CHAPTER 11
LIVESTOCK GRAZING AND VERNAL POOLS

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ABSTRACT

This chapter presents the results of an intensive literature review and interviews with numerous experts regarding the ecological relationships between livestock grazing and vernal pools. It also discusses the synergies that exist between economically viable ranching practices and the conservation and management of vernal pool biota. The region of focus is California's Central Valley and the surrounding regions that support vernal pools within an annual grassland or oak savanna setting.

Livestock grazing affects vernal pools in three primary ways: phytomass removal (consumption of vegetation), trampling, and nutrient input (defecation/urination). Though there is currently a dearth of scientifically-controlled, research-based data on the effects of grazing on vernal pools, the researchers and land managers interviewed for this study provided a wealth of observational data gained through years of field experience. Most researchers and land managers currently agree that some level of grazing is beneficial if not necessary for maintaining the ecological health and functioning of vernal pools. In contrast, excessive overgrazing and undergrazing both are regarded as detrimental to the long-term health of vernal pools. The primary benefit of grazing comes from the reduction, through phytomass removal and trampling, of non-native invasive annual grasses and other weedy species from the pool margins and surrounding uplands. If left unchecked, these species competitively exclude native vernal pool plants (especially around pool margins); negatively affect pool hydrology by reducing inundation period through increased evapotranspiration; promote the growth of periphytic algae which appears to negatively affect vernal pool crustaceans; and can inhibit the overland migration of vernal pool-breeding amphibians. The differential effects of altering timing and intensity within the context of a "moderate" grazing regime are poorly understood.

Some information is available on the effects of different grazing regimes on certain vernal pool rare species. Late season grazing appears to negatively affect rare Orcutt grasses that primarily inhabit very large vernal pools ("playa pools"). Effects on other vernal pool rare plants appear to be related to the species hydrologic preferences. Those species that inhabit shallower pool margins generally decline when undergrazed due to the invasion of non-native grasses. Those species that inhabit deeper pool bottoms appear to be less directly affected by undergrazing, but can suffer due to an overall decline in pool health. While severe over-grazing is assumed to be detrimental to vernal pool rare plants, the effects of moderate to heavy grazing are poorly understood and the available information is somewhat contradictory. As with rare plants, rare vernal pool crustaceans and amphibians appear to be negatively affected by severe under- or overgrazing, but the effects of moderate to heavy grazing are poorly understood.

Before ranchers and other land managers can develop specific grazing regimes for conservation of vernal pools, specific management goals must be clearly articulated. Managers need to decide if specific pools or pool complexes are to be managed holistically as part of the greater landscape or for specific taxa, especially those that are rare or endangered, such as special-status plants, large branchiopods, or amphibians. Also, it is important to understand the various grazing regimes currently implemented in vernal pool landscapes and the potential for flexibility within these regimes for balancing between financially viable ranching and vernal pool conservation goals. Because ranching is at best a marginal economic endeavor, it is important for scientists and land managers to understand that even moderate additional management or cost requirements imposed through easements could make livestock production economically unfeasible.

Because there is a high degree of uncertainty regarding both life histories of rare biota and the effects of specific grazing regimes on those species, regular monitoring, adaptive management, and research must be undertaken to increase our understanding of these relationships and adjust management to reflect the latest available information.

11.1 INTRODUCTION

Vernal pools are unique seasonal wetlands that support a diversity of native and often rare plant and animal species. Within California, vernal pools were historically concentrated around the low gradient terraces and basin rim surrounding the Central Valley (Holland 1978). There were scattered concentrations elsewhere in California, such as coastal California, especially the San Diego and Modoc Plateau regions. Due to their occurrence on flat to low-gradient terrain, most of the original vernal pool habitat in California has been lost and continues to be lost through farmland conversion and urban and suburban development. Aerial photo studies indicate that as much as 80 to 90 percent of the historic habitat has been lost and that the loss continues unabated (Holland 1978 and 1998). As a result of this dramatic and continuing loss of habitat, many endemic species that rely on these pools are becoming increasingly rare. There are currently more than twenty-five vernal pool species listed or proposed for listing by the federal or state government as threatened or endangered.

Most of the remaining vernal pool habitat, including all of the densest and largest concentrations, occurs within undeveloped annual grasslands on privately owned cattle ranches. As a result, conservation of the remaining vernal pools necessarily involves protection of these ranchlands from development. At present, conservation easements are the most commonly used and effective mechanism for achieving ranchland protection. These easements prohibit future development on rangelands and compensate landowners through a process of assigning a financial value to open space and the biota it protects, thus allowing responsible ranching to continue in the face of mounting economic pressure. Conservation easements are established through a variety of mechanisms, including voluntary sale or donation by the landowner, land purchase and subsequent placement of an easement by a conservation organization or government agency, and mitigation banking. Currently, thousands of hectares (acres) of active rangelands have been or are currently in the process of being placed into different types of conservation easements (Macon pers. comm.).

Beyond basic protection of ranchlands from development, there is further interest in the long-term stewardship and enhancement of vernal pools within protected lands. Although the complex interactions between stochastic climatic events and long-term soil forming processes play the most profound roles in shaping vernal pool ecosystems, anecdotal information suggests that land management practices, such as livestock grazing, can play a significant role in the protection, restoration, and enhancement of the unique biota associated with these systems (King et al. 1996). Since most remaining vernal pool landscapes are currently grazed by livestock and are likely to continue to be grazed, it is imperative that we understand both the positive and negative effects of grazing on these systems and the ways in which grazing can be used as a tool for vernal pool management. Today, with the absence of large native herbivores, the introduction of invasive flora, and the lack of regular fire in California's annual grasslands, many ecologists and rangeland managers have come to believe that livestock grazing, if properly managed, can play an important role in the conservation and restoration of vernal pool ecosystem and the surrounding grassland matrix.

At the same time, cattle ranching is recognized as, at best, a marginal economic enterprise, especially within California's Central Valley given elevated land prices and land use pressures relative to other ranching regions in the western United States. As such, grazing management regimes developed for the conservation and enhancement of vernal pools on private ranchlands must consider the overall impact on ranching economics and suitability within the context of economically viable ranching practices.

Recognizing these two elements, this report summarizes currently available information on the effects of grazing, both positive and negative, on vernal pools, and examines where vernal pool management and economically viable ranching practices find common ground. Information is also provided on general vernal pool ecology and ranch management practices as background to the discussion. This study is intended for use by both vernal pool preserve managers and private ranchers so that both can improve the practical stewardship of the lands they manage. Because each vernal pool complex and the pools within that complex are shaped by a unique set of interacting abiotic (climate, soils, slope, aspect, area, depth, and fire) and biotic (native flora/fauna and grazing regime) variables, and because each ranch has its own unique operational requirements, this report is not meant to provide a set of "cookie-cutter" land management prescriptions. Instead, it should be viewed as a guide to the process of formulating management protocols appropriate for specific species and sites. In addition, this report provides the reader with a reference list of researchers and managers across the state who have previously been or are currently involved in vernal pool research and grazing studies related to vernal pools.

11.2 METHODS

This study reviewed the available peer-reviewed literature, gray literature, and agency reports pertaining to the interactions between livestock grazing and vernal pool biota. A total of 46 articles and reports were reviewed (see the literature cited section below) which represents the large majority of available literature on the subject. In addition to the literature review, in-depth interviews were conducted with 36 experts across the state. A complete list of the individuals that were contacted is provided in Appendix 11a. These experts included research scientists, vernal pool or annual grassland preserve managers, consultants, and ranchers with specific experience in the management or study of vernal pool or annual grassland habitats.

Currently, there is a dearth of literature based on scientifically-controlled replicated experiments providing information on the relationships between grazing and vernal pool biota. There are numerous studies that have been either recently completed with the data not yet available or that have been recently implemented. These studies are expected to add significantly to the state of scientific knowledge of the subject, but they were unavailable at the time this report was prepared. As a result, this report relies on the limited literature that is currently available, and augmented by an abundance of observational and anecdotal information from the preliminary data sets of the interviewed experts.

11.3 BACKGROUND INFORMATION

This section of the report provides background information on vernal pool ecology and basic ranching operations and practices, especially as they pertain to the subjects of this report. This study will inform both vernal pool ecologists and ranchers about the ecological and land use contexts of the relationships between grazing and vernal pools, and for developing grazing management strategies that both improve vernal pool habitats and function within the practical needs of a ranching operation. Obviously, both of these subjects are complex and a complete discussion of either is beyond the scope of this report. For those interested in further reading on vernal pools, some excellent and readily available references include Holland (1988) and Witham (1998), both of which can be ordered through the California Native Plant Society of Sacramento, California. For those interested in further reading on ranching practices and rangeland management, some excellent and readily available references include Senft et al. (1987), Heistschmidt and Stuth (1991), and the California range production classic, Bentley and Talbot (1951).

11.3.1 Overview of Vernal Pool Ecology

Vernal pools are seasonal wetlands that become inundated during California's winter rainy season and gradually dry up in the spring with the cessation of precipitation and the onset of increased evaporation and plant transpiration. During the summer and fall, the pools remain dried and desiccated until the onset of the next rainy season. Ponding in vernal pools is caused by an impermeable sub-surface soil layer (hardpan, claypan or bedrock) underlying a surface depression. The period of inundation for a given pool can last anywhere from a few weeks to a few months depending on the size and depth of the depression, local climate conditions, and the type of sub-surface.

Vernal pools support a unique suite of native plant and animal species that have developed life history strategies allowing them to cope with the extreme environmental conditions resulting from the annual cycle of stress from both prolonged inundation and drought (Holland and Jain 1988; Bliss and Zedler 1998). Within each annual cycle, pools experience four distinct physical phases: filling, ponding, drawdown, and desiccation. The native biotic constituents are often highly specialized in order to exploit specific spatial and temporal niches. This hyper-specialization within vernal pools explains the high rates of endemism and rarity observed in these systems (Holland and Jain 1981 and 1988; King et al. 1996).

In addition to an annual cycle of inundation and drought, vernal pool species must also cope with significant year-to-year variations in the timing and amount of rainfall. During the wettest years, pools can become inundated in October and remain continuously inundated through April or May. During drought years, pools can remain dry or fill only intermittently during the course of a single season. Most of the plant and animal species endemic to vernal pools have developed life history strategies that enable them to survive over the long term in spite of the great fluctuations in year-to-year conditions.

