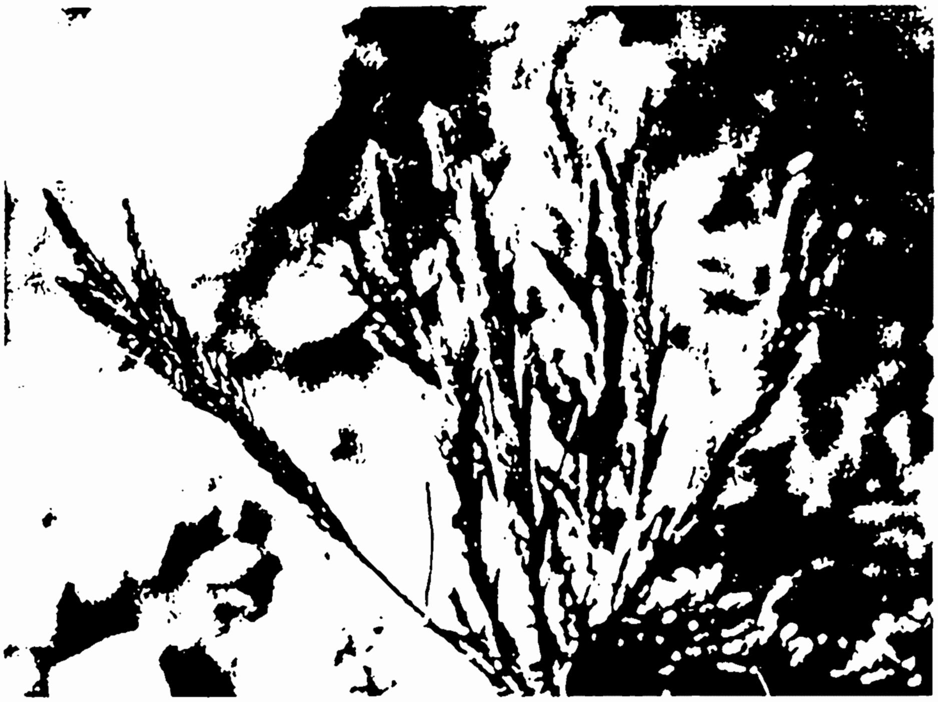
EFFECTS OF PRESCRIBED FIRE AND CATTLE GRAZING ON A VERNAL POOL GRASSLAND LANDSCAPE: RECOMMENDATIONS FOR MONITORING



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DEDICATION

In memory of Dr. Oren Pollack, who conceived the idea to study fire, livestock grazing, and biodiversity at Vina Plains Preserve. Oren's love for California grasslands, his infectious enthusiasm for this study, and his countless hours of work permeate this manuscript. Oren is remembered as a forward thinker and teacher with an uncontainable zeal for grassland ecology and wildfire. A research endowment to fund future students of grassland ecology has been established in Oren's memory by The Nature Conservancy and his friends and family.

SYNOPSIS. After an eight-year period (1988-1996) of no livestock grazing, managers of the Vina Plains Preserve (Preserve) in Tehama County, California noticed a decline in native plants species cover and an increase in noxious weeds at the Preserve. In response, The Nature Conservancy (TNC) introduced cattle grazing and prescribed fire as management tools to encourage an increase in native plant species abundances and to control noxious weeds. A program was established to monitor the effects of fire and grazing on the habitats and associated species occurring at the Preserve. The goal of this effort was to assess the effects of fire and grazing, especially on rare, threatened, and endangered species, and to make recommendations on how to design a long-term monitoring program for the Preserve. TNC's ultimate goal was to transfer the most succesful management techniques to other important vernal pool systems in the northern Central Valley.

The study addressed the following questions. Does grazing and fire have a significant effect (i.e., change in species abundance or richness) on vernal pool grassland ecosystems? In particular, does grazing and fire have an effect on: 1) the species richness of native and nonnative plants, 2) percent cover of native and nonnative plants, 3) density of rare vernal pool plant species (i.e., orcutt grasses, Hoover's spurge, and Greene's tuctoria), 4) concentration of rare large branchiopods (i.e., conservancy fairy shrimp, vernal pool fairy shrimp, and vernal pool tadpole shrimp), and 5) water quality of the vernal pools occurring at the Preserve?

The Preserve consists of five pastures (Lassen, Big Pool, Safe, Barn, and Wurlitzer). The sampling design entailed two types of monitoring: 1) pasture-wide monitoring, and 2) experimental–plot monitoring. Pasture-wide monitoring focused on systematically sampling the upland vegetation throughout the five pastures. Experimental plot monitoring consisted of sampling vegetation, large branchiopods, and water quality within paired grazed and ungrazed enclosures (using barbed-wire fencing) and within burned and unburned plots within these enclosures.

Vegetation data were collected within each pasture (pasture-wide monitoring) from quadrats that were regularly spaced along a series of evenly-spaced parallel transects (i.e., systematic sampling grid). Quadrats were then randomly positioned within each habitat (i.e., grassland, vernal swale, and vernal pool) along the sampling transects. Within each quadrat, data on species composition and cover, and priority weed distribution was collected. Priority weeds sampled included medusa-head grass (*Taeniatherum caput-medusae*), yellow starthistle (*Centaurea solstitialis*), and bind weed (*Convolvulus arvensis*) among others.

Vegetation monitoring within the experimental-plots consisted of collecting data on species composition and cover from randomized quadrats placed within paired grazed and ungrazed plots. In contrast, monitoring rare plants consisted of an adaptive cluster design to measure species density and estimate population size. Adaptive cluster sampling entailed establishing a baseline through the center of each pool at its greatest dimension from which a series of perpendicular sampling transects were randomly located within regular intervals. The number of core quadrats was proportional to the

length of the transect (one core quadrat per 5 meters of transect length). Whenever a core quadrat was found to contain a rare plant species designated for sampling in that pool (i.e., the "target" species), then additional quadrats were positioned contiguous with the core quadrat until the last quadrats did not contain any more of the target species.

Large branchiopod monitoring consisted of dry-season and wet-season sampling. Wet-season sampling involved collecting (dip netting), counting, and promptly returning large branchiopod specimens to the pool. Dry-season sampling involved collecting surface soil from the bottoms of dried pools and processing the soil to extract large branchiopods cysts (embryonic eggs) for subsequent identification and enumeration. Wet-season sampling was conducted four times during each of the wet-seasons at roughly 30-day intervals. Sampling was random stratified and semi-quantitative.

Water quality sampling was conducted from December 1997 to April 1997 in pools both grazed and ungrazed by livestock. Parameters monitored within the eight pools sampled included nitrite and nitrate, DO, pH, and water temperature.

Lassen, Big Pool, Safe, and Barn Pastures were grazed periodically throughout the study. All pastures were burned at least once. Grazing and burning effects were tested across pastures and experimental plots using a fixed-block design and analyzed using the Mann-Whitney test. One pasture (Werlitzer Pasture) was left ungrazed as a control.

