandhills conservation efforts. After defining the terms that will be used in this plan to refer to different types of projects, this chapter discusses the potential benefits and negative impacts of such projects on sandhills species and communities, and provide guidelines for different types of projects.

11.1 OVERVIEW OF SANDHILLS RECLAMATION, RECONSTRUCTION, AND RESTORATION

The terminology used to describe projects designed to improve habitat conditions is complex and inconsistently applied. Though people have a general understanding for the terms "rehabilitation", "revegetation", "restoration", "reclamation", "reconstruction" and "enhancement", there is little consensus on how the terms distinguish projects according to their goals, techniques, or the habitat that they affect. Though efforts within the scientific literature have attempted to establish consistent terminology, multiple efforts have resulted in multiple meanings for different terms (Jordan et al. 1987, Hunter 1996, Spellerberg 1996, Primack 2002).

Moreover, these terms take on additional meanings in contexts other than science and management including legal and regulatory arenas. For example, in the conservation biology literature, "enhancement" has been used to refer to efforts to improve an ecosystem that has *not* been degraded, for example by adding watering holes to facilitate waterfowl (Hunter 1996). In mitigation projects, the term "enhancement" can be used to describe general efforts to increase habitat value in areas that have been degraded, as by recreational use or exotic species. Legal documents regarding past and ongoing sandhills projects have also used many of these terms, yet most have lacked accompanying definitions, resulting in some controversy over what was intended and what is required.

This section will define, for purposes of this plan, terms that will be used to distinguish different types of activities in damaged sandhills habitat. The terms are designed to differentiate the projects according to two main aspects: 1) the state of the system at project inception, and 2) the goals of the project. In addition, two main goals are distinguished: 1) returning ecosystem function—the processes that an ecosystems provides including plant productivity, animal habitat, erosion control, and groundwater filtration, among numerous others, and 2) reinstating ecosystem structure— the composition of species and their relative abundances (Bradshaw 1984).

Reclamation

The term "reclamation" will be used to describe projects that return derelict or highly damaged lands to productive habitat with greater ecosystem function. Reclamation projects attempt to establish communities of plants and animals in areas that formerly supported sandhills habitat in order to improve the function of the land, without attempting to establish sandhills plant and animal species, and thus reinstate ecosystem structure. "Rehabilitation" is a term often used synonymously with reclamation, the term used in the context of mines as outlined in SMARA.

Reconstruction

The term "reconstruction" will be used to refer to projects that attempt to restore both ecosystem structure and function following destruction of previous habitat.

Restoration

The term "restoration" will be reserved for projects designed to return both natural structure and function to habitat that has been degraded, but not destroyed. As described in Section 4.3, the term "degraded" is used to describe habitat which has been altered in such a way that it supports reduced populations and diversity of species and communities, while "destroyed" habitat does not support the majority of the species present originally.

Management vs. Restoration

What is the difference between restoration, reconstruction, and reclamation, discussed here, and management, examined throughout this plan? The term 'management' is used to describe activities within intact habitat that are designed to reduce or reverse the stresses caused by habitat degradation including fire exclusion, exotic species, and recreation. It is most closely related to restoration, which also occurs in degraded habitat and is similarly designed to improve degraded habitat, yet may include active planting and perhaps translocation of animals. Like restoration, reclamation and reconstruction include active planting (i.e. revegetation), the difference being that reclamation and reconstruction occur in habitat that has been destroyed rather than merely degraded.

Implications for Sandhills Development

Restoration and reconstruction projects in the sandhills can play an important role in minimizing the negative impacts of habitat degradation and destruction associated with development projects on adjacent intact sandhills habitat, as described in detail in the next section. Projects that attempt to reestablish native sandhills populations increase the potential benefit to intact habitat as well as the likelihood of project success, as most non-sandhills plants cannot establish self-perpetuating populations in sandhills habitat, especially that which has been dramatically altered. Many sandhills plants have been found to persist on highly degraded or destroyed habitat. These include a suite of native herbaceous plants that require early successional conditions in sand parkland, including the three herbaceous endemic plants. Such projects may provide habitat for native sandhills animals as well.

Though establishment of native populations should be a goal of reclamation, reconstruction, and restoration projects in the sandhills, population establishment does not constitute re-creation of sandhills communities, which include not only the species composition but also the spatial arrangement and relative abundances. Despite extensive efforts to re-establish sandhills communities following habitat destruction due to mining, these efforts have not succeeded in recreating sandhills habitat (B. Davilla, pers. comm. 2002.). This is not surprising as such efforts cannot recreate the natural geologic substrate, topography, and soils which developed over millions of years and are the basis for sandhills communities.

As a result, while reconstruction projects would benefit from using native sandhills species, which can in turn enhance conservation of adjacent intact habitat, such projects should not be considered mitigation for development of sandhills habitat.

Past and Ongoing Projects

Several projects have been implemented to improve habitat quality in sites which previously supported intact sandhills habitat. Most were related to reclamation efforts for the three active quarries: Hanson, Quail Hollow, and Olympia. Over the past several decades, each quarry has been operated by multiple companies that have mined different areas and employed different consultants and revegetation specialists on their various reclamation projects, rendering the history of sand quarry projects complex and beyond the scope of this plan. This section will briefly illustrate some types of projects that have occurred to date in the sandhills.

<u>Reclamation Projects</u>

Three quarry operations in sandhills habitat were completed prior to the passage of SMARA in 1975. They are Scotts Valley, Geyer, and Old Kaiser (aka "old Ferrari quarry"). Though it is not known whether any attempts were made to reclaim any aspect of these quarries following cessation of mining, their current states suggest little was done (J. McGraw, pers. obs.; Figure A.42).

The three active quarries each have separate, ongoing reclamation projects as part of their compliance with SMARA (Figure A.43). These projects are designed to increase plant cover on the formerly denuded surfaces created by quarrying, reduce wind and water erosion (and thus impacts to air and stream quality), provide habitat for animals, and create populations of plants native to California (Schettler and Kiguchi 1995, Schettler et al. 1997, Haley 2002). Referred to as 'revegetation plans', these projects constitute reclamation or reconstruction, depending on the extent to which they attempt to reestablish sandhills species on the site prior to quarrying.

Other Projects

Degradation of sandhills habitat due to operations at the Ben Lomond Landfill was followed by a project designed to re-establish sandhills plant assemblages on the site (Schettler et al. 1995). Explicitly designed to establish natural plant populations on the degraded area using a combination of erosion control and active planting, this project constitutes a restoration using the terms of this document.

11.2 Potential Beneficial and Negative Impacts of Projects

Efforts to improve habitat quality in destroyed or highly degraded sandhills can play an integral role in conservation efforts designed to recover endangered species and maintain natural communities in intact sandhills habitat. At the same time, such projects have the potential to inadvertently negatively impact sandhills species and communities. This section highlights some of the potential benefits of projects, and then describes some potential negative impacts that can occur. Based on these, the following sections recommend guidelines for implementation of different types of projects.

Benefits

Efforts to improve habitat in sand quarries can have many benefits. Depending on the goals of the project (i.e. reclamation vs. reconstruction) benefits can include: 1) reduce negative edge effects on adjacent sandhills habitat, 2) provide corridors for migration between sandhills habitat patches, and 3) create habitat for sandhills species.

Reduce Negative Edge Effects on Adjacent Sandhills Habitat

Human uses that destroy or highly degrade sandhills habitat not only impact sandhills species and communities by removing the habitat that they impact directly, but also by reducing habitat quality in adjacent, intact habitat due to negative edge effects—impacts to habitat that result from adjacent non-habitat. In the case of reclamation projects, all three quarries are contiguous with intact sandhills habitat that is being managed for its conservation value. Efforts to reclaim quarries by establishing plant cover on the soil surface can potentially reduce the impacts of the quarry on adjacent habitat by: 1) reducing wind erosion and associated sediment deposition, 2) reducing the potential for increased temperature changes due to open conditions inside quarries, and 3) providing resources to plants and animals located on the quarry edges, including pollinators for native plants and food for native sandhills animals.

Provide Corridors for Migration Between Sandhills Habitat Patches

Many sand quarries are located between protected sandhills habitat patches. Reclamation of sand quarries can increase the likelihood of animal migration and plant dispersal between the otherwise isolated patches of habitat. Using native sandhills species as part of reconstruction projects can increase this likelihood of migration for both animals and plants native to the sandhills, including the two endangered insects and the four endangered plants. Although long distance dispersal via wind and animals may also occur following reclamation projects, non-sandhills vegetation may create conditions unsuitable for sensitive sandhills species migration.

Reconstruction projects that are able to encourage migration between patches of habitat that were previously contiguous can play a crucial role in the conservation of species and natural communities by increasing population persistence and avoiding inbreeding depression. Habitat loss and fragmentation reduce population sizes. Smaller populations are more vulnerable to extinction due to demographic stochasticity and environmental stochasticity (Primack 2002). Persisting populations in fragmented habitat may reflect an extinction debt—that is, current conditions will lead to extinction through time yet populations are persisting presently due to the time lag.

Migration between small populations may facilitate persistence in the long run, potentially as a metapopulation—a population of populations connected by migration. While individual populations might be extirpated, colonization from nearby populations occurs such that the metapopulation persists. Thus, if remaining habitat patches are too small to support self-sustaining populations, colonization via migration through the reconstructed habitat in the quarry could allow the individual patches and thus the overall metapopulation to persist, whereas unsuitable habitat within former quarries would not.

Increasing migration between presently isolated habitat patches can enhance the exchange of genetic material amongst currently isolated populations. Habitat loss and fragmentation associated with quarrying likely reduced genetic diversity in remaining sandhills patches due to genetic bottlenecks (Section 4.2). Isolated, small populations have strong potential for inbreeding depression, which creates less fit individuals and decreases population growth, causing the population to spiral downward to extinction (extirpation). Reconstruction that allows migration between previously isolated populations can increase the genetic diversity within a population and thus reduce inbreeding depression.

Provide Habitat for Sandhills Species

Reconstruction projects that create habitat for sandhills species have the greatest potential to enhance sandhills conservation efforts. In addition to resulting in the beneficial effects described above (reduced edge effects, increased migration), projects that establish native species can increase population persistence by creating new populations or expanding the areal extent of populations in adjacent intact habitat. The three currently quarry operations cover 150 acres, 190 acres, and 110 acres. If populations were allowed to expand from within their current small fragments adjacent to the quarries into reconstructed habitat within even a portion of the mined areas, the increased population sizes would increase population and thus species persistence.

Reclamation (i.e. revegetation) efforts to date have successfully established populations of the four endangered plants (Schettler and Kiguchi 1995, Schettler et al. 1997, Haley 2002). As stated previously, the three endangered herbaceous plants (*Chorizanthe, Erysimum, Eriogonum*) are preferentially found in open sandy areas within intact habitat (Chapter 5; McGraw 2004). These species have been found to colonize areas post-mining even in the absence of active planting, which has successfully increased populations of these endangered species. Though difficult to propagate, *Arctostaphylos silvicola* also has been established through revegetation projects (Schettler and Kiguchi 1995, Schettler et al. 1997, Haley 2002).

The potential for reconstructed sandhills habitat to support sandhills animal species is uncertain. Current projects have been specifically designed to increase the likelihood that the reconstructed habitat can support native sandhills species (Haley 2002). Presently, there is no evidence that the two endangered insects can utilize reconstructed habitat within quarries. Incepted in the 1970s, revegetation at Hanson quarry represents the earliest effort to reconstruct sandhills habitat. Mount Hermon June beetles were only observed in areas of deep loose soil deposited by erosion from the intact habitat upslope, and Zayante band-winged grasshoppers have not been observed in these sites. The very thin soil, combined with the use of stabilizing agents (e.g. lignin sulfonate) to control erosion on the steep slopes, may inhibit burrowing by these endangered animals (D. Arnold, pers.comm.).

Potential Negative Impacts

Though reconstruction projects clearly have the potential to benefit overall sandhills conservation efforts, they can also negatively impact sandhills species and communities within intact habitat by the following mechanisms: 1) increase genetic erosion, 2) reduce native species populations, and 3) facilitate invasion of non-native plants into intact sandhills habitat. Through careful consideration of the potential for these impacts and the ecology of the system in planning, these impacts can be reduced or avoided, as described in Section 11.3.

<u>Genetic Erosion</u>

Genetic erosion is the loss of unique genetic material including alleles, genes, and genotypes (Section 4.4). Reclamation and reconstruction efforts in highly degraded sandhills habitat involve active revegetation in which propagules (seeds, cuttings, divisions, etc.) of plants obtained from elsewhere are placed in the area to be revegetated. There has been no research examining the genetic structure of sandhills plant species, which will invariably differ due to differences in dispersability, mating system (outcrossers, selfers), and distribution, among other factors influencing genetic structure. However, observations of morphological variation between populations in different sites, many of which have likely been separated for millions of years (Section 4.4) suggests that at least some sandhills species have high between population genetic diversity.

Lacking high dispersability, many species in the sandhills likely would not exchange genes between populations at different sandhills sites—contiguous areas of sandhills habitat (Section 6.2). Thus, movement of propagules between sites as part of revegetation programs has the potential to greatly erode genetic diversity. The consequences of this include not only lower success of outplantings in revegetation areas, but also genetic contamination of the local populations in adjacent intact sandhills habitat. This contamination has the ability to halt the evolutionary process by which species become differentiated due to geographic isolation, while reducing the genetic diversity that exists between sites (Section 4.4).

Reduce Native Populations in Intact Habitat

Propagules for active revegetation are often collected in large quantities from intact habitat (Schettler and Kiguchi 1995, Haley 2002). In the case of reclamation, cessation of quarrying in one part of a mine is often immediately followed by an intense effort to establish vegetation on slopes in order to avoid erosion that can pollute water and air as well as inhibit successful revegetation. Because several acres are often planted in a single year, hydroseeding (spraying seed) and/or broadcast seeding (throwing seed by hand and raking into soil) are used to sow seed rather than placing individual seeds into protected containers, which can increase success but requires a far greater effort. Low germination rates for scattered seeds has lead to seeding rates of 10 seeds per square inch or 67,726,400 seeds per acre (Schettler et al. 1997). Revegetation projects often re-apply seed annually following cessation of mining over several acres. As a result, the amount of seed collected from intact sandhills habitat can be extremely high.

Repeated collection of large quantities of seed may impact plant populations. There have been no known studies specifically designed to quantify the impacts of seed collection on resulting plant populations. There is a black box over the many steps that can occur between seed maturation and seed germination (predation, disease, dispersal to an unfit site, dormancy), making it difficult to detect impacts on natural populations. In the case of annual plants with seeds that are not subject to predation nor dispersed through space or time (e.g. seedbanks) but instead germinate close to the mother plant at such high densities that self thinning results in high mortality, harvesting a proportion of the seed from the mother plant may indeed not impact the amount of seed produced the following year. However, for species with long life spans, seed banks, highly dispersability, and/or high rates of seed predation, even seemingly small amounts of seed removal can impact plant population dynamics, especially if conducted annually in the same population.

Repeated collection of large quantities of seed may similarly impact animal populations. Many animals in the sandhills, from insects to birds to small mammals, are granivores whose diet is comprised primarily or exclusively of plant seed. Reducing the availability of seed for these animals can reduce their populations that, in turn, can impact populations of other animals who may predate upon these species. Though these aspects of seed collection have not been studied in the sandhills, their potential effects merit consideration.

Reconstructed areas might reduce populations of sensitive animal species in the sandhills by acting as population sinks. Sensitive animals in adjacent intact habitat might be attracted to reconstruction areas because they have one or more habitat features the animals prefer (e.g. open habitat for thermoregulation, a preferred food item, water from irrigation). If habitat conditions are not suitable for these animals to complete their lifecycles (e.g. soil too think for burrowing or egg laying), or are perhaps even deleterious to the animals (e.g. high predation rates), these areas could act as population sinks—areas with negative population growth.

This potential role of adjacent disturbed areas in reducing populations in intact habitat has not been evaluated. If a targeted study determined that this were the case, measures could be taken to exclude sandhills animals from these areas until such time they can support positive population growth. In the meantime, quarry slopes must be revegetated and it is very difficult if not impossible to establish non-sandhills plant species to create 'unattractive' habitat in these areas. Given this and the potential benefits of reconstructed areas for sandhills animals in the long term (described above), reconstruction represent the best alternative and should continue.

<u>Introducing Species into Intact Sandhills Habitat</u>

Reclamation and reconstruction projects can promote the invasion and spread of exotic plant species into adjacent, intact sandhills habitat (Williamson and Harrison 2002). In an effort to stabilize erosive slopes immediately following mining, revegetation often involves hydroseeding—a process by which seed and a surface stabilizer are sprayed onto soil. The seed used includes 'Zorro' fescue alone or as a mix with non-site specific deer weed (*Lotus scoparius)* and native seed collected on or off site (Schettler and Kiguchi 1995, Schettler et al. 1997, Haley 2002). So-called 'Zorro' Fescue is a horticultural variety of the European annual *Vulpia myuros,* which is preferred for hydroseeding on sand quarry slopes because it is adapted to low soil moisture, low nutrient availability conditions. *Vulpia myuros* is the most widespread and abundant exotic plant in open sand parkland (McGraw 2004. Adapted to the same open conditions in sand parkland as the diverse assemblage of unique sandhills specialty herbs, *V. myuros* (rat tail fescue) is a strong competitor for soil moisture and greatly reduces native species richness as well as the survivorship and fecundity of the two endangered species (Brown and Rice 2000).

The extent to which hydroseeding with 'Zorro Fescue" increases *V. myuros* abundance and distribution within adjacent intact habitat has not been examined. As with many grasses, *V. myuros* produces small seeds that appear well-adapted for dispersal by animals (e.g. on fur) and perhaps by wind. Though abundant within open sand parkland habitat at most sites, *V. myuros* might increase its distribution and abundance within other communities (e.g. sandhills chaparral) as a result of widespread application of its seed in revegetation projects. In addition, such application might inhibit success of management efforts to reduce exotic plant abundance in habitat preserves adjacent to such projects (Chapter 9).

Reclamation and, to a lesser extent, reconstruction projects, can also degrade intact habitat by facilitating the invasion and spread of plant species that may be native to California, Santa Cruz County, and perhaps the sandhills, but not natural components of the adjacent sandhills community. Revegetation projects designed to increase ecosystem function (e.g. reduce erosion, create animal habitat) but not necessarily reestablish indigenous community structure, plant species not found on the site may invade adjacent sandhills habitat. Fortunately, the adverse conditions posed by intact sandhills soils and the even more difficult conditions for plant growth in former quarries renders it difficult to establish non-sandhills natives in quarries, and somewhat unlikely that they will be able to invade. However, native plants that are included in revegetation projects and might invade adjacent intact habitat include *Lupinus arboreous, Baccharis pilularis,* and *Heterotheca grandiflora*.

Given the increased likelihood of success with sandhills species, a source of propagules in adjacent habitat, and a general desire to establish truly indigenous vegetation to former sites, revegetation projects have focused primarily on using sandhills species native to the site

(Schettler and Kiguchi 1995, Schettler et al. 1997, Haley 2002). Such reconstruction projects can still potentially negatively impact adjacent sandhills habitat, however, if species planted spread into adjacent intact habitat where they are not currently found. This is primarily a concern when quarried areas abut intact sand parkland habitat, which supports a high diversity of sensitive species including the four federally endangered species. Planting shrubs, trees, and perhaps even herbs characteristic of chaparral communities might facilitate their invasion into sand parkland (Schettler and Kiguchi 1995). Though sand parkland habitat may have an abiotic barrier to such invasion (e.g. substrate prevents some species from establishing), intense propagule pressure resulting from active revegetation and subsequent natural dispersal may ultimately facilitate establishment of chaparral plants in sand parkland. Shrubs and trees compete vigorously with native herbaceous plants in sand parkland and alter site conditions rendering them unsuitable for future establishment (McGraw 2004). Therefore, planting even native sandhills species has the potential to degrade intact sandhills habitat.

11.3 Conservation Guidelines for Reclamation and Reconstruction

Revegetating highly disturbed ground, especially that which occurs in sandhills, is an inherently difficult process. Revegetation specialists must balance their efforts to provide positive impacts to adjacent habitat with their project's immediate needs, including erosion control. Recognizing the difficulty inherent in this work, this section provides some general guidelines for projects designed to improve habitat conditions based on the previous section's outline of potential benefits and negative impacts. Separate recommendations are provided in the following section for restoration projects in degraded habitat.

Large scale projects in areas previously supporting sandhills habitat, especially those immediately adjacent to intact sandhills habitat managed for its conservation value, should be designed to increase both ecosystem function *and* ecosystem structure. By the definitions used in this chapter, reconstruction, rather than merely reclamation, should be the goal. Reclamation has greater potential to introduce non-sandhills species into sandhill habitat, and lower potential to enhance the persistence of sandhills populations and communities. Reconstruction projects should be carefully designed to avoid potential negative impacts while maximizing the success of the potential benefits for such projects outlined in the previous section. The following guidelines are provided.

Erosion Control

Controlling erosion due to water, wind, and gravity presents a significant challenge to reconstruction projects in former quarries. Revegetation specialists are continually developing new methods of erosion control, including sandhills-specific strategies (Schettler and Kiguchi 1995, Schettler et al. 1997, Haley 2002). Concern remains over the ongoing use of invasive exotic plants and soil stabilizers to control erosion.

Revegetation projects should ideally use only native plants propagated form site-specific sources. Efforts to develop an alternative method of stabilizing steep slopes without applying the invasive *Vulpia myuros* should be initiated. Within the sandhills communities, at least four other species of *Vulpia* (annual fescues) are known to occur (Appendix B). Though they are currently quite rare, likely as a result of intense competition by *V. myuros*. *Vulpia megalura,* an annual grass native to the sandhills, is being propagated for use in revegetation projects at the Quail Hollow Quarry (S. Schettler, pers. comm. 2004). Contract growers could be used to propagate this or other suitable native cover plants for other projects.

Observations suggest that soil stabilizers applied to slopes and benches to control erosion in revegetation projects prior to or during hydroseeding may reduce habitat suitability for Mount Hermon June beetle and Zayante band-winged grasshoppers. Both of these endangered insects prefer loose sand soil (Arnold 1999a), and their colonization of revegetation areas may be inhibited or slowed by the use of stabilizers (D. Arnold, pers. comm. 2004). Efforts to enhance populations of these two endangered insects might consider applying stabilizers only to the slopes, not the benches where the insects are most likely to colonize.

Efforts to control erosion by managing runoff may reduce the need to establish dense exotic plant cover immediately following quarrying, and instead allow more slow growing native plants to establish. Applied in the short term, mulches including pine needles, rice straw, or erosion control blankets can reduce the impact of rainfall and dissipate runoff (S. Singer, pers. comm. 2004). These mulches may prevent establishment of native species in the long run, but might perhaps be used as an interim measure until greater cover of native plants is established.

Plant Procurement, Propagation, and Planting

Collecting, propagating, and planting sandhills plants should follow strict guidelines in order to minimize the potential for negative impacts to natural populations and communities. Though general guidelines for plant procurement have been developed (Guinon 1992), such approaches will not sufficiently protect sandhills species and communities as they do not take into account the extreme rarity and unique biogeography of sandhills species which necessitates more conservative approaches to revegetation and restoration projects in the sandhills. Instead, the following guidelines have been developed specifically to protect biodiversity within the sandhills.

<u>Source Considerations</u>

Propagules (seeds, cuttings, and divisions) should be obtained only from populations *within the same sandhills site* where they are to be used, where a sandhills site is a naturally contiguous patch of sandhills habitat not separated by more than 500 feet of non-sandhills habitat (Section 6.2). In the case of quarries or other areas that have been dramatically altered, historical aerial photographs dating back to 1943, available at the UC Santa Cruz Map Room or from the author (Appendix E), can aid determination of the prior boundary of sandhills sites. Collecting within the same watershed will not be sufficient to protect the site-specific genotypes that have evolved in the multiple, separate sites that occur within the same watershed.

Within the same sandhills site, seed should be collected from populations as close in proximity to the target area for planting as possible. Collecting seeds from the same aspect as the site into which they will be planted can be crucial to planting success, as species differ greatly between cooler, moister north slopes and the hotter, drier south, east, and west slopes in sandhills habitat.