The plant species associated with vernal pools have a range of life histories to cope with both the abiotic and biotic conditions within and surrounding vernal pools. Most of the associated species are annuals (they germinate, grow, flower, set seed, and die within a single season). The seeds of these species reside within the pool bottom during the long hot period of drought. The yearly growth cycle typically produces an excess of seeds, which then form a seed bank in the pool bottom. Each year, a portion of the seed bank germinates and grows while the remainder of the seed bank remains dormant until subsequent years. In this way, the annual plant species can survive over time within the highly unpredictable environment of a vernal pool.

Many vernal pool plant species have distinctive aquatic and terrestrial life stages to cope with the changing hydrologic conditions. During germination and initial growth, plants are submerged. To cope with the low-oxygen environment, many species develop succulent, hollow or porous stems (aerenchyma) that can transport oxygen to the roots. As the waters recede, these stems are too weak to support themselves and the soft, porous tissues become much more dense and firm.

Most of the smaller annual plant species flower during drawdown or just after the pools dry. At this time, the surrounding upland annual grasses are still green and thus, preferred forage is available for herbivores (such as cattle) in the uplands. Some of the plant species, however, flower later in the season, after the upland grasses have died and turned brown. These species are targets for late-season herbivory and most have developed herbivory avoidance strategies that make them either unappealing or difficult to eat. Coyote-thistle (*Eryngium* spp.) is a common vernal pool species that blooms later in the season and exhibits a mechanical avoidance strategy. In its early life stages, when the pressure from herbivory is low, it grows as a soft-stemmed succulent species. Later, it develops hard stems and the flowering heads develop tough sharp spines that are difficult to chew, much less consume. Other species develop biochemical avoidance strategies rather than mechanical strategies. The suite of very rare vernal pool grasses (Orcutt tribe: *Neostapfia*, *Orcuttia*, and *Tuctoria* genera) exhibits effective biochemical strategies. These species usually flower well into summer after most other plant species have died and turned brown. To deter herbivory, they produce sticky pungent exudates that coat the leaves and stems and make the vegetation generally unpalatable. One species in particular, Colusa grass (*Neostapfia colusana*) produces such an acrid and sour exudate that some landowners refer to it as the "battery acid plant" (Myers pers. comm.).

While inundated, vernal pools provide important breeding sites for many invertebrates and amphibians. Among the most studied groups of invertebrates are the freshwater crustaceans ("large branchiopods") including the fairy shrimp, tadpole shrimp, and clam shrimp. There are several species of large branchiopods that are endemic to California (occurring nowhere else). Many of these species are considered rare with very narrow habitat requirements or restricted ranges within California. As result, seven species are currently listed as threatened or endangered by the federal government and other species are under consideration for listing. Responding to the annual cycle of inundation and drought, these crustaceans have developed a life history strategy remarkably similar to vernal pool annual plants. The adults breed while the pools are inundated. Females then lay eggs, which hatch and develop into young embryos. These embryos quickly become cysts encased in a tough outer case that survive in the pool bottom during the drought period (Eriksen and Belk 1999). These cysts are entirely analogous to plant seeds that contain a young plant embryo with nascent first leaves (cotyledons). When the pools become filled during the next rainy season, the cysts hatch and the young embryos are able to quickly develop into adults. Of all the branchiopod species, the midvalley fairy shrimp (*Branchinecta mesovallensis*) has the shortest recorded period (16 days) between hatching and egg-laying (Helm 1998). Other species, such as the vernal pool tadpole shrimp (*Lepidurus packardi*) require a much longer period (45 days or more) to complete their lifecycles.

Like the annual plant species, the vernal pool crustaceans develop cyst banks in the pool bottoms that allow them to survive over the long term within the highly variable vernal pool environment. Each season, a portion of the cysts hatch, while the remainder stay in the pool until a later season. Studies have shown the cysts to be highly durable through long periods and across severe environmental conditions (Eriksen and Belk 1999). Some researchers have successfully hatched decades old cysts contained within collected soils samples. Other researches have successfully hatched cysts following several years within an oxygen-free and water-free environment.

Several native amphibian species utilize vernal pools for breeding and larval development, including the California tiger salamander (*Ambystoma californiense*), western spadefoot (*Scaphiopus hammondii*), western toad (*Bufo boreas*), and Pacific tree frog (*Hyla regilla*). Among these species, the California tiger salamander and western spadefoot (a type of toad) use vernal pools primarily or exclusively for breeding while the other species use a more broad range of habitats for breeding (see Chapter 5). Since vernal pools are becoming an increasingly rare habitat, both the California tiger salamander and western spadefoot have been considered for listing as threatened or endangered by state and federal agencies.

The California tiger salamander and western spadefoot are most often associated with grassland habitats, but can also be found in open chaparral and pine-oak woodland (Stebbins 1985). Adults of both species migrate from terrestrial upland sites to seasonal pools when they become inundated during the rainy season. They breed and the females lay eggs, which hatch into larvae. Again, like many of the vernal pool plant species, these amphibians have distinct aquatic and terrestrial stages that allow them to survive the changing conditions within the pool environment from inundation to drought. The larvae of California tiger salamanders have external feathery gills that allow them to breathe underwater. As the larvae mature and transform into juvenile salamanders, the gills are absorbed and replaced by lungs to survive the terrestrial phase. Like other anurans (frogs and toads), western spadefoot larvae are tadpoles. During transformation, the tails of the tadpoles are absorbed and the limbs develop in preparation for the terrestrial phase. While western spadefoots can complete their lifecycle in as short as a few weeks (Allaback pers. comm.), both California tiger salamanders and western spadefoots typically breed in larger vernal pools that remain inundated well into spring. These pools provide the long period of inundation typically required by these species to complete larval transformation. California tiger salamanders also regularly breed in seasonal stock ponds (generally those free of non-native fish and introduced bullfrogs [*Rana catesbeiana*]) (see Chapter 5). In areas where most vernal pools have been eliminated, these stock ponds can provide the only remaining suitable breeding habitat for California tiger salamanders (Jennings pers. comm.). Currently available data indicate western spadefoots, unlike tiger salamanders, rarely use stock ponds for breeding (see Chapter 5).

After transformation, the juveniles of both species leave the drying vernal pools and aestivate in subterranean sites within the surrounding upland habitat during the long dry period of summer and fall. California tiger salamanders typically occupy burrows dug by California ground squirrels (*Spermophilus beecheyi*), Botta's pocket gopher (*Thomomys bottae*) and other burrowing mammals (Jennings and Hayes 1994). They can also occupy soil cracks, crevices in rock outcrops, and other subterranean cavities. California tiger salamanders are fairly long-lived, with individuals surviving for 15 years or more. Yet, current research indicates that individuals can breed only once or at most a few times during their lifetimes, when the seasonal rainfall provides conditions favorable for larvae to complete development. Western spadefoots seek temporary refuge in mammal burrows and soil crevices, but they aestivate primarily in self-constructed burrows in which they spend most of the year surrounded by a water-retaining mucus ball. There are almost no available data on the upland habitat requirements for either species in terms of vegetation density or soil conditions. Field observations of closely related spadefoots in Arizona

(*S. multiplicatus*) and controlled experiments of spadefoots in Florida (*S. h. holbrookii*) indicate a preference for friable soils (Ruibal et al. 1969).

Various wintering and breeding bird species use vernal pools as a source of water and food. Certain species of wading birds commonly feed in vernal pools, such as the greater yellowlegs (*Tringa melanoleuca*), dunlin (*Calidras alpina*), western and least sandpipers (*Calidras mauri* and *Calidras minutilla*, respectively), killdeer (*Charadrius vociferous*), and long-billed curlews (*Numenius americanus*) (see Chapter 7). These species feed, at least in part, on aquatic invertebrates, including vernal pool crustaceans, present within the pools (Silveira 1998). In addition, the abundance of upland songbirds (primarily savanna sparrows (*Passerculus sandwichensis*), California horned larks (*Eremophila alpestris*), and water pipets (*Anthus spinoletta)*) have a higher abundance within annual grasslands that support high-density vernal pools versus grasslands without pools (see Chapter 7).

Though currently undocumented, small mammals as well as some large mammals probably use vernal pools as a source of drinking water during the spring and early summer. It is unknown if any mammals feed on vernal pool endemic plant or animal species.

11.3.2 Overview of Ranching and Grazing Practices in California's Annual Grasslands

Ranching Economics

Ranching is generally considered to be a borderline industry in economic viability. In the California context, skyrocketing land values, extremely variable forage production and low beef prices have made ranching in California's grasslands and oak woodlands a tenuous economic enterprise at best. Traditionally, as economic pressures mounted, California ranchers were faced with two choices: incur debt or sell off/rent land to more profitable ventures. The economic viability of ranching in the Sierra Nevada foothills and Coast Ranges is clearly illustrated by the disparity in economic return between cattle ranching and grape production. The average profit from California rangelands, in the Central Valley, under cattle production is approximately $20/acre/year (Chance pers. comm.). On the other hand, that same rangeland could be rented and converted to grape production at an average rent of $450/acre/year rent (Sweet pers. comm.). Outright sale of rangeland into vineyard production can fetch an average of $5000/acre. Moreover, once the upfront costs are outlaid and grape production is in full swing, that same land then can produce income between $1,500 to $2,500/acre/year, or would sell for between $15,000 to $20,000/acre (Bokish pers. comm.). An even greater disparity exists between ranching and suburban or commercial development. Rangeland parcels sold to suburban or commercial developers can bring a one-time payment of between $50,000 to $100,000/acre depending on location and proximity to utilities (Sweet pers. comm.).

Currently, there are an estimated 8,094,000 hectares (20 million acres) of California rangeland under private ownership. Land use transformation is occurring at such a blistering rate that in many regions of California privately managed rangelands provide the last remaining habitat for a variety of rare grassland, oak woodland, and vernal pool species. In jeopardy of losing an important component of western heritage and thousands of hectares (acres) of open space, state resource agencies and public land trusts have begun aggressively implementing conservation easement programs via the 1965 Williamson Act. Additionally, numerous private land trusts now exist with the sole mission of protecting open space through direct acquisition of key parcels, development of mitigation banks, and creation of private party conservation easements on private ranchlands.