Pasture-wide monitoring indicated that prior to the reintroduction of livestock grazing in 1996, the total number of plant species varied slightly among pastures (Barn 55, Big Pool 67, Lassen 49, Safe 63, and Wurlitzer 61). With the exception of the Lassen pasture, the number of plant species (derived from pasture-wide sampling) declined over the course of the study (Barn 55 to 44, Big Pool 67 to 44, Lassen 49 to 53, Safe 63 to 46, and Wurlitzer 61 to 35). Similarly, the mean percent relative cover of native plant species (hereafter referred to as %RCNS) (derived from pasture-wide sampling) occurring in each pasture declined over the course of the study (although in some cases not significantly) (Barn $_{n=17, 27,}$ 30.63 and 13.76, p = 0.0283; Lassen $_{n=28, 30}$ 21,40 and 8.57, p = 0.2830; Big Pool $_{n=33, 23,}$ 41.80, 16.93, p = 0.0002; and Wurlitzer $_{n=28, 25}$ 38.75 and 2.24, p = 0.0000).

Paired-plot data indicated that, with the exception of the ungrazed plot in the Barn pasture and the grazed plot in the Lassen pasture, the mean %RCNS (although in some cases not significant) declined within all of the pastures' grazed and ungrazed plots (Barn [grazed] $_{n=6, 8}$ 21.92 and 10.94, p = 0.7469; Lassen [ungrazed] $_{n=6, 8}$ 16.10 and 0.80, p = 0.3886; Big Pool [ungrazed] $_{n=8,8}$ 49.30 and 19.15, p = 0.0406; Safe [grazed] $_{n=8, 8}$ 29.80 and 6.67, p = 0.1279; and Safe [ungrazed] $_{n=8, 8}$ 27.4 0 and 4.81, p = 0.0013). In contrast, the data concerning differences between mean %RCNS within burned plots among and between years was ambiguous. However, for the Wurlitzer pasture where repeated burning in the absence of grazing was applied, data indicated a significant decrease in the %RCNS of upland vegetation over the course of the study ($_{n=28,25}$ 38.75 and 2.24, p = 0.0000).

Data regarding rare plants and large branchiopods population changes between treatments within and among years were inconclusive. Inconclusive results are largely the result of an inadequate statistical design for these groups.

In most instances, the mean %RCNS collected within vernal pools and swales did not change significantly between years regardless of treatment effects within plots (Barn [grazed] $_{n=5,8}$ 7.90 and 100.00, $p = 0.0000$; Barn [ungrazed] $_{n=8,8}$ 100.00 and 99.95, $p = 1.0000$; Lassen [grazed] $_{n=8,8}$ 97.40 and 100.00, $p = 1.0000$; Lassen [ungrazed] $_{n=8,8}$ 96.80 and 99.90, $p = 1.000$; Big pool [grazed] $_{n=8,8}$ 55.00 and 33.50, $p = 0.3442$; Big Pool [ungrazed] $_{n=8,8}$ 22.89 and 55.90, $p = 0.2890$; Safe [grazed] $_{n=8,8}$ 100.00 and 100.00, $p = 1.000$; Safe [ungrazed] $_{n=8,8}$ 100.00 and 100.00, $p = 1.000$; Wurlitzer [ungrazed] $_{n=8,8}$ 34.90 and 23.55, $p = 0.5635$).

The overall number of plant species (obtained from pasture-wide monitoring) including the noxious weeds medusa-head grass and yellow starthistle, within the upland habitats declined over the course of the study. This decline in species richness could not be directly attributed to the effects of grazing or burning or a combination thereof and may be a weather-related phenomenon. The study was conducted over El Nino weather conditions and a increase in water loving ryegrass was recorded over much of the preserve. The decline in native species over all treatments is likely due to increased rainfall. The decline in the abundance of medusa-head grass and yellow starthistle may be attributable to burning. This observation is consistent with the results of other researcher's studies on prescribed fire effects on noxious weeds. Nonetheless, plant species abundances and their relative cover within vernal pool and vernal swale habitats did not change during the course of study regardless of treatment effects.

Recommendations are made to help guide managers to develop an effective and cost efficient monitoring strategy for Vina Plains Preserve. The pasture wide sampling provided the most useful information in regards to preserve management. Perhaps of more importance to future monitoring designs is the discovery of which methods failed to provide useful information. Of particular importance to managers is the finding that it was not possible to sample many of the parameters chosen in this study at a sufficient intensity to overcome the extreme variability that climate, soils, and topography interject into the data. The sample designs and stratification chosen were not able to isolate enough of the variability in the data to enable testing of the principle hypotheses. It is important that a future monitoring design for this property provides "real time" input into adaptive management of the Preserve. To accomplish effective adaptive management the monitoring design must be simplified to the point where statistical inference in the short run is not possible or even needed.

INTRODUCTION

The Nature Conservancy (TNC) purchased its first parcel of land at Vina Plains in Tehama County, California in 1982. The land was in reasonably good shape and it had grazed by livestock for many years. At that time it was generally believed by "conservationists" that livestock grazing was detrimental to the Conservancy's mission of preserving native species diversity. It was this belief that led TNC to experimentally remove livestock from the Preserve and monitor the results.

In 1982, The Nature Conservancy removed a single pasture from grazing to monitor the response of the grassland and vernal pools. In 1988, it appeared that livestock removal was benefiting native plant species so all grazing was halted over the entire Preserve. In 1995, monitoring indicated that the Preserve was undergoing 2 major changes. First, the lack of grazing had allowed the previously compacted soil time to recover. Gophers mixed the soil and it was now much softer than surrounding lands that were grazed. Secondly, annual grass thatch had begun to accumulate. As a result several weed species were increasing and the cover of annual wildflowers was decreasing. One weed, medusahead (*Taeniatherum caput-medusae*), had become particularly troublesome and in some areas began to dominate the Preserve. Frequency sampling in the spring of 1995 revealed nearly twice as much medusahead on the preserve compared to the adjacent grazed property (Pollak 1995). Medusahead, if left uncontrolled, could threaten the ecological health of a number of native plant populations.

In response to the increasing threat of medusahead TNC managers reintroduced cattle to a single pasture in the spring of 1996, and then monitored the impacts to the native flora and the medusahead (Dittes and Guardino 1996). The next step was to understand the use of prescribed fire as a control for medusahead. Based on a review of the literature and experiments conducted by TNC at Jepson Prairie (Pollack and Kan 1998), TNC hypothesized that if medusahead were burned in the late spring, just as the plants are ripening seed, then next year's seed crop could be greatly reduced. In the spring of 1996, two units at the Preserve were burned, one in late May and the other in early June. Preliminary results indicated that both the reintroduction of fire and grazing were reducing weeds and having a positive effect on native plant species.