Only species that historically occurred at the site should be planted in the revegetation project. All current revegetation projects for quarries have intact habitat surrounding them. This habitat should be used to determine the species list for the quarry. If there is a strong reason to believe that a species that is currently not at the site was previously at the site, then a reintroduction might be considered. Before translocated material is introduced, it should be documented through surveys conducted by qualified botanists that the species is nowhere remaining in adjacent intact habitat, in order to avoid genetic contamination. Introductions, or transplantations designed to establish populations in areas where they were not known to occur, should not be done simply to enhance native diversity. The species composition of different patches of sandhills habitat represents the typical nested subsets observed in island biogeography. This variability between sites should be maintained as part of a regional conservation strategy.

<u>Seed Collection</u>

Given the high quantities of seed required to revegetate former quarries, reconstruction efforts should include a means of propagation plants *ex situ* (off or out of the habitat) to generate propagules for planting efforts. To maximize genetic diversity of outplanted populations, source material should be obtained from as many individuals as possible within the site, and new individuals introduced to the *ex situ* population annually. The Quail Hollow Quarry is using such a method of increasing availability of propagules through what it calls and increase plot or seed orchard— a propagation areas within the quarry from which seeds, cuttings, and divisions are obtained for out planting into the revegetation areas as mining is completed (Schettler et al. 1997). Such *ex situ* propagation not only reduces the negative impacts of large-scale reconstruction programs on populations and communities in intact habitat, but can also reduce costs associated with annual seed collection (Schettler et al. 1997), thus providing a more efficacious as well as responsible method of reclamation.

Procurement of plant material for small-scale projects that require active revegetation without the benefit of *ex situ* propagation, or to create and augment propagation efforts, should remove as little material as possible. No more than 1% of the seed of any one species at any one site should be collected in a given year. No more than 1% of the seed from any individual plant should be collected in a given year. Seed should only be collected from populations that exceed the following minimum sizes:

- <u>Annual</u>: >10,000 aboveground individuals
- <u>Biennials and monocarpic perennials</u>: >10,000 adults
- <u>Herbaceous Perennials</u>: >5,000 adults
- <u>Suffrutescents and Subshrubs</u>: >1,000 adults
- <u>Shrubs and Trees</u>: >100 adults

Seed collection should follow even more cautious guidelines during droughts, insect outbreaks, or other periods of below average seed production. Seed should not be collected from the same population or plant in consecutive years. Any seed not used the following season should be given to a seed bank (e.g. Rancho Santa Ana Botanical Garden) unless appropriate storage facilities are available. Seed from the same species should be collected during a series of trips throughout the season to spread the impact amongst early, middle, and late producing individuals.

Planting Design

The design of plantings should be carefully planned to maximize revegetation benefits while reducing likelihood of their negative impacts. Elements of landscape architecture combined with knowledge of sandhills species and community ecology can facilitate such planting design.

Patch Mosaic

As with natural communities, a patch mosaic of different assemblages can maximize diversity of plant species and habitats for animals. Underlying variability in site conditions following mining including slope, aspect, and substrate conditions might generate habitat heterogeneity over the long term, even if the same species are planted throughout. However, competitive plants that are able to tolerate the range of conditions within the revegetation area could dominate the revegetation site over time, thus reducing diversity. Planting large, successful species (e.g. *Arctostaphylos silvicola, Ceanothus cuneatus*) throughout the area may facilitate dominance by just a few species and reduce overall diversity. Designing the revegetation to incorporate multiple, smaller compartments receiving different assemblages of species known to co-occur may facilitate heterogeneity and diversity

Buffer Zones

Reconstruction projects can reduce the likelihood that adjacent intact sandhills habitat will be invaded or experience negative edge effects by carefully designing the revegetation to match, as closely as possible, the composition and structure of the area immediately adjacent to intact habitat. "Buffer zones" or "buffer plantings", as they have been termed, have been proposed for revegetation projects in two of the quarries (Schettler and Kiguchi 1995, Schettler et al. 1997). These areas should be incorporated to minimize the negative impacts and increase likelihood of creating larger tracks of contiguous habitat required by many species.

Exotic Plant Control

Revegetation projects should incorporate exotic plant control efforts that will prevent aggressive exotic plant species from becoming established within the revegetation area, and then spreading to the adjacent habitat (Schettler and Kiguchi 1995, Schettler et al. 1997, Haley 2002). Plants that are native to California but not the sandhills should similarly be removed as part of such control efforts (Schettler et al. 1997).

Goals, Monitoring, and Testing

The goals of reconstruction projects should reflect the potential benefit of projects for native sandhills habitat (Section 11.2). At a minimum, however, revegetation projects in quarries should "do no harm" (Schettler et al. 1997) and goals of avoiding potential negative impacts should be articulated.

Monitoring should be conducted not only for compliance purposes, but because such monitoring, if designed properly, has the benefit to enhance understanding of the biology o sandhills species and communities. In addition, oftentimes revegetation techniques are applied as tests, in order to evaluate effectiveness and thus inform future efforts in these oftentimes long-term projects (Schettler et al. 1997, Haley 2002). Quantitative approaches to such monitoring or testing has the potential to reveal much about the potential for such projects to facilitate overall conservation goals for sandhills communities and species. Partnering with research institutions may facilitate conducting such studies within reconstruction projects (Chapter 12).

11.4 CONSERVATION GUIDELINES FOR RESTORATION PROJECTS

As described in section 11.1, restoration projects are designed to return ecosystem structure and function to mildly or moderately degraded habitat. Restoration projects include repairing damage caused by grading or other disturbances that remove established cover and some soil, yet not the geological substrate underlying the community.

In general, restoration projects in the sandhills should focus on removing the stress that degraded the site and employ natural processes to reverse the damage and restore the system. As described throughout this plan, the sandhills are disturbance-adapted. Once the cause of disturbance is removed, many species will readily colonize disturbed areas from adjacent intact habitat. In many cases, the disturbance will follow a natural successional trajectory that includes colonization by early successional species, including many of the most sensitive sandhills species, then ultimately establishment of later successional plants and habitat by animals.

The specific approach to restoration should, of course, depend on various aspects of the disturbed site including its size, proximity to intact habitat, topography (e.g. slope), and the habitat type, among other factors. However, the following guidelines are suggested.

Erosion Control

Restoration of disturbed areas in most sandhills sites may require erosion control to arrest ongoing disturbance and facilitate plant colonization of the disturbance. When the disturbed area is on a steep slope, erosion due to water and wind may cause pollution, degrade adjacent intact habitat, and/or prevent natural colonization of the site by native species. In these cases, erosion control methods that will facilitate native plant colonization should be used. These include: water bars, dips, log steps, wattles, and thin erosion control cloth that can break up overland flow yet allow native plant seedling establishment. Immediately following degradation, and prior to recolonization, it may be advised to grade the disturbed area to direct water overland water flow so that it will not result in rilling and gullying. Water bars or straw wattles (long, tubular bundles of straw) can be used to break up overland flow and avoid gullying. Placing loose ground cover such as straw within specific rills or gullies as they form can also be appropriate to head off potentially larger erosion problems. Rice straw is recommended as any exotic seeds it may contain would have a low probability of establishing in intact sandhills habitat (Schettler et al. 1997). On steep, wide expanses, erosion control cloth or thin blankets made of biodegradable material could be used to hold the soil in place and allow establishment by early successional species; however, thick mulches of straw, pine needles, or blankets of other material will inhibit establishment of many sandhills herbs (Schettler et al. 1997, McGraw 2004, *in prep.*).

Revegetation

Restoration projects that remove the cause of degradation, repair substrate loss, control erosion, and remove aggressive exotic plants should not require active revegetation to enhance native community structure in the sandhills. Provided that the area to be restored is adjacent to intact habitat, native species will recolonize the habitat. Natural recolonization is preferred to active revegetation and is thus recommended for restoration projects in the sandhills for several reasons. First, recolonization will create natural community structure and composition which, quite simply, humans cannot create through revegetation plantings. Second, planting interferes with future research to study the ecology of sandhills communities in intact habitat, which relies heavily on observations of distribution and abundance patterns (Chapter 12). Third, revegetation has the potential to introduce genotypes and species that are not native to the restoration area. And finally, active revegetation can be costly component and reduce funds available to other forms of management that can provide greater benefit to sandhills species and communities.

Natural recolonization has been observed in disturbed areas that have been proposed for active revegetation. For example, the 10 m wide recreation trail atop the South Ridge of Quail Hollow Quarry has begun the process of natural recolonization following efforts to reduce recreation. While traffic has been reduced, but not eliminated, a suite of sandhills specialty herbs including the Ben Lomond spineflower, Santa Cruz wallflower, curly leaved monardella (*Monardella undulata*) pussy paws (*Calyptridium umbellatum*), and *Minuartia californica,* among several others, have colonized the formerly denuded ridgetop. Perennial species and more recently subshrubs have begun to colonize this site as well, as expected as part of the natural successional trajectory (J. McGraw, unpublished data). Similar natural recolonization has greatly increased the areal extent and population density of rare native plants in the Olympia Wellfield site, where patrols and fencing have greatly reduced OHV use since 2001 (J. McGraw, pers. obs.).

If aspects of the a potential restoration area (e.g. size, propagule supply, etc.) raise concern that native plant recolonization will not effectively attain the goals of restoration, it is recommended that erosion control methods be conducted, as needed, and that the area be monitored to determine whether native plant cover and diversity increases naturally. Active revegetation in such areas should only be used if realistic quantitative objectives for natural recolonization are not attained, including that there is no trend towards increasing native plant cover.

11.5 Conservation Guidelines for Landscaping

Residential developments can also play a role in the conservation of sandhills species and communities. Like quarries, residential developments are often adjacent to patches of intact habitat, and can provide important buffers, corridors, and in some cases augment habitat area that can facilitate the persistence of the endangered species. Developed areas are not typically considered in conservation plans and instead, most conservation strategies exclude such areas from their analysis. However, due to the extreme rarity of sandhills habitat (<4,000 acres), and its high level of fragmentation, residential areas may be an important component of long-term conservation efforts for sandhills species (Chapter 6).

Throughout the sandhills region, residential developments support plants and animals native to the sandhills. Some low and moderate density developments (i.e. parcels >10 acres), still have intact patches of habitat equal in quality to those found in sandhills preserves (e.g. Martin Road, Vista Robles, southern portion of Quail Hollow, Weston Rd; Appendix D). Though fragmented by the developments (e.g. houses, driveways, roads), these small patches of contiguous habitat support many native sandhills species.

Though community structure has been greatly modified in high density residential developments (e.g. 1 acre parcels), recent surveys have showed that many of these still support populations of native sandhills species, including several sensitive species such as the Ben Lomond spineflower, Ben Lomond buckwheat, and Mount Hermon June beetle (e.g. Whispering Pines, Hidden Valley, Hihn Road; Appendix D).

Recognizing the uniqueness of sandhills habitat, many private residential landowners in the sandhills have expressed interest in assisting conservation efforts for endangered species by creating or maintaining habitat on the undeveloped portion of their parcels. In response to request from these landowners for assistance with appropriate techniques, the Sandhills Alliance for Natural Diversity held two public workshops entitled “Gardening in the Sandhills”. These workshops provided guidelines as well as practical techniques for landscaping with native plants that would enhance populations of sandhills animals. Though the techniques are beyond the scope of this plan, the following section summarizes some of the guidelines. The details and rationale for many recommendations are provided in the previous sections of this chapter.

Hard Surfaces

Landowners should minimize the area of the parcel covered by impervious surfaces (structures, roads, paved patios, concrete paths). This will not only increase habitat area for native plants and animals, but increase infiltration of rainfall into the Santa Margarita aquifer, from which most sandhills residences get a high proportion of their water (Section 2.5). Avoid paving over ponderosa pine roots, which may preclude habitat use by Mount Hermon June beetle, damage pines, and likely result in damage to pavement due to root growth.

Erosion Control

In sloped areas, erosion control efforts should follow recommendations for reconstruction projects (Section 11.3). Dense ground cover including mulches (e.g. bark, gorilla hair) and non-native ground cover plants should be avoided as ground cover renders habitat unsuitable for many unique sandhills plant and animal species, including the endangered herbaceous plants and the endangered insects. Instead, erosion control techniques which manage runoff should be utilized so that open habitat is maintained (e.g. water bars, logs, etc.).

Soils

Though the low fertility and low soil moisture holding capacity of the Zayante soils renders them inhospitable for ornamental species (Section 2.3), native plants are adapted to tolerate the unique soil conditions (Section 3.2). If soils are altered, either through fill, fertilizers, composts, and even excessive watering, native sandhills plants will lose their competitive edge over plants that are not indigenous to the sandhills. In addition, chronically wet soils and those high in organic matter often host microorganisms that can be pathogenic to sandhills natives and fertilizers can chemically burn some sandhills shrubs (V. Haley, pers. comm.. 2004). Therefore, soil amendments should not be required in most cases and are not recommended.

Plants

The plant community composition in the landscape can greatly influence its habitat value. In areas that have not been already modified (i.e. cleared, landscaped) including new developments, populations of native plants should be enhanced by efforts to reduce exotic plant abundance (Chapter 8). Native shrubs and trees, especially ponderosa pines, should not be removed unless they pose threats to the structure. If additional plant species are desired in the landscape, the guidelines below for planting in already landscaped areas should be followed.

In areas with prior non-native landscapes, non-sandhills plants should be removed. Many sandhills plants can easily be substituted for common ornamental species, and provide ground cover, wildflower displays, shade, and other desirable aspects of a landscape, while also potentially providing habitat and food (including pollen) for sandhills animals. Sandhills plants should be native to the site in which the parcel is located (Section 6.2; Appendix D). Neighboring landowners may be willing to provide seed or cuttings for planting. Landowners interested in planting species such as California poppy and ponderosa pines should use only genetic material from the sandhills region (and not cultivars or plants from other areas such as the Sierra Nevada Mountains) in order to avoid genetic contamination. For more information about planting native species in the sandhills, please contact Val Haley, Suzanne Schettler, Jodi McGraw, or another sandhills biologist (Appendix E).

If ornamental plants are desired as components of the landscape, invasive species including Acacia, brooms, pampas (or jubata) grass, and Eucalyptus should not be included.

In large areas, variability in plant cover may enhance animal use. Small patches of open sand are beneficial for establishment of herbaceous native plants and thermoregulation by insects and should be included throughout the landscape.

Turf (or sod-forming) grasses should not be planted in sandhills landscapes. The sandhills do not have any native, sod-forming grasses. Without soil amendments and abundant watering, exotic turf grasses (e.g. fescue lawns, Bermuda grass) will not grow well in the Zayante sandy soils. Once they are established, these grasses outcompete native sandhills plants and preclude use of the landscape by most sandhills animals which are not adapted to contiguous grass cover.

Herbicides and Pesticides

Herbicides and pesticides should be avoided in and around native sandhills landscapes to avoid potential impacts to native sandhills plants and animals, including the rare insects, and avoid any risk to the Santa Margarita aquifer below (Section 2.5).

CHAPTER 12

SANDHILLS RESEARCH

INTRODUCTION

Research is a cornerstone of all conservation efforts in the sandhills. It provides the information about sandhills species and communities necessary to inform sound policies and planning for sandhills habitat, and management strategies for protecting biodiversity in preserved habitat. In addition, research develops the knowledge about sandhills species and communities used in education and interpretation programs that increase sandhills understanding, awareness, and appreciation. This chapter describes the importance of research, examines the role of different types of research in informing management, discusses the potential negative impacts of research, recommends approaches for research, and examines mechanisms for facilitating research in the sandhills.

12.1 ROLE OF RESEARCH IN SANDHILLS CONSERVATION

Research enhances sandhills conservation efforts including management, planning, policy development, and education, by both informing and inspiring conservation efforts.

Information

Information about sandhills species and systems is integral to all conservation. Throughout the development of this plan, previous research has been used to examine all aspects of the sandhills, including their distribution, geology, soils, flora, fauna, ecology, threats, and management strategies, among others. The importance of reliable data on sandhills systems has been underscored through this effort to plan for sandhills conservation, devise policies for sandhills habitat, and develop management strategies for preserving biodiversity in protected sandhills habitat. Research also informs education curricula about sandhills that can be used in a variety of school and interpretive programs that enhance appreciation of the uniqueness, rarity, and fragility of the sandhills, thus facilitating their protection (Chapter 13).

Inspiration

Research also inspires sandhills conservation efforts by bringing new information and people to sandhills conservation. New and exciting results from sandhills research can reinvigorate sandhills conservation and management efforts by increasing confidence in their success. For example, results of a fire and fire surrogates experiment lead managers at the Mount Hermon Conference Center to remove dense accumulations of pine needles through raking to facilitate native diversity in their sand parkland habitat (D. Pollock, pers. comm. 2004). New researchers involved in sandhills studies oftentimes become interested in sandhills conservation efforts, and inspire other interested people who, in turn, conduct research in the sandhills. Such a positive feedback loop has been initiated by research conducted through the lab of Dr. Rachel O'Malley at San Jose State University, which has examined a series of questions regarding the biology of the endangered insects since 2000.

Complex Feedbacks

Adaptive management can also initiate positive feedback loops between research and management that simultaneously increase knowledge and benefit sandhills species and communities. Adaptive management is the process by which management is conducted in a scientific framework that allows the success of management actions to be evaluated and changes to management introduced, if necessary, until objectives of management are reached (Figure 7.1). This process enhances success of management efforts on behalf of the sandhills while augmenting knowledge about the system and species. In addition, documenting the success of management efforts through research can increase support for future active management efforts and research. This support can buoy other aspects of sandhills conservation. For example, increased understanding of sandhills management can encourage habitat preservation by organizations otherwise intimidated by the daunting task.

While previous sandhills research has been crucial to this effort, it is clear that more information about sandhills species and systems would greatly enhance efforts to plan for sandhills land preservation, develop policies regarding sandhills species and habitats, and manage sandhills to preserve native biodiversity.

12.2 Previous and current Sandhills Research

Sandhills research can be distinguished both by the field of science it explores, and the methods of inquiry used. Efforts to pigeonhole research into one or more discrete categories are difficult and often met with consternation. The purpose here is not to classify research, rather to sketch the various types of research and illustrate their conservation applications.

Descriptive Studies and Planning Efforts

Sandhills research began with the earliest collecting trips by botanists and zoologists who endeavored to document the flora and fauna of the region in the early part of last century. Though Thomas acknowledged "two endemics species" to the sandhills in his flora (Thomas 1961), and Griffin documented the disjunct populations of ponderosa pine (Griffin 1964), surprisingly few scientists studied the sandhills prior to the 1970s, despite their proximity of several research institutions (e.g. Universities, museums, herbaria, etc.).

Beginning in the 1970s, biologist Randall Morgan surveyed the flora and fauna during repeated visits to most known sandhills sites. His data and analysis provided much of the earliest information about the natural history of the sandhills (Morgan 1983). In addition, his species lists provide the most comprehensive information available about sandhills species at different sites and were incorporated in previous efforts to characterize and prioritize sandhills habitat (Marangio 1985, Heady 1993, Lee 1994) as well as those used in this plan (Chapter 6; Appendix D).

Acknowledging the uniqueness of the sandhills and their imperilment, Michael Marangio completed a preservation study of the sandhills for his master's degree in landscape architecture at UC Berkeley (Marangio 1985). In a subsequent collaboration, Marangio and Morgan

(Marangio and Morgan 1987) described the rare sandhills communities, highlighting the diversity and uniqueness of the sandhills flora in a paper that served to galvanize conservation efforts.

Paul Heady similarly compiled available data on the species composition and distribution at eleven intact sandhills sites in his undergraduate thesis at UC Santa Cruz (Heady 1993). His work assigned habitat quality values to the 11 sites based on their species composition, and suggested a method of evaluating site-level impacts on habitat due to development (e.g. through Environmental Impact Reports) based on calculations that reduced the quality index.

San Jose State University student David Lee combined description of sandhills vegetation with efforts to determine their historical distributions and quantify areal coverage in his project assessing sandhills conservation threats (Lee 1994). His analyses were not completed, leaving some outstanding questions about the acreages of habitat provided in his draft report.

Taxonomy and Systematics

Due to their island-like distribution and many disjunct populations, the sandhills pose fascinating biogeographical, evolutionary, and biosystematic questions. To date, three researches have addressed the taxonomic differences between sandhills species and their close relatives. Dr. Barbara Ertter chronicled her collaboration with other eminent taxonomists to establish the taxonomic validity of the endemic Ben Lomond spineflower (Ertter 1996). In her article, Ertter provided insightful commentary on the lesson such determinations of taxonomic identity should teach us about conserving genetic diversity, rather than simply species (Ertter 1996).

Using controlled growth experiments to show that the morphological differences exhibited by sandhills poppies (*Eschscholzia californica*) are in part genetically determined (genotypic in origin) rather than simply a result of the unique sandhills environment (phenotypic), San Jose State University masters student Erin Espeland recommended that the poppy be considered a unique ecotype (Espeland and Myatt 2001).

In collaboration with Dr. James Patton of the UC Berkeley Museum of Vertebrate Zoology, San Jose State University masters student Caitlin Bean determined through DNA analysis that the population of Santa Cruz kangaroo rats represent a “distinct population segment” which merits protection pursuant the Federal Endangered Species Act (Bean 2003).

Several other species merit such critical taxonomic evaluation (Section 3.1). In collaboration with Randall Morgan, Dr. Roy Buck compiled a list of “Rare or Unusual Plants of the Ben Lomond Sand Hills”, many of which may be determined unique through future taxonomic research (Buck 1998).

Ecology

The majority of sandhills research has endeavored to understand the ecology of the unique sandhills species and communities. Beginning in the early 1980’s, much of this research was conducted by undergraduate students from UC Santa Cruz who have examined the ecology of rare sandhills animals (Roest 1984), rare plants (Jacobson 1994, Pollock 1995, Brunette 1997, McGraw and Levin 1998, Kluse and Doak 1999) and the unique plant communities (Potts 1993, Jones and Paige 1999).

A flush of research resulted from the efforts of UC Santa Cruz conservation biologist Dr. Dan Doak, who in the early 1990s began a "conservation biology practicum"—a course in which students conducted research in the sandhills, often as senior thesis research in Biology and/or Environmental Studies Departments. The vast majority of studies were conducted at the Bonny Doon Ecological Reserve (Potts 1993, Jacobson 1994, McGraw and Levin 1998, Kluse and Doak 1999). However, later research examined plant ecology of the Ben Lomond sandhills and included investigations of Santa Cruz wallflower demography (Brunette 1997) and an determinations of the age structure of ponderosa pines (Jones and Paige 1999). Though some of the research conducted by undergraduates was never finalized (Brunette 1997, Jones and Paige 1999), manuscripts provide some preliminary information that can guide future research and management. Unfortunately, in the late 1990s, Dr. Doak ceased to offer his conservation practicum in the sandhills.

Ongoing concern about the persistence of sandhills communities and sensitive species spawned several graduate research projects on the ecology of sandhills species and communities. Jodi McGraw, who completed undergraduate research on the ecology of the Ben Lomond spineflower (McGraw and Levin 1998), examined the factors influencing the demographic performance of the two endangered plants and natural community structure in the sand parkland of the Ben Lomond sandhills for her dissertation at UC Berkeley (McGraw 2004). Specifically, her dissertation research examined the role of soil disturbances, fire, exotic plants, interannual variability in rainfall, and herbivory impacts, among others, on sandhills plants.

San Jose State master's student Caitlin Bean (Bean 2003) examined the population dynamics of the Santa Cruz kangaroo rat in her thesis. She found that this rare animal has been extirpated from several sandhills sites, and quantified important population parameters that can be used in population viability analyses (Section 5.7).

San Jose State master's student Jennifer Chu examined the frass, behavior, and distribution patterns of the Zayante band-winged grasshopper in the conservation areas of the Quail Hollow Quarry to determine the diet and habitat preferences of the endangered insect (Chu 2002).