Grazing Practices

Although sheep are grazed on vernal pool landscapes, the vast majority of acreage used for livestock is under cattle production. Thus, the bulk of this discussion will focus on cattle ranching operations. Within the universe of cattle ranching, there are a variety of different types of ranching operations including cow-calf, stocker, dairy, and replacement diary heifer operations. The dominant ranching operation in California annual grasslands is the cow-calf operation. This type of operation is designed for beef production and involves maintaining a year-round herd. Profits come from birthing and raising calves. This operation is financially attractive since the rancher owns the "factory" (i.e., the mother cows) that produces the calves (Nelson pers. comm.). In this operation, cattle use grassland and oak woodland range from approximately October to May. After May, cattle are usually moved to leased mountain rangelands or irrigated pastures where they can find green feed. Because of the high land and water prices in California, cattle operations relying on irrigated pasture are rare in the state. In most cases, cows and any remaining calves are moved to mountain range on federal lands. The cows and remaining yearlings are then returned to their home range between late September and late October. Breeding of mature cows occurs from April to June, and calves are born the following year from January to March (Nelson pers. comm.). In this type of operation the young calves, or weanlings, remain with their mothers at least through the late spring. Depending on forage availability and market price, weanlings are either sold to stocker operations immediately or remain with the herd until they are yearlings.

Stocker operations are more financially risky than cow-calf operations because operators are less protected from the whims of the market due to the fact that they have to buy stockers each season. The main benefit of these operations is that they often offer a higher economic return if well managed (Chance pers. comm.). Stocker operations are specifically focused on purchasing weanlings between October and December and fattening them up for sale to feedlots or slaughterhouses the following fall. A stocker operator will utilize valley and foothill range during the same grazing season as a cow-calf operation. In the summer, unlike the common cow-calf operations where the entire herd is moved to leased mountain pastures, stocker operators will often truck their stockers a far distance to regions where high quality irrigated pasture is inexpensive and available. Irrigated pasture provides plentiful high quality forage to fatten up the stockers for sale to feedlots or slaughterhouses. Long distance hauling of stockers is cost-effective because truck-hauling costs are calculated by weight and stockers are not full-grown and weigh a significant amount less than mature cows (Chance pers. comm.).

The last two types of ranching operations, dairy production and dairy heifer replacement ranching, are far more resource-intensive and often provide a substantially higher return on investment than either cow-calf or stocker production. They key difference between beef and dairy production ranching is that dairy production ranching is generally dependent upon irrigated pasture to meet high quality forage demands year-round. Moreover, unlike beef cattle production systems where management often focuses on maximizing animal distribution across rangeland, dairy production management is dependant on constant easy access to cows for regular milking. Lastly, where beef cattle grazing operations utilize valley and foothill open rangeland from October through April, dairy production relies on local pasture for the entire calendar year (Oltjen pers. comm.). Thus, dairy cow production systems generally do not utilize vast acreages of rangeland, but instead rely on small pastures. Dairy heifer replacement production, a ranching system growing in popularity, focuses on raising heifers that are sold to dairies. This operation often relies on open rangeland for a portion of the year (Farley pers. comm.). Unlike cow-calf operations where cattle are put on the range before green-up has begun, replacement dairy weanlings typically use rangelands from January to April when high quality forage is available. Also, whereas cow-calf breeding occurs at the same time each year, dairy cow breeding occurs throughout the calendar year. In this situation, only calves weaned in the winter will be able to utilize rangelands, while cows calves weaned before or after green-up will remain on irrigated pasture (Oltjen pers. comm.).

Obviously, the type of livestock operation employed by a given ranch will have significant implications for the utilization of local resources. Because beef production operations are the most common livestock operations in vernal pool landscapes, the bulk of the following discussion will focus on beef cattle ranching. Although not specific to beef production, the following four rangeland management strategies form the building blocks of any livestock grazing regime: (a) kind and breed of livestock; (b) timing and duration of grazing; (c) stocking rates; and (d) animal distribution. All four of these strategies are used to balance economic production goals with rangeland condition goals.

Although cattle are the dominant livestock in California annual grasslands and woodlands, there are still numerous sheep ranches functioning in the vernal pool landscapes of the Coast Range. As far as management of natural resources is concerned, there are important distinctions between the range utilization of cattle and sheep. Cattle are true grazers and show a strong preference for grasses and high nitrogen forbs like those in the Legume family (*Lotus spp*., *Medicago spp*., *Trifolium spp*.). Cattle will resort to eating low nitrogen and high cellulose dry grass and browse only when no other forage is available. On the other hand, sheep are considered intermediate grazers and will readily eat grasses, forbs, and shrubs, depending on availability.

While the majority of the cattle on California's open rangeland are crossbreeds, there are two species of cattle from which all breeds descend, *Bos taurus* and *Bos indicus*. *Bos taurus* or English breeds are generally cold tolerant, produce high quality meat and have high reproductive efficiency. The most common breeds within the species are Hereford and Angus. *Bos indicus* or Indian breeds are generally more heat tolerant, parasite and fly tolerant, and are able to survive on lower quality forage than their English counterparts. Thus, where English breeds are better adapted to cold winters and high quality forage, Indian breeds are superior in hot climates where water availability and forage production are variable. The most common Indian breed is Brahman. Because of these genetic differences, climatic conditions will play a major role in determining the type of cattle that will produce the greatest economic return on a given ranch. Due to the various strengths and weaknesses of each of these species (and breeds within each species), crossbreeding helps ranchers select for the specific traits that best match the conditions of the ranch. Decisions regarding cattle breeding and the selection of desirable traits must take into consideration not just the conditions of the home range, but also summer range and yearling range. For example, if a California rancher intends to sell his calves to a stocker operation in the arid southwest, Brahman traits would likely be preferable. On the other hand, if a rancher intends to sell the livestock to stockyards in Kansas, cold tolerant English traits should dominate the herd (Chance pers. comm.). Obviously the most critical component of a rancher's decision regarding cattle breeds is the market. Although crossbred calves (both within species and between species) have historically produced a better economic return than straightbred calves, current market trends favor calves with a high percentage of Angus traits (Brown 2002; Sweet pers. comm.). This market shift is an apparent response to the name recognition and product consistency associated with Certified Angus Beef (CAB). The high demand for CAB has resulted in long waiting lists for the product and a rush in the cattle industry to meet that demand (Sweet pers. comm.).

Although abiotic factors, such as climate, soil types and slope, have a profound affect on rangeland productivity, they are generally difficult to manage. On the other hand, biotic factors such as grazing intensity can be managed by ranchers (Heitschmidt and Stuth 1991). For the purposes of this report, grazing intensity is defined as the relationship between a pasture's carrying capacity and stocking rate. Grazing intensity is commonly measured in California annual grassland at the end of a grazing season as residual dry matter (RDM). RDM is the average amount of aboveground biomass left on a pasture at the end of the grazing season. This metric is important because it is more than just a gauge of grazing intensity, but can be a useful tool for predicting future forage production and plant species composition (Bartolome pers. comm.). Moreover, RDM can serve as "hay in the bank" during the early part of the subsequent grazing season by providing low quality palatable forage before the onset of green-up (Nader pers. comm.).

Understanding the carry capacity of a given range site and the critical stocking rate (the rate at which grazing intensity begins to degrade forage production) is fundamental to the success of any grazing operation. Not only is forage production negatively affected when the critical stocking rate is exceeded, but animal production is also adversely impacted. As stocking rates increase, production per individual animal decreases, while production per unit area of land increases until carrying capacity is reached and then declines (Heitschmidt and Stuth 1991).

Although the grazing season in California's vernal pool grasslands is generally between mid-October and mid-April, rangeland managers can manipulate the temporal and spatial distribution of livestock to maximize profits and maintain rangeland health. There are four basic types of grazing systems, each of which use timing, duration, stocking rate and spatial distribution to accomplish management goals. The four types are: deferred rotation (DR); rest rotation (RR); high-intensity short-duration (HISD); and low-intensity long-duration (LILD).

DR grazing systems are designed so that cattle will consume only high quality, preferred forage at light to moderate intensities. The theory is that high quality forage will increase animal production, while light to moderate-intensity grazing will maximize long-term forage production. These systems are based on a multiple-pasture and multiple-herd organization where each pasture experiences light to moderate grazing every year with a season of use that is generally longer than the period of rest (Heitschmidt and Stuth 1991). In California annual grasslands, a DR system might use four pastures with three herds and every year each pasture will be rested for two to three months. Generally, each pasture will have a different rest period each year to maximize long-term productivity and diversity of forage species. RDM will vary from pasture to pasture, but more importantly the species contributing to the RDM will also vary.

RR systems rely on multiple-pastures, but can use either multiple herds or a single herd. In a three pasture RR system, one pasture will be rested from October to December, another pasture will be rested from December on and a third pasture will be rested for an entire season. In order to make up for the long pasture rest periods and maintain economically viable cattle production, stocking rates and grazing intensities must be kept high while pastures are in use. The theory behind an RR system is that each pasture will experience different timing and duration of grazing every year and will also experience a full season of rest every third year. At the end of the season one pasture will have high RDM, one will have medium RDM and the third will have low RDM (Heitschmidt and Stuth 1991). The rested pasture will be the first pasture utilized the following season at which time cattle will be forced to use the remaining low quality, dry forage.

HISD systems are derivatives of the Savory Method of Holistic Resource Management championed by Allan Savory (Savory 1983). These systems are generally single herd systems, which employ multiple pastures and regular movement of livestock. Stocking rates are high, but cattle are only on a specific pasture for a limited time. This type of system allows a rancher to maintain high grazing pressure on a focused area for a short duration. While DR systems focus on high quality preferred forage to enhance cattle production, HISD systems limit preferential grazing and maximize use of all available forage. Thus, the grazing pressure in a HISD system will be more evenly spread across plant taxa.

The final type of grazing system is an LILD. This is probably the most common system in California and it requires the least amount of management. Unlike the DR, RR and HISD systems, ranchers using a LILD system need not move the herd regularly from one pasture to the next. Instead, a rancher will use a combination of multiple developed water facilities and strategically placed salt licks to ensure that the herd is well distributed across the rangeland. LILD systems will use the same pastures for the entire grazing season. With good physical distribution and light stocking rates a rancher can insure that the herd will maximize use across the entire landscape throughout the grazing season. If managed properly, LILD systems will have somewhat uniform, medium to low RDM across the landscape. This type of season-long, low-intensity grazing is thought to reduce overall impact on the rangeland system (Lis and Eggeman 2000a).