In response to the positive results seen after the reintroduction of fire and grazing TNC devised a new management program for the Preserve, which included rotational grazing, and periodic burning. With the help of funding by the EPA and TNC, a study was designed to monitor the reintroduction of fire and grazing to the Vina Plains landscape. To meet the study's primary goal, the following questions were addressed: Does grazing and fire have a significant effect (i.e., change in species abundance or richness) on vernal pool grassland ecosystems? In particular, does grazing and fire have a significant effect on the:

- Species richness of native and nonnative plants,
- Percent cover of native and nonnative plants,
- Frequency of native and nonnative plants, .

- Concentration of rare large branchiopods (fairy and tadpole shrimp); and
- Water quality of the vernal pools occurring at the Preserve?

The primary goal of this study was to determine the effects of grazing and prescribed burning on the health of the Vina Plain ecosystem from the management plan established by TNC. The secondary goal of this study was develop an exportable monitoring framework that will allow land managers to assess the impacts of grazing and prescribed burning on the health of similar grasslands and vernal pool ecosystems throughout California's northern Central Valley.

The following study evaluates the methods and results of monitoring the upland vegetation, spring and summer vernal pool flora, large branchiopods, and water quality over a period of three years to determine responses under the different grazing and burning regimes. From the study results the Preserve Management Plan will be modified and a long term monitoring program designed. The monitoring program will provide the necessary input to develop an adaptive management program at the Preserve. TNC will work in collaboration with public and local private partners to develop plans and implement a management program designed to improve forage quality and native species composition, while maintaining rare species populations and controlling noxious weeds. TNC's goal is to transfer successful management and monitoring techniques to other important vernal pool systems in the northern Central Valley.

STUDY SITE

The Preserve was established in 1982 by TNC, to protect a unique example of a vernal pool grassland ecosystem classified by Holland (1986) as a Northern Hardpan Vernal Pool Grassland. The Preserve is situated on a low terrace along the eastern edge of the Great Central Valley about 24 km (15 mi) north of the town of Chico (Figure 1). The Preserve's current size is 1,862 ha (4,600 ac). This study was primarily conducted on 619 ha (1,529 ac) located east of State Highway 99 and northwest of Singer Creek (Figure 2). This portion of the Preserve has been divided by fences into four pastures: Barn, Big Pool, Lassen, and Safe (Figure 3). A fifth and separate pasture (Wurlitzer) was also utilized for study, located west of State Highway 99 (Figure 3).

The study site is characterized by gently rolling hills and relatively flat valleys oriented in a north-south direction varying in elevation from 69 m (225 ft) in the northwest to less than 61 m (200 ft) in the south. The study site's climate, soils, hydrology, and communities are described below.

The climate in Tehama County is typical of the Central Valley of California with relatively cool wet winters and hot dry summers. Temperatures rarely fall below freezing in the winter for any significant duration; however, temperatures frequently exceed 35° Celsius (C) (95° Fahrenheit [F]) during the summer. In Red Bluff, approximately 40 km (25 mi) north of the study site the average annual high temperature is 24° C (75.5° F) and the average annual low is 10° C (50.5° F). During the summer months, it is not

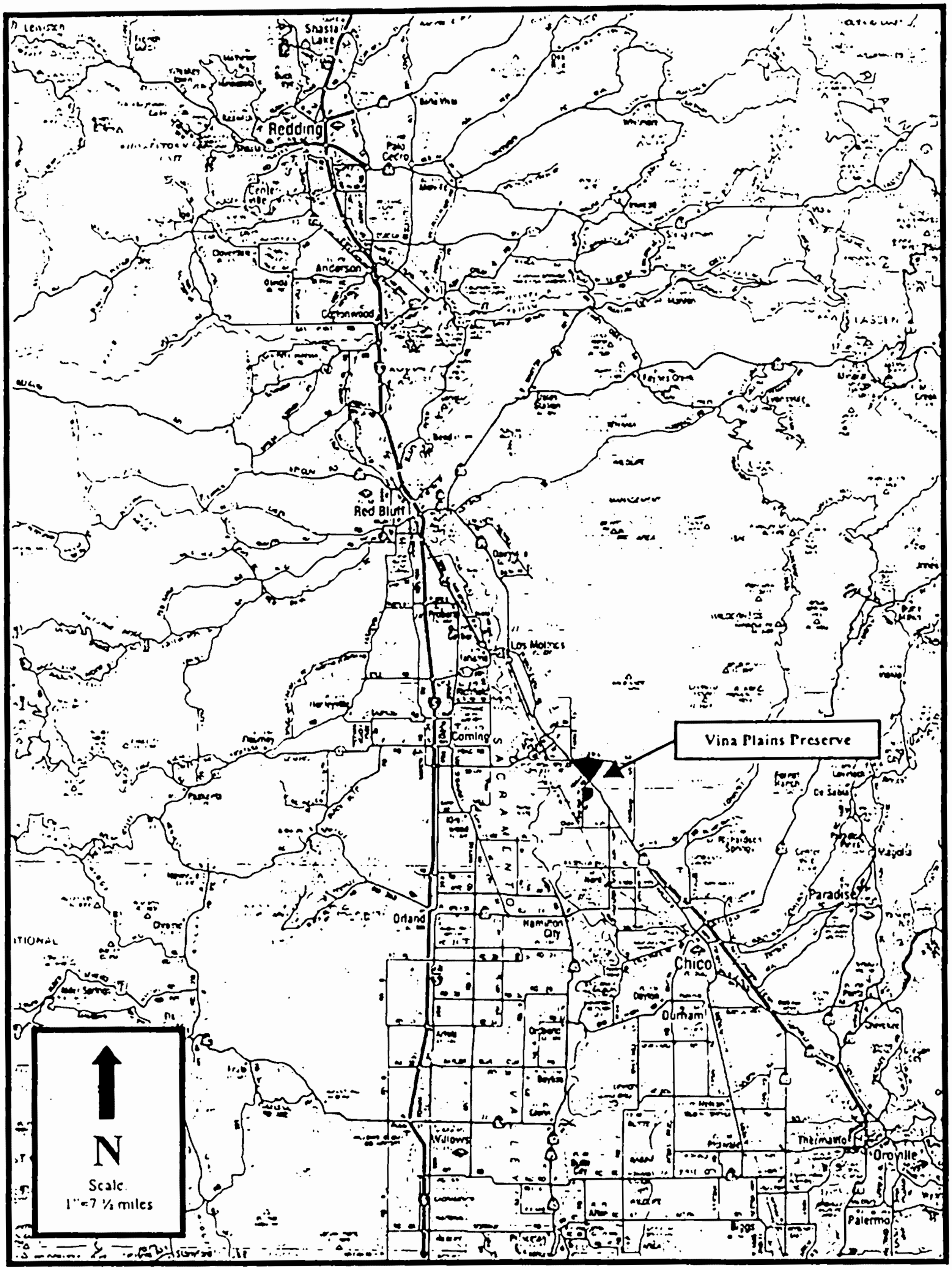


Figure 1. Vicinity of the Vina Plains Preserve.