Concurrent with research by individuals from academic institutions, studies conducted by biological consultants in monitoring and management projects have also yielded new information about sandhills communities and species. In an early biotic assessment in the sandhills, Bill Davilla described the vegetation and species found in sandhills near Bonny Doon (Davilla 1980). Dick Arnold has compiled historical observations of the two endangered insects with results from his own monitoring work in a database which provides the known distributions of these rare insects, used in the conservation planning portion of the plan (BUGGY 2004). As part of his monitoring work, Dr. Arnold has also contributed to knowledge of the endangered insects' habitat preferences, activity periods, and dispersal abilities, as well as population sizes (Arnold 1999a, 2000, 2001, 2002; Sections 5.5 and 5.6).

As part of her efforts to help prepare the Long Term Management and Maintenance Plan, Jodi McGraw analyzed the plant assemblages in the conservation areas of the Quail Hollow Quarry. Incorporated in a draft plan, results of this work are not yet available. Important information held in such "grey literature" can be difficult for researchers and managers to locate and thus utilize in their work. An effort to bring such studies together has been initiated here, but should be continued.

Current and Future Research

Research in the sandhills is ongoing. Dr. Rachel O'Malley of San Jose State University is working to determine the host plant(s) of Mount Hermon June beetle larva in attempts to understand the ecology of the cryptic stage in this endangered animal. As part of their Long Term Management and Maintenance Plan, Graniterock will be conducting extensive monitoring of the endangered species and communities and completing adaptive management to enhance biodiversity in the over 104 acres of intact sandhills habitat that they manage for the next several decades. Though these studies will contribute to our knowledge of the ecology of the sandhills, more research is needed to inform management of sandhills habitat and recover endangered species (USFWS 1998).

12.3 Types of Research

Despite the blanket terms applied, "research" in the sandhills can vary greatly in approach that can influence the information it provides and thus the conservation value. Like topics, the methods of research are diverse and varied, and therefore difficult to pigeonhole. The purpose of this section is to discuss aspects of research that can influence the information they provide to sandhills conservation.

Basic vs. Applied

The terms "basic research" or "pure research" are used to describe studies designed to answer questions for which there is no current known application. These terms are typically contrasted with "applied research", which is said to have a specific and immediate application for conservation and management (or agriculture and technology, though this plan is not specifically concerned with these applications).

Though concern about research impacts on fragile sandhills communities (Section 12.5) has prompted some to assert that only research that can be applied to sandhills conservation and management be conducted within intact sandhills habitat, such suggestions are short-sighted as basic research can promote conservation. Research examining basic questions oftentimes generates knowledge about species or the system that informs conservation in the long run if not immediately. Furthermore, research programs that begin with basic questions can evolve to examine conservation-based questions as the interests or focus of the research shifts. Finally, published research on basic questions conducted in the sandhills can attract other researchers interested in conducting applied work in the sandhills.

Applied research that can inform pressing conservation concerns in the sandhills should be given priority over basic research, or research that has only limited relevance to conservation. Such priority might be used when allocating scarce funds for research, if space for research is limited at a given site, or research access is constrained to minimize impacts.

Ex situ* vs. *In situ

From the latin phrase meaning 'out of the situation'(Jaeger 1955), *ex situ* research is that which is conducted off site, including green house experiments, laboratory studies, and common garden experiments (though some can be *in situ*). In most *ex situ* research, investigators collect materials from a site or sites, including soils, propagules, specimens, tissues, or individual organisms, then work in other facilities. In contrast, *in situ* research is conducted within sandhills habitat. *In situ* research can vary greatly in approach, as described below.

Many types of research are primarily or exclusively conducted *ex situ.* For example, taxonomic and systematic questions regarding sandhills species will typically be addressed in laboratory facilities. Analyses of soils in the sandhills would be accomplished through laboratory work on soils collected from sandhills habitat. In contrast, many research questions must clearly be addressed through *in situ* research. These include, for example, projects examining the geology of the sandhills, evaluating whether coast live oaks conduct hydraulic lift, or determining the home range of male Santa Cruz kangaroo rats.

Research in a variety of fields can often be addressed through either *in situ* or *ex situ* research. For example, one can elect to examine the competitive effects of European annuals in a greenhouse experiment, or through removal experiments in the field (McGraw 2004). The diet of Zayante band winged grasshoppers might be determined through a so called "cafeteria study" in the lab or, alternatively, through field observations and analysis of frass (Chu 2002).

Typically, there is a trade off between *ex situ* and *in situ* research. *Ex situ* research allows greater control over the system and thus more precise results. For example, experiments designed to examine soil moisture effects on plant growth can be more precisely executed in a greenhouse, whereas microhabitat variability in the field will cause variation in treatments. *Ex situ* research can be conducive to complex experiments manipulating several factors in combination (i.e. fully factorial experiments) as the system can be compressed into small area. For example, researchers examining the interactive effects of soil nutrients and water on growth in 5 different genotypes of rare plants can more easily accommodate the 45 or more treatment combinations in a facility than *in situ*. *Ex situ* research is also more protected from vandalism or dramatic natural events (i.e. floods etc.) that can damage experiments conducted *in situ* (Figure A.44).

In contrast, researchers cannot control for environmental variability in space and time when working *in situ*. Excessive rainfall (or drought), herbivory, pathogens, soil heterogeneity, plant assemblage mosaics, and disturbances (e.g. gopher mounds), just to name a few, can influence experiments *in situ*. In many cases, this environmental heterogeneity can create within treatment variability or "noise" which can make it more difficult to detect significant differences when testing hypotheses. For example, attempts to compare performance of different genotypes of a rare plant may be more difficult, as the different growth conditions may cause environmental variability. In some cases, environmental influences *in situ* can fundamentally alter the conclusions of the experiment. For example, a greenhouse experiment may show that the exotic annual grass (e.g. *Vulpia myuros*) does not reduce survivorship of Santa Cruz wallflowers while a removal experiment *in situ* might find strong competitive effects on the rare plant. This would not be surprising, as environmental conditions (e.g. resources, herbivores, etc.) can fundamentally alter the outcome of competition. Thus, while *ex situ* research allows greater control and precision, *in situ* research provides greater realism.

While many research questions are best addressed through *ex situ* approaches, studies designed to directly inform management should be conducted *in situ* or incorporate a field component whenever possible. This is simply because treatments may have different effects when applied in the field than observed in controlled situations, due to a variety of indirect mechanisms and feedbacks which might occur in the field but not in a controlled facility. Managers wishing to implement techniques based solely on *ex situ* research should carefully evaluate potential factors that can alter treatment effectiveness *n situ* prior to implementation, then conduct management at a small spatial scale using adaptive management techniques to evaluate impacts in the field prior to large scale implementation.

Given the importance of experiments conducted in the field in accurately informing management, it would be unwise to discourage *in situ* experiments in favor or *ex situ* trials prior to implementation. Research should, however, follow the guidelines for minimizing impacts of their experiments on intact habitat provided in Section 12.6.

Description, Observation, Manipulation, and Adaptive Management

In situ research can be conducted via four main approaches: description, observational studies, manipulative experiments, and adaptive management. These approaches differ in many ways that can influence the information they can provide for conservation and management.

<u>Description</u>

Research is often referred to as "descriptive" when it is designed to describe the condition of a species of the system but not test hypotheses, as through the scientific method. As the name connotes, some descriptive studies rely exclusively on non-quantitative data, including species lists, or qualitative descriptions. However, many descriptive studies involve quantitative data. For example, descriptive studies were conducted to examine the age structure of ponderosa pines at various sandhills sites (Jones and Paige 1999) and describe sandhills vegetation in terms of average cover of plant species (Lee 1994). Descriptive studies differ from observational studies in that they lack specific hypotheses and the statistical analyses to test them.

Observational

Observational studies are those in which investigators use quantitative measurements of species or habitat characteristics as they naturally occur in the field to test specific hypotheses using statistical analyses. Types of observational studies include monitoring, correlational studies, mensurative experiments, and natural experiments (*sensu* (Hurlbert 1984).

In monitoring, a variable is followed through time to detect change. For example, a rare plant population might be monitored within intact habitat to determine whether it is increasing or decreasing. Correlational studies are those in which researchers assess whether there is a significant relationship between two or more factors within the system through comparisons of measurements of one with the other(s). For example, one might examine the distribution of a rare plant on different soil types to assess potential factors influencing habitat suitability. Mensurative experiments are those in which measurements are taken under different conditions or along a gradient within the system that the investigator did not manipulate. For example, spineflower fecundity could be measured under a series of habitat conditions by placing plants as "phytometers" (Pavlik et al. 1993) in areas of different environment to measure their growth and thus assess habitat suitability. These mensurative studies differ from manipulative experiments in that the researcher is not actively manipulating the factor or factors they would like to evaluate (Hurlbert 1984). So called 'natural experiments' are those where investigators use natural processes (e.g. disturbances) as the treatment in an experiment. For example, following a wildfire that burns two sandhills sites, a researcher might collect data from plots within the sites that burned and compare them to data from unburned sites to assess the effects of fire.

Observational studies that incorporate appropriate sampling and statistical analyses can be used to objectively describe patterns in ways that some descriptive studies cannot. Understanding patterns provides the first and crucial step in many projects designed to evaluate important processes that can be important for conservation. For example, a correlational study showing that Santa Cruz wallflowers were more abundant on slides and washes than on adjacent undisturbed habitat lead to the hypothesis that wallflower performance is higher on these disturbances (McGraw 2004). Observational studies showing that Zayante band-winged grasshoppers were preferentially found in open microhabitats within sand parkland lead researchers to hypothesize that these provide better conditions for individual survivorship and population growth (Chu 2002).

The processes behind even statistically significant patterns should only cautiously be inferred from analyses of observational data. This is because factors that are found to covary spatially or temporally are not necessarily causally linked (i.e. correlation is not causation). In the examples above, while higher density wallflower populations might suggest that individual wallflowers perform better on slides, it is also possible that slides provide poor conditions for plant growth but support larger populations due to lower incidence of herbivory by gophers. An experiment manipulating disturbance and comparing plant performance in areas on and off disturbance is needed to isolate disturbance effects and evaluate the utility of soil disturbances in management strategies (McGraw 2004).

In the absence of additional research, significant correlations or differences detected through observational studies should be considered as hypotheses to be tested through manipulative experiments or adaptive management.

Manipulative research

In manipulative experiments, investigators alter conditions within the system through experimental treatments to examine the effects of one or more factors on one or more variables measured. For example, to determine litter effects on rare plant performance, litter was added to treatment plots in which plant performance was measured (McGraw 2004). Comparing plant performance to control (unmanipulated) plots allowed isolation of the effects of litter (Figures A.45 and 46). Such experiments avoid the risk inherent in inferring causation from correlation associated with observational studies, for example, that might examine plant performance in areas with and without litter present naturally.

At a minimum, manipulative experiments must include adequate controls, sufficient and interspersed replicates, measurements of relevant, quantitative response variables, and sufficient monitoring duration, in order to provide reliable results (Hairston 1989, Underwood 1997). Moreover, if the results of manipulative research are to be used to prescribe management practices, experiments should be conducted in a variety of sandhills sites, which allows the generality of the effects to be examined, or at a minimum, the site of proposed management. Similarly, because sandhills communities differ greatly, experiments should be conducted across all communities or in the community for which management is proposed.

For example, an experiment examining the effects of fire in sand parkland was conducted in three isolated patches of sandhills habitat at two sandhills sites (Figure A.46). In addition, because fire effects were hypothesized to vary depending on the aspect of sand parkland (and they did!), experiments were conducted on south, west, east (hot) and north slopes (cool; McGraw 2004). However, no experimental treatments were conducted in sandhills chaparral communities. Therefore, the results of this research should not be used to infer management effects in this very different community.

Manipulative experiments are essential to evaluate the effects of treatments hypothesized to have beneficial effects on species and communities in the sandhills. The perception that research is costly combined with the skill research requires and the delay in management implementation can lead managers to skip this crucial step. This is unfortunate as manipulative research can help avoid widespread negative impacts to sandhills species and communities and increase the likelihood that management efforts will succeed.

Adaptive Management

Through adaptive management, treatments hypothesized to positively impact sandhills habitat and species can be implemented using the basic components of manipulative experiments and therefore increase understanding while *doing* management (Lee 1999, Elzinga et al. 2001). Though ideally adaptive management would be implemented following prior experimental trials, it also offers a method by which management can proceed in the absence of research examining treatment impacts, provided managers have developed hypotheses for the potential management effects. For example, though there was no prior information about the effects of prescription burning on ponderosa pine forest in the sandhills, State Parks Resource Ecologists conducted small scale experimental burns at Henry Cowell State Park in February 2003 (Figure A.47). If monitored, these treatment areas could provide some insight into the effects of fire in this system and inform larger-scale fire management.

Adaptive management should employ quantitative monitoring of treatments applied at small spatial scales to avoid widespread deleterious impacts of potentially inappropriate management. In this way, manipulative experiments designed to examine potential management strategies (e.g. fire, or exotic plant removal) and adaptive management used to enhance habitat conditions are very similar processes. This interplay between research and management is developed in more detail as part of the discussion of general management strategies in Section 7.5

12.4 Potential Negative Impacts of Sandhills Research

Despite the importance of research to inform conservation and management strategies, research has the potential to negatively impact sandhills species and communities. The potential depends greatly on the type of research as described below. The three potential impacts of research are: 1) direct negative impacts to sensitive species populations, 2) habitat degradation, and 3) genetic erosion.

Direct Negative Impacts on Sensitive Species Populations

Like any type of human activity, research within intact sandhills habitat might reduce sensitive species populations directly, by killing individuals, and indirectly, by degrading habitat (below). Destructive marking of individuals can harm or kill individuals, as could trampling which can kill plants and animals directly or uproot or compromise plants and collapse animal burrows. Unfortunately, while adhering to established trails can confine impacts within the habitat, it cannot eliminate negative impacts, as many sensitive sandhills species are preferentially found in such disturbed areas (e.g. Santa Cruz wallflower, Zayante band-winged grasshopper, etc.).

Research that involves extensive collecting might potentially reduce populations of sensitive species. When individuals or their propagules are taken off site or otherwise removed from the population during the course of either *ex situ* or *in situ* research, these individuals are not able to contribute to population growth. Permits are required to collect federally endangered animals and state listed plants (e.g. *Erysimum teretifolium* and *Cupressus abramsiana*) as well as animals. There are no such rules governing collection of other sandhills plants. Researchers should follow guidelines for collection outlined in Section 11.3, including collecting as little material as possible, collecting from multiple trips at multiple sites (if possible). Conducting field experiments at several sites can similarly diffuse the impacts of collecting (as well as other impacts) on any one site (McGraw 2004).

Degrade Habitat

Research in the sandhills has the potential to degrade habitat by causing erosion, manipulating habitat, and introducing or spreading exotic plants.

Erosion

Because Zayante soils are highly erosive (Section 2.3; (USDA 1980), research in the sandhills can cause erosion. Like other types of disturbance such as recreation, research impacts will depend on characteristics of the use, including the intensity, frequency, and seasonality of use, among other factors, and the characteristics of the habitat, including the slope, vegetation, and soil conditions (Section 10.2). While *ex situ* research which involves visiting sandhills sites a few times or infrequently (e.g. to collect material) may cause only minimal disturbance, research conducted *in situ* can potentially have greater impacts, depending on the intensity and frequency of use. Observational studies involving a single researcher accessing a single area one or a few times may have minimal affects. However, experimental research during which one or more researchers repeatedly monitor study plots over long periods of time could cause erosion if precautions are not taken.

Though research must be monitored at the appropriate frequency to be effective, precautions should be taken to avoid impacts of research in the sandhills by reducing the intensity of disturbance and targeting areas that are less prone to erosion. Disturbance intensity can be subtly though perhaps significantly reduced in the sandhills by walking flat footed on the loose sand soils, rather than allowing one's toe or heel to dig into the substrate. This simple 'step' to reduce soil movement can reduce, though by no means eliminate, the impacts of foot steps on soils (J. McGraw, pers obs.).

Minimizing disturbance impacts to microhabitats within the study area that are more prone to erosion can also reduce impacts of research. Whenever possible, access should be limited to areas of flat or gentle slope, rather than on steep slopes where soils are more prone to movement. If researchers must access steep slopes (e.g. in sand parkland), movement should be directed in diagonal or perpendicular trajectories with respect to the slope, to avoid the erosion that results when soils are loosened by walking straight up and down the slope. Researchers should also preferentially walk on areas covered with dense leaf litter and/or dense cover of European annual grasses and forbs, as these areas are less prone to move and thus erode, and support a lower density of native species.

Manipulations

The manipulations of habitat characteristics during experiments and adaptive management can also degrade habitat. Study plots in which treatments are applied can make conditions less favorable for sandhills species and communities. For example, experimental research to examine the effects of litter on native sandhills herbs used litter addition to areas away from trees (McGraw 2004). This research unequivocally showed that litter inhibits native herb germination and seedling establishment and provides the overriding mechanism by which trees inhibit native sandhills specialty plant species distributions in the sandhills. During the four-year span when the experiment was monitored, the 60 individual 1 m^2 areas covered with litter located at two sandhills sites were not suitable for most sandhills plant species. Following removal of the litter, however, re-establishment from the adjacent unmanipulated areas was rapid (J. McGraw, pers. obs.).

Clearly the size of the treatment areas, both as individual replicate study plots as well as the cumulative area, will play a role in determining negative impacts on sandhills species. In general, however, manipulative treatments hypothesized to have negative impacts should not be implemented at large spatial scales. All manipulated areas should be returned to their previous state, to the fullest extent possible, following experimental monitoring. This includes removing all plot markers and flagging.

Exotic Plants

Research can potentially enhance the invasion and spread of exotic plant species and thus degrade habitat. First, disturbances associated with all human uses within intact habitat can potentially facilitate establishment of exotic plant species, though this effect is greater when disturbances occur adjacent to already invaded habitat, and open up canopy conditions. For example, research to examine impacts of shrub removal (e.g. as a fire surrogate) in silverleaf manzanita communities and ponderosa pine forest might enhance exotic plant invasion and spread. Low intensity, low frequency pedestrian use of sandhills habitat has been observed to promote native plant species diversity by reducing exotic plant abundance in sand parkland (McGraw 2004), suggesting that such disturbance will not enhance invasion. However, researchers should take all precautions to avoid vectoring exotic plants into intact sandhills habitat, including using only "clean" equipment, keeping shoes and other garments free from seed (Section 8.2).

Research examining exotic plants impacts and factors influencing the invasion and spread of exotic species in the sandhills may provide important management insights. However, research proposing to introduce exotic plants not already widespread or abundant at the site should be discouraged. Similarly, exotic plant impacts can readily be measured through removal experiments, such that research incorporating the addition of exotic plants already within the system should similarly be discouraged and approved only under the strictest conditions.

Genetic Erosion

If not conducted using appropriate genetic guidelines for collecting, propagating, and out planting material (or moving individual animals), research could potentially cause genetic erosion—the loss of unique genetic material including alleles, genes, gene frequencies, and genotypes from sandhills populations (Section 4.4). To avoid genetic erosion, research should follow guidelines for the procurement, propagation, and planting of materials outlined for habitat reconstruction projects (Section 11.3).

While these guidelines restrict movement of genetic material to areas within a site, research should adhere to even stricter guidelines such that no materials should be moved between *patches* of isolated habitat within a site. For example, while seed for revegetation at the

Quail Hollow Quarry might be collected from anywhere within the Quail Hollow site (i.e. contiguous sandhills habitat), a researcher conducting experiments on rare plants within intact habitat in the conservation areas of the site should not move seed or plants from South Ridge to North Ridge or West Ridge, even though these isolated patches of sand parkland habitat are part of the same sandhills site. Such movement would prevent future research examining the genetic implications of habitat fragmentation, among other potentially interesting studies.

12.5 Facilitating Sandhills Research

Given the important role of ongoing research, research should be actively promoted as part of a conservation strategy for the sandhills. The following measures are recommended to overcome three specific barriers that might inhibit research: access, awareness, and funding.

Access

Access to sites supporting suitable habitat may present a barrier to some important research projects. Several sandhills sites are primarily or exclusively owned by private entities. While many private landowners have been supportive of research in the past (e.g. Save-the-Redwoods-League, Graniterock), many others have not allowed researchers access to their habitat. While many studies can successfully be conducted within a few sandhills sites that do permit access, research projects in the field of biogeography as well as other important research questions may require access to multiple sites.

Research in the sandhills might be promoted by efforts to increase access to previously inaccessible sandhills habitat. Though manipulative research on private land may not be possible, landowners might consider allowing access to their sites for purposes of descriptive and observational studies if they knew the benefit such access would have on larger conservation efforts and that the research would not negatively impact the habitat on their land.

Researchers looking to establish manipulative experiments or other long-term studies in sandhills habitat might be deterred by their fear that projects will be vandalized or otherwise harmed by human use. During the last three years alone, deliberate vandalism jeopardized two separate research projects. In a fire experiment conducted at the South Ridge, plots in two experimental blocks were deliberately destroyed by trespassers (McGraw 2004). At the Save-the-Redwoods-League site, trespassers removed flagging and destroyed live traps used to monitor Santa Cruz kangaroo rat populations (C. Bean, pers comm.).

Landowners interested in facilitating research on their property can take steps to deter unauthorized access including installing fences and signage. In public and private land allowing access, separate research areas within which public access is restricted can be established to protect research projects. Hopefully, outreach and education efforts will reduce such trespassing and deliberate destruction of research projects in the long term (Chapter 13).

Awareness

Outreach to local institutions can facilitate sandhills research. Within just two hours of the sandhills, there are 11 universities containing faculty, staff scientists, graduate students, and undergraduate students, all of whom may be interested in conducting research in the sandhills. They are: UC Santa Cruz, San Jose State University, Santa Clara University, Stanford University, Cal State University Monterey Bay, Cal State University Hayward, San Francisco State University, University of San Francisco, UC Berkeley, UC Davis, and Sonoma State University.

In addition, there are several community colleges and private colleges that might similarly be interested in research opportunities in the sandhills. Efforts to provide these institutions with information about the sandhills can facilitate filling of important data gaps. Opportunities for outreach include: 1) hosting sandhills research symposia for faculty and prospective students, 2) providing research presentations and talks to faculty and students at departmental seminars, and 3) developing a brochure highlighting the opportunities for research within the sandhills that can be provided to faculty and new students.

Funding

Perhaps one of the greatest barriers to research in the sandhills is lack of funds. Prospective researchers from senior scientists to undergraduate students interested in conducting research in the sandhills may ultimately choose alternative projects if funds are not available to support their research in the sandhills. The amount of funding required varies depending on several factors including the project duration, research methodology, and experience level of the researcher.

Funding research through academic institutions can provide a highly cost effective means of obtaining crucial management information because academic institutions typically match the funds they are provided, leveraging the project in several ways. First, researchers at academic institutions match the funds they receive from outside sources through the facilities that they can provide to the research, including laboratory space, lab equipment, and computer facilities, among others. Second, institutions provide support staff that facilitates the research, including facilities managers, accountants, librarians, and numerous other individuals who often work on projects without being directly paid through a grant (including the overhead). Third, academic organizations often enlist the help of students who, in exchange for their education and learning experience gained through research, work on projects for minimal remuneration. And finally, researchers themselves bring their salaries as well as grants from other funding sources to enhance the project.

As a result, funds provided to researchers at academic or other research institutions can often provide a large return in information. In addition, funding for an initial project in the sandhills can perhaps lead to an entire research program being developed, with alternative funding sources (e.g. University resources, National Science Foundation, etc.) providing a larger portion of the research funding over time. As a result, "seed" grants for sandhills research may effectively initiate productive research programs in the sandhills.

12.6 Recommendations for Sandhills Research

General Research Recommendations

1. Research of all types should be highly encouraged in the sandhills.

2. Proposed research projects should be evaluated on their own merits; however, research that can be directly applied to conservation should be given priority for potentially limited access, space, and funds.

3. Research designed to evaluate potential management strategies should incorporate small-scale manipulative experiments conducted within the community for which management is proposed and be replicated at multiple sites, when possible.

4. Researchers should take all possible precautions to avoid potential negative impacts.

5. Sandhills sites supporting or allowing research should include some basic monitoring to detect negative impacts associated with use and make necessary changes.