11.4 THE EFFECTS OF LIVESTOCK GRAZING ON VERNAL POOLS

At various sites throughout the state, scientists, land managers and ranchers have observed negative trends in native plant species composition in vernal pools after multiple seasons of complete rest from grazing. In general, an increase in non-native annual grasses and forbs has been observed as well as a decrease in native forb distribution and abundance (Barry 1995, 1996, and 1997; Griggs 2000; Holland pers. comm.; Reiner pers. comm.; Vollmar pers. comm.). Although these effects appear to be particularly pronounced along the margins of vernal pools and in the upland areas surrounding pools, non-native plant invasions have also been observed within pool bottoms. There are fewer data on the effects of grazing on threatened and endangered vernal pool fauna, most notably the various species of fairy shrimp (*Branchinecta* spp.), tadpole shrimp (*Lepidarus packardi*), and the California tiger salamander (*Ambystoma californiense)*, but anecdotal information suggests that livestock activity can have a net positive effect on habitat quality for some of these species. Today, although experts maintain that the relationship between domestic livestock grazing and vernal pool habitat is complex and difficult to quantify, the prevailing attitude is that livestock grazing, if managed properly, can play an important role in the conservation of vernal pool biota.

This section discusses the existing empirical and anecdotal information on the direct effects of domestic livestock grazing in and around vernal pools via three process: eating (phytomass removal), trampling and defecating/urinating (changes in nutrient balance).

11.4.1 Phytomass Removal

Phytomass removal or reduction of RDM is a common management tool in annual rangelands used to reduce cover of non-native plant invaders and favor preferred ranch grasses and annual forbs. Our literature review and interviews indicate it is also generally regarded as an important tool for managing vernal pools. Much of our current understanding of the effects of biomass accumulation on vernal pools comes from data collected at The Nature Conservancy's Vina Plains Preserve, established in 1982, in southern Tehama County. These vernal pools had historically been grazed with a seasonal grazing regime that lasted from November to mid-May. Because the landscape appeared intact, containing over 300 species of plants, including many rare native grasses and forbs, the current grazing regime was continued through 1987. According to Griggs (2000), TNC decided to remove grazing in 1987 because of the perception that cattle impacts on native plants were becoming quite severe. Although monitoring after cattle removal revealed an initial increase in abundance of rare vernal pool flora, after seven years without grazing the wildflowers that had carpeted the pool margins virtually disappeared (Griggs 2000; Reiner pers. comm.). Observations of adjacent grazed landscapes indicated that the grazed lands had maintained the colorful wildflower rings so common to vernal pools. Floristic surveys on the preserve and in adjacent private rangelands illustrated that the ungrazed pastures still supported more species of rare plants than the grazed pasture, but that the ungrazed pool margins and uplands were facing much greater pressure from the non-native grass medusa-head (*Taeniathrum caput-medusae*). TNC managers hypothesized that the invasion by medusa-head and the ensuing thick, persistent thatch left in the absence of grazing was suppressing wildflowers such as meadowfoam (*Limnanthes douglasii* ssp. *rosea*) (Griggs 2000; Griggs pers. comm.). This hypothesis as well as the observations at other vernal pool complexes throughout the state put the threat of thatch accumulation from non-native grasses (and in some cases native *Eleocharis macrostaycha* and non-native herb *Mentha pulegium*) on the "radar screen" as a potential threat to conservation of the vernal pool flora. As such, many of the land managers and scientists interviewed for this report cited thatch build-up from non-native grass incursion into vernal pool habitats as the major management concern for maintaining vernal pool flora.

Our interviews indicate that preserve managers across the state are concerned about the effects of phytomass accumulation from non-native species on competition for light, nutrients, and soil moisture with native forbs. Although the prevailing hypothesis is that grazing could be the most practical tool for reducing RDM and pushing the competitive advantage back toward native species, there is little experimental data to test this hypothesis in vernal pools.

Although TNC, with funding from the EPA, implemented a major study to investigate this and other vernal pool management questions, the results are of little management value due to the extreme variability shown in the data (Gause pers. comm.; Reiner pers. comm.). Although numerous studies are currently being implemented and developed across the state to try and better understand these issues, the most compelling data come from field observation and anecdotal evidence found in the literature and gleaned from interviews.

Pool margins, due to the variability of seasonal inundation, appear to be the vernal pool component most vulnerable to invasion by non-native annual grasses such as medusa-head and Italian ryegrass (*Lolium multiflorum*), both of which produce thick canopies of thatch. Vollmar (1998) studied the regional ecology of the federally endangered Contra Costa goldfields (*Lasthenia conjugens*) in Solano County. This study examined the habitat parameters of vernal pools supporting Contra Costa goldfields, including pool size, depth, location of the goldfields within the pool's hydrologic gradient, and associated species. The study found that Contra Costa goldfields typically inhabit shallow vernal pools or the margins of deeper vernal pools, often in competition with non-native marginal wetland grasses, such as Italian ryegrass and Mediterranean barley (*Hordeum marinum* var. *gussoneanum*). At sites that were regularly grazed (or mowed as on Travis Air Force Base), populations of goldfields generally thrived. In contrast, sites that had been left ungrazed generally supported smaller populations. In particular, two sites that previously supported robust populations of Contra Costa goldfields under a regular grazing regime (Ornduff pers. comm.) but had not been recently grazed were found to support only one individual each during the study. No plants were observed during surveys conducted in subsequent years (Vollmar pers. comm.).

Pavlik et al. (2000), in their recent report on research being conducted in vernal pools on the Santa Rosa Plain in Sonoma County, referred to historical data indicating that populations of two rare plants, Baker's blennosperma (*Blennosperma bakeri*) and Sebastopol meadowfoam (*Limnathes vinculans*), were capable of at least maintaining themselves and at times flourishing under intensive grazing. Additionally, Pavlik et al. found that at the same site populations of Burke's goldfield (*Lasthenai burkei)* had steadily declined after the removal of livestock. Their current hypothesis is that this population of Burke's goldfields could have been extirpated as a result of the dense residual thatch canopy resulting from ungrazed non-native annual grasses.

Holland (pers. comm.) reported the deleterious effects of non-native grass invasion and the resulting thatch build-up in the Phoenix Park vernal pools of Sacramento County. Similarly, Griggs (pers. comm.) and Koshear (pers. comm.), working in the Big Table Mountain region of Madera County, both cited build-up of thatch from non-native grasses along vernal pool margins as the primary threat to rare wildflowers. The California Department of Fish and Game and California State Parks have implemented grazing studies to investigate the use of cattle to reduce thatch and support native vernal pool flora. Concerned about the potential for medusa-head invasion into pool margins at their Orchard Creek Preserve, Wildlands Inc. has recently instituted a grazing regime to control this invasive grass and to foster native flora (DeYoung pers. comm.).

Barry (1997) compared the physical changes in the width and floral composition of pool margins of a partially grazed and a partially ungrazed vernal pool on the Vina Plains Preserve. Her results indicate that the grazed section of the pool, with approximately 560 kilograms/hectare (500 lbs/acre) of RDM, had a wide gradual pool margin. Barry noted that early in the spring the margin was a three to 4.5 meters (ten to 15 feet) wide band of meadowfoam (*Limnanthes doulgasii)* and that later in the spring Fremont's goldfields (*Lasthenia fremontii)* began to dominate a band three to six meters (ten to 20 feet) wide. Additionally, within the grazed bands she found other native vernal pool plants, including white-headed navarretia (*Navarretia leucocephala*), woolly marbles (*Psilocarphus spp,*) and popcornflower (*Plagiobothrys ssp*.). In comparison, the portion of the pool that had been rested from grazing for 15 years had approximately 3150 kilograms/hectare (2800 lbs/acre) of RDM. Barry reported that the vernal pool margin was very distinct with a thick cover of Italian ryegrass growing right up to the pool edge. In the early spring, the band of meadowfoam was less than 0.3 meters (one foot) wide and the late spring goldfield band extended only 0.3 to one meter (one to three feet). Additionally, no individuals of white-headed navarretia were found on the ungrazed side of the fence. Thus, Barry's observations support the contention that livestock grazing can be a useful tool for managing invasive grass thatch and increasing the area and abundance of vernal pool wildflowers.

In addition to the effects of increased thatch canopy on native forbs, researchers have hypothesized that dense thatch could be an obstacle to success for juvenile tiger salamanders during their migration from pools during draw-down. Laurner (pers. comm.) and Jennings (pers. comm.) agreed that although there is no experimental data confirming the effect of phytomass accumulation on tiger salamander migration, it is possible that thick thatch could slow down migrating juveniles, thereby increasing their susceptibility to predation and desiccation.

Although quantifying the nature of the competitive interaction between annual grasses and native vernal pool forbs has proven difficult, research in uplands suggest that annual grasses are able to out-compete natives through a positive feedback loop. In essence, annual grasses are able to maintain a competitive advantage in ungrazed pastures because the thick canopy of thatch and resulting lack of light penetration favors germination of annual grasses over native plants (Evan and Young 1970).

In addition to restricting light penetration for the germination of vernal pool forbs, thatch build-up from non-native grasses has also been attributed to changes in pool hydrology. Barry (1995, 1997, and pers. comm.) referred to the rangeland hydrology literature to support the hypothesis that thatch build-up around vernal pools negatively effects the period of pool inundation. Barry cited Blackburn's (1975) study, which demonstrated that rangeland runoff decreased in proportion to increased in vegetation. Because runoff from vernal pool margins is believed to play an important role in regulating pool fluctuations after initial filling, increased RDM might shorten the inundation period of local pools (Barry 1997). In addition to reducing runoff into vernal pools, dry thatch can also reduce net moisture accumulation through increased interception, direct evaporation, and soaking into dry plant material (Barry 1997; Dittes pers. comm.).

The work of Bauder (1987) and Holland and Jain (1984) lends support to the contention that reduced duration of pool inundation can have a negative effect on pool flora. Holland and Jain (1984) found that the frequency and abundance of upland ruderal species in vernal pool margins increased during drought years. In a controlled greenhouse experiment, Bauder (1987) found that the mortality of vernal pool margin exotics, such as filaree (*Erodium botyrs*) and cat's ear *(Hypochoeris glabra)* reached approximately 75 percent after three weeks of inundation and 100 percent after eight weeks of inundation. Similarly, Griggs (pers. comm.) observed a major filaree invasion into vernal pools during the 1976-1977 drought. However, Griggs noted that after the drought broke and inundation periods regularly lasted beyond two to three weeks, the filaree was replaced by vernal pool species. Thus, reduction of thatch could be a crucial management strategy for increasing the period of pool inundation during dry years to protect rare vernal pool species from extirpation.