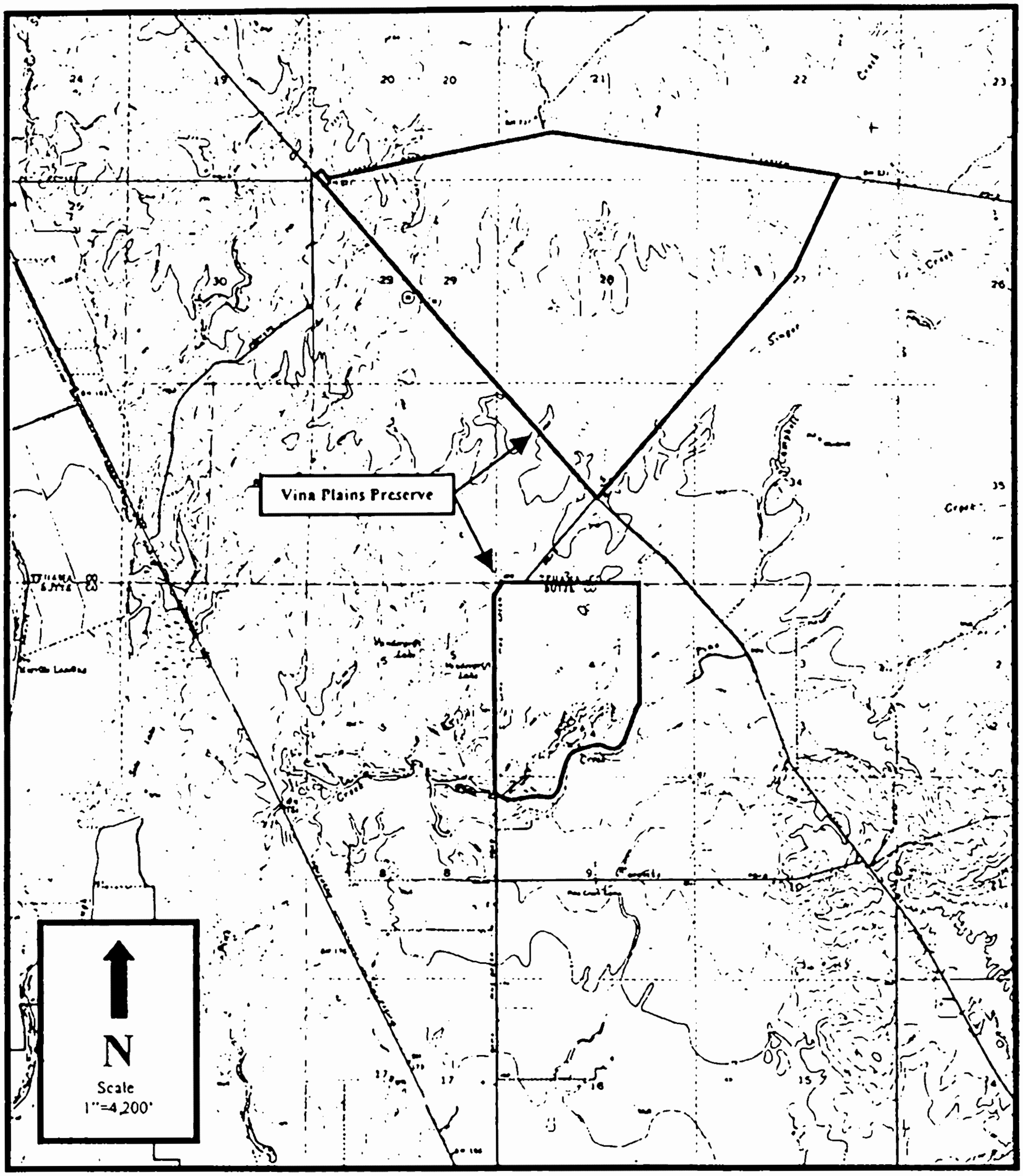


Figure 2. Location of the Vina Plains Preserve
(Source Vina, Richardson Springs, Nord and Foster Island USGS 7 ½ minute Quadrangle Maps)