6. All management should be conducted within the adaptive management framework to facilitate gathering of information about sandhills species and communities required for long-term conservation.

Future Research Topics

The number of research topics that can be examined in the sandhills is infinite. The following is a brief list of specific topics of interest in informing sandhills conservation and management.

<u>Systematic/Genetic Questions</u>

1. To what extent do sandhills populations of ponderosa pine (*Pinus ponderosa*) differ from those in the coast mountain populations and widespread Sierra Nevada populations? Genetically? Morphologically?

2. To what degree do populations of other sandhills ecotypes and subspecies differ from more widespread populations? Potential study species include *Malacothrix floccifera, Layia platyglossa,* and *Dudleya palmeri* (Appendix B).

3. To what degree do populations within different and isolated sandhills habitat patches differ genetically? Species exhibiting morphological variation among sites including *Meconella linearis, Malacothrix floccifera,* and *Linanthus parviflorus* might be good candidates for this research.

4. What is the taxonomic identity of the undescribed species of robber flies, flesh flies, and mellitid bees, and the Antioch sphecid wasp in the sandhills and how are they related to known species?

Rare Species Distribution, Abundance, and Habitat Characteristics

1. What species (described and potentiall undescribed) are found in the assemblage of moths that inhabit the sandhills? Other insect, animal, or fungal assemblages?

2. What is the distribution and abundance of remaining populations of coast horned lizards in the sandhills? Western whiptail lizards? Night snakes? Genetically speaking, how are these populations related to other more widespread occurrences of these reptiles? What factors influence population densities and the distributions of these species?

3. What are the characteristics of the habitat (e.g. plant community structure and species composition) supporting Mount Hermon June beetles? Does the density of Mount Hermon June beetle populations differ among different plant communities? Different sites?

4. What factors influence the distribution and abundance of the Santa Cruz monkeyflower (*Mimulus rattanii* ssp. *decurtatus*)?

Management

1. What is the relative success of different management techniques to reduce the abundance of European Annual grasses and forbs in sand parkland and increase habitat for native herbaceous plants and the Zayante band-winged grasshopper?

2. What are the effects of fire and fire surrogates (e.g. mechanical and manual removal) in dense parkland, ponderosa pine forest, and sandhills chaparral communities on the endangered insects? Santa Cruz kangaroo rats? Other animals? Native plants?

3. Given the demonstrated impacts of various management techniques on the two endangered plants, which management regimes can maximally their enhance populations? (i.e. use population viability analyses to project population growth rates based on different management scenarios).

CHAPTER 13

EDUCATION, INTERPRETATION, AND OUTREACH

"In the end we will conserve only what we love.
We will love only what we understand.
We will understand only what we are taught."

—Baba Dioum, Senegalese conservationist

INTRODUCTION

Education, interpretation, and outreach efforts will play a crucial role in long-term sandhills conservation. Due to the extreme rarity or sandhills habitat, human activities in and around the sandhills can influence endangered species persistence. Increasing awareness and appreciation of sandhills habitat through various types of informational efforts can influence activities and attitudes affecting the sandhills. This chapter discusses methods for developing a mutually beneficial relationship between residents of the area and sandhills communities. It focuses on education, interpretation, and outreach programs that teach the fascinating natural history lessons of the sandhills that can in turn inspire the stewardship that is crucial to sandhills conservation.

Education, interpretation, and outreach may function similarly in their ultimate role in sandhills conservation efforts: increase appreciation and enhance preservation while providing human enrichment. However, the three types of activities may vary in their proximate goals and mechanisms. Though the terms are not mutually exclusive, for purposes of this document, *education* will refer to activities conducted as part of a larger educational program emphasizing intellectual enrichment, *interpretation* refers to activities that integrate the intellectual aspects of education with an emotional component that can add to the sandhills experience, and *outreach* refers to a wide variety of activities designed to provide information to the public, including through education and interpretation programs.

13.1 EDUCATION

The sandhills can be valuable component of educational programs as part of many different organizations and institutions including:

1. **schools**: elementary, secondary, community college, universities, outdoor science, environmental education
2. **research institutions**: herbaria, museums, field stations, research laboratories, arboretums
3. **organizations**: native plant societies, nature clubs, gardening associations

Though it is beyond the scope of this plan to devise specific curricula, which instead should be created based on specific educational goals, this section is designed to outline the value of the sandhills for education. These include the fascinating lessons the sandhills teach and the local example they provide.

Fascinating Lessons

The sandhills system can provide a seemingly infinite number of fascinating lessons designed to advance understanding and intellectual development in several fields. Most obviously, the sandhills are a great place to study many field of science. In the physical sciences, sandhills geology is fascinating conceptually and can be used to illustrate the basic concepts of the field. In addition, the open vegetation facilitates examination of properties of sandhills geology, including the Miocene marine deposits with approximately 15 million year old sand dollars and other fossils that can captivate students of any age.

As described throughout this plan, several facets of sandhills biology including biogeography, evolution, and ecology, can provide fascinating lessons. The unique conditions for plant and animal life presented by the nexus of unique soils and climate in the sandhills provide an excellent opportunity to examine adaptation, behavior, evolution, interactions, and distribution and abundance patterns, which are readily observable and easily grasped (Chapter 3). This is especially true for the field of plant ecology, which utilizes ecological patterns (species distributions, abundances, and/or performance) as an often first step in examining ecological process at work (interactions, adaptations, etc.). The harsh conditions of the sandhills environment result in dramatic patterns that reveal how several factors (e.g. climate, soil conditions, competition) influencing the distribution and abundance of organisms.

In addition, an increasing number of educational programs emphasizing multidisciplinary study could be well-served by education opportunities in the sandhills. The interdisciplinary nature of sandhills conservation issues could provide for an integrated curriculum in environmental studies, which identifies the interrelationships between the science, economics, and politics, among other fields. The sandhills are similarly well-suited for providing outdoor science and education, as presently conducted within the Mount Hermon Outdoor Science School.

Local Examples

Though the sandhills can't possibly be *the* best system for illustrating concepts in all fields, they are a local system that can afford students opportunities to explore material first hand "in their own backyard". Educators who try to pair global concepts with local examples can turn to the infinitely instructive sandhills. For example, an evolution instructor would no doubt discuss the Burgess shale of the Rocky Mountains in Canada to teach how macroevolutionary processes can be examined through geological strata. However, the sandhills could provide a local example and system for hands-on examination of the same concepts that will bring home the lesson and enhance conceptual learning.

Several past and current programs have utilized the sandhills as such a local teaching tool. Dr. Dan Doak at the University of California at Santa Cruz used the sandhills to illustrate the broader concepts and applications in the field of conservation biology. He also provided students with the opportunity to further enhance their understanding through experiential learning in a "conservation practicum" – a course in which students examined general concepts and problems by conducting research in the sandhills. In addition, naturalists at the Mount Hermon Outdoor Science School teach $5^{th}$to 8^{th} grade students about unique sandhills environment as part of their weekly residential program (Rick Oliver, pers. comm. 2004; Section 13.4).

13.2 INTERPRETATION

Used primarily to describe the programs and activities provided by parks, interpretation is designed to stimulate interest and curiosity in the natural or cultural resources and thus enhance the experience of a visitor to a park or other natural area. Thus, interpretation places greater emphasis on enjoyment and appreciation of the sandhills where educational programs would focus primarily on learning (L. Summers, pers. com.). Another distinction is that interpretative programs often highlight a characteristics of a park or natural area, whereas educational programs (i.e. curricula) are designed primarily to teach content.

Parks and other natural areas that contain sandhills habitat and current (or potential) interpretive programs include: Henry Cowell State Park, Wilder Ranch ("Gray Whale") State Park, the Bonny Doon Ecological Reserve (CA Dept. Fish and Game), Quail Hollow Ranch County Park, and the Mount Hermon Christian Conference Center.

Value of the Sandhills for Interpretation

The sandhills can be a huge asset to interpretive programs designed to aid enjoyment or appreciation of natural areas due to their uniqueness, diversity, fascinating natural history, and aesthetic beauty.

Uniqueness

When asked what they experienced during their trip to parks or other natural areas, people often recount the unique features they encountered, such as the tallest tree in the world (a redwood), the largest grove of giant sequoias, the grand canyon of the Colorado river, or the labyrinth of caves through which they walked. Though the sandhills are less famous, they provide many great opportunities to dazzle people with their uniqueness. Indeed, knowing that they visited the only area in the world to support sand parkland and sand chaparral and perhaps seeing one of more of the six endemic species, visitors often greatly enjoy their visit to the sandhills.

Diversity

Many people have an innate appreciation for diverse areas. There is just something about being in the presence of a diverse host of organisms that makes a place more memorable. With over 90 species of unique plants and a diverse assemblage of animals (especially insects) that is yet to be fully appreciated, the sandhills can be a great asset to interpretive programs emphasizing the importance and fascination of diversity.

Natural History

The complete natural history of the sandhills, including the geology, climate, flora, fauna, complex ecology, and how they interact in space and time to produce the communities we see can be a great learning tool for interpretive programs, especially those designed to instill a sense of place. Teaching how 15 million year old sand dollars and fire conspire to bring about the evolution of plants and animals found nowhere else in the world is one of the many ways to enhances appreciation for the sandhills and visitor enjoyment.

Aesthetic Beauty

Many aspects of the sandhills are aesthetically appealing and engender appreciation solely for their beauty. Views from atop sandhills ridges and the towering ponderosa pines surrounded by carpets of wildflowers in sand parkland often result in sighs of joy from visitors.

Others aspects of the sandhills may require interpretation of their natural history to enhance appreciation. For example, though some find the chaparral a beautiful community, others regard it as a shrubby impenetrable thicket that that evokes thoughts of a forest after being clear cut. Still others may not immediately appreciate the splendor of the Mount Hermon June beetle or Zayante band-winged grasshopper, despite their unique coloration. Like fine art, these sandhills resources may require interpretation, yet once their uniqueness or fascinating ecology is explained, visitors can be left with an increased appreciation for a new system.

13.3 THE VALUE OF EDUCATION, INTERPRETATION, AND OUTREACH FOR THE SANDHILLS

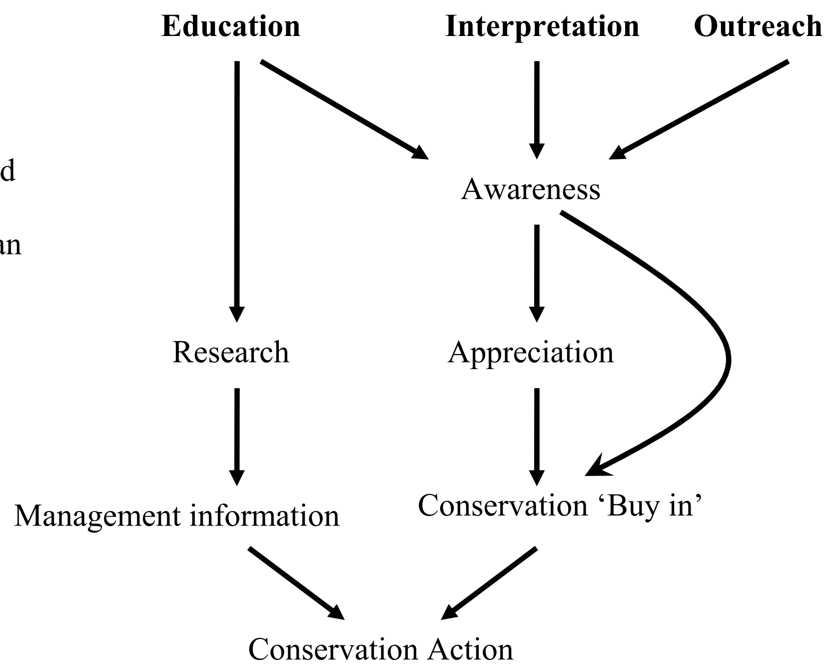
Having established that the sandhills can benefit education and interpretation efforts in the region, the question germane to development of a conservation strategy for the sandhills is: *What value do sandhills education and interpretation have for sandhills conservation*? Sandhills education, interpretation, and outreach can increase awareness and foster appreciation, which can enhance regulatory compliance and a variety of conservation actions on behalf of the sandhills. Educational programs can increase research in the sandhills, which can in turn provide a clearing understanding of this unique system. Therefore, education and interpretation act in complex ways to facilitate persistence of sandhills communities and species (Figure 13.1).

Awareness

Increasing awareness is the first step to enhancing conservation. Efforts to alert people to the existence of the sandhills should also increase their awareness to the uniqueness, rarity, and fragility of the endangered communities and species. This is because alerting people to their existence alone can increase human use that degrades sandhills habitat. This is especially important with regard to recreation, as increasing awareness can increase use which degrades sandhills habitat (Chapter 10).

Many residents and visitors to the region are aware that the sandhills exist. Hundreds of people live in the sandhills, and many more pass through habitat on major thoroughfares (e.g. Graham Hill Road, Mount Hermon Road, and Quail Hollow Road), and trails (e.g. Henry Cowell State Park, Quail Hollow County Park). The abrupt discontinuity in vegetation perceived by even the casual observer as well as place names such as “Whispering pines”, “Ponderosa Camp”, and the “Pine Ridge trail”, among others, lead to a general awareness of the unique community in their midst. Few people realize the uniqueness, rarity, and fragility of the sandhills, which can enhance appreciation critical to conservation.

Figure 13.1: Complex interactions and conservation benefits that can result from sandhills education, interpretation, and outreach activities.



Appreciation

In order to appreciate the sandhills, many require more understanding of the sandhills environment. This understanding can come directly from someone knowledgeable of the sandhills, or a variety of media which can carry information including the internet, newspapers, public presentations, and brochures, among others. Oftentimes gaining information during direct experience *in the sandhills*, either independently or on a guided walk, can greatly facilitate appreciation. Education, interpretation, and outreach efforts can be designed to provide the types of information about the sandhills that enhance appreciation.

Conservation "Buy in"

Increasing appreciation of the sandhills will increase conservation buy in—public participation in conservation efforts that benefit the sandhills, including regulatory compliance, conservation support, and conservation action.

<u>Regulatory Compliance</u>

Increasing awareness and appreciation of the sandhills will increase compliance with regulations designed to protect sandhills habitat and species. Here regulation is used broadly to include any type of rules, codes, or laws. These include no trespassing laws, rules governing recreational activities, planning codes, California Environmental Quality Act (CEQA) regulations, and State and Federal Endangered Species laws. Increased appreciation will increase the likelihood that an individual will comply with said rules and encourage other people such as their neighbors, fellow members of a community group, or people they encounter while in the sandhills, to do the same.

Conservation Support

Though current regulations play a crucial role in sandhills conservation, they are by no means sufficient to protect sandhills communities and species. Instead, additional active efforts to preserve and manage sandhills habitat are necessary to preserve this unique system. These efforts require resources including time and skills (as described below) but also funds. Much of the funding for preservation and management comes from Local, State, and Federal government through a wide variety of agencies and public programs. Citizens fund these programs through taxes, bonds, and fees. Conservation support must include the backing of the citizenry for these programs.

Citizens also influence the activities of governmental and non-governmental programs which may influence the sandhills. Citizens participate in the general planning process which can determine how sensitive habitat areas are treated through regional planning, and they can influence decisions about uses in sandhills habitat preserves, especially those that are publicly owned. Increasing appreciation of the sandhills increases the likelihood that citizens will support conservation efforts on behalf of sandhills through these and numerous other mechanisms.

Conservation Action

Increasing appreciation of the sandhills through education, outreach, and interpretive programs can increase conservation actions: the provision of resources directly to sandhills conservation efforts including funds, work, time, and skills. Some people will channel their appreciation of the sandhills into conservation actions that are necessary supplements to current programs and efforts and can include: volunteer work on stewardship projects (i.e. exotic species removal), donations to sandhills conservation groups, and facilitating outreach programs which can, in turn, increase awareness among others, thus completing a cycle that begins with awareness. Organizations such as the Sandhills Alliance for Natural Diversity (SAND), California Native Plant Society (CNPS), and other conservation and stewardship organizations include among their members people who are motivated toward conservation action. These organizations play a central role in providing opportunities for people to turn their appreciation into conservation action on behalf of the sandhills

Research

Programs designed to provide information about the sandhills can benefit long-term conservation by promoting scientific research, which is the basis for informed management strategies in the sandhills (Chapter 12). Education programs in the sandhills have the potential to directly increase research and therefore needed knowledge. At Universities, undergraduate and graduate students exposed to the sandhills through coursework may develop research programs in the sandhills. Professors can find that their course needs and research needs can both be met through the sandhills, creating entire research and education programs surrounding these rare communities. Published research often inspires further research by sharing the questions and results from this fascinating system. New research results that inform conservation management can provide the impetus for new management programs for sandhills habitat and reinvigorate management efforts overall. In this way, education plays a crucial role in sandhills conservation efforts by facilitating research.

Complex Feedbacks

As illustrated (Figure 13.1), education, interpretation, and outreach activities can facilitate sandhills preservation by a complex array of direct and indirect effects and positive feedbacks loops. Thus, when carefully managed, these programs have a large potential to enhance sandhills conservation efforts in the long term.

13.4 Recommendations for Education, Interpretation, and Outreach

The types of education, outreach, and interpretive programs for the sandhills are as numerous and varied as the creative minds that develop them. The following is a sample of the types of educational, interpretation, and outreach activities than have been or could be used to enhance conservation. Though it is beyond the scope of this document to develop specific programs, this next section provides some guidelines by which programs might maximally enhance conservation.

Elementary and Secondary Schools

School curriculum based on or including the sandhills can increase awareness and foster appreciation of the sandhills, while providing educators with local examples from which to teach lessons in a variety of subjects (Section 13.1). Separate, age-specific curricula developed for elementary and secondary school children could combine classroom lessons with field trips to sandhills habitat. The Scotts Valley Middle School, as well as the former Quail Hollow Elementary school (now offices), is located within sandhills habitat, while other schools are within a short bus ride of sandhills habitat that could be used for educational trips.

Like many community members, educators may not be aware of the sandhills and the opportunities that they can provide, necessitating outreach efforts by sandhills community groups (e.g. SAND). Providing educators with information directly or via access to a ‘sandhills library’ can facilitate the development of such curricula.

One goal in sandhills outreach might be to develop separate curriculum for elementary, junior high, and high school students that could be used in schools throughout a district (e.g. San Lorenzo Valley, Scotts Valley) that would be linked by themes that transcend the grade levels. Specific lessons examining topics in both natural and social sciences could be used to provide a cohesive framework within which students could explore concepts and information in the sandhills, while developing a connection to the environment around them and their community. Home school educators seeking stimulating ways to teach students of different ages simultaneously could also use such a curriculum.

Outdoor Science Schools and Environmental Education

Outdoor science schools and environmental education programs are designed to teach children grades 5-8 science and environmental stewardship during 4 or 5 day residential programs. In most programs, students examine concepts in geology, botany, zoology, and ecology (often using the California Department of Education Science Framework) through activities emphasizing outdoor experiential learning. The specific curriculum in such programs is greatly influenced by the instructors or teachers who typically cater their lessons to the natural environment of that camp or adjacent areas that they use as their 'classroom'.

The sandhills should be integrated into outdoor science curricula. This is very feasible for two programs located in or near the sandhills: Mission Springs, and the Mount Hermon Outdoor Science School (MHOSS) located at the Ponderosa Camp at the Mount Hermon sandhills site. At the MHOSS, the school's naturalists can opt to take their class into the sandhills as part of their daily activities. In addition, MHOSS offers students the option of participating in a stewardship elective each Wednesday afternoon in which up to 25 students can manually remove Portuguese and French broom seedlings from their sand parkland habitat (Section 9.4)—allowing students to learn about exotic plant impacts on a sensitive plant community while they work to reduce seedling recruitment.

Staff members at the MHOSS are very interested in sandhills conservation and have expressed a strong interest in integrating more information about sandhills ecology in their curriculum (Rick Oliver, pers. comm. 2004). Such outreach has the potential to:

1) raise sandhills awareness for the nearly 6,000 5th-8th grade students (R. Oliver, pers. comm. 2004), including many residents of Santa Cruz County and the San Lorenzo Valley, who attend the school each year, and
2) facilitate sandhills appreciation of MHOSS staff members, who may then conduct sandhills management or perhaps research (naturalists have undergraduate degrees and some pursue graduate school programs following employment).

Mission Springs, which is located off Lockhardt Gulch Road near Scotts Valley, also has an environmental education program. It is not known whether this program features current sandhills information in its curriculum. Three other environmental education/outdoor science school programs in the Santa Cruz County include: Camp Campbell, which is in the redwoods in Boulder Creek just 5 miles from Bracken Brae; Monte Toyon, which is in the redwoods near Aptos, and Camp Koinonia which is in Watsonville. Outreach efforts could be extended to the directors of these programs to provide them with information about the sandhills and their potential role in environmental education programs.

College and University Education

Instructors and professors at universities including UC Santa Cruz, Stanford, San Jose State, Cal State University Monterey Bay, and community colleges including Cabrillo College, West Valley College, Foothill College, and De Anza College, among others, may wish to incorporate the sandhills in their regular course curricula, either as part of survey courses, topical courses, or intensive field studies.

Survey courses designed to provide students an overview of a broad range of topics, oftentimes incorporate a series of field trips to various systems to illustrate course content and provide students with hands on access. Courses such as “Ecosystems of California”, “Environmental Case Studies of the Bay Area”, or “Geology of California”, for example, could include content about and field trips to the sandhills. Courses on specific topics such as vertebrate zoology, plant ecology, field geology, among others, can incorporate examples from sandhills species, communities, and/or formations from single or multiple trips as well.

The sandhills can provide a great system in which to focus an entire class, such as a naturally history of the sandhills course. Though this may sound narrow in scope, the sandhills illustrate several important themes in many fields and as such can provide a local, real-world example through which students can examine a broad spectrum of topics unified within a single system. The sandhills could also provide a system in which to conduct a field methods course, plant ecology field section, or independent research course (e.g. like Dr. Dan Doak’s Conservation practicum at UC Santa Cruz; Section 12.2). Studying a single local system through repeated lessons can provide continuity for students who get the opportunity to thoroughly investigate material by iteratively building on previous work.

While all courses can increase awareness and appreciation of the sandhills, intensive field courses or conservation practica have the potential to generate important research, both in and of themselves. When students are encouraged to intensively examine various aspects of a system intensively, and to pursue independent projects, they are more likely to take ownership of the conservation issues surrounding the system, than when they simply visit a site as part of a survey course.

Field Tours

Guided walks lead by individuals experienced in sandhills natural history can be an integral part of education, interpretation, and outreach programs for the sandhills. For example, the author took her Plant Ecology course from UCSC to the sandhills in fall 2002 to illustrate how patterns are detected and processes examined in the field (Figure A.48). Docents at the Bonny Doon Ecological Reserve and the park interpreter and docents at Quail Hollow Ranch County Park lead walks through their respective natural areas to examine sandhills natural history. And the Sandhills Alliance for Natural Diversity and California Native Plant Society provide guided walks through the sandhills as part of their education and outreach programs.

Guided walks can examine all aspects of natural history of the sandhills or focus on specific areas of interest to the group (e.g. wildflowers, insects, geology). They can be conducted for people of all ages or specifically target certain age groups (e.g. children). Guided walks can include one site or several adjacent sites to survey a variety of sandhills communities.

In most guided walks, participants are there voluntarily, so making the experience worthwhile is essential to successful outreach. The following are specific recommendations for aspects of content and the logistics of walks that can facilitate their success.

Content

Tour content depends on the purpose of the tour (coursework, natural history walk, native plant society field trip, etc.) the audience, and the expertise and interest of the tour leader, among other factors. The following are some important considerations for enhancing appreciation through field visits.

Topics

Though topical courses and trips lead by specific societies (e.g. CNPS) may focus on certain aspects of the sandhills, many participants benefit from learning the overall natural history of the sandhills first, as it provides context a more logical, complete package that lends itself to comprehension and retention. Oftentimes, a "bottom up" approach can provide the most intuitive framework for teaching sandhills natural history. That is, information about the geology, climate, and soils, can provide a context for understanding the unique sandhills plant life (adaptations, communities, unique species), which can in turn facilitate learning about the sandhills fauna (adaptations, unique species). In addition to natural history, a discussion of human activities and conservation issues is typically included in most walks, as the evidence of human impacts are apparent and many people are interested to learn what is being done to protect these communities.