Vernal pool bottoms are inundated for a longer duration than pool margins and hence they appear to be less easily invaded by mesic upland species. Barry's (1997) observations on Vina Plains and Cadman's (pers. comm.) observations in the Santa Rosa Plain indicated that, unlike in the pool margins, there is little visible difference in pool bottom species abundance or composition between the grazed and ungrazed pools. However, Stone et al. (1987), Rogers (pers. comm.), Lis and Eggeman (2000b) and Heise (pers. comm.) each observed increases in standing vegetation in the ungrazed pools bottoms. Anecdotal evidence suggests that the common vernal pool species pale spikerush *(Eleocharis macrostaycha* and *palustris*) and Vasey's coyote thistle (*Eryngium vaseyi*) often dominate ungrazed pool bottoms, and out-compete downingias (*Downingia spp*.) and rare vernal grasses from the *Orcuttia* and *Neostapfia* genera (Barry 1995; Crampton 1957; Griggs pers. comm.; Stone et al. 1987). An additional threat to native pool bottom species might be the invasion of Bermuda grass (*Cynodon dactylon*), which has been observed covering the bottom of vernal pools in Mendocino County following the removal of sheep (Heise pers. comm.).

Increased density of standing vernal pool bottom vegetation might not only affect resource competition between plants, but increased pool vegetation might have profound implications on vernal pool fauna. Lis and Eggeman (2000b) found that pools with a large amount of decaying vegetation from the previous season had fewer fairy shrimp. Although their preliminary data analysis does not directly link livestock grazing with populations of rare crustaceans, they hypothesize that grazing could be beneficial to fairy shrimp by reducing the amount of vegetation in the pool during inundation. According to Helm (pers. comm.), although it is not experimentally documented, it is common knowledge that less vegetation in pools is better for fairy shrimp populations. He and Rogers (pers. comm.) cite the need for an open water column that permits good plankton production for the success of rare fairy shrimp. This relationship between standing vegetation in pools and crustaceans can be explained by changes in the trophic structure resulting from the shift from a detrital-based system to a periphyton-based system during early inundation. Generally, vernal pools start each inundation cycle as detrital systems with food chains based on bacterial decomposition of unattached dead material. Helm (pers. comm.) suggests that the existence of perennial plants or standing residual phytomass in the pool bottom can act as an anchor for periphytic algae. These algae can form dense floating mats, which reduce dissolved oxygen and increase potential habitat for opportunistic predatory macro-invertebrate species. Livestock grazing can reduce the amount of standing vegetation and control the invasion of dense exotic aquatic grasses such as mannagrass (*Glyceria declinata*), thereby shifting the system back to a detrital system which favors success of endemic vernal pool crustaceans and plankton (Rogers pers. comm.).

Although livestock grazing could be the most practical tool for reducing standing phytomass in vernal pool systems, grazing management must be tailored to the life histories of specific species of interest. For example, although biomass removal via livestock grazing appears to help many native vernal pool forbs, Griggs (pers. comm.) found that cattle show a preference for the native wildflower checkerbloom (*Sidalcea spp.*) and that it rarely appears in pastures receiving late spring grazing. Anecdotal data suggest if livestock are removed by early April, before checkerbloom bolts, then populations are unaffected and often abundant (Griggs pers. comm.).

11.4.2 Trampling

One of the most ubiquitous signs of livestock grazing in vernal pool systems is the occurrence of hoof prints. Referred to here as trampling, this activity is perhaps the most controversial impact of livestock grazing in vernal pools. In fact, it was the belief that trampled vernal pools were a sign of habitat deterioration that prompted The Nature Conservancy to remove all livestock grazing from the Vina Plains Preserve in 1987 (Griggs 2000). Moreover, Lis and Eggeman's (2000a) research design at Dales Lake Ecological Reserve specifically cited cattle trampling as a potentially negative consequence of experimental grazing in vernal pools. They specifically designed their research program to avoid this potential problem by removing livestock prior to pool draw-down. Additionally, Griggs (pers. comm.), Koshear (pers. comm.), and Pavlik (1998) each cited trampling or compaction as a potential undesirable effect of cattle grazing (and mowing in the case of Pavlik). Although there is debate regarding when and how much different types of livestock will wallow in inundated vernal pools, it is commonly believed that cattle and sheep will use the mud from pools to protect their ankles from biting flies during the end of the pool season. Unlike cattle, sheep have been known to bed in dry pools at Jespon Prairie and Hopland Cooperative Extension Research Station (Heise pers. comm.; Serpa pers. comm.) and this activity might increase the potential for compaction. Although trampling is perceived to be a potential problem in vernal pool systems, not all data support this contention.

For example, Cooley (pers. comm.), Dittes (pers. comm.) Griggs (pers. comm.), and Vollmar (pers. comm.) all observed pools that were heavily trampled during draw-down, but still maintained abundant native wildflowers the following season. Moreover, because cattle and sheep rarely wade into pools during peak inundation (February-April) it is unlikely that livestock grazing could directly impact rare vernal pool fairy shrimp (Griggs pers. comm.; Rogers pers. comm.). On the other hand, it is possible that cattle trampling could result in increased mortality of migrating juvenile California tiger salamanders (Jennings pers. comm.). This issue could be remedied by removal or reduction of livestock during migration. One additional potential benefit of livestock trampling in muddy pools is the increased opportunity for livestock to act as vectors, transporting fairy shrimp cysts from one pool to another. Thiery (1997) found numerous cysts stuck in mud attached to the legs of sheep that had been trampling through muddy pools in Morocco.

Additionally, recent observations indicate that trampling can also portend benefits to the entire vernal pool ecosystem via increased soil compaction, creation of micro-topography, destruction of standing biomass, and mixing of vernal pool sediments. Gifford and Hawkins (1978), in their review of the literature on hydrologic impacts of grazing, concluded that areas under complete rest from grazing had infiltration rates statistically higher from grazed sites. Their work supports the findings of Liacos (1962), who found that complete rest from grazing increased infiltration, percolation and water holding capacity of soils. Observations by Barry (1995 and 1997), Dittes (pers. comm.) and Helm (pers. comm.) support the notion that soil compaction from cattle trampling can positively effect vernal pool hydrology by decreasing infiltration and increasing the period of inundation. This relationship between cattle trampling and soil compaction was observed by Griggs (pers. comm.) on the Vina Plains Preserve in 1998 when cattle grazing was resumed after more than ten years of no grazing. He noticed that the cattle on the preserve were sinking into the wet clay soils while across the fence line, on the same soils, the cattle did not appear to be having the same problems. Griggs hypothesized that the soils on the preserve had been aerated by gophers, worms and root action for the previous ten years and, in the absence of compaction by grazers, had fluffed-up and become much less rigid during saturation.

Increased periods of inundation caused by decreased infiltration rates could have especially profound impacts on vernal pool biota during dry years when a few extra days of inundation could mean the difference between completion of a life cycle or not. This would be especially true for species that require longer inundation regimes, such as the California tiger salamander, western spadefoot, and vernal pool tadpole shrimp. However, Bauder (1987) cautioned that if inundation periods are extended too long, then the floral competitive advantage would shift from species adapted to the vernal pools to aquatic species, such as cattails (*Typha* spp.) or sedges (*Scripus* spp.).

Another potential benefit from trampling is the creation of micro-depressions along pool margins in the pool shallows. Barry (1997) asserted that these micro-depressions can have the net effect of increasing the percentage of suitable habitat sites for native plants and animals. Barry (1997) and Rogers (pers. comm.) observed the vernal pool flower, *Downingia bella* flourishing in hoof marks in shallower pools as opposed to its more usual habitat in the bottom of deeper pools. Vollmar (pers. comm.) has also observed plant species typically found in deeper portions of vernal pools within hoof marks around the pool margins. Gause (pers. comm.) and Helm (pers. comm.) indicated that anecdotal evidence supports the theory that increased inundation periods within micro-depressions can result in rare vernal pool macro-invertebrates fulfilling their life cycle during drier years.

The previous section discussed the importance of reducing the standing biomass both along pool margins and within pools. Livestock management can accomplish this task via trampling as well as consumption. Valletine (1990) asserted that livestock trampling can destroy vegetation through shearing action. Helm (pers. comm.) argued that cattle trampling is beneficial for maintaining a detrital trophic structure in vernal pools by mechanically breaking down vegetation that would otherwise act as attachment sites for periphytic algae. Although trampling might be an effective tool for managing standing pool bottom phytomass, this can be a potential problem if your target species flourish in pools during draw-down. Rare Orcutt grasses are a prime example of this conflict. In the early days at Vina Plains, managers found that cattle trampling during draw-down was decimating the remaining populations of these rare grasses. The simple solution was to alleviate trampling pressure on these grasses by removing cattle on approximately May 1st instead of May 15th or June 1st. Early removal of cattle made a significant difference and the Orcutt populations responded as expected (Griggs pers. comm.). If managers still wanted to use cattle to manage pre-inundation standing phytomass, then they could simply put the cattle on earlier in the season and use them to trample or eat the remaining phytomass. Although the Orcutt grass example is straightforward, the relationship between vernal pool biota and livestock activity can be difficult to understand. For example, Koshear (pers. comm.) has observed that the state and federally listed plant species, succulent owl's-clover (*Castilleja campestris ssp. succulenta*) is simply not found in grazed vernal pools in the Big Table Mountain region of Madera County. Without a greater understanding of succulent owls-clover life history, it is difficult to ascertain when and how these populations are being affected by livestock grazing practices. Conversely, succulent owl's-clover is found extensively in eastern Merced County in pools that are lightly to moderately grazed (Vollmar pers. comm.).

Although livestock grazing does not appear to pose a significant threat to fairy shrimp and tadpole shrimp after they hatch, the relationship between branchiopod cyst survival and trampling appears to be quite complex. Hathway et al. (1996) and Eriksen et al. (1986) found that branchiopod cysts were easily crushed by minimal forces (>1.00 Newton). Hathaway et al. (1996) also found that wet cysts were even more vulnerable to crushing than dry cysts and that anostrocan (fairy shrimp) cysts were more easily crushed than notostracan (tadpole shrimp) cysts. The authors note that because this research was conducted on a rigid static surface in a laboratory, it is possible that wet soil in vernal pools could cushion cysts and lead to lowered mortality. Nonetheless, it is unknown what impact the repeated loss of a significant portion of a cyst bank could have on branchiopod populations. Thus, if cattle are trampling pools during draw-down or during the dry phase, then cyst mortality should be considered a management concern.