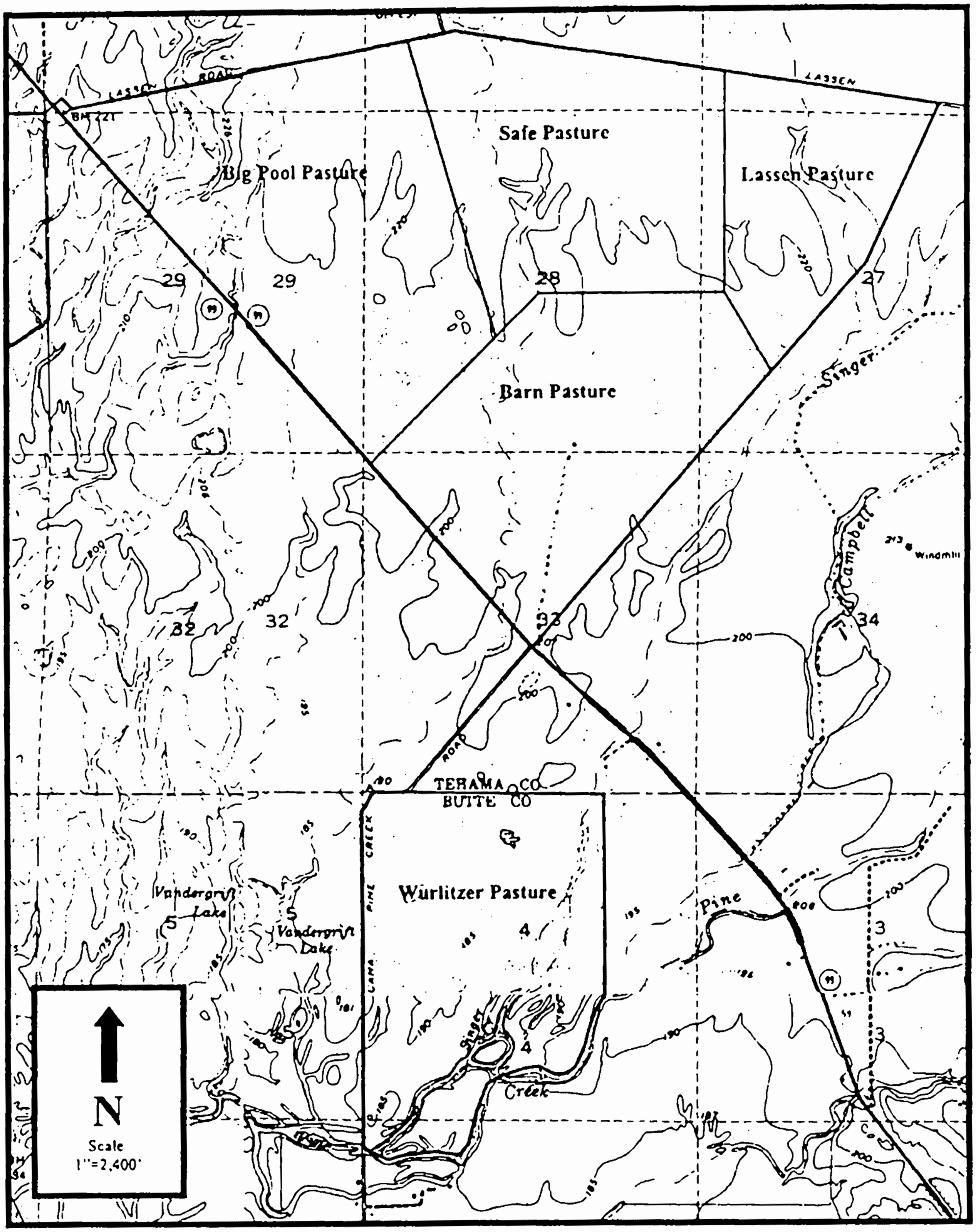


Figure 3. Vina Plains Preserve Pasture Location
(Source Vina, Richardson Springs, Nord and Foster Island USGS 7 ½ minute Quadrangle Maps)

uncommon to have temperatures in excess of 35° C for several successive days. The average annual rainfall is approximately 53 cm (21 in) with the majority of the rain coming in the winter months (Soil Conservation Service 1967).

The Soil Survey of Tehama County (Soil Conservation Service 1967) indicates that there are three distinct soil series within the study site: Tuscan, Anita, and Keefer. The erosion hazard of these soils is considered slight. Each of these soil series is described briefly below.

Tuscan Series - These soils are well drained; however, permeability is very slow, allowing for vernal pools and swales to form in low-lying areas. Soil texture at the surface varies from clay loam to loam, underneath which is a cobbly clay loam layer that impedes water infiltration, below which is an indurated hardpan that further impedes water infiltration. (Soil Conservation Service 1967)

Anita Series - These soils are nearly level, imperfectly drained soils that formed in basins or seeped areas of the old stream terraces. Because of the poorly drained nature of the Anita soil, it generally supports seasonal wetlands (i.e., clay flats, vernal pools, and vernal swales). The surface layer of the Anita series is dark clay beneath which is a cemented hardpan. Vegetation tends to remain green much later into the spring and summer due to the high water holding capacity of the clay soil. (Soil Conservation Service 1967)

Keefers Series - These are nearly level to gently sloping, well-drained soils formed from old alluvium. Surface texture is a loam, underlain by very cobbly clay. Vegetation is mostly annual grasses and forbs, but does include scattered oaks. (Soil Conservation Service 1967)

Because of the micro-topography and impervious layers that underlay the majority of the study sites soils, precipitation that does not infiltrate the uplands nor intercepted by the wetland basins, flows in sheets downslope to numerous swales and intermittent drainages. These water conveyance systems flow intermittently during and for short periods after the rainy season. The majority of these drainages flow in a southwest direction off site. The largest of these drainages, Singer Creek has been dammed to create a small reservoir (resulting in emergent marsh habitat) that historically served as a livestock watering area at the Wurlitzer property.

The combination of the study sites' climate, hydrology, and soils supports community types associated with the Central Valley floor. Community types in the study site are characteristic of the region with annual grassland being the predominant community type followed by clay flat, vernal pool, vernal swale, intermittent drainage, and emergent marsh. Each of the community types occurring in the study site is described in detail below.

Annual grassland is the predominant community type at the study site and is typically found on high topographic positions with convex slopes. Annual grasslands intergrades with all the community types described below. Non-native annual grasses dominate this herbaceous community type with some native perennial grasses and native and non-native forbs also present. Dominant non-native grasses include soft chess (*Bromus hordeaceus)*, ripgut brome (*Bromus diandrus*), Italian ryegrass *(Lolium multiflorum*), and medusa-head grass. Small stands of purple needlegrass (*Nasella pulchra*), a native perennial grass are present in small clusters scattered through the study site, but mainly occur on the margins of the clay flats and drainages. Native forbs found in California annual grassland series include blue dicks (*Dichelostemma capitatum*), bicolored lupine (*Lupinus bicolor*), tidy-tips (*Layia fremontii*), butter and eggs (*Tryphysaria eriantha*), and California goldfields (*Lasthenia californica*). Non-native forbs within the study site include filarees (*Erodium* spp.), yellow starthistle (*Centaurea solstitialis*), wild lettuce (*Lactuca serriola*), wild radish (*Raphanus sativus*), and wild mustards (*Brassica* spp.).

Perhaps the most unique habitat type in the study site, vernal pools are prominent features in the otherwise topographically featureless landscape. Vernal pools occur within enclosed basins within the annual grasslands and clays, and within deep depressions or drainages. Vernal pools are seasonally flooded landscape depressions where shallow water ponds because of limitations to surface (closed basin) and subsurface drainage. Subsurface drainage is inhibited by soil layers that greatly slow the downward infiltration of water. Vernal pools support a distinct association of plant species that are adapted to periodic or continuous inundation during the wet season, and the absence of either ponded water or saturated soil during the dry season.

Vernal pools pond water throughout the winter months and typically dry by mid to late spring and remain dry until the onset of fall and winter rains. The pools have a unique flora adapted to the harsh cycle of winter inundation and summer drought. Vernal pools at the study site support species typical of the Sacramento Valley vernal pool flora. The pool basins at the study site are dominated by coyote thistle (*Eryngium castrense*), Fremont's goldfields (*Lasthenia fremontii*), small stipitate popcorn flower (*Plagiobothrys stipitatus* var. *micranthus*), woolly marbles (*Psilocarphus brevissimus*), common spike rush (*Eleocharis macrostachya*), bractless hedge-hyssop (*Gratiola ebracteata*), toad rush (*Juncus bufonius*), water-starwort (*Callitriache marginata*), and quillwort (*Isoetes* sp.).

Vernal pool margins support vegetation that is transitional between the annual grasslands and vernal pools. Typical species of vernal pool margins at the study site include Mediterranean barley (*Hordeum marinum* ssp. *gussoneanum*), Italian ryegrass, coyote thistle, six-weeks fescue (*Vulpia bromoides*), toad rush, and spikeweed (*Hemizonia fitchii*).

Several of the vernal pools at the study site have very large surface areas (5,475 - 30,362 m) (Syradhl 1993) and occur within the Anita Clay soil series. Because of the large size and substrate material theses pools are very different in terms of floral and fauna inhabitants from the rest of the vernal pools on site and therefore are referred to as "playa pools". The playa pools pond water for up to three months longer than the other vernal pools onsite. The relative flat and treeless topography and large fetch of the playa pools allow the winter winds to entrain clay particles within the water column. The high turbidity this creates does not allow for much light penetration into the water column. Therefore plant species occupying these pools are mostly annuals which are relying on energy reserves from endosperm (i.e., seed) during their aquatic phase. After draw down of the pool the plants are exposed to direct sunlight allowing photosynthesis to be more efficient. Hence, due to the harsh condition presented by these playa pools the plants occurring are sparsely distributed.