Detail

Though the ecology of sandhills species and communities is fascinating, the complexity and detail inherent in describing some of the more minute aspects may be beyond the scope of most field tours. Though a few, carefully placed details can pepper an overall broad assessment, attempts to describe minutia can overwhelm participants. Though in education, some details are necessary to challenge student thinking and expand knowledge, the goal in interpretation is to balance the intellectual information with an emotional experience, and the latter can be thwarted if too much emphasis is placed on the former. This is a difficult lesson for some sandhills enthusiasts with extensive experience in the system (including this author) to learn, but is essential avoid overwhelming general audiences.

Props

Teaching aids can greatly enhance interpretation of sandhills natural history and appreciation of sandhills habitat. The author has employed the following in her guided tours:

- maps to orient participants
- aerial photographs of the larger region to illustrate geology, vegetation, and land use (Figure A.33)
- fossils of sand dollars to show on routes where they will not otherwise be encountered (Figure A. 4)
- photographs of sandhills animals that are similarly less likely to be observed (Figures A.22, 25, & 26).

The author also developed a series of “Sandhills Interpretive Cards” –small (4 x 6”) laminated cards, each with a photograph of a sandhills species on the front and a description of its natural history on the back (Figure A.49). These cards are issued at the beginning of the field trip to participants (one each) who are asked to alert the group when they see their species, most of which are readily identifiable plants. Then, rather than the tour leader providing the information, the participant reads the information on the card. Such active participation increases enjoyment, enhances the memorability of the event, and leaves many participants with a sense of ownership of the sandhills. Children respond particularly well to the cards as they have a mission that keeps them focused and turns what could end up being “another boring tour” into a “fun game.” Currently used by staff at Quail Hollow Ranch County Park for their interpretive sandhills walks, a copy of these cards can be made available by contacting the author (Appendix E).

Logistical Considerations

Considerations of many logistical aspects of leading a field tour can be as crucial as determining content to the overall success of the trip. The following are some specific considerations for the sandhills.

Group Size

The size of the group should be considered both in terms of the effectiveness of the tour as well as the impacts of human disturbance on sensitive habitat. Though the goal of outreach is to reach out to as many people as possible, interpretive events can be marginalized if crowded. Participants often want to be able to access the tour leader to ask questions and certainly need to be able to hear. In many sites, trails through intact habitat are wildlife trails that are used only occasionally by researchers and field tours. Some of the most sensitive plants as well as the Zayante band-winged grasshopper inhabit such low intensity, moderate disturbance areas.

Because of this, single file progression of groups is a good rule. As a result, a group of more than 15 people can create a progression too long for a single trip leader to address without yelling or using a blow horn, either of which can degrade the experience (Figure A.48). In sand parkland, the experienced sandhills tour leader can often identify areas where he/she can step off the trail without impacting habitat negatively (i.e. areas covered with litter or dense European annual cover); however, this is often not an option in sandhills chaparral communities or ponderosa pine forest due to the dense shrub and tree cover. Groups of 15-25 should have at least two instructors strategically separated within the group. Groups greater than 25 should be separated into two groups which use alternate routes to minimize impacts.

Season

The season in which the sandhills are visited can factor greatly into the enjoyment derived from the visit and the appreciation the sandhills engender, primarily by influencing phenology and weather. Given that the appreciation many people have for the sandhills results from their aesthetic enjoyment (Section 13.2), the sandhills are best visited during the early spring when the greatest abundance and diversity of wildflowers are visible. Specific groups might appreciate the later flowering perennials (June to August) and perhaps the early flowering shrubs (November to February). However, members of the general public typically respond most to the diverse assemblages of abundant annuals which flower between March and May, but typically hit their peak in April. Wildflower abundance and phenology (i.e. seasonal occurrence) are greatly influenced by the year's precipitation regime, so groups that are flexible can use field reconnaissance to determine the best time to visit. El Niño years that bring high rainfall in winter and spring typically create a carpet of wildflowers in sand parkland sites which can capture the appreciation of many.

Weather should also be considered in planning sandhills walks to ensure participant enjoyment. The sandhills habitat can be an absolutely hot and foreboding place during the late spring, summer, and early fall (May to September). Due to the open nature of the vegetation and white sand soil which reflects radiant energy from the sun, sandhills habitat can be (or at least feel) more than 10 °F hotter than adjacent non-sandhills habitat. Moreover, there is no reliable canopy in open sand parkland or sandhills chaparral communities; therefore no respite. Though May brings later blooming annuals and early perennials, it also brings early heat spells to the region and temperature exceeding 100 °F that can render even a mid-morning walk unenjoyable. Summer fog that reaches the sandhills between June and August can provide comfortable weather for tours, yet the fog is unreliable. Rain is less of a concern for most tours, as it is uncommon in April and May. Based on this, tours in April and early May are recommended for general outreach. Tours should be conducted before noon if possible, to reduce likelihood of excessive heat.

Self-guided tours

Tours lead by enthusiastic and knowledgeable people are a great way to increase awareness and appreciation of the unique sandhills communities. Because they provide a learning environment that is interactive and collaborative, field tours are more informative, enjoyable, and memorable than self-directed methods of learning via self-guided tours and interpretive signage. In addition, sandhills habitat at some sites is not open to the public except during guided tours (e.g. Quail Hollow Ranch County Park).

However, resources including staff members are often limited, and thus reduce the number of tours that can be provided. In addition, many people enjoy exploring natural areas without a group. Self-guided tours, in which interpretive materials are provided in pamphlets or directly upon "permanent" signposts located at regular intervals throughout a designated route can also provide outreach. Though necessarily much briefer due to the media used, the content of a self guided trail through the sandhills could be similar to that of the guided tours (discussed above). To prevent damage due to such unsupervised use of sandhills habitat, the interpretive materials should emphasize the fragility of the sandhills habitat and encourage careful use within the prescribe regulations of the area just as a human guide might instruct. Self-guided trails should be only open for pedestrian use, sited deliberately to reduce negative impacts to habitat associated with human activity, regularly patrolled to ensure compliance, and monitored for negative habitat impacts as described in greater detail in Section 10.6.

Interpretive Signage

Large format interpretive signage can also play a role in providing information about the uniqueness, rarity, and fragility of sandhills habitat that can enhance appreciation. Permanent, encased, large poster displays or interpretive kiosks that are complete with eye-catching and illustrative photographs, maps, and information similar to that of self-guided walks and brochures, could be posted at key places throughout the sandhills including: park nature centers, trailheads to sandhills habitat, entrances to sandhills preserves, and roadside turnouts or "waysides" located on routes through the sandhills (e.g. Graham Hill Road, Mount Hermon Road).

At parks and other areas with access regulations, such interpretive signage can potentially enhance compliance by providing the rational behind limitations. For sandhills habitat that is permanently or temporarily closed to public access, such signage can provide the all too important justification to people who otherwise might feel entitled to enter the site, especially if the site is on public land and/or has a history of public uses.

Once created, large format interpretive posters for the sandhills could be printed and displayed in local schools, natural history museums, and other public buildings including libraries and city or County offices on a permanent or rotating basis. In this way, interpretive posters can bring awareness of the sandhills to the public.

Brochures

Interpretive brochures or pamphlets that provide information about the unique natural history of the sandhills are another mechanism for sandhills education and outreach. In the 1990s, the California Department of Fish and Game Natural Heritage Division developed a sandhills brochure that provided interpretive information about sandhills and has been circulated at parks and events in the region. Upon forming as a group, the Sandhills Alliance for Natural Diversity (SAND) created a trifold color brochure that contained information about the sandhills distribution, geology, flora, fauna, and threats, as the community group itself (Figure A.50). Using the content of interpretive signage, brochures can provide a way for sandhills visitors to take sandhills information with them from nature centers, park offices, trailheads, and kiosks. Brochures can also be distributed to the public at fairs, environmental events, natural history museums, libraries, city offices, and other appropriate venues.

Website

The sandhills ecosystem needs a website. Private citizens as well as agencies and organizations rely on the internet for their information. Developed in consultation with sandhills experts and maintained in perpetuity, such a website should ideally include natural history information, sandhills references and links to other sandhills information and organizations involved in sandhills preservation.

Natural History Information

The sandhills website should include a natural history section through which the geology, soils, climate, flora, fauna, threats, and conservation efforts are interpreted. The purpose of the information should be general education, rather than detailed scientific information which can be provided through the literature as described below. Though the main audience should be adults, a "children's section" could be created to provide age specific information for school children conducting internet based research. Photographs and other illustrations provided by sandhills enthusiasts should be used to make the sandhills come to life for people who otherwise have not and perhaps cannot visit the sandhills.

Literature

Many people including land managers, agency representatives, planners, scientists, and consultants working on sandhills projects, would benefit from having access to sandhills literature on the web. At a minimum, a list of available literature (i.e. a sandhills bibliography) should be included in the website. Ideally, however, website links would allow people to download actual documents (e.g. this one). This document will provide a sandhills specific bibliography, as well as contain many chapters that can and should be included for download on the sandhills website. Ideally, there would be an agency or organization that can maintain the website including updating the literature as more becomes available.

Notices

The sandhills website would ideally feature up to date information about sandhills education and conservation issues that provide people with more information about how they can support conservation efforts on behalf of sandhills or take conservation action. Notices from organizations like SAND, CNPS, natural history museums, State Parks, County Parks, or other groups involved in sandhills education, conservation, and/or management might be posted including: volunteer opportunities (work days, docent positions, etc), interpretive activities (hikes, festivals, research presentations), and community meetings (e.g. SAND, scoping meetings for projects), among others.

Links and Contact Information

Contact information for or links to agencies and organizations involved in any aspect of sandhills conservation, research, and management should be provided on a sandhills website. In addition, organizations involved in other aspects of natural lands management and protection in the region should be encouraged to feature links to the sandhills site.

Presentations

Presentations about the sandhills can increase awareness and appreciation of this unique habitat. Presentations for audiences assembled at society meetings (e.g. CNPS), museum functions, or as outreach to other groups (e.g. recreational groups, environmental groups) can provide general information about sandhills natural history and conservation. These presentations can readily be catered to emphasize the interests of the individual group. Provided computers, projectors, and screens are available, so-called "power point" presentations can merge text and photographs, just as in brochures and interpretive signs, to illustrate important aspects of the system. Presentations rich with color photographs can provide the next best thing to a sandhills tour in terms of enhancing awareness and appreciation for the sandhills. Once created, presentations developed by sandhills enthusiasts can be provided on a sandhills website as an easy way to convey information beyond the audience.

Sandhills Video

Like a presentation, a video of the sandhills can be used as an outreach and education tool that takes the sandhills to the public. A professionally created video incorporating footage of sandhills sites with text regarding sandhills natural history could provide powerful visual evidence to the sandhills uniqueness, rarity, and fragility. A video could be provided to schools, included as a part of grant proposals for sandhills conservation and management, and provided to other organizations interested in learning more about the sandhills. A video of a sandhills presentation (e.g. power point slide show) could be effective in the short term, until resources for a professional movie are obtained.

13.5 Coordinating Sandhills Education and Interpretation

Funds for interpretation, outreach, and education projects are often limited. Given that multiple individuals, organizations, and agencies desire to create and promote education and interpretation in the sandhills, collaborations can increase awareness and appreciation of the sandhills throughout the region by sharing staff hours and funds.

Resource Pooling

By pooling their resources, the various independent organizations involved in education, interpretation, or outreach projects for the sandhills can increase the success of their projects in terms of the quality of the project and the number of people reached. Presently, several organizations including non-profits organizations, government agencies, and private industry groups are involved in projects to provide information about the sandhills for one purpose of another. They include:

- Sandhills Alliance for Natural Diversity
- California Native Plant Society
- Mount Hermon Outdoor Science School
- Land Trust of Santa Cruz County
- California Department of Parks and Recreation
- United States Fish and Wildlife Service
- California Department of Fish and Game
- City of Scotts Valley
- Santa Cruz County Planning Department
- Santa Cruz County Parks SC County Parks
- Granite Rock Corporation.

These organizations could pool their resources available to develop materials and programs. For example, organizations with expertise in the sandhills natural history including can provide much of the raw materials including information, photographs, or simply expertise for development of project content. Trained educators and interpreters in these organizations as well as in staff positions within government agencies can provide their expertise and other resources (facilities, funds, etc.) to the development of the projects. Organizations with funds yet perhaps lacking the interest in project development can provide much needed funding.

The following are descriptions of two recent collaborations that have been initiated among these organizations.

MHOSS and SAND

In a recent example of such a partnership (September 2003), the Mount Hermon Outdoor Science School (MHOSS) partnered with the Sandhills Alliance for Natural Diversity (SAND) to provide a workshop entitled "Gardening in the Sandhills". In this partnership, MHOSS provided the venue and logistical support while SAND provided the volunteer effort to develop content and implement the program.

The "Gardening in the Sandhills" workshop had two goals:

1) to provide information to sandhills landowners about using sandhills native plants in their landscaping, and
2) to provide general natural history information to naturalists working at MHOSS, as well as members of the larger community.

As a result of the event, 20 MHOSS naturalists learned more information about sandhills natural history, and approximately 25 other members of the community learned about the sandhills unique ecology and flora, and what they can do in their own backyard to preserve native biodiversity. In addition, discussion of management strategies sparked one naturalist's interest in monitoring the effects of a recent effort initiated by Mount Hermon's facilities engineer, Dale Pollock, to rake litter in hopes of increasing native herbaceous plants while reducing European annuals in their sand parkland—the first large scale implementation of this strategy (Section 8.3).

SAND and County Parks

Members of the Sandhills Alliance for Natural Diversity (SAND) and docents and staff of Quail Hollow Ranch County Park also collaborate on sandhills outreach and interpretation projects. SAND provided County Parks with a set of sandhills interpretive cards for use in their annual guided tours to the sand parkland habitat at the park. In addition, SAND and County Parks staff collaborated in providing a second Gardening in the Sandhills workshop (March 2004) which was held at the County Park and taught by SAND members.

SAND and Graniterock

The Granite Rock Corporation ("Graniterock") and Sandhills Alliance for Natural Diversity (SAND) also recently developed a partnership (January 2004). Graniterock is providing SAND with funds to implement the outreach and education programs that SAND designed including a website, workshops, and brochures, among other projects. In turn, SAND's work will satisfy a previously arranged agreement as part of Graniterock's HCP to provide education and outreach efforts to the community on behalf of the sandhills.

Future Collaborations

Collaboration could similarly stretch resources for development of interpretive materials including props, brochures, and signage. Public and private landowners may find that large format interpretive signs alerting neighbors, authorized users, or would-be trespassers to the uniqueness, fragility, and rarity of the sandhills can increase conservation 'buy in' by enhancing compliance with regulations (i.e. trail rules, no trespassing) and perhaps even inspiriting conservation support and action. To save costs, multiple landowners could pool their resources to fund the development of the signs, and production and installation costs could also be lower per sign if multiple signs were developed. Similar signs posted throughout the sandhills habitat could perhaps increase public awareness regarding the concern for protecting sandhills habitat.

Additional outreach by SAND to facilitate the MHOSS program interest in sandhills education might include providing regular guided walks for naturalists as part of their annual training in September, providing the school's director, Rick Oliver, with printed information about sandhills natural history, and working with naturalists to develop sandhills-based activities and curricula for their students.

Grants

Sandhills education and interpretation projects can also be funded through grants. Recognizing the value of such projects for conservation and community development, several organizations provide small grants to assist development of education and interpretation projects. In addition, local business and corporations might be willing to support the development of education and interpretive programs that enhance public awareness and appreciation for the environment. Given the important role of public awareness and conservation 'buy in' in many facets the sandhills conservation efforts described in this plan, agencies and organizations should consider funding outreach in the sandhills.

Chapter 14

Next Steps: From Plan to Action

INTRODUCTION

The uniqueness, rarity, and fragility of the sandhills necessitate conservation action to preserve biodiversity in this biological treasure. The multiple threats to biodiversity at the genetic, species, and community level require a multifaceted approach. The different approaches should draw on numerous resources, including various sources of expertise, time, and funds.

Fortunately, a variety of organizations in several different sectors are willing to assist in these efforts. No single organization has all the necessary resources; therefore, collaboration can greatly enhance the success of sandhills conservation efforts. Effective coordination among groups will be essential to attaining and maintaining the regional conservation targets for the sandhills.

This chapter highlights the most critical and immediate conservation actions and provides suggestions for how achieving a coordinated effort among the various individuals and organizations involved in sandhills conservation which together can turn this conservation plan into conservation action.

14.1 THE PLAYERS

Coordination requires recognizing the individuals and organizations that should participate in the process. Table 1 outlines the players involved in sandhills conservation. In many cases, different entities are involved in different facets of the conservation strategy. The success of conservation efforts will be improved by greater coordination among these players.

Sandhills Alliance for Natural Diversity

Individuals and organizations involved in various aspects of sandhills conservation are encouraged to coordinate efforts through involvement in a unifying organization: the Sandhills Alliance for Natural Diversity (SAND). Formed in October 2001, SAND is a consortium of agency representatives, scientists, consultants, landowners, educators, and other individuals involved in sandhills issues (Figure A.52). Upon forming, SAND identified a need for a regional conservation strategy to guide future efforts. SAND members helped secure funding for the Sandhills Conservation and Management Planning Project through which this plan was created.

At a SAND workshop to share the findings of the SCMP on January 30, 2004 at Quail Hollow Ranch County Park, 55 individuals and organization representatives involved in sandhills conservation and management discussed next steps in sandhills conservation. The participants formed discussion groups for each of the main components of the sandhills

Table 14.1: Individuals and organizations involved in sandhills conservation efforts, by non-mutually exclusive categories.

Category	Sub-category	Example Entities Involved
Private landowners	Residential	Individual homeowners, homeowners associations, developers
	Commercial	Quarry operators, conference centers, storage companies
	Non-profit conservancy	Land Trust of Santa Cruz County, Trust for Public Land, The Nature Conservancy, others
	For profit conservancy	mitigation banks
Public landowners	Local	City of Scotts Valley, City of Santa Cruz, Santa Cruz Co., San Lorenzo Valley Water District
	State	California Department of Fish and Game, California Department of Parks and Recreation
Land managers	Private	private landowners, private land management companies, security companies, independent firms and consultants, Natural Resources Employment Program
	Public	California Department of Fish and Game, California Department of Parks and Recreation, San Lorenzo Valley Water District
Agencies	General land use	County of Santa Cruz, City of Scotts Valley , City of Santa Cruz, Coastal Commission
	Trustee Agencies	United States Fish and Wildlife Service , California Department of Fish and Game
Conservation groups		Sandhills Alliance for Natural Diversity, California Native Plant Society, South Ridge-West Ridge Watershed Association, Sierra Club
Researchers		Research scientists (e.g. Universities), students, independent scientists, biotic consultants
Educators	Schools	public schools (K-12), outdoor science, home school programs, colleges and universities
	Parks	park interpreters, docents
Funding organizations	Private	foundations, individual philanthropists, private companies
	Public	City, County, State, or Federal revenue and grant programs

conservation strategy: land preservation, fire management, recreation management, exotic plant management, and education and outreach. The feedback generated in these discussions is provided in the following section.

It is recommended that individuals who participated in this workshop continue their involvement in sandhills conservation work through participation in one or more working groups within SAND. Such coordinated efforts will be most effective in ensuring that information, ideas, and resources are provided where they are needed to effect conservation. Though perhaps not all participants of the SCMP workshop would be available for continuing participation in SAND, ideally many of these enthusiastic and highly knowledgeable individuals would continue to contribute their expertise to sandhills conservation efforts.

14.2 NEXT STEPS

Based on the previous chapters of this plan and the discussions of the working groups at the SCMP Workshop, the following is a list of the key priorities for conservation in the sandhills.

Habitat Preservation

There was broad agreement among the SCMP workshop participants that available resources should be pooled over the next several decades to preserve as much remaining habitat as is available. Sand parkland habitat should be especially targeted, though the large patches of sandhills chaparral communities and ponderosa pine forests adjacent to already protected habitat identified in the SCMP planning project should also be targeted (Chapter 6). As outlined in Section 6.4, several mechanisms may be available for land preservation.

Acquisition

Land acquisition is one method of preserving sandhills habitat. In 2002, the United States Fish and Wildlife Service and California Department of Fish and Game received a grant to purchase sandhills habitat. The Land Trust of Santa Cruz County is working to identify willing sellers from which to purchase property that the SCMP planning project recognized as having extraordinary conservation value.

Develop a Habitat Conservation Plan

Many SCMP workshop participants, including representatives of the government agencies regulating development within the sandhills, emphasized the importance of developing a regional Habitat Conservation Plan (HCP) for the sandhills. A regional HCP would provide a mechanism to fund many of the land preservation and management actions outlined in this plan that protect and enhance populations of the sensitive species of the sandhills, while allowing certain human use of sandhills habitat that causes "take" of endangered insects and is therefore otherwise prohibited by the Endangered Species Act. Presently, landowners can only obtain incidental take permits by preparing individual HCPs.

These are costly for the landowners, require United States Fish and Wildlife Service representatives to spend a large amount of time processing applications, and result in a piecemeal approach to conservation planning that is less effective for attaining the conservation goals outlined in this plan. The development of a regional HCP is identified as a critical step for the recover of the four federally endangered species in the sandhills (USFWS 1998).

The County of Santa Cruz and City of Scotts Valley are working cooperatively to develop a Sandhills Regional HCP. Began in March of 2004, this project is in the early stages of development and will take several years to complete. As a public process, the HCP development will be influenced by public input. Individuals and organizations involved in sandhills conservation should actively support the development of an HCP that will affect the regional conservation goals for the sandhills.

The United States Fish and Wildlife Service is in the final stages of preparing an Interim Programmatic Habitat Conservation Plan (IPHCP) for the sandhills that would permit small residential projects (e.g. room additions, swimming pools, etc.) in small parcels (approx. 1 acre) in moderate to high density residential development. At the time of the SCMP finalization (June 2004), this IPHCP was not yet available for public review.

Fire Management

Participants at the SCMP workshop expressed strong concern about the impacts of ongoing fire exclusion for sandhills species and communities, as well as the increased risk of wildfire in developed areas that results from fuel accumulation. Representatives of the California Department of Forestry and Fire Protection (CDF) and the California Department of Parks and Recreation (CDPR) as well as others with experience in fire management outlined the following steps towards fire management at the SCMP workshop.

<u>Develop Partnerships</u>

Agencies involved in fire management in the region including local fire districts, CDF, and CDPR should develop partnerships to implement sandhills fire management. Pooling resources and coordinating efforts can help facilitate the myriad steps necessary to effectively manage using fire.

<u>Determine the Sandhills Fire History</u>

Focused research to determine aspects of the natural fire regime in the sandhills should be conducted. Historical fire records maintained by CDF, as well as dendrochronology (tree aging) and fire scar examination should be used to help fire managers determine the season of fire as well as the appropriate return interval.

Develop a Fire Management Plan for the Bonny Doon Ecological Reserve

The Bonny Doon Ecological Reserve (BDER) is the largest area of sandhills habitat under single ownership (CA. Dept. of Fish and Game) and is located in the largest sandhills site (Martin Road). Sandhills habitat at the BDER has undergone dramatic changes in community structure in the absence of fire (Section 8.1). A fire management plan for the BDER should incorporate adaptive management and research to examine the effectiveness of different fire management treatments (Section 8.3). Fire management at this site can be used to demonstrate the importance and relative safety of prescription burning.

Conduct Outreach and Education Regarding Fire Management

A program of public outreach should be developed and implemented to share information and gain support for the role of fire management in reducing risk of catastrophic wildfire and promoting sandhills species and community persistence.

Recreation Management

Participants in the working group on recreation management recommended that efforts begin immediately to arrest and reverse the negative impacts of recreation on sandhills habitat managed for its conservation value. They recommended the following actions.