Wilcox (pers. comm.), conducting research on meta-population dynamics of vernal pool fairy shrimp and tadpole shrimp in the San Luis National Wildlife Area, proposes that cattle trampling in vernal pools plays an important role in mixing sediments, vertically moving cysts, and reducing cyst predation. Wilcox argues that cattle trampling might be responsible for maintaining fairy shrimp cyst banks over time through two mechanisms. First, deep burial via hoof action or mixing of sediments can lead to a net loss in the viability of the current cyst crop, but a net increase in future cyst crops when buried cysts are later uncovered by subsequent hoof action. Of course, if grazing is removed these buried cysts would be lost until another disturbance uncovers them. Additionally, deep burial can temporarily protect cysts against predation by vernal pool tadpole shrimp and other predators.

Another potentially positive effect of sediment mixing via cattle trampling is increased pool turbidity. Research on California tiger salamanders, western spadefoots, and a variety of rare and endangered vernal pool fairy shrimp indicates that these species prefer turbid pools to clear pools (Jennings pers. comm.; King et al. 1996; Rogers pers. comm.). This argument is directly related to pool vegetation dynamics because limited light penetration in turbid pools generally results in a lack of emergent vegetation and a more open water column, a situation that appears to be conducive to the maintenance of these species (Helm pers. comm.; Rogers pers. comm.; Wilcox pers. comm.). In addition, Wilcox (pers. comm.) hypothesizes that the lack of visibility conferred by pool turbidity could decrease predation pressure from wading birds on fairy shrimp, tadpole shrimp and juvenile tiger salamanders. Predation pressure would also be reduced on other amphibian larvae, such as western spadefoot.

Livestock trampling is commonly cited as a major cause of destruction of cryptogrammic crusts, a living soil crust composed of liverworts, lichen and bacteria that increases surface run-off and impedes infiltration (Dittes pers. comm.; Griggs pers. comm.). These crusts can play an important role in the hydrology of vernal pools and often form the basis of the detrital food chain. Anecdotal evidence suggests that although trampling can damage these crusts, thick thatch canopies resulting from undergrazing of annual grasses can suppress cryptogrammic crust production in California rangelands. Observations by Griggs (pers. comm.) indicate that these crusts can be limited to the perimeter of cattle trails and hoof prints where livestock have trampled and grazed annual grasses, but not over-trampled the crusts.

11.4.3 Nutrient Dynamics

The effect of nitrogen accumulation, from both atmospheric sources and biotic sources (defecation from domestic livestock), into traditionally nitrogen-limited rangeland ecosystems is a major topic of research (Claasen and Marler 1998; Joffre 1990; McColl and Firestone 1991; Wedin and Tilman 1996). Because vernal pools are closed lentic systems, they act as nutrient sinks, accumulating nitrogen from uplands via processes such as phytomass leaching, surface runoff of atmospherically deposited nitrogen, and livestock defecation (Pavlik et al. 1998; Weiss pers. comm.). Recent research by Pavlik et al. (2001) supports the hypothesis that vernal pools represent nutrient sinks. They found statistically higher soil nitrogen levels in samples from vernal pool margins and bottoms as opposed to uplands. Dahlgren (pers. comm.) argues that vernal pools function like other wetlands in that they accumulate nutrients like nitrogen and then work like kidneys to remove excess nitrogen via denitrification or through binding of available nitrogen into living biomass.

The scientists interviewed and literature reviewed for this report indicate that livestock grazing can either exacerbate this problem by increasing nutrient inputs via defecation or attenuate this problem through removal of nitrogen by incorporation into tissue. Although nitrogen from livestock urine and feces can form the basis of the detrital food chain in recently inundated pools, it can also act as the basis for vernal pool eutrophication (Griggs pers. comm.; Helm pers. comm.). In other words, both too little and too much nutrient input can pose a problem for vernal pool biota. Observations indicate that in a situation where vernal pool grasslands are overgrazed, increased nutrient loads via manure and urine can turn vernal pools into eutrophified ponds. These pools often appear to be clogged by dense algal mats, which reduces the light penetration and depletes the dissolved oxygen, and has a negative effect on the vernal pool biota (Helm pers. comm.; Rogers pers. comm.; Vollmar pers. comm.).

In addition to the implication that overgrazing has negative effects on vernal pool nutrient dynamics, Pavlik (pers. comm.) hypothesizes that increased soil nitrogen from atmospheric deposition favors non-nitrogen efficient invasive annual grasses over native plants with high nitrogen use efficiency. Pavlik argues that if this hypothesis is accurate, then managing for lower soil nitrogen will shift the competitive balance toward non-ruderal native species. Moreover, he argues that phytomass removal is perhaps the most practical way to remove nitrogen from a grassland system. Pavlik et al. (1998) designed a series of phytomass removal experiments in uplands and vernal pools on the Santa Rosa Plain in Sonoma County. These experiments are targeted at reducing the cover of Italian ryegrass, an exotic annual grass known to encroach on vernal pool margins. Due to the proximity of these pools to urban areas, the researchers decided to use mowing instead of grazing to test their hypotheses. Preliminary results indicate that phytomass removal had a significant effect on soil nitrogen and the abundance of Italian ryegrass in the uplands, but after one season there were no significant effects along the pool margins. Pavlik attributes this to the increased baseline nitrogen levels in vernal pool soils. The important caveat is that although livestock grazing can continue to transfer nitrogen from uplands to vernal pool via deposition of waste, that livestock biomass represents a net loss of nitrogen from the system. Thus, if Pavlik's hypothesis is valid, then it could be possible for managers to use livestock to mitigate the effects of increased nitrogen from atmospheric deposition.

Larry Serpa of The Nature Conservancy added one last anecdote regarding the relationship between livestock feces and rare vernal pool biota. Serpa (pers. comm.) observed that the removal of sheep grazing from Olcott Lake on the Jepson Prairie has resulted in the extirpation of the Delta green ground beetle (*Elaphrus viridis*) population. Currently, Delta green ground beetles only exist in the margins of grazed pools at Jepson Prairie (Serpa pers. comm.). Serpa attributes this relationship to the lack of sheep feces in ungrazed vernal pools. He argues that the Delta green beetle no longer inhabits the margins of Olcott Lake because their preferred food source, a species of springtail, subsists primarily on a fungus that only grows on livestock dung. Thus, removal of the foundation of the Delta green beetle's food chain has resulted in the loss of this federally listed species from ungrazed sites. Although Serpa also argues that the low RDM and high levels of trampling associated with livestock grazing will hamper the Delta green's ability to capture prey, he asserts that plans for conservation of the Delta green ground beetle must include some type of livestock grazing, preferably sheep grazing for food web maintenance.

11.5 DISCUSSION

Although research exists on the effects of livestock grazing on grasslands and the use of grazing as a tool for restoration of grasslands, much less research has been conducted on the relationship between livestock grazing and the conservation of vernal pools. The trend toward establishing conservation easements on private ranchlands as a means of conserving vernal pool ecosystems begs the question: Is there a natural synergy between economically viable ranching activities and the conservation and enhancement of vernal pools? The literature reviewed and interviews performed for this report demonstrate a shift in perception during the past several years from livestock grazing as a major negative impact on vernal pools to livestock grazing as an important tool, when properly managed for maintaining and enhancing the populations of many native plant and animal species endemic to California's vernal pools, including many rare or endangered species.

11.5.1 General Benefits of Grazing on Vernal Pool Ecosystems

Vernal pool landscapes have evolved since the late Pleistocene (300,000 to 10,000 years ago) with a disturbance regime dominated by wildfire and mega-faunal grazing (Edwards 1996). In more recent history, wildfire has been suppressed and natural herbivory has been shifted to domestic grazers and occasional mule deer (*Odocoileus Hemionus*) or tule elk (*Cervus elaphus nannodes*). Research for this report indicates that vernal pool ecosystems, like the grassland and oak savanna uplands surrounding them, depend on disturbance to maintain a diverse flora and fauna. Four lines of evidence inform this general notion.

The first line of evidence comes from research conducted in uplands and focused on the effects of grazing management on plant diversity and native plant populations. The literature provides two basic messages. First, California grasslands and foothill oak woodlands have been fundamentally altered by the introduction and subsequent dominance of non-native annual grasses. Research indicates that although historic overgrazing likely advanced this invasion, the removal of livestock grazing does not reverse this trend and in fact can exacerbate the problem (Bartolome 1993; Carlsen et al. 2000; Dyksterhuise 1949; Hamilton et al. 1999; Hatch et al. 1999; Meurk et al. 1989; Meyer and Schiffman 1999). Second, control of RDM or standing phytomass levels can be used to effectively manage floral species assemblages in California rangelands (Heady 1956 and 1965, Evans and Young 1970, Bartolome 1984). In essence, although environmental variables play the most fundamental role in inter-year rangeland plant composition, the amount of RDM after the growing season has a profound effect on competition for light and soil moisture the following season. Non-native grasses such as medusa-head typify the effects of RDM on competition. Medusa-head thatch has such high silica content (80 percent) that it breaks down very slowly. Research indicates that native forbs and perennial grasses are out-competed by medusa-head seedlings in this light restricted environment. Similar competitive interactions have been reported for other annual non-native grasses such as Italian ryegrass (*Lolium multiflorum)* and others (Pavlik pers. comm.; Witham pers. comm.).

The second line of evidence is based on our understanding of the historic extent of cattle grazing throughout California's vernal pool grasslands. Most of today's remaining vernal pools and their associated biota have persisted and, in many cases, flourished in cattle-grazed landscapes. Livestock grazing has been the primary land use in California's remaining intact Central Valley grasslands and foothills for over 150 years. As such, we can deduce that the majority of remaining vernal pool complexes in California have experienced some disturbance via livestock grazing. Thus, what we define as healthy or reference vernal pools have likely evolved under the influence of some livestock grazing.