Vernal swales are broad, shallow, poorly defined drainage ways that convey water primarily during and shortly after rain events. At the study site vernal swales connect to vernal pools, filling or draining them, while others generally meander through the annual grassland and vernal pool complexes but do not physically connect with individual vernal pools. Surface runoff collects in swales, wetting and saturating the soil for short periods. Often, swales drain into intermittent drainages (described below).

Typical plants dominating the vernal swales onsite include many of the same species listed above for vernal pool margins and include Mediterranean barley, coyote thistle, Italian ryegrass, toad rush, six-weeks fescue, hairgrass, little quaking grass (*Briza minor*), and virgate tarweed (*Holocarpha virgata*).

Clay flats are grass and forb dominated areas with heavy clay soils (Anita soil series) that retain moisture longer than the surrounding upland soils. The topographic setting of clay flats at the study site varies from nearly level to gently sloping. Nearly level sites tend to be wetter and are dominated by Italian ryegrass in comparison to the gently sloping sites which tend to have fewer annual grasses with more showy forbs such as Fremont's zigadene (*Zigadenus fremontii*) and soap-root (*Chlorogalum pomeridianum*). This vegetation type is often transitional between upland annual grasslands and wetland habitats such as vernal swales or vernal pools.

Drainages are unvegetated or sparsely vegetated (1-10% total cover) watercourses with well-defined beds and banks derived from erosion. The drainages are gently sloped and convey surface water during the rainy season through late spring (occasionally summer) but are usually dry by fall (except for the occasional deep pool within its basin). The drainages in the study site vary in size, slope, and degree of incision. When vegetated, ephemeral drainages support a sparse assemblage of plant species associated with vernal swales and annual grasslands described above.

Emergent marsh in the study site is characterized by a prevalence of perennial monocots, which grow in permanently or semi-permanently flooded or saturated soil that is associated with freshwater. Emergent marsh occurs in the Wurlitzer property and has resulted in the impoundment of Singer Creek with a earthen dam creating a reservoir.

The emergent marsh on the study site is mostly dominated by common spikerush (*Elocharis macrostachya*); however, cattails (*Typha latifolia, T angustifolia*), water plantain (*Alisma plantago-aquatica*), and burhead (*Echinodorus berteroi*) also occur in less numbers.

The Preserve is home to many rare and endangered species. At present, eight federally or state listed species are resident at the Preserve. Most of the rare species are associated with vernal pools, in particular the playa pools. Of particular interest are the federally listed (under the federal Endangered Species Act) Hoover's spurge (*Chamaesyce hooveri*), hairy orcutt grass (*Orcuttia pilosa*), slender orcutt grass (*O. tenuis*), and Greene's tuctoria (*Tuctoria greenei*). These rare plants occupied the largest of the vernal pools onsite. Six large brachiopods are known to occur in the Preserve's vernal pools and swales: vernal pool fairy shrimp (*Branchinecta lynchi*), vernal pool tadpole shrimp (*Lepidurus packardi*), Conservancy fairy shrimp (*Branchinecta conservatio*), California clam shrimp (*Cyzicus californicus*), lentil clam shrimp (*Lynceus branchiurus*), and California linderiella (*Linderiella occidentalis*). The Conservancy fairy shrimp and vernal pool tadpole shrimp are listed as endangered while the vernal pool fairy shrimp is listed as threatened under the federal Endangered Species Act. California linderiella, lentil clam shrimp, and California clam shrimp have no official status. Conservancy fairy shrimp occurring at the Preserve are limited to the largest pools. In contrast, vernal pool fairy shrimp have been found to occur only in the smaller pools. California linderiella and vernal pool tadpole shrimp occur in some of the large pools and in a few of the smaller ones. California clam shrimp occur in some of the larger vernal pools.

Large branchiopods occur mostly in seasonal wetlands that dry up during the summer months, and produce spherical-shaped cysts (embryonic eggs) that lie dormant during the dry season at the bottom of the pool. The eggs are resistant to desiccation and extreme temperatures, and may remain dormant as a "cyst bank" through many years of wetting cycles. When the rains return, the pool basin begins to fill and the appropriate conditions present, some eggs hatch and the young quickly go through a series of "molts" until reaching maturity. Successful large branchiopods can hatch, mature, mate, and lay eggs before the pool dries.

METHODS AND MATERIALS

GRAZING AND PRESCRIBED FIRE REGIME

Livestock grazing was reintroduced in 1996 to four pastures at the Preserve (i.e., Barn, Big Pool, Lassen, and Safe). Livestock grazing was limited to cow-calf pairs, cows, and a limited number of bulls during the "green feed" period extending roughly from mid-November to mid-April of the following year. Because the 1997-1998 winter was particularly wet (El Nino), grazing was continued into early May. Cattle were rotated between pastures during the grazing period to minimize trampling effects and to ensure a balanced pattern of use. The assumption was that cattle represent the major plant consumer at the Preserve. Table 1 shows the schedule of grazing within each pasture.

Table 1. Grazing Rotation at the Vina Plains Preserve, 1996-1999

		1996-1997			1997-1998			1998-1999		
Pasture[1]	Size (Acres)	Fall	Winter	Spring	Fall	Winter	Spring	Fall	Winter	Spring
Barn	412	G	G		G	G		G		
Big Pool	529		G	G			G		G	G
Lassen	240		G	G	G	G			G	
Safe	348		G	G		G	G		G	

G=grazed
Fall=Nov 15-Dec 31
Winter=Jan 1- Feb 28
Spring=Mar 1-May 30
[1] Wurlitzer pasture was not grazed

Prescribed fire was initiated in late spring of 1996 and was timed to correspond with early seed maturation in medusahead grass. Burning medusahead grass when the seed heads are beginning to mature (before seed break) has resulted in control of the grass elsewhere in the state (Pollack and Kan 1998). Table 2 shows the prescribed burning schedule.

Table 2. Prescribed Burning at the Vina Plains Preserve, 1996-1999

Pasture	1996	1997	1998	1999
Barn	B[1]	--	B[2]	--
Big Pool	B	--	--	--
Lassen	--	--	--	B[3]
Safe	--	--	B	--
Wurlitzer	B	B	B	--

B = burned

[1] northern 1/3 burned

[2] southern 1/3 burned

[3] burned following vegetation monitoring

Within grazed/ungrazed and burned/unburned treatments, upland vegetation, rare plants, swale and pool vegetation, large branchiopods, and water quality were studied and described below.