Develop and Post Interpretive Signage

Efforts to curtail negative impacts should begin by posting interpretive signage at sites experiencing degradation due to unlawful recreation (Section 13.4). Landowners experiencing trespassing could collaborate in the development of signage to reduce costs.

Enforce Existing Regulations

Regulations prohibiting recreational uses should be enforced. Land owners might reduce costs and increase compliance through a coordinated campaign involving stepped up patrol for example, by working together to contract private security that can patrol multiple sandhills sites within the same region.

Develop Recreation Management Plans

In areas where recreation is to be allowed, the guidelines outlined in Chapter 10 should be followed and specific plans for minimizing, monitoring, and mitigating the negative effects of recreation on sandhills species and communities should be developed.

Exotic Species

Participants at the SCMP workshop emphasized the need to begin to reclaim sandhills habitat lost to infestations of aggressive exotic species through eradication and control efforts.

Develop a Working Group

Though all sandhills conservation efforts would benefit from the formation of a cohesive working group, land managers involved in exotic plant control would especially benefit from efforts to share information about the techniques, relative effectiveness, and lessons learned from their efforts to manage exotic plants.

Eradicate Isolated Species

Isolated individuals or small patches of aggressive exotic plants should be quickly eradicated before a change in conditions allows them to proliferate beyond the point where they can be removed. Following this general recommendation at the SCMP Workshop, docents at the Bonny Doon Ecological Reserve removed two large jubata grass plants that had been present in the reserve for more than 10 years. Other sites similarly have small infestations of exotic plants that could currently be removed at low cost, both economically and biologically speaking.

Research/Adaptive Management

More information about the relative effectiveness and impacts on sensitive species of different techniques for controlling exotic plants is needed. Funding should be provided to this important area of research, and managers implementing projects should do so within the adaptive management framework to learn from their efforts (Section 7.5).

Conduct Workshops

Land managers with experience controlling exotic plants in the sandhills should hold workshops to share their sandhills-specific techniques with anyone interested in conducting exotic plant removal efforts in the sandhills, from private landowners to regional land managers.

Coordinate Volunteer Efforts

Sandhills land managers should coordinate with volunteer groups who conduct exotic plant removal projects (e.g. Wildwork, California Native Plant Society Habitat Restoration Team), and/or assemble a volunteer crew of sandhills enthusiasts to conduct specific projects or facilitate ongoing projects. For example, a volunteer crew could be assembled to remove broom on the County's property on Graham Hill Road, adjacent to the Mount Hermon Conference Center's broom removal project, to both enhance habitat on the County's property and reduce re-infestation of Mount Hermon's project area.

Research

A group of scientists, graduate students, and agency representatives made the following recommendations based on their discussion of sandhills research at the SCMP Workshop.

Create a Sandhills Research 'Library'

Because so many important sandhills studies have yet to be published and therefore are not widely available in University libraries, it is important that a sandhills research library be compiled so that researchers can readily access and build upon sandhills information.

Appoint a Research Coordinator

A research coordinator in the sandhills is needed to facilitate and coordinate various aspects of sandhills research including:

1. outreach to research institutions to encourage new research projects
2. coordinating access between landowners and researchers
3. facilitate collaboration between organizations requiring studies and potential researchers
4. facilitate collaboration among researchers

Establish a Science Advisory Committee

A group of scientists should be assembled to provide scientific input to sandhills related projects. Members of this committee should be knowledgeable of the sandhills and able to critically evaluate studies.

Education and Outreach

The working group focused on determining education and outreach priorities identified many of the programs outlined in Section 13.4 of the plan as priorities, especially the development of a sandhills website, yet also added the following.

Coordinate an Annual Sandhills Festival

Akin to the annual festivals for salmon, monarch butterflies, and artichokes held in other regions, a sandhills festival could increase public awareness, appreciation, and local 'ownership' of conservation efforts for the unique sandhills communities.

Create a Sandhills Interpretive Center

A sandhills interpretive center should be established in the new "downtown" being created on Mount Hermon Road in the City of Scotts Valley.

14.3 GETTING IT DONE

The "short list" of next steps in sandhills conservation will require a concerted effort. The question becomes: Who will complete these crucial projects? The fact that many agencies share responsibility for sandhills conservation and several organizations have stepped forward to assist (Section 14.1) adds immensely to the collective sense that sandhills conservation can be accomplished. Due to tight budgets and reduced personnel in many organizations, individuals working on sandhills conservation are all involved in multiple other projects as well. Volunteers often work to fill the gaps; however, volunteer work is limited.

By applying for grants and other intermittent sources of funding individuals can move sandhills conservation projects forward intermittently. The pace of this work is slower than that which would be observed if dedicated resources were available. Indeed, though motivated individuals can apply for grants, even the time spent preparing the grant applications is hard to come by for individuals that must otherwise work for a living.

The following recommendations are designed to increase the efficacy of sandhills conservation efforts.

Memorandum of Understanding

A memorandum of understanding, or other formal mutual agreement, should be established between government agencies, and perhaps non-governmental organizations, that are involved in sandhills conservation issues. Individually, several local, state, and federal agencies are all working on aspects of sandhills conservation, with their specific work related to their specific mandates. Because many of the projects have overlapping jurisdictions and therefore differing agency responsibilities, individuals within these different groups are already collaborating in these projects. A memorandum of understanding would help codify the relationships between the organizations and lay out the resource commitments of each.

Sandhills Preserve Manager

Progress toward sandhills conservation would be greatly enhanced through establishment of a Sandhills Preserve Manager position. Despite the broad recognition of the importance of sandhills conservation and the multiple entities involved, there is no one person who solely works on sandhills issues. Though collaborations will remain a huge component of sandhills conservation work, several people involved in sandhills conservation who have been frustrated by a lack of cohesiveness to the efforts have independently suggested that having one person coordinate sandhills conservation could unite the effort.

Working with individuals and organizations involved in all aspects of sandhills conservation, the Sandhills Preserve Manager could function in many roles including the following:

1. develop regional conservation strategies in collaboration with organizations
2. work with landowners to develop sites-specific conservation and management plans
3. coordinate management implementation and conduct management
4. coordinate and conduct monitoring and research
5. collaborate with education organizations to develop programs and conduct outreach
6. generate funds for sandhills conservation projects through grant writing and other development efforts
7. collect and disseminate sandhills information to organizations

The Sandhills Preserve Manager (SMP) position could be funded through the Memorandum of Understanding between organizations involved in sandhills conservation. Though single agencies can not individually afford the salary of a staff person dedicated to sandhills conservation work, several organizations could support a fraction of the costs associated with the SPM. The SPM position might also be funded by mitigation fees from the Sandhills Regional HCP. Though funding for the position could be tied to outside grants and contracts, the position would be less effective if the SPM has to generated his/her own funding. The uncertainty of funding could derail progress on projects and would likely lead to greater turn over in the position, which could greatly diminish progress in the long term.

14.4 Conservation Action through Adaptive Management

The contents of any conservation plan become dated following publication. In the sandhills, new information about sites is becoming available; meanwhile conditions in sandhills sites are changing. Research to further inform sandhills management is being conducted and new conservation projects are being implemented. While it is the author's hope that the information in this document will be useful to those involved in conservation efforts, it is also hoped that much of the content will become dated very soon as a result of a rapid acceleration in sandhills conservation action. Those involved in sandhills conservation should continue to share new information that is gained through project implementation to inform future efforts to enhance and preserve biodiversity in the endemic sandhills communities.

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APPENDICES

APPENDIX A

ANNOTATED LIST OF FIGURES

This appendix provides color plates with photographs designed to illustrate the important aspects of sandhills conservation, as well as information about the photographs located on the chapter pages within the text. All photographs in this plan are by the author unless otherwise indicated.

Chapter Title Page Figures

Chapter	Content
1	North slope sand parkland habitat of the South Ridge of Quail Hollow (foreground) to the North Ridge of Quail Hollow (background). May 2003.
2	The South Ridge of Quail Hollow from the South, showing the sand chaparral community (foreground) and open sand parkland habitat (background).
3	Open sand parkland habitat of South Ridge, with ponderosa pines (background), silverleaf manzanita surrounded by the orange flowers of sticky monkeyflower (center), and flowering silver bush lupine (foreground).
4	Sand quarries (background) beyond the flowering plants of north aspect sand parkland habitat on the South Ridge of Quail Hollow (foreground).
5	Santa Cruz wallflower inflorescence.
6	Sample view of the SCMP Geographic Information System, showing sites (outlined) and endangered insect observations (symbols) in the central portion of the planning area.
7	Bill Reid sampling plant species cover and diversity following closure of the South Ridge trail for recreational use. April 2002.
8	California Department of Parks and Recreation Resource Ecologist, George Gray, monitors a test burn in the ponderosa pine forest of Henry Cowell State Park. February 2003.
9	A wall of silver wattle (*Acacia dealbata*) in the Olympia Wellfield sandhills site.
10	Jumps created forged from pine limbs and hardware for mountain bicycle recreation in the Mount Hermon/SRL site. June 2003.
11	Silver bush lupines near the seed orchard in Graniterock's Quail Hollow Quarry.
12	Experimental plots used to examine the effects of tree on the distribution and abundance of native herbaceous plants in sand parkland at Quail Hollow Ranch County Park.
13	Exploring the diversity of fossil organisms at an abandoned sand quarry.
14	Agency representatives, land conservators, and biologists visit a sandhills site proposed for preservation as part of a Sandhills Alliance for Natural Diversity (SAND) event. May 2002.
Append.	West ridge of Quail Hollow (foreground), north, up the San Lorenzo Valley.

Color Plates

Figure	Content
1	**Aerial photograph** of region of central Santa Cruz County (CA) where sandhills are located, with sites from the Sandhills Conservation Planning Project outlined in yellow. (AirphotoUSA)
2	**Topographic map** of the San Lorenzo Valley and surrounding areas illustrating the patchiness of the Zayante Soils outcrops (yellow) that occur primarily on ridge tops and adjacent slopes (Matt Freeman)
3	**Outcrop of the indurated sand dollar facies**—the substrate that underlies sand parkland habitat in the sandhills of the Ben Lomond and Scotts Valley area.
4	**Miocene (15 million years old) sand dollar fossils** found in the sand dollar facies of the Ben Lomond sandhills.
5	**The South Ridge of Quail Hollow**, which rises over 300 feet above the residential area of Olympia below, exemplifies the steeply sloped habitat that supports the sand parkland community. Preserved in the 1990's, the South Ridge is the largest and most biological diverse patch of sand parkland remaining.
6	**Soil of the Zayante series**. The light color of this soil reflects its poor development, low level of organic matter, and low nutrient availability which combine with its coarse sandy texture to create unfavorable conditions for plant growth.
7	**Biological soil crust** found in sandhills chaparral community gaps. Where the crust is left intact, these gaps support native plants, such as the Ben Lomond spineflowers (pink), but only low abundance of annual exotic plant species.
8	**The 'aspect-effect' is remarkable in sand parkland**, where the cooler, moister, north aspects support dense woody vegetation and ground cover while the south aspects support lower plant cover comprised of species uniquely adapted to the hotter, drier conditions. (AirphotoUSA).
9	**Fog** and the morning marine layer in the summer months provide a respite from hot droughty conditions and may be essential to the persistence of many plant species in this xeric system.
10	Sandhills plants like this seedling pussy paws (*Calyptridium umbellatum*) may be able to take up **fog water**—perhaps the only water they receive during the summer drought (June-October).
11	The **Ben Lomond spineflower (*Chorizanthe pungens* var. *hartwegiana*)** is a winter spring prostrate annual herb in the Buckwheat family (Polygonaceae). Listed as federally endangered in 1994, this endemic plant occurs primarily in open areas away from shrubs, trees, and dense exotic cover. This plant is named for the spiney margins of the flower bracts.
12	The **Ben Lomond buckwheat (*Eriogonum nudum* var. *decurrens* Polygonaceae*)*** is a perennial herb endemic to the sandhills. It is listed as *most endangered* (status 1B) on the California Native Plant Societies list of Rare Endangered plants.

Figure	**Content**
13	The **Santa Cruz wallflower (*Erysimum teretifolium*)** is a monocarpic herb (i.e. reproduces once) that produces a basal rosette of narrow leaves in its first year then flowers one to four years after germinating. Endemic to the sandhills, this extraordinarily rare plant is found only in open areas away from woody vegetation and dense exotic cover in 12 remaining sites.
14	The **silverleaf manzanita (*Arctostaphylos silvicola*)** is an endemic shrub that dominates many of the sandhills chaparral communities. It's small, white urn-shaped flowers produced in late fall and early winter provide nectar to many hummingbird and insect species.
15	**Ponderosa pine (*Pinus ponderosa*)** are the dominant trees of sand parkland and ponderosa pine forest. These disjunct coastal populations of this primarily montane trees may be genetically distinct and thus a unique species or subspecies of pine.
16	**Silverleaf manzanita chaparral with ponderosa pine** is one of six plant communities used in the vegetation classification proposed in this plan. One of the three communities dominated by silverleaf manzanita, this assemblage includes scattered tall ponderosa pines throughout.
17	**Silverleaf manzanita mixed chaparral** is dominated by shrubs including silverleaf manzanita, *Ceanothus cuneatus*, and *Adenostoma fasiculata,* and shrub sized oaks including coast live oak (*Quercus agrifolia*) and interior live oak (*Quercus wislizenii*).
18	**Sand chaparral** is the dominated by silverleaf manzanita with few scattered other shrubs and tree species. In the gaps between shrubs, sand chaparral supports a diverse assemblage of native herbaceous plants (Table 8.1), several of which are not found in the other communities.
19	**Ponderosa pine forest** is dominated by trees including ponderosa pine, coast live oak, and madrone (*Arbutus menziesii*) and includes shrubs including *Ceanothus* and *Arctostaphylos* in the understory. Diminutive native sandhills herbs are restricted to gaps or are not found at all.
20	**Open sand parkland** is the characterized by a sparse canopy of trees, primarily ponderosa pine but also coast live oak, and a dense and diverse assemblage of herbaceous and suffrutescent (subshrub) species unique to the sandhills. Occurring only on ridges, this extraordinarily rare community is found on only 57 acres left in the world.
21	In **dense sand parkland,** tree and shrub cover is greater than in open parkland. As a result, the diversity and abundance of plant and animal species adapted to open conditions is reduced. Plant (and perhaps animal) species requiring greater shade are found in this community.
22	**Santa Cruz kangaroo rat (*Dipodomys venustus venustus)*** is a nocturnal, granivorus, burrowing small mammal that collects food in external check pouches. Known from only one remaining sandhills site, this rare species' persistence is threatened by illegal recreation which degrades habitat and collapses burrows.
23	Disjunct populations of **California whiptail lizards (*Cnemidophorus tigris mundus)*** are found in a few sandhills sites in the Ben Lomond area in Santa Cruz County, isolated from the nearest other populations. (Chuck Haznedl)

Figure	Content
24	**Coast horned lizard (*Phrynosoma coronatum*)** is a Federal and State Species of Special Concern that occurs in disjunct populations in the Santa Cruz sandhills. Rarely observed, the few remaining sandhills populations of this species may be in decline due to predation by cats and invasion of non-native ants, which displace the native ants on which this reptile feeds.
25	**Mount Hermon June beetle (*Polyphylla barbata*)** is an endemic insect of the sandhills. This federally endangered species lives belowground as a larva feeding on plant roots for most of its life, but then emerges as a beetle to reproduce at dusk in the summer.
26	**Zayante band-winged grasshopper (*Trimerotropis infantilis*)** is a small, well-camouflaged grasshopper endemic to sandhills. Found only in the open habitat in sand parkland, this federally endangered insect is threatened by recreation, fire exclusion, and exotic plant species.
27	**Slides** form due to aboveground movement of water on steep slopes characteristic of sand parkland ridges. These disturbances create and maintain open habitat required by many diminutive native plants in the sandhills, including pussy paws and the Santa Cruz wallflower, by removing accumulated leaf litter and reducing the abundance of exotic plants.
28	**Wildlife trails** used by deer, coyote, and bobcat, among other animals, form readily in the loose sand soil. These disturbed areas also have lower litter and exotic plant cover and similarly support a greater abundance and diversity of native herbaceous species than the adjacent undisturbed areas. Due to their higher intensity and greater frequency of use, recreation trails do not similarly support native species (see figures 39-41).
29	**Gopher mounds** created by burrowing pocket gophers (*Thomomys bottae*) are found throughout the sandhills. In areas of dense tree leaf litter or exotic plant cover, these disturbances enhance rare native plant establishment and provide a low-competition environment that facilitates their growth and survival
30	**Martin Road Site (incl. Bonny Doon Ecological Reserve) in (a) 1943 and (b) 2002.** Note the decrease in white sand soil visible, indicating a reduction in the amount of open sand habitat required by many native herbaceous plants**.** Though a small fire burned the parkland habitat, the majority of this site has not burned during this interval. (AirphotoUSA)
31	**The North Ridge of the Quail Hollow Quarry Site, in (a) 1963 and (b) 2002.** This site burned in a wildfire in 1954 (the dump fire), which removed shrub cover and several trees, especially on the north aspect (top of the frame); however, many ponderosa pines and oaks survived, especially on the south aspect. Since the fire, the cover of woody vegetation has increased, with the increase most rapid on the north aspect and in the sand chaparral patch located near the bend in the quarry access road (bottom of frames). (AirphotoUSA)
32	**The north portion of the Mount Hermon Road/SRL Site in (a) 1943 and (b) 2002.** Once open sand parkland habitat north of Graham Hill Road (open road in picture), has succeeded to dense sand parkland near the peak (at the Mount Hermon Cross) and ponderosa pine forest on the slopes. While the former still supports small populations of some native sandhills species, including the Ben Lomond spineflower and Zayante band-winged grasshopper, woody vegetation in the latter community excludes most native species. (AirphotoUSA)

Figure	Content
33	**The Zayante Creek Watershed including the Quail Hollow region in (a) 1943 and (b) 2002.** Sandhills habitat has been reduced and fragmented by sand quarrying, urban development, viticulture, and the landfill (upper left corner). (AirphotoUSA).
34	**A sand quarry** where sand the Santa Margarita formation is extracted. Quarrying removes habitat and fragments remaining habitat.
35	**Residential development** is found throughout the sandhills range and varies from high density (<1acre lots) to rural (>10 acre lots). Roads, landscaping, and other alterations associated with residential development reduce and fragment habitat.
36	**Sand parkland habitat with (a) low and (b) high density infestations of exotic plants** (brown grass in picture). European annual grasses and forbs including *Vulpia myuros* and *Hypochaeris glabra*, outcompete native plants for precious soil moisture, reduce populations of the endangered plants, and can reduce habitat suitability for Zayante band-winged grasshopper.
37	**Acacias including silver wattle (*Acacia dealbata*)** can invaded the sandhills and create dense stands which preclude habitat use by native species. These nitrogen-fixing trees may amend the nutrient poor soils and render the sandhills more invasible by other exotic species.
38	**The exotic jubata grass (*Cortaderia jubata*)** is not presently abundant in the sandhills; however, conditions could change (e.g. fire, climate, etc.) and allow these aggressive plants to spread, as they have in other sandy soil areas throughout coastal California.
39	**Equestrian use** can completely denude sandhills habitat, as observed for this increasingly wide trail in Quail Hollow Quarry site. Unlike wildlife trails which support native species, these trails remove all plant cover, and can cause erosion where sloped during rainfall events.
40	**Mountain biking** in the sandhills removes plant cover and creates a channel through which water flows and rapidly erodes the loosely consolidated Santa Margarita Formation. Extensive gullying results, as observed on this trail at the Mount Hermon/SRL site due to mountain bike use between 2002 and 2003. (Ruskin Hartley)
41	**Off highway vehicles** remove plant cover, cause erosion, and greatly degrade habitat, as observed in this unprotected sand parkland site where trespassing by motorcycles has reduced populations of sensitive plants including the Ben Lomond spineflower, Santa Cruz wallflower, and perhaps Zayante band winged grasshopper.
42	**Passive revegetation** has occurred in the three sand quarries closed prior to inaction of the Surface Mine Reclamation Act (SMRA) in 1975 which required reclamation. Perhaps because not all of the sand substrate was removed in this operation (The Old Kaiser Quarry), the steep slope has been naturally recolonized by native plants including the Ben Lomond buckwheat and Ben Lomond spineflower.
43	**Active revegetation** of quarry slopes as part of mine reclamation attempts to establish sandhills plants and provide habitat for sandhills animals. This task is difficult due to the steep slopes that require extensive erosion control and the very thin soils available plants to root.

Figure	**Content**
44	***Ex situ* research**, or research that is done outside of the habitat such as this greenhouse seedbank study, can play an important role in ongoing sandhills research.
45	***In situ* research,** or that which is conducted within the sandhills habitat, is essential for devising management strategies for sandhills species. Here a field assistant creates experimental plots in which dense ponderosa pine leaf litter is removed through raking, to test whether this technique can mimic the beneficial effects of fire.
46	**Small scale experiments, such as these experimental fires** conducted within bottomless burn boxes, allow researchers to statistically evaluate management techniques in small areas throughout various habitats, thus ensuring their effectiveness before widespread implementation while reducing any potential negative impacts of the treatments.
47	**Fire management trials such as these experimental burns in the ponderosa pine forest at Henry Cowell State Park in February 2003** can aid determination of the effectiveness of fire management, especially if they are conducted and monitored using an adaptive management framework which allows resource managers to "learn by doing."
48	**Field tours for education, interpretation, and outreach** purposes can enhance awareness and appreciation of sandhills habitat and play a crucial role in long-term preservation efforts, by increasing sandhills research, conservation work, and regulatory compliance.
49	**Sandhills interpretive photocards** can provide an active learning experience to field tour participants. After locating the plant (or other habitat feature) on the front of the card they were issued at the beginning of the tour, each participant reads the information about the feature on the back of the card to the entire group.
50	**An interpretive brochure developed by the Sandhills Alliance for Natural Diversity** describes the uniqueness, rarity, and fragility of sandhills communities and invites people to become informed and involved in sandhills conservation efforts. These brochures are distributed at local events (e.g. environmental fairs), museums and parks, sandhills preservations, and sandhills walks.
51	**An interpretive display developed by The Sandhills Alliance for Natural Diversity** featuring pictures and text illustrating the unique features and conservation issues of the sandhills provides an attractive way to share sandhills information at environmental fairs and other venues.
52	**The Sandhills Alliance for Natural Diversity** is a group of agency representatives, biologists, planners, landowners, and other concerned citizens dedicated to preserving our rare and unique sandhills habitat through research and management, education, and integrated land use planning. Coordination of conservation efforts outlined in this plan through SAND would greatly facilitate attainment of regional conservation goals.