The third line of evidence comes from a variety of sites throughout California where complete rest from grazing was implemented in the mid-1980s and early 1990s, when the prevailing belief was that livestock grazing was fundamentally detrimental to vernal pool ecosystems. The installation of grazing enclosures and/or the complete removal of domestic livestock from vernal pool systems appears to have resulted in trends toward lower native plant species abundance, invasions of non-native grasses into vernal pool margins, and increased herbaceous cover within pools (Barry 1995, 1996, and 1997; Griggs pers. comm.; Holland pers. comm.; Reiner pers. comm.). Although these effects appear to be particularly pronounced along the pool margins and in the upland areas surrounding pools, weedy invasions have also been observed within the pool bottoms (Heise pers. comm.; Helm pers. comm.; Rogers pers. comm.). Moreover, data from Lis and Eggeman (2000b), Helm (pers. comm.), Rogers (pers. comm.), Serpa (pers. comm.), Vollmar (pers. comm.) and Jennings (pers. comm.) indicate that although there is less information on the direct effects of livestock grazing on threatened and endangered vernal pool fauna, livestock grazing appears to be compatible with the persistence of these species.

Lastly, because California rangelands have evolved with varying degrees of ecosystem disturbance via fire or herbivory, many of the scientists and managers interviewed for this report cited livestock grazing as a means to maintain a disturbance regime in vernal pool systems. Lis and Eggeman (2000a) referred to livestock disturbance as a means to maintain non-equilibrium and Helm (pers. comm.) alludes to the "Intermediate Disturbance Hypothesis" to explain the importance of livestock grazing in maintaining a diverse vernal pool biota. The "Intermediate Disturbance Hypothesis" proposes that the highest levels of biotic diversity are maintained at intermediate levels of disturbance (Connell 1978). This concept might explain why some level of grazing-induced disturbance can be integral to the successful conservation of species diversity within vernal pools.

Today, although experts maintain that the relationship between domestic livestock grazing and vernal pool habitat condition is complex and difficult to quantify, the prevailing belief is that livestock grazing can play an important role as a management tool in vernal pool landscapes. However, our research also indicates that the perceived need for some level of ecosystem disturbance should not be interpreted as a "carte blanche" invitation to indiscriminately graze vernal pool landscapes. Because target native vernal pool species exhibit a variety of life history strategies, certain grazing regimes will differentially affect species. As such, grazing regimes must take into consideration the needs of the specific target taxa. Without exception, all of our interviewees warned that grazing inappropriate to those target taxa and/or general overgrazing could result in ecosystem problems that are comparable to or perhaps of far greater severity than those encountered with complete rest.

11.5.2 Application of Different Grazing Regimes

Understanding the various grazing regimes currently being implemented in vernal pool landscapes and the potential for flexibility within these regimes is fundamental to striking a balance between maintaining a financially viable ranching operation and meeting habitat conservation goals. A basic review of California valley and foothill grazing practices and the general criteria upon which they have been developed is provided above. Although climate, slope, and soil type are the principle abiotic factors influencing both vernal pool production and livestock production, they are beyond the control of individual ranchers or land managers. On the other hand, ranchers and managers *can* control grazing intensity and the spatial and temporal distribution of livestock through a variety of means (Heitschmidt and Stuth 1991).

Efforts to use easements as a means of altering grazing regimes to enhance vernal pools should carefully weigh the real benefits to vernal pools and their biota against the hardships, in terms of both management and cost, imposed on a ranching operation. Not only will this increase the interest among ranchers in establishing easements, it will also provide operational examples that could be adopted on non-easement ranchlands. Particular attention should be given to such potentially burdensome easement requirements as early removal of cattle, year-long rest-rotation regimes, labor-intensive cattle rotation regimes, and construction of extensive permanent fencing as a means to implementing grazing rotation.

Before land managers and ranchers can develop specific grazing regimes for conservation of vernal pools, specific management goals must be clearly articulated. In other words, decision makers need to decide if specific pools or pool complexes are to be managed holistically as part of the greater landscape or for specific taxa, especially the special status plants, large branchiopods, and amphibians. Once specific management goals are articulated, then life history information for the target taxa can be used to inform development of an appropriate grazing regime. Finally, because there is a high degree of uncertainty regarding both life histories of rare biota and the effects of specific grazing regimes on those species, regular monitoring, adaptive management, and research must be undertaken to increase our understanding of these relationships and adjust management to reflect the latest available information.

Although grazing regimes can be tailored to specific species, our research indicates that the following rules for grazing are applicable across most vernal pool taxa.

(a) The complete removal of livestock from vernal pool landscapes is detrimental to the vast majority of native flora and fauna due to the build up of phytomass from non-native annual grasses and other weedy species. These plants, when unrestrained, competitively exclude or inhibit native plant and wildlife species. It is unclear if occasional rest rotation is beneficial or detrimental to vernal pool biota. As discussed above, Griggs noted an initial increase in the diversity and abundance of native plant species when cattle were removed from the Vina Plains Preserve. The mechanism for this increase has not been studied.

(b) Season-long, high-intensity grazing (i.e. overgrazing), defined as nothing left but stubble at the end of the season, is detrimental to all rangeland resources due to excessive removal of vegetation, excessive nutrient inputs from defecation, and excessive trampling. This level of grazing is especially detrimental when practiced on an ongoing basis. It is unclear, however, what are the long-term effects of overgrazing for a single season or for short durations within a single season (SDHI grazing regime). Short-term, intensive grazing has been found to be a useful management tool in the perennial grasslands in the southwest region of the United States (Arizona and New Mexico) (Dagget pers. comm.), but it is unknown if this practice is suitable for California annual grasslands or vernal pools.

(c) A moderate level of grazing appears to be generally beneficial to most vernal pool species due primarily to the reduction and trampling of non-native annual grasses and other weedy species from the pool margins and surrounding uplands. There is little information, however, on the differential effects of variations within the context of a "moderate" grazing regime in terms of grazing intensity, duration, and rest-rotation. It is likely that certain grazing regimes will yield a greater diversity and abundance of native vernal pool species, but these regimes are not clearly defined, based on existing information.

(d) Putting cows out on the rangeland before green-up forces the cattle to utilize existing "hay in the bank" (dead forage from the previous growing season), thereby reducing the RDM along pool margins and the standing biomass in the pool bottoms prior to the germination of vernal pool plant species.

(e) It is unclear if trampling has net negative or positive effects (except for late-season vernal pool plants, which appear to be negatively affected). However, if managers are concerned about the effects of wading in inundated pools or trampling in pools during draw-down they can utilize livestock breeds that are less prone to congregating around water sources. As an example, at the Orchard Creek Preserve in Placer County, Wildlands Inc. chose to use Mexican longhorn cattle for medusa-head grass control because they are less likely than other breeds to wade into inundated vernal pools (DeYoung pers. comm.). Of course, breed selection is a critical factor for commercial beef cattle operations and more information needs to be developed on the grazing styles of economically desirable cattle breeds, such as Black Angus in relation to vernal pools.

11.5.3 Management Considerations for Rare Species

General guidelines are provided below for management of specific suites of vernal pool rare species. While these guidelines are based on the best available information (as presented above), most have not been tested through research or monitoring, and should therefore be regarded as preliminary. Future research and monitoring should be conducted to more conclusively determine the best approaches for using grazing as a management tool for these rare species.

Rare Orcutt Grasses

The Orcutt tribe is composed of a unique group of grasses that occur primarily within large vernal pools (playa pools) (see Chapters 2 and 3 for complete discussions). These grasses are thought to have evolved from an ancestral species that inhabited the edge of the sea that formerly occupied the Central Valley region. The tribe consists of three genera (*Neostapfia*, *Orcuttia*, and *Tuctoria*) with a combined total of nine species. All but one of these species are restricted to the Central Valley of California and all are listed as threatened or endangered under the state and federal Endangered Species Acts. Their rarity is due to the overall rarity of playa pools in the landscape combined with significant historic and continuing loss of these pools to cropland conversion and development.

The Orcutt grasses have a life history that differs significantly from most other vernal pool plants species (see Chapter 3). They require a longer inundation period to successfully germinate, which is why they are generally restricted to larger or deeper pools. They typically flower during the summer when most other vernal pool species as well as the surrounding upland annual grasses have flowered and died. In addition, most other vernal pool species cannot tolerate the prolonged inundation within the playa pools and, as a result, the beds of these pools often have a low cover of vegetation that reduces the competitive stress for Orcutt grasses.

Given these ecological characteristics, playa pools and their associated Orcutt grasses are highly susceptible to excessive trampling in the late spring and summer when they are one of the few sources of green forage in the landscape, and the pools are one of the few remaining sources of standing water. (Excessive grazing [i.e., phytomass removal] might not be an issue for these species since they all produce sticky pungent exudates that probably deter grazing.) As described above, Griggs noted a decline in Orcutt grass populations in the large pools of the

Vina Plains Preserve (Tehama County) subjected to late season grazing. Early removal of the cattle (removed May 1st instead of May 15th or June 1st) reversed this decline, and the grasses recovered. Ranchers and preserve managers of lands with Orcutt grasses should consider taking similar measures. Since early removal of cattle might not be an economically feasible option, other alternatives would be to rotate the cattle out of pastures with Orcutt grass pools or set up a temporary two-strand solar-powered electric fence around the perimeter of the pool to exclude cattle from the pool bed. Developing alternative water sources could also reduce pressure on playa pools. While these measures would probably prove beneficial to Orcutt grasses, they are based on a very limited amount of information, and more experimental or monitoring data would be useful. Also, while it could be valuable to remove cattle in the late spring, early season grazing is still important as it reduces the density of invasive non-native or aggressive native species, which can competitively exclude Orcutt grasses when left unchecked.

Non-Orcutt Vernal Pool Rare Plants

Grazing management considerations for non-Orcutt vernal pool rare plants depend in large part on the hydrological preferences of the target species. Some rare species, such as Contra Costa goldfields, Baker's blennosperma, and Sebastopol meadowfoam occupy the beds of shallow vernal pools and the upper margins of deeper pools. These species are highly susceptible to decline under low-intensity grazing regimes due to increased competition from weedy species around the pool margins and beds of shallow pools. Ranchers and land managers should consider grazing with sufficient intensity that these invasive species are kept in check. There is currently no information (observational or experimental) on the effects of rest-rotation or SDHI grazing regimes on pool margin rare species. Monitoring is recommended to track population trends and insure that sites are not either under or over-grazed. Based on observations made by biologists and land managers, the typical grazing regimes practiced on well-managed ranches appear to be beneficial to pool margin dwelling rare plants.