UPLAND VEGETATION

In 1996, a study was conducted at the Preserve to characterize the floristic composition of the Barn, Big Pool, Lassen, Safe, and Wurlitzer pastures prior to the restart of livestock grazing at the Preserve (Dittes and Guardino 1996). This study utilized sampling methods very similar to those used for pasture-wide sampling for this study (described below); however, vegetation cover data (i.e., relative vegetative cover data) was not collected. Yet, the 1996 study does contain data on species richness within the five pastures and therefore this data is included in this study and will be used to represent the pre-treatment species richness baseline condition for upland vegetation.

For this study, two types of monitoring were conducted in the upland grasslands: 1) pasture-wide monitoring and 2) experimental-plot monitoring. Pasture-wide monitoring focused on systematically sampling the upland vegetation throughout the five pastures. Experimental-plot monitoring consisted of sampling upland vegetation within grazed and ungrazed enclosures and within burned and unburned plots within these enclosures. Both monitoring techniques are further described below.

PASTURE-WIDE MONITORING

In 1997, sampling was initiated for monitoring the number of native and non-native plant species (i.e., species richness) and the percent relative cover of native species (%RCNS) across the five pastures that comprise this study. Data were collected within each pasture from quadrats that were regularly spaced along a series of evenly-spaced parallel transects (i.e., systematic sampling grid). A specified fence-line served as the baseline for each pasture with one end of the baseline serving as the starting corner for the monitoring transects (Figures 4a and 4b). Each year transects were repositioned along the baseline from a new, randomly chosen start position. Additionally, each year the starting position of the first quadrat was also determined by random number selection.

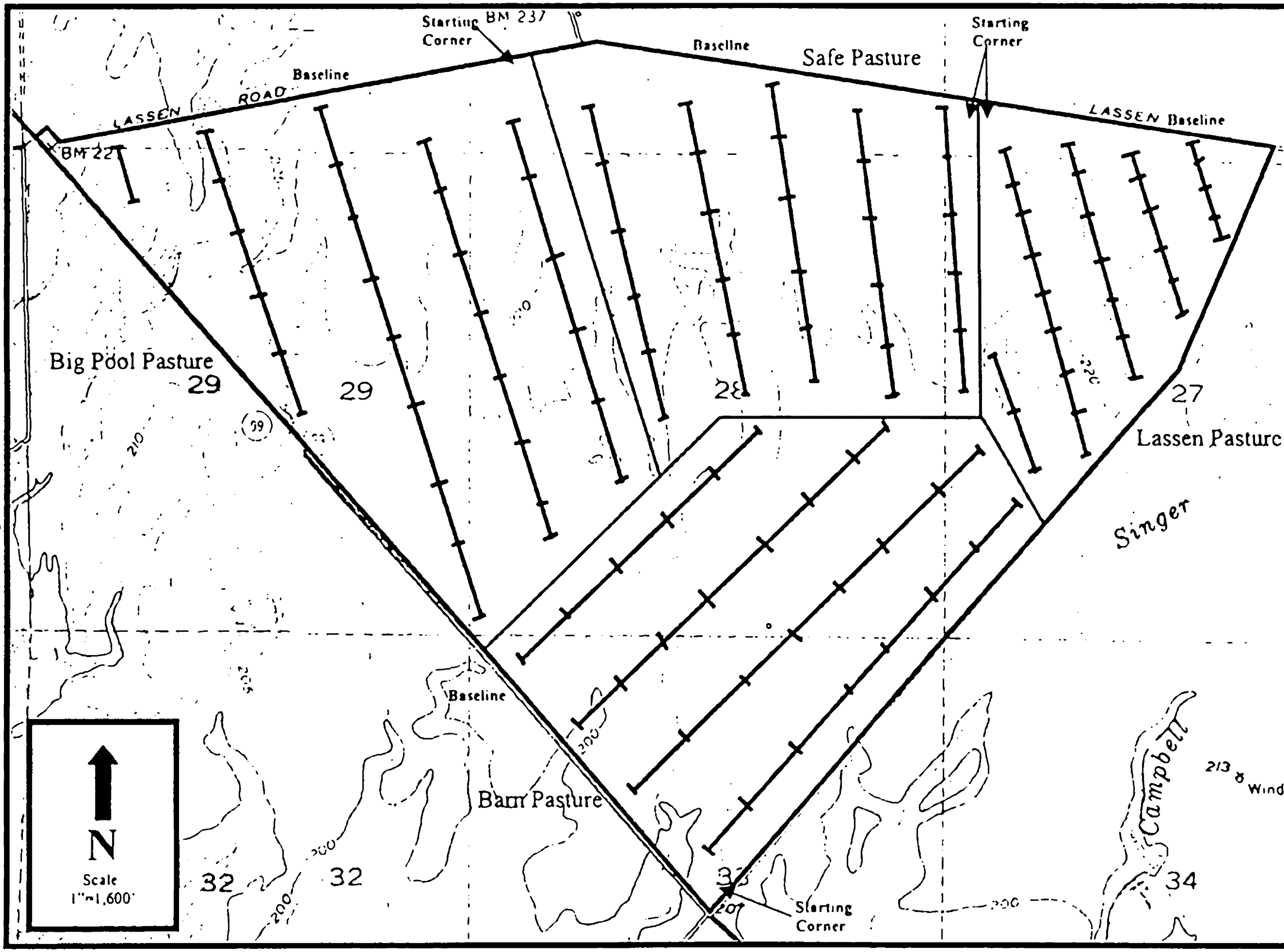


Figure 4-a. Systematic Sampling grid used on the Big Pool, Safe, Lassen, and Barn Pastures.