Color Plates

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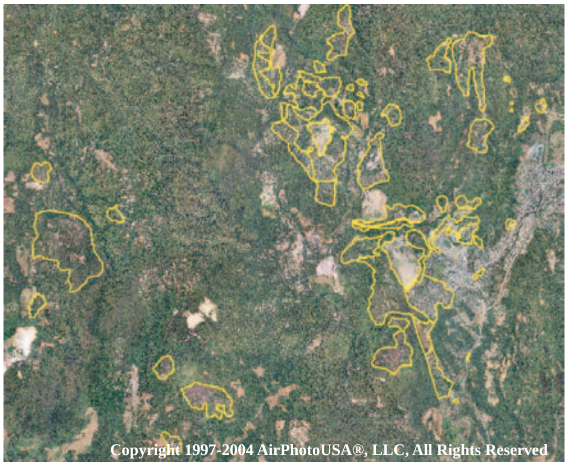

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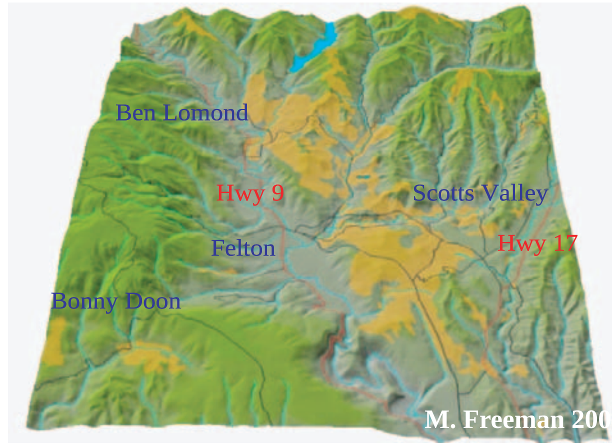

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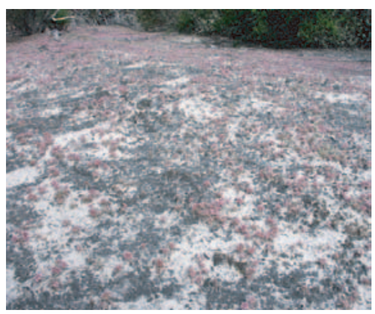

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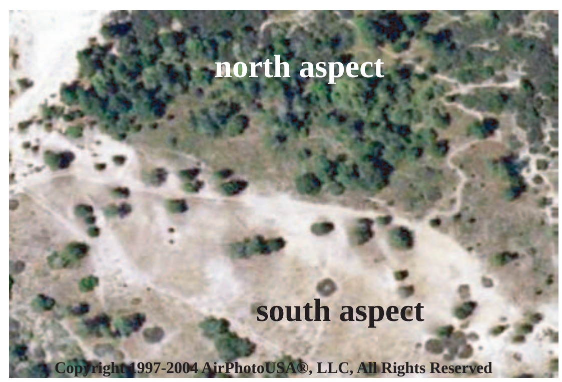

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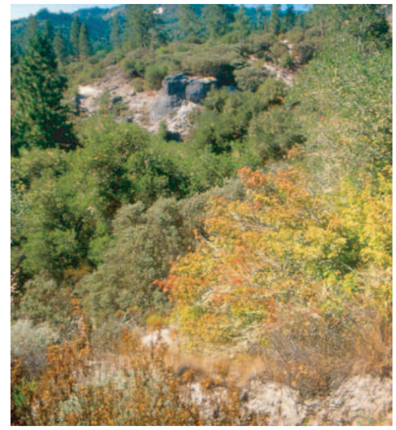

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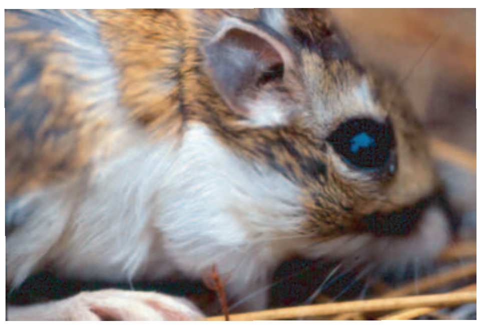

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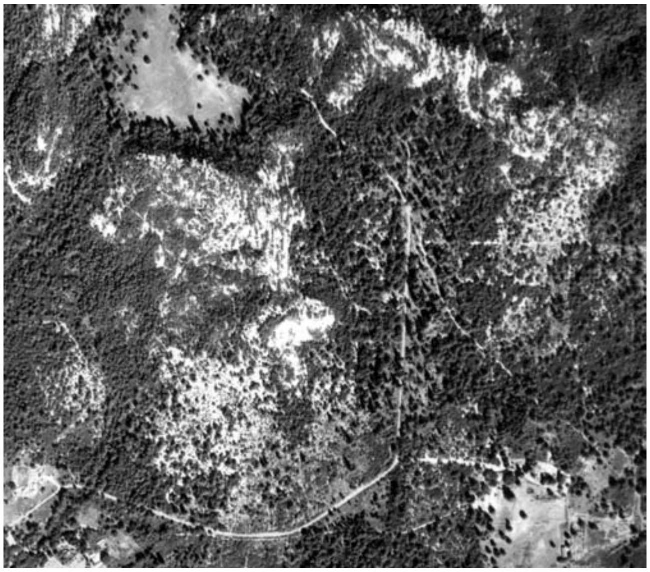

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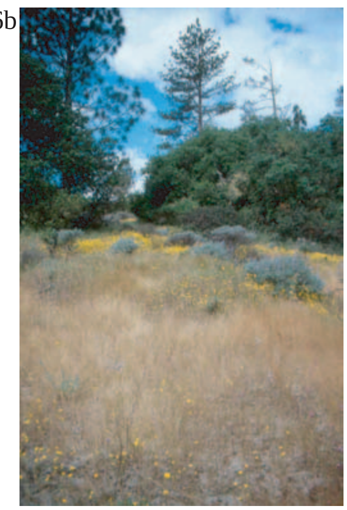

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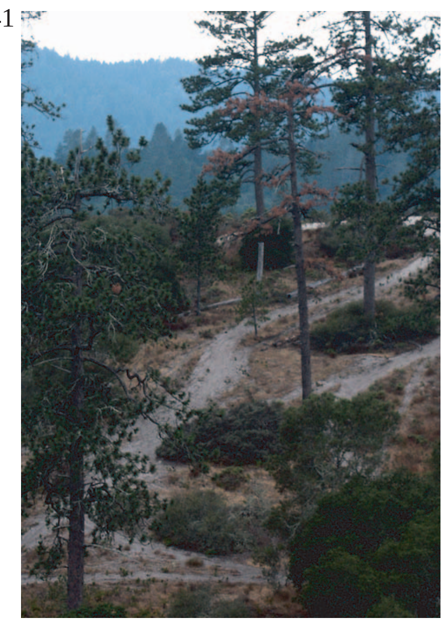

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WOOLY DESERT DANDELION

Scientific Name: *Malacothrix floccifera* (Asteraceae)

Life History: annual (lives 1 year)

Flowering Period: April-June

Distribution: The species is found throughout California but the sandhills have a form with all-yellow ray flowers that is found nowhere else.

Sandhills Habitat: open, sand areas especially on slides or washes and along trails in sand parkland.

Status: May be a unique subspecies; needs research.

The common name refers to the tufts of white hairs found on rosette of leaves at the base of the plant.

Yellow and white flower form

Sandhills yellow flower form

50

Sandhills
Alliance for
Natural
Diversity

Help SAND Preserve our Rare and Unique Sandhills Habitat!

51

52

Appendix B

Sandhills Flora

This sandhills flora was compiled from species lists and information provided in Morgan 1983, Marangio and Morgan 1987, Lee 1994, and McGraw 2004.

Genus	Species	Family	Jepson Page	Life Form	Native	Sand Specialty*	Status
Achillea	millefolium	Asteraceae	189	H	Y	2	
Adenostoma	fasciculatum	Rosaceae	946	S	Y		
Aira	caryophyllea	Poaceae	1230	G	N		
Antirrhinum	multiflorum	Scrophulariaceae	1015	H	Y	5	
Arctostaphylos	nummularia	Ericaceae	555	S	Y		
Arctostaphylos	silvicola	Ericaceae	556	S	Y	1,5	1B
Arctostaphylos	tomentosa ssp. crinita	Ericaceae	556	S	Y		
Armeria	maritima ssp. californica	Plumbaginaceae	822	H	Y		
Artemesia	pycnocephala	Asteraceae	204	H/S	Y		
Baccharis	pilularis	Asteraceae	210	S	Y		
Briza	maxima	Poaceae	1239	G	N		
Bromus	diandrus	Poaceae	1242	G	N		
Bromus	laevipes ssp. rubens	Poaceae	1243	G	N		
Bromus	tectorum	Poaceae	1243	G	N		
Calochortus	venustus (extirpated?)	Liliaceae	1188	H	Y		
Calyptridium	umbellatum	Portulacaceae	898	H	Y	2,3,5	
Camissonia	contorta	Onagraceae	782	H	Y	2,5	
Camissonia	micrantha	Onagraceae	782	H	Y	2,5	
Campanula	angustiflora	Campanulaceae	460	H	Y	5	
Cardionema	ramosissimum	Caryophyllaceae	480	H	Y	3,4	
Carex	globosa	Cyperaceae	1126	H/S	Y	2	
Castilleja	affinis	Scrophulariaceae	1018	H	Y	3	
Castilleja	exserta	Scrophulariaceae	1018	H	Y	2,5	
Ceanothus	cuneatus var. cuneatus	Rhamnaceae	935	S	Y	2,5	
Ceanothus	papillosus	Rhamnaceae	937	S	Y		
Chlorogalum	pomeridianium	Liliaceae	1190	H	Y		
Chorizanthe	diffusa	Polygonaceae	858	H	Y	5	
Chorizanthe	pungens var. hartwegiana	Polygonaceae	859	H	Y	2,5	FE, 1B
Chrysolepis	chrysophylla	Fagaceae	658	T	Y		
Clarkia	purpurea	Onagraceae	792	H	Y		
Clarkia	rubicunda	Onagraceae	792	H	Y		
Clarkia	unguiculata	Onagraceae	793	H	Y		
Collinsia	bartsiifolia	Scrophulariaceae	1026	H	Y	2,3,5	
Crassula	connata	Crassulaceae	525	H	Y		
Cryptantha	clevelandii	Boraginaceae	373	H	Y		
Cryptantha	micromeres	Boraginaceae	376	H	Y		
Cryptantha	muricata	Boraginaceae	376	H	Y		
Cupressus	abramsiana	Cupressaceae	112	T	Y		CE, FE, 1B
Cynara	sp.	Asteraceae	243	H	N		
Cynosorus	echinatus	Poaceae	1248	G	N		
Delphinium	parryi	Ranunculaceae	920	H	Y	2,3,5	
Dendromecon	rigida	Papaveraceae	811	S	Y		
Dichelostemma	capitatum	Liliaceae	1192	H	Y		
Dudleya	palmeri	Crassulaceae	530	H	Y	1'	
Epilobium	minutum	Onagraceae	797	H	Y		
Ericameria	ericoides	Asteraceae	252	S	Y		
Eriodictyon	californicum	Hydrophyllaceae	684	S	Y		

Genus	Species	Family	Jepson Page	Life Form	Native	Sand Specialty*	Status
Eriogonum	nudum var. decurrens	Polygonaceae	876	H/S	Y	1	1B
Eriogonum	vimineum	Polygonaceae	882	H	Y		
Eriophyllum	confertifolium	Asteraceae	264	S	Y	2,5	
Erodium	cicutarium	Geraniaceae	672	H	N		
Erysimum	teretifolium	Brassicaceae	422	H	Y	1	CE, FE, 1B
Eschscholzia	californica	Papaveraceae	814	H	Y	1',5	
Festuca	rubra	Poaceae	1260	G	Y	4	
Filago	californica	Asteraceae	268	H	Y	5	
Galium	spp.	Rubiaceae	978	H	Y		
Genista	monspessulana	Fabaceae	609	S	N		
Gilia	tenuiflora	Polemoniaceae	834	H	Y	2,3,5	
Gnaphalium	californicum	Asteraceae	271	H	Y		
Gnaphalium	canescens ssp. beneolens	Asteraceae	271	H	Y	5	
Gnaphalium	"zayantense"	Asteraceae				1'	
Helianthemum	scoparium	Cistaceae	518	H	Y	5	
Heteromeles	arbutifolia	Rosaceae	953	S/T	Y		
Heterotheca	grandiflora	Asteraceae	286	H	Y		
Heterotheca	sessiliflora ssp. camphorata	Asteraceae	287	H/S	Y	2,5	
Horkelia	cuneata ssp. cuneata	Rosaceae	955	H	Y	2,4,5	
Horkelia	cuneata ssp. sericea	Rosaceae	955	H	Y	2,4,5	
Hypochaeris	glabra	Asteraceae	294	H	N		
Hypochaeris	radicata	Asteraceae	294	H	N		
Koelaria	macrantha	Poaceae	1267	G	Y	2,5	
Lasthenia	californica	Asteraceae	299	H	Y	2	
Layia	platyglossa (?)	Asteraceae	303	H	Y	1'	
Lessingia	filaginifolia var. filaginifolia	Asteraceae	305	H	Y	2,5	
Linanthus	parviflorus	Polemoniaceae	843	H	Y	2,5	
Linaria	canadensis var. texana	Scrophulariaceae	1036	H	Y	5	
Lithocarpus	densiflora	Fagaceae	658	T	Y		
Loeflingia	squarrosa	Caryophyllaceae	482	H	Y	2,5	
Lotus	scoparius	Fabaceae	620	S	Y	5	
Lotus	strigosus	Fabaceae	622	H/S	Y	5	
Lupinus	albifrons	Fabaceae	626	S	Y	2,5	
Lupinus	arboreus	Fabaceae	626	S	Y		
Lupinus	bicolor	Fabaceae	628	H	Y	2,5	
Luzula	comosa	Juncaceae	1166	H	Y	5	
Madia	madioides	Asteraceae	313	H	Y		
Malacothrix	clevelandii	Asteraceae	314	H	Y	2,5	
Malacothrix	floccifera	Asteraceae	315	H	Y		
Meconella	linearis	Papaveraceae	815	H	Y	2,3,5	
Mimulus	androsaceus	Scrophulariaceae	1040	H	Y	2,3,5	
Mimulus	aurantiacus	Scrophulariaceae	1040	S	Y		
Mimulus	rattanii car. decurtatus	Scrophulariaceae	1044	H	Y	2,5	4, SC
Minuartia	californica	Caryophyllaceae	484	H	Y	2,3,5	
Minuartia	douglasii	Caryophyllaceae	484	H	Y	5	
Monardella	undulata	Lamiaceae	722	H	Y	2,3,5	4, SC
Monardella	villosa	Lamiaceae	722	H	Y	2,5	
Montia	fontana	Portulacaceae	904	H	Y		

Genus	Species	Family	Jepson Page	Life Form	Native	Sand Specialty*	Status
Muilla	maritima	Liliaceae	1202	H	Y	5	
Navarettia	atractyloides	Polemoniaceae	847	H	Y	5	
Navarettia	hamata	Polemoniaceae	847	H	Y	2,5	
Nemophila	pedunculata	Hydrophyllaceae	691	H	Y	2,5	
Pectocarya	penicillata	Boraginaceae	384	H	Y	2,3,5	
Pellaea	mucronata	Pteridaceae	106	F	Y	5	
Pentagramma	triangularis	Pteridaceae	108	F	Y		
Phacelia	distans	Hydrophyllaceae	698	H	Y	5	
Phacelia	douglasii	Hydrophyllaceae	698	H	Y	2,3,5	
Phacelia	nemoralis	Hydrophyllaceae	702	H	Y		
Phacelia	ramosissima	Hydrophyllaceae	705	H	Y	2,5	
Pinus	attenuata	Pinaceae	118	T	Y		
Pinus	ponderosa	Pinaceae	120	T	Y	2,3,5	
Pinus	sabiniana	Pinaceae	120	T	Y	2,5	
Plagiobothrys	tenellus	Boraginaceae	390	H	Y	2,5	
Plantago	erecta	Plantaginaceae	821	H	Y	2	
Poa	secunda ssp. secunda	Poaceae	1289	G	Y		
Polypodium	californicum	Polypodiaceae	108	F	Y		
Psuedotsuga	menziesii	Pinaceae	118	T	Y		
Pteridium	aquilinum var. pubescens	Dennstaedtiaceae	91	H	Y		
Quercus	agrifolia	Fagaceae	660	T	Y		
Quercus	chrysolepis	Fagaceae	661	T	Y		
Quercus	wislizenii	Fagaceae	662	T	Y		
Rhamnus	californica	Rhamnaceae	942	S	Y		
Ribes	divaricatum	Grossulariaceae	678	S	Y		
Rumex	acetosella	Polygonaceae	894	H	N		
Salvia	columbariae	Lamiaceae	728	S	Y		
Salvia	mellifera	Lamiaceae	728	S	Y	2	
Saxifraga	californica	Saxifragaceae	1009	H	Y		
Scutellaria	tuberosa	Lamiaceae	730	H	Y	5	
Senecio	sylvaticus	Asteraceae	342	H	N		
Sequoia	sempervirens	Taxodiaceae	122	T	Y		
Silene	verecunda ssp. platyota	Caryophyllaceae	493	H	Y	2,3,5	
Stephanomeria	virgata	Asteraceae	348	H	Y	2	
Stylocline	gnaphaloides	Asteraceae	349	H	Y	3,5	
Thysanocarpus	curvipes	Brassicaceae	447	H	Y	2	
Toxicodendron	diversilobum	Anacardiaceae	136	S	Y		
Tragopogon	sp.	Asteraceae	354	H	N		
Vaccinum	ovatum	Ericaceae	567	S	Y		
Vulpia	microstachys var. ciliata	Poaceae	1302	G	Y		
Vulpia	microstachys var. confusa	Poaceae	1302	G	Y		
Vulpia	microstachys var. pauciflora	Poaceae	1302	G	Y		
Vulpia	myuros	Poaceae	1302	G	N		
Vulpia	octoflora	Poaceae	1302	G	Y	5	
Vulpia	octoflora var. hirtella	Poaceae	1302	G	Y	5	

Jepson page: page in the Jepson Manual of Higher Plants of California (Hickman 1993)
Life Form: H=herb, S=shrub, H/S=herb or subshrub, G=grass, F=fern, T=Tree
Native: Y=yes, native to California, N=No, not native to California
Sand Specialty: ***From Marangio and Morgan 1987**

1=endemic
1'=endemic but not yet described
2=sandhills population deserving critical taxonomic study to determine whether endemic
3=disjunct population isolated from other by at least 50 miles
4=coastal relict
5=more evident or frequent in sandhills than other parts of SC County

Status

CE=California Endangered
FE= Federally Endangered
1B= CNPS List 1B: most threatened and endangered
4= CNPS List 4: "watch" list
SC= "Locally unique" according to SC County General Plan

APPENDIX C

SITE DATA SHEET AND INSTRUCTIONS
FOR CONSERVATION PLANNING PROJECT (CHAPTER 6)

The data sheet and instructions in this section were created to facilitate collection of comprehensive data on sandhills sites from experts as part of the conservation planning project for the sandhills, as described in Chapter 6 of this plan.

SANDHILLS CONSERVATION MANAGEMENT PLAN
Sandhills Site Information Sheet Respondent information

Name ____________________Date_________ Phone _____________ e-mail ___________________________________

Site Information
Site Name____________________________ Site ID_________ Ownership_________________ Parcel number(s)____________

Acreage_____ Location (UTMs, address, street/cross street etc.)____
____

Site Conditions

Condition	Present	Info Code(s)	Date	Source Information, Explanation, Comments
Geology	–	–	–	–
Zayante Soils				
Zayante rock formation				
Habitat Quality Factors	–	–	–	–
Mine/Quarry (Currently?____)				
Residential Development				
Other Development specify________________				
OHV Use				
Other degrading use of habitat specify_______________				
Woody invasive plants present				
Past or current restoration efforts				
Currently preserved				
Currently managed				

Fauna

Animal Species	Present	Info Code(s)	Date	Source Information, Explanation, Comments
Invertebrates	–	–	–	–
Trimerotropis infantilis				
Polyphylla barbata				
Philanthus nasalis	–	–	–	–
Plecoma conjugens conjugens				
Vertebrates				
Dipodomys venustus				
Perognathus californicus				
Phrynosoma coronatum				
Cnemidophorus tigris				
OTHER:				

Plant Community

Plant Community Attributes	Present	Info Code(s)	Date	Source Information, Explanation, Comments
Plant Communities	–	–	–	–
sand parkland				
sand chaparral				
northern maritime chaparral				
ponderosa pine forest				
Plant Species	–	–	–	–
Pinus ponderosa				
Arctostaphylos silvicola				
Erysimum teretifolium				
Chorizanthe pungens var. *hartwegiana*				
Eriogonum nudum var. *decurrens*				
Mimulus rattanii ssp. *decurtatus*				
Monardella undulata				
Artemesia pycnocephela				
Delphinium parryi				
Calyptridium umbellatum				
Malacothrix floccifera				
Gnaphalium sp. nov.				
Minuartia californica				
Gilia tenuiflora				
Linanthus parviflorus				
Collinsia bartsiifolia				
Silene verecunda ssp. *platyota*				
Layia platyglossa				
Meconella linearis				
Lasthenia californica				
Armeria maritima				
Cupressus abramsiana				
Pinus attenuata				
OTHER:				

Site Rating________

Additional Information

____
____
____
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____

Thank you for contributing your knowledge of sandhills sites to the Sandhills Conservation Management Plan. Before your begin, please read the following instructions for completing the "Sandhills Site Information Sheets."

General Instructions

- Complete one sheet for each sandhills site. A site is defined as a contiguous area of sandhills habitat, be it comprised of one or more parcels owned by one or more landowners.
- Complete the form as thoroughly as possible, but do not worry if you do not know everything about a site.
- If you have no information about a field, simply leave it blank.
- If you are unsure about a response, please indicate so by placing a "?"after your response.

Respondent Information

- Name: Please provide your full name on each sheet that you complete
- Phone and e-mail: Please provide a way for us to contact you should we have any questions about the information that you provide. You need only provide this on your first sheet.

Site Information

- Site Name: Provide the name of the site. If no name is commonly used, please create a descriptive name.
- Site ID: Please create a brief code for each site that will allow us to link the information sheet to your notations on a map (e.g. "JM3" might indicate Jodi McGraw's site 3).
- Ownership: Indicate the landowner.
- Parcel Number(s): Provide the County parcel number(s) that comprise(s) the site.
- Acreage: State the number of acres of sandhills habitat. Indicate approximations with a "+/-".
- Location: Provide any and all information to help us locate the site, including UTMs, Lat/Long coordinates, street address, street and nearest cross street, etc.

Site Characteristic Tables (site conditions, fauna, and plant community)

- Scientific nomenclature (Jepson Manual) is used for species in these tables. See reverse for explanations.
- Present: Indicated the presence of a feature with an "X", the absence of a feature with a "0". If you have no information about that feature, simply leave the cell blank. Reminder: Use a "?" following a response to indicate uncertainty about your response. (e.g. "X?" indicates that you think something is present, but are not certain.)
- Information Code: Please indicate the source of your information by using the codes provided in the table below. If you have more than one source of information, please list the codes in the order presented in the following table

Source of information	Code	Description
Personal Research	PR	Knowledge obtained through a systematic study (e.g. survey, aerial photograph analysis, etc.) in which you personally participated
Literature	L	Knowledge obtained through printed information
Personal Observation	PO	Knowledge obtained through your direct observations of the site
Personal Communication	PC	Knowledge obtained through communication with knowledgeable individual
Other	O	Knowledge obtained from another source (please specify in comments)

- Date: Indicate the most recent date (month and/or year) to which you are certain of the accuracy of the information you provided.
- **Source Information, Explanation, Comments:** PLEASE take a moment to fill out this field for each response. **ANY information you provide will facilitate this project. If you require additional space, create a footnote to the "Additional Information" section or to an attached sheet of paper. Examples of important information include:**
  - literature references (author, year, and title)
  - source contact information (name, phone number of your personal communication source)
  - additional information (e.g. relative population size, proportion of site that is developed or degraded, exotic plant species present, nature of conservation easement, etc.)
  - explanation for uncertain responses (e.g. population small, may have been extirpated, etc.)

Site Rating: On a scale of 1-10, (10 being highest), give each site a relative "gut level" rating of its biological quality/value.

Additional Information: Use this space for comments on other site aspects, or for footnotes to previous responses.

Geology

Zayante Soils: Does the site have the course textured sand soil classified by the USDA Soil Service as "Zayante Series"?

Zayante Rock formation: Does the site have the indurated layer (e.g. rock outcrops) from which Zayante soils are derived?

Habitat Quality

Mine/Quarry (Currently?___): Has the site been mined? If it is currently mined, check the box next to "Currently?___".

Residential Development: Does the site have a house or houses on it? Please indicate how many in the explanation column.

Other Development: Does the site have other development on it? If so, please specify the type.

OHV Use: Is the site currently used by off-highway vehicles (motorcycles, quads, etc.), legally or illegally?

Other degrading use of habitat: Is the site otherwise degraded? If so, please specify the type(s) of degradation (e.g. equestrian use, local hangout with fire pit, hiking use, dumping grounds etc.)

Woody invasive plants preset: Does the site have woody exotic plant specie (e.g. broom, 'pampas' grass, acacia, etc.?)

Past or current restoration efforts: Has the site received any restoration efforts? Currently?

Currently preserved: Does the site have some type of protection currently? If so, please specify source in comments.