In contrast to the species described above, other vernal pool rare plants, such as succulent owl's-clover, pincushion navarretia, and various rare species of coyote-thistle (such as *Eryngium spinosepalum* and *E. constancei*) typically occupy the beds of deeper pools (generally greater than four-inch maximum potential ponding depth). These species are much less susceptible to direct competition from invasive species because there are very few grassland invaders that can withstand the severe hydrologic conditions experienced in pool bottoms. Nonetheless, weedy invasion of the pool margins can indirectly impact these rare pool bottom species by reducing the inundation period through increased rates of evapotranspiration, thereby affecting habitat suitability for these species.

The vernal pools in which these rare bottom species grow generally remain inundated longer than shallower vernal pools, and therefore could be susceptible to concentrated trampling and grazing pressure in late spring after smaller pools have dried. Current data and observations are somewhat conflicting on the effects of moderate to heavy grazing regimes on the vernal pool bottom dwelling species. As described earlier, succulent owl's-clover was found to be completely absent from a grazed site in Madera County, while it occurred abundantly on adjacent ungrazed sites. In contrast, this species occurs throughout ranches in eastern Merced County, all of which are subject to regular moderate grazing. Pincushion navarretia provides another conflicting example. This species was observed in numerous vernal pools on a ranch in eastern Merced County, but was entirely absent from similar pools just over the fenceline at an adjacent ranch (Vollmar pers. comm.). Although both ranches were regularly grazed, information on the specific grazing practices employed at each ranch was not examined and thus it is difficult to draw any conclusions regarding what variables could be impacting the survival of this species over time. Coyote-thistle is somewhat different from either succulent owl's-clover or pincushion navarretia in that it produces tall, succulent, early-season growth that appears to be highly favored by cattle (Vollmar pers. comm.). On sites with moderate to heavy grazing, most coyote-thistle plants are grazed to just above the waterline in vernal pools during the early season. While this would seem detrimental to the species, most plants continue to send up new shoots. Later in the season, when the pools dry, the plants develop spiny vegetation and flowering heads that greatly deter grazing (Vollmar pers. comm.).

Given these conflicts, ranchers and land managers should consider the potential negative and positive effects of grazing on bottom dwelling vernal pool rare plants in terms of undergrazing as well as excessive trampling, cropping, or defecation during the late-stage growth and flowering phase. Monitoring is recommended to track population trends, especially if grazing is particularly heavy or light.

Vernal Pool Large Branchiopods

There are no clear data on either the negative or positive effects of livestock grazing on vernal pool large branchiopods (crustaceans, i.e. tadpole shrimp, fairy shrimp and clam shrimp). Various researchers have considered the effects of phytomass removal, trampling and defecation on the adults and cysts with mixed conclusions, except to conclude that non-grazing and excessive grazing both appear to be detrimental. Most researchers agree that very heavy cattle use negatively affects the crustaceans through excessive nutrient input, which leads to pool eutrophication (and putrification). Extreme use can also lead to direct trampling of adults and cysts. Though no experimental data are available, larger pools with longer inundation periods could be particularly susceptible to extreme use since they attract a concentration of cattle in late spring after smaller pools and the surrounding uplands have dried. Vernal pool tadpole shrimp prefer these larger pools and often persist longer in the season than most vernal pool dwelling fairy shrimp species. Given their larger size and association with larger longer-ponding pools, they could be more susceptible to the negative effects of excessive trampling and defecation. However, it should be noted that the increased turbidity caused by trampling could also be beneficial since it could protect crustaceans from predation by wading birds.

The Conservancy fairy shrimp (*Branchinecta conservatio*) might warrant special consideration. This species is exceptionally rare and is generally found only in large, clay-bottom playa pools. While this species might be given some of the same management considerations as the Orcutt grasses (which often co-occur with the Conservancy fairy shrimp), the adults usually complete reproduction and die before the surrounding landscape dries and cattle begin concentrating in the pools. Excessive late-season trampling of the pools could negatively affect the cysts.

Ranchers and land managers should consider the potential effects described above when developing grazing regimes on sites with vernal pool crustaceans. Based on observations made by biologists and land managers, the typical grazing regimes practiced on well-managed ranches appear to be compatible with the conservation of vernal pool crustaceans. There is currently no information on the differential effects of rest-rotation or SDHI grazing regimes on vernal pool crustaceans. Monitoring is recommended to track population trends, especially if grazing is particularly heavy or light.

Vernal Pool-Breeding Amphibians

As with vernal pool crustaceans, there are no clear data on either the negative or positive effects of livestock grazing on rare vernal pool-breeding amphibians (primarily the California tiger salamander and western spadefoot). Various researchers have considered the effects of phytomass removal, trampling and defecation on the adults and cysts with mixed conclusions. Some researchers believe that excessive use by cattle can negatively affect larval and juvenile amphibians through direct trampling both in the pools and in the uplands during overland migration. This might be especially true since the trampling and grazing pressure on the larger pools preferred by these species could increase in late spring and early summer when larvae are transforming and juveniles begin migration. Eutrophication seems to be less of a concern since the larvae of both California tiger salamanders and western spadefoots are known to occur in extremely muddy and nutrient-enriched pools. In fact, both species could have higher survival rates in very murky pools where they are less susceptible to predation by wading birds (Wilcox per. com).

The greater concern among many researchers is not overgrazing but undergrazing. Undergrazing can lead to the build up of thatch around pool margins and surrounding uplands. This could in turn impede overland migration of juveniles and adults leading to increased predation and desiccation. Considering all available experimental and observational data, it appears that ranchers and land managers should maintain a moderate grazing regime on sites that support California tiger salamanders or western spadefoots. If feasible for the ranching operation, it could be beneficial to concentrate grazing from late fall through mid spring and then remove or reduce cattle in late spring and early summer during the time of juvenile transformation and migration. Of course, the removal of cattle during this period could lead to less pool turbidity and a consequently higher level of predation by birds. Since existing information is conflicting, these guidelines should be regarded as preliminary. More research and monitoring are needed, especially on larval and juvenile mortality rates under different grazing regimes.

11.6 CONCLUSION

Grazing influences vernal pool ecology through three primary mechanisms: phytomass removal, trampling, and the alteration of nutrient dynamics. Understanding the nuances of these mechanisms is crucial to implementing a successful management regime for vernal pool ecosystems. While most researchers and land managers currently agree that some level of grazing is important for maintaining ecosystem health within vernal pools, the variable effects of different grazing regimes in terms of timing and intensity of grazing are poorly understood. Although the inherent physical and biological variability of vernal pools makes it difficult to use a "one size fits all" approach to management, this report should provide ranchers and land managers with a road map for designing grazing management protocols specific to sites and target biota. Moreover, because vernal pool ecosystems are both complex and dynamic, any management regime should be carefully monitored and adaptively managed to incorporate new information and to avoid unforeseen pitfalls.

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APPENDIX 11a

LIST OF EXPERTS INTERVIEWED FOR INFORMATION ON RANGELAND ECOLOGY

Appendix 11a. List of experts interviewed for information on rangeland ecology.

Name	Affiliation	Email	Phone
Jackie Ball	State Parks (Goldfields)	jball@parks.ca.gov	916-988-0205
Michael Barbour	UC Davis	mgbarbour@ucdavis.edu	530-752-2956
Sheila Barry	UC Coop Ext-Santa Clara	sheilabarry@hotmail.com	408-299-2635
Denise Cadman	Sonoma State University	laguna@sonic.net	707-543-3350
Jim Chance	Snelling Ranch	NA	209-643-1488
Jean Cooley	CDFG	NA	707-944-5524
Hall Cushman	Sonoma State University	cushman@sonoma.edu	707-664-2142
Randy Dahlgren	UC Davis	radahlgren@ucdavis.edu	530- 752-2814
Greg DeYoung	Wildlands, Inc.	NA	916-331-8810
John Dittes	Private	NA	530-895-0349
Matt Gause	May Consulting	NA	916-776-2500
Mary Anne Griggs	CDFG	mgriggs@dfg.ca.gov	559-243-4017
Tom Griggs	Chico State University	tgriggs@jps.net	530-898-5294
Kerry Heise	UC Extnesion, Hopland Research Station	NA	707-744-1270
Brent Helm	May Consulting	NA	916-776-2500
Bob Holland	Private	NA	530-888-9180
Peter Hujik	TNC-Dye Creek	NA	530-527-4261
Diane Ikeda	CDFG	dikeda@dfg.ca.gov	916-324-3818
Mark Jennings	Rana Resources	ranaresources@aol.com	530-753-2727
Steve Johnson	TNC	NA	415-482-0786
David Kelley	Kelley and Associates	NA	530-753-1232
Jeanne Koshear	State Parks (Friant)	jkoshear@hotmail.com	559-822-2332
Alan Laurner	Center forConservation Biology	aelauner@leland.stanford.edu	650-725-1854
Richard Lis	CDFG	rlis@dfg2.ca.gov	530-225-2142
Dan Macon	Rangeland Trust	dmacon@pacbell.net	916-444-2096
Jaymee Marty	TNC	jmarty@cosumnes.org	916-683-1741
Glen Nader	UC Ext-Butte and Sutter	NA	530-822-7515
Jim Oltjen	UC Davis Cooperative Ex.	jwoltjen@ucdavis.edu	530-752-5650
Bruce Pavlik	Mills College, Dept. of Biology	bruce@mills.edu	510-430-2158
Chuck Peck	Sierra Foothills Conservancy	NA	559-855-3473
Rich Reiner	TNC	rreiner@tnc.org	530-527-0494
Jim Robins	Natural Heritage Institute	jrobins@n-h-i.org	510-644-2900
Christopher Rogers	Jones and Stokes	chrisr@jsanet.com	916-503-6681
Larry Serpa	TNC	lserpa@tnc.org	415-459-2137
Darrel Sweet	California Rangeland Trust/ Sweet Ranch	dksweet@cattlemen.net	925-443-7692
Marie Simovich	Univ. of San Diego	simo@acusd.edu	619-260-4083
John Vollmar	Private	vollmarconsult@aol.com	510-848-9001
Stuart Weiss	Private	NA	650-854-9732
Carol Witham	Private	NA	530-753-5872
Chris Wilcox	UCSC	norton@cats.ucsc.edu	831-459-4942