Currently managed: Is the site actively managed to protect habitat quality? If so, specify nature of management.

Plant Communities

sand parkland: A sparse canopy of ponderosa pines (<20% cover) with a well-developed understory of herbaceous species.

sand chaparral: Dominated by silver-leaf manzanita with other shrub species and trees present but less abundant.

northern maritime chaparral: Chaparral comprised of a mix of manzanita(s), ceanothus, chamise, sage, and oaks.

ponderosa pine forest: A denser stand (>20% canopy cover) of ponderosa pine trees, mixed with other tree species (oaks, madrone), an understory of shrub species, and herbaceous species present in shrub gaps?

Animal and Plant Species listed on the Site Information Sheet

Scientific name	Common Name
Animals	
Cnemidophorus tigris	western whiptail lizard
Dipodomys venustus	Santa Cruz kangaroo rat
Philanthus nasalis	Antioch flower wasp
Phrynosoma coronatum	coast horned lizard
Plecoma conjugens conjugens	Santa Cruz rain beetle
Polyphylla barbata	Mount Hermon June beetle
Trimerotropis infantilis	Zayante band-winged grasshopper
Plants	
Arctostaphylos silvicola	silverleaf manzanita
Armeria maritima	thrift, sea-pink
Artemesia pycnocephela	coastal sagewort
Calyptridium umbellatum	pussy paws
Chorizanthe pungens var. *hartwegiana*	Ben Lomond spineflower
Collinsia bartsiifolia	white Chinese houses
Cupressus abramsiana	Santa Cruz cypress
Delphinium parryi	Parry's larkspur
Eriogonum nudum var. *decurrens*	Ben Lomond buckwheat
Erysimum teretifolium	Santa Cruz wallflower
Gilia tenuiflora	gilia
Gnaphalium *sp. nov.*	undescribed sandhills endemic
Lasthenia californica	goldfields
Layia platyglossa	(tipless) tidy-tips
Linanthus parviflorus	linanthus
Malacothrix floccifera	wooly desert dandelion
Meconella linearis	meconella
Mimulus rattanii ssp. *decurtatus*	Santa Cruz monkeyflower
Minuartia californica	sandwort
Monardella undulata	curly leaf monardella
Pinus attenuata	knobcone pine
Pinus ponderosa	ponderosa pine
Silene verecunda *ssp.* platyota	catchfly, campion

Other significant species: Please list any other occurrences of significant species in the appropriate rows of the tables.

APPENDIX D

SANDHILLS CONSERVATION PLANNING PROJECT (CHAPTER 6)

SITE BY ATTRIBUTE MATRIX

Site Name	Site #	Acres	Scores				Tier	sources	Zayante?
			Size	Integrity	Biology	Total			
Weston West Ridge	1	70	2	3	3	14	2	RM	Y
Weston Rd	2	104	3	2	5	20	1	RM, BD, RA	Y
Redwood Glen North	3	1	0	4	3	13	2	RM	N
Redwood Glen South	4	1	0	4	3	13	2	RM	N
Redwood Glen East	5	12	2	3	3	14	2	RM, JM	Y
Glenwood	6	13	2	2	2	10	2	RM	Y
Canham	7	6	1	1	1	5	3	JM	Y
Scotts Valley Quarry	8	10	1	1	1	5	3	RM	Y
Scotts Valley Center	9	7	1	1	1	5	3	JM	N
Highway 17	10	2	0	2	3	11	2	RM, JM	Y
El Rancho	11	2	0	1	3	10	2	BD, JM	Y
Graham Hill South	12	85	3	0	1	6	3	JM	Y
Henry Cowell	13	169	4	4	3	17	1	JM, RM	Y
Mt Hermon/SRL	14	347	4	3	4	19	1	RM,JM,CB	Y
Whispering Pines	15	201	4	0	1	7	3	JM, RA	Y
Mt. Hermon Residential	16	100	3	0	1	6	3	JM	Y
Hanson	17	73	3	2	3	14	2	RM, RA	Y
Mount Hermon Road South	18	40	2	3	3	14	2	JM, RM	Y
Mount Hermon Road North	19	103	3	3	5	21	1	PE	Y
Nelson Road South	20	18	2	2	1	7	3	JM	Y
Fernbrook Road	21	32	2	4	1	9	3	JM	Y
Lockhart Gulch East	22	79	3	1	2	10	2	RM	Y
Montevalle	23	39	2	0	4	14	2	RM, JM	Y
Bean Creek	24	10	1	2	1	6	3	JM	N
Olympia Wellfield	25	154	3	3	5	21	1	RM, JM, BD	Y
Zayante School Rd	26	42	2	2	4	16	1	RM, BD, JM	Y
Maymac South	27	6	1	4	3	14	2	JM	Y
Camp Maymac North	29	6	1	3	3	13	2	RM	Y
QHRCP--East Ridges	30	28	2	4	5	21	1	JM	Y
QHRCP--Sunset	31	5	1	4	2	11	2	JM	Y
West Lompico	32	93	3	3	4	18	1	RM, JM, RA	Y
Sunset Ridge	33	13	2	4	4	18	1	BD	Y
QHRCP--Northwest	34	73	3	3	4	18	1	BD, JM	Y
Vista Robles	35	28	2	1	5	18	1	RM, JM	Y
Marion	36	84	3	2	4	17	1	BD, JM	Y
Hidden Valley	37	29	2	0	4	14	2	RM, BD, JM	Y
Glen Arbor-Quail Hollow	38	13	2	1	3	12	2	JM	Y
Quail Hollow Quarry	39	375	4	2	5	21	1	RM, JM, SM, RA	Y
Hihn Rd	40	115	3	0	2	9	3	JM, BD, RA	Y
South Hihn Road	41	67	3	3	2	12	2	RM, JM, RA	Y
Glen Arbor East	42	93	3	0	2	9	3	BD	Y
Landfill Heights	43	95	3	2	4	17	1	JM, RM	Y
Rebecca	44	31	2	2	3	13	2	JM	Y
Pinecrest	45	22	2	3	1	8	3	JM	Y
West Park	46	36	2	3	1	8	3	JM	Y
Hilton	47	100	3	3	4	18	1	JM, RM	N
Jameson Creek	48	24	2	3	4	17	1	JM, RM	Y
Bonny Doon	49	45	2	3	3	14	2	BD, JM, RM	Y
Martin Rd	50	532	4	3	4	19	1	BD, JM	Y
Woodpecker	51	36	2	3	1	8	3	JM	N
Gray Whale Ranch	52	167	4	4	3	17	1	TH, CB, JM, RA	Y
Ice Cream Grade	53	26	2	4	2	12	2	JM	N
Smith Grade South	54	39	2	4	3	15	2	GH	N
Graham Hill north	55	60	2	3	2	11	2	JM	Y
Sun Mountain Road-North	C-1	75	3	4	NA	NA	C	JM	N
Sun Mountain Road-West	C-2	5	1	4	NA	NA	C	JM	Y
Sun Mountain Road-South	C-3	20	2	4	NA	NA	C	JM	Y
Nelson Road	C-4	86	3		NA	NA	C	JM	N
Mackenzie Creek	C-5	3	1	4	NA	NA	C	JM	Y
Smith Grade	C-6	48	2	4	NA	NA	C	JM	N
Camp Maymac-- Central	C-7	3	1	4	NA	NA	C	JM	Y
Boulder Creek-S of 236	C-8	23	2	4	NA	NA	C	JM	N
Boulder Creek-N of 236	C-9	14	2	4	NA	NA	C	JM	N
Boulder Creek-N of 236-2	C-10	31	2	4	NA	NA	C	JM	N

Site Name	Site #	Mine	Resident	trails	OHV	Invasives	Preserved	Managed	Parkland
Weston West Ridge	1	N	Y	Y			N		
Weston Rd	2	N	Y	Y			N		
Redwood Glen North	3	N	N				N		
Redwood Glen South	4	N	N				N		
Redwood Glen East	5	N	N	Y	Y		N		
Glenwood	6	N	Y				N		N
Canham	7	N	Y				N		
Scotts Valley Quarry	8	Y	N	Y		Y	N		N
Scotts Valley Center	9	N	N				N		N
Highway 17	10	N	Y	N	N	N	N		
El Rancho	11	N	N				N		
Graham Hill South	12	N	Y				N		
Henry Cowell	13	N	N	Y	N	Y	Y	Y	N
Mt Hermon/SRL	14	N	Y	Y	Y	Y	Y		Y
Whispering Pines	15	N	Y				N		
Mt. Hermon Residential	16	N	Y				N		
Hanson	17	N	Y			Y	N		Y
Mount Hermon Road South	18	N	Y				N		
Mount Hermon Road North	19	Y	N	Y	Y	Y	N		Y
Nelson Road South	20	N	Y				N		
Fernbrook Road	21	N	Y				N		
Lockhart Gulch East	22	N	Y				N		
Montevalle	23	N	Y				N		Y
Bean Creek	24	N	Y				N		
Olympia Wellfield	25	Y	N	Y	Y	Y	N		Y
Zayante School Rd	26	N	Y	Y		Y	N		Y
Maymac South	27	N	N	N			N		Y
Camp Maymac North	29	N	Y	Y	N		N		
QHRCP--East Ridges	30	N	N	Y			Y		Y
QHRCP--Sunset	31	N	N				Y		
West Lompico	32	N	N	Y	N	Y	N		Y
Sunset Ridge	33	N	Y				N		Y?
QHRCP--Northwest	34	N	Y	Y			N		
Vista Robles	35	N	Y	Y			N		Y
Marion	36	Y?	Y				N		Y
Hidden Valley	37	N	Y	Y			N		N
Glen Arbor-Quail Hollow	38	N	Y				N		N
Quail Hollow Quarry	39	Y	Y	Y	N	Y	N		Y
Hihn Rd	40	N	Y				N		N
South Hihn Road	41	N	Y				N		
Glen Arbor East	42	N	Y			Y	N		N
Landfill Heights	43	N	Y				N		Y
Rebecca	44	N	Y				N		N
Pinecrest	45	N	Y				N		N
West Park	46	N	Y				N		N
Hilton	47	N	Y				N		N
Jameson Creek	48	N	Y				N		N
Bonny Doon	49	N	Y				N		N
Martin Rd	50	N	Y	Y			N		Y
Woodpecker	51	N	Y				N		N
Gray Whale Ranch	52	N	N	Y	Y	Y	Y	Y	N
Ice Cream Grade	53	N	N				N		N
Smith Grade South	54	N	N				N		
Graham Hill north	55	N	Y				N		
Sun Mountain Road-North	C-1	N	Y				N		
Sun Mountain Road-West	C-2	N	N				N		
Sun Mountain Road-South	C-3	N	N				N		
Nelson Road	C-4	N	Y				N		
Mackenzie Creek	C-5	N	N				N		
Smith Grade	C-6	N	N				N		
Camp Maymac-- Central	C-7	N	N				N		
Boulder Creek-S of 236	C-8	N	N				N		
Boulder Creek-N of 236	C-9	N	N				N		
Boulder Creek-N of 236-2	C-10	N	N				N		

Site Name	Site #	NMC	MCRPPF	Trin	Poba	Phna	Plco	Dive	Peca	Phco	Cnti	Pipo	Arsi
Weston West Ridge	1	Y		Y?									
Weston Rd	2	Y		Y?								Y	Y
Redwood Glen North	3												Y
Redwood Glen South	4												Y
Redwood Glen East	5												Y
Glenwood	6												
Canham	7				Y?								
Scotts Valley Quarry	8												Y
Scotts Valley Center	9												
Highway 17	10												
El Rancho	11		Y		Y							Y	
Graham Hill South	12	Y	Y										
Henry Cowell	13	N	N		Y							Y	Y
Mt Hermon/SRL	14	Y	Y	Y	Y			Y				Y	Y
Whispering Pines	15				Y								
Mt. Hermon Residential	16				Y								
Hanson	17	Y										Y	Y
Mount Hermon Road South	18												
Mount Hermon Road North	19	Y	Y	Y	Y		Y					Y	Y
Nelson Road South	20												
Fernbrook Road	21												
Lockhart Gulch East	22	Y										Y	
Montevalle	23											Y	Y
Bean Creek	24												
Olympia Wellfield	25	Y	Y	Y	Y							Y	Y
Zayante School Rd	26	Y										Y	
Maymac South	27	N											
Camp Maymac North	29											Y	Y
QHRCP--East Ridges	30	Y	Y	Y	Y						Y	Y	Y
QHRCP--Sunset	31	Y										N	Y
West Lompico	32	Y	Y		Y							Y	Y
Sunset Ridge	33	Y	Y									Y	Y
QHRCP--Northwest	34	Y	Y		Y							Y	Y
Vista Robles	35	Y	Y								Y	Y	Y
Marion	36	Y			Y						Y?	Y	Y
Hidden Valley	37											Y	Y
Glen Arbor-Quail Hollow	38											Y	Y
Quail Hollow Quarry	39	Y	Y	Y	Y	Y	N			Y	Y	Y	Y
Hihn Rd	40		Y		Y							Y	
South Hihn Road	41											Y	Y
Glen Arbor East	42	Y	Y									Y	Y
Landfill Heights	43	Y										Y	Y
Rebecca	44	Y											Y
Pinecrest	45												
West Park	46												
Hilton	47												
Jameson Creek	48												
Bonny Doon	49												
Martin Rd	50	Y	Y									Y	Y
Woodpecker	51												
Gray Whale Ranch	52	Y	N		Y?		Y	N				Y	Y
Ice Cream Grade	53												
Smith Grade South	54												
Graham Hill north	55		Y									Y	
Sun Mountain Road-North	C-1												
Sun Mountain Road-West	C-2												
Sun Mountain Road-South	C-3												
Nelson Road	C-4												
Mackenzie Creek	C-5												
Smith Grade	C-6												
Camp Maymac-- Central	C-7												
Boulder Creek-S of 236	C-8												
Boulder Creek-N of 236	C-9												
Boulder Creek-N of 236-2	C-10												

Site Name	Site #	Erte	Chpu	Ernu	Mira	Moun	Arpy	Depa	Caum	Mafl	Gnsp	Mica	Gite
Weston West Ridge	1												
Weston Rd	2	Y	Y	Y		Y	Y			Y	Y		
Redwood Glen North	3	Y		Y		Y							
Redwood Glen South	4	Y		Y		Y							
Redwood Glen East	5	Y		Y						Y			Y
Glenwood	6												
Canham	7												
Scotts Valley Quarry	8										Y		
Scotts Valley Center	9												
Highway 17	10	Y		Y									
El Rancho	11		Y										
Graham Hill South	12												
Henry Cowell	13		Y		Y						Y		
Mt Hermon/SRL	14		Y										Y
Whispering Pines	15		Y										
Mt. Hermon Residential	16												
Hanson	17	Y	Y	Y									
Mount Hermon Road South	18												
Mount Hermon Road North	19	Y	Y	Y	Y	Y	Y?		Y		Y		
Nelson Road South	20												
Fernbrook Road	21												
Lockhart Gulch East	22												
Montevalle	23	Y	Y	Y		Y		Y		Y			
Bean Creek	24												
Olympia Wellfield	25	Y	Y	Y	Y	Y		Y		Y	Y	Y	Y
Zayante School Rd	26	Y	Y	Y	Y	Y		Y			Y		Y
Maymac South	27												
Camp Maymac North	29			Y							Y		
QHRCP--East Ridges	30	Y	Y	Y	Y	Y				Y	Y	Y	Y
QHRCP--Sunset	31	N											
West Lompico	32		Y	Y							Y		
Sunset Ridge	33		Y	Y									
QHRCP--Northwest	34	Y	Y	Y	Y								
Vista Robles	35	Y	Y	Y	Y						Y	Y	Y
Marion	36		Y	Y		Y							
Hidden Valley	37	Y	Y	Y		Y					X		
Glen Arbor-Quail Hollow	38	Y	Y	Y									
Quail Hollow Quarry	39	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hihn Rd	40												
South Hihn Road	41		Y	Y									
Glen Arbor East	42		Y	Y		Y							
Landfill Heights	43			Y	Y								
Rebecca	44												
Pinecrest	45												
West Park	46												
Hilton	47		Y										
Jameson Creek	48		Y										
Bonny Doon	49												
Martin Rd	50	Y	Y		y								
Woodpecker	51												
Gray Whale Ranch	52	N	Y	N	Y	N	N						N
Ice Cream Grade	53												
Smith Grade South	54												
Graham Hill north	55												
Sun Mountain Road-North	C-1												
Sun Mountain Road-West	C-2												
Sun Mountain Road-South	C-3												
Nelson Road	C-4												
Mackenzie Creek	C-5												
Smith Grade	C-6												
Camp Maymac-- Central	C-7												
Boulder Creek-S of 236	C-8												
Boulder Creek-N of 236	C-9												
Boulder Creek-N of 236-2	C-10												

Site Name	Site #	Lipa	Coba	Sive	Lapl	Meli	Laca	Arma	Cuab	Piat
Weston West Ridge	1									
Weston Rd	2	Y								Y
Redwood Glen North	3	Y		Y		Y				
Redwood Glen South	4	Y		Y		Y				
Redwood Glen East	5	Y		Y						Y
Glenwood	6									
Canham	7									
Scotts Valley Quarry	8									
Scotts Valley Center	9									
Highway 17	10									
El Rancho	11									
Graham Hill South	12									
Henry Cowell	13									Y
Mt Hermon/SRL	14			Y			Y			Y
Whispering Pines	15									
Mt. Hermon Residential	16									
Hanson	17									Y
Mount Hermon Road South	18									
Mount Hermon Road North	19		Y	Y			Y			Y
Nelson Road South	20									
Fernbrook Road	21									
Lockhart Gulch East	22									
Montevalle	23	Y	Y	Y	Y	Y				
Bean Creek	24									
Olympia Wellfield	25	Y	Y	Y	Y	Y		Y	N	Y
Zayante School Rd	26	Y	Y	Y						Y
Maymac South	27									
Camp Maymac North	29									Y
QHRCP--East Ridges	30	Y	Y	Y	Y		Y			N
QHRCP--Sunset	31									
West Lompico	32									Y
Sunset Ridge	33									
QHRCP--Northwest	34									Y
Vista Robles	35			Y						Y
Marion	36									Y
Hidden Valley	37	X		X						Y
Glen Arbor-Quail Hollow	38									
Quail Hollow Quarry	39	Y	Y	Y	Y	Y	Y	Y	N	Y
Hihn Rd	40									
South Hihn Road	41									
Glen Arbor East	42									
Landfill Heights	43									Y
Rebecca	44									
Pinecrest	45									
West Park	46									
Hilton	47								Y	Y
Jameson Creek	48									Y
Bonny Doon	49									
Martin Rd	50									Y
Woodpecker	51									
Gray Whale Ranch	52						N	N	N	Y
Ice Cream Grade	53									Y
Smith Grade South	54									
Graham Hill north	55									
Sun Mountain Road-North	C-1									
Sun Mountain Road-West	C-2									
Sun Mountain Road-South	C-3									
Nelson Road	C-4									
Mackenzie Creek	C-5									
Smith Grade	C-6									
Camp Maymac-- Central	C-7									
Boulder Creek-S of 236	C-8									
Boulder Creek-N of 236	C-9									
Boulder Creek-N of 236-2	C-10									

Site Name	Site #	Other (incl. CNDDB Information)
Weston West Ridge	1	
Weston Rd	2	
Redwood Glen North	3	
Redwood Glen South	4	
Redwood Glen East	5	*O. kisutch, O. mykiss irideus, N Cent Coast Sac Sucker/Roach River*
Glenwood	6	
Canham	7	
Scotts Valley Quarry	8	
Scotts Valley Center	9	
Highway 17	10	
El Rancho	11	
Graham Hill South	12	
Henry Cowell	13	
Mt Hermon/SRL	14	
Whispering Pines	15	
Mt. Hermon Residential	16	
Hanson	17	
Mount Hermon Road South	18	
Mount Hermon Road North	19	
Nelson Road South	20	
Fernbrook Road	21	
Lockhart Gulch East	22	
Montevalle	23	
Bean Creek	24	
Olympia Wellfield	25	
Zayante School Rd	26	P sabiniana
Maymac South	27	
Camp Maymac North	29	
QHRCP--East Ridges	30	
QHRCP--Sunset	31	
West Lompico	32	*P. sabiniana*
Sunset Ridge	33	*Ceanothus cuneatus blakei*
QHRCP--Northwest	34	
Vista Robles	35	
Marion	36	*Ceanothus cuneatus blakei*
Hidden Valley	37	
Glen Arbor-Quail Hollow	38	
Quail Hollow Quarry	39	Smith's Blue Butterfly, robber fly, night snake
Hihn Rd	40	
South Hihn Road	41	
Glen Arbor East	42	*Ceanothus cuneatus blakei*
Landfill Heights	43	
Rebecca	44	
Pinecrest	45	
West Park	46	*O. kisutch, O. mykiss irideus, N Cent Coast Sac Sucker/Roach River*
Hilton	47	*C. abramsiana, N. Inter. Cypress For., N. Cen Coast Sac Sucker/Roach River, O. mykiss irideus*
Jameson Creek	48	*O. kisutch, O. mykiss irideus, N Cent Coast Sac Sucker/Roach River*
Bonny Doon	49	
Martin Rd	50	*SC Cypress closed cone forest, Arctostaphylos andersonii*
Woodpecker	51	
Gray Whale Ranch	52	
Ice Cream Grade	53	
Smith Grade South	54	
Graham Hill north	55	
Sun Mountain Road-North	C-1	
Sun Mountain Road-West	C-2	
Sun Mountain Road-South	C-3	
Nelson Road	C-4	
Mackenzie Creek	C-5	
Smith Grade	C-6	
Camp Maymac-- Central	C-7	
Boulder Creek-S of 236	C-8	
Boulder Creek-N of 236	C-9	
Boulder Creek-N of 236-2	C-10	

Field	Description
Site #	arbitrary numbers used to label sites in figures 6.1 and 6.2
Acres	estimated acreage of sandhills habitat as outlined
Size score	score given to site based on size as in table 6.1 of text
Integrity score	score given to site based on integrity as in table 6.1 of text
Biology score	score given to site based on biology as in table 6.1 of text
Total score	calculated as size+ integrity + 3(biology) as described in text
Tier	based on total score, three tiers designated: >15 = tier 1, 10-15 = tier 2, <10 = tier 3
sources	individuals who provided info about site: RM=Randy Morgan, BD=Bill Davilla, JM=Jodi McGraw, TH=Tim Hyland, CB=Caitlin Bean, RA=Dick Arnold, PE=Peg Edwards

NOTE: For the following fields are from the data sheet used to collect site attribute information. More information about these fields can be obtained from Appendix C. Y=presence, N=absence, and an empty cell indicates the lack of information.

Zayante soils	Zayante soils mapped in at least some poriton of the site
Mine	sand quarry in the site
Residential	houses in the site
Trails	trails in the site
OHV	evidence of OHV use in the site
Invasives	aggressive exotic plants including trees, shrubs, and pampass grass
Preserved	is ALL of the site preserved? If not all site is preserved, N is designated
Managed	Is the site actively managed?
parkland	is there any type of sand parkland at the site?
NMC	is there habitat characterized (broadly) as northern maritime chaparral
MCRPPF	is there habitat characterized (broadly) as maritime coast range ponderosa pine forest

NOTE: Fields with four letter headings are the sensitive and indicator species referred to by their four letter code (first two letters of genus, and first two letters of species). A list of species is provided in Appendix c

Other	other unique resources as indicated on data sheets or from the CNDDB

APPENDIX E

SANDHILLS RESOURCES LIST:

CONTACT INFORMATION FOR PEOPLE EXPERIENCED IN SANDHILLS CONSERVATION AND MANAGEMENT

Last	First	Title	Organization	Address	City	Zip	Phone	E-mail
Arnold	Richard	Entomologist	Entomological Consulting Services, Ltd.	104 Mountain View Court	Pleasant Hill	94523	925-825-3784	bugdctr@comcast.net
Bean	Caitlin	Graduate Student	Miami University	5707 Brown Rd. Oxford	Oxford, OH	45056	513-523-2979	beance@muohio.edu
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