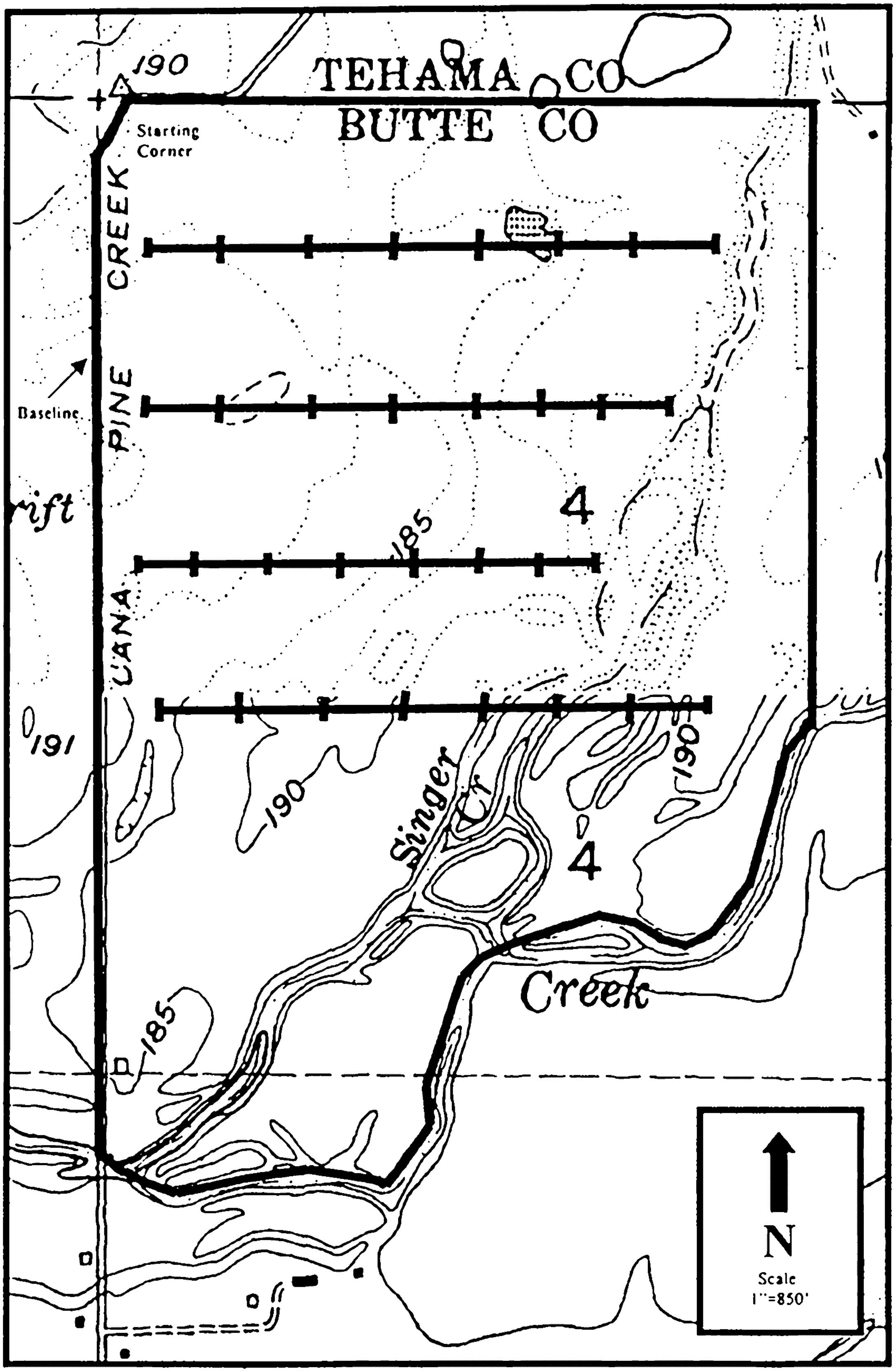


Figure 4-b. Systematic Sampling grid used on the Wurlitzer Pasture.

Distances between transects and between quadrats along transects were determined by calibrated pacing in the field. Calibration of pacing was conducted by having each monitor walk along a measuring tape for 100 meters. The numbers of paces of each monitor was then divided by 100 meters to reach an average distance (in meters) per pace. Table 3 shows the length and direction of the monitoring transects.

Table 3. Quantity, Direction, and Approximate Length of Pasture-Wide Upland Vegetation Sampling Transects

Pasture	No. of Transects	Direction	Total Length (km)
Barn	4	NE – SW	9.0
Big Pool	6	ENE –WSW	8.0
Lassen	5	NNW – SSE	5.0
Safe	5	ESE – WNW	7.2
Wurlitzer	6	E – W	3.7

Each quadrat consisted of a wire frame with the dimensions of 35 cm x 70 cm, thus having an area of 0.245 m^2. Table 4 shows the number of quadrats per transect.

Table 4. Number of Quadrats Per Transect for Each Pasture

	Sample Size[1]			
Pasture	Estimated[2]	1997[3]	1998	1999
Barn	35	17	23	27
Big Pool	35	33	25	23
Lassen	35	28	29	30
Safe	35		22	28
Wurlitzer	35	28	26	25

[1] Sample size varied between years due to those quadrats landing in wetland habitats that were bypassed.

[2] The data of Dittes and Guardino (1996) suggested that about 5-10% of the sample points for this study would land in non-upland habitat (i.e., vernal pools and swales).

[3] Data collected for Safe pasture in 1997 was lost.

Within each quadrat data on species composition and cover, RDM, and priority weed distribution was collected and discussed below.

SPECIES COMPOSITION AND COVER

The lower right-hand corner of each quadrat was placed at the position paced-off along the transect and an ocular cover class (Table 5) of each species was estimated. Additionally, the type of habitat (i.e., vernal pool, vernal swale, or annual grassland), soil (i.e., Soils Conservation Service soil series), and burning regime (i.e., burned or unburned) was noted.

Table 5. Cover Classes Used for Vegetation Sampling at the Preserve, 1997-1999

Cover Class	Percent Cover	Class Midpoint
0	0	0%
1	> 0 and 1	0.5%
2	> 1 and 5	3%
3	> 5 and 25	15%
4	> 25 and 50	38%
5	> 50 and 75	63%
6	> 75 and 95	85%
7	> 95	98%

Data concerning vegetation cover and composition were collected in the spring of 1997-1999 to correspond with peak grass flowering to maximize the number of identifiable species. Data on soil and burn type was not collected in 1997; however, it was collected in 1998 and 1999.

PRIORITY WEED MONITORING

Priority weed monitoring consisted of ocular estimates of the abundance of each priority weed species within a 6-m radius of each quadrat location. Table 6 shows the abundance classes assigned to each priority weed species.

Table 6. Abundance Classes for Priority Weed Species

Class	Relative Abundance
4	dominant (most abundant species)
3	common (greater than 10% cover)
2	occasional (present but less than 10% cover)
1	occurred nearby but outside 6-m radius
0	absent

Priority weed species meet the following criteria:

1. newly arrived and known to be invasive in similar habitats.
2. known to significantly displace native vegetation.
3. significantly modify vegetation structure or ecosystem processes.

4. control is possible with available technology and resources.

Species meeting the above stated criteria and known to occur at the Preserve were targeted during this weed abundance monitoring. The targeted weed species include:

- Tumbleweed (*Amaranthus albus*);
- Mat amaranth (*Amaranthus blitoides*);
- Yellow star-thistle (*Centaurea solstitialis*);
- Bindweed (*Convolvulus arvensis*);
- Wild lettuce (*Lactuca* spp.);
- Curly dock (*Rumex crispus*);
- Sow-thistles (*Sonchus* spp.);
- Johnson grass (*Sorghum halepense*);
- Cocklebur (*Xanthium strumarium*); and
- Medusahead grass (*Taeniatherum caput-medusae*).

The Jepson Manual Higher Plants of California (Hickman 1993) was used to determine species and native or non-native status of plants.

RESIDUAL DRY MATTER

RDM data were collected during a separate sampling period at the end of the grazing season that employed the same systematic sampling grid procedure used to collect vegetative cover and composition and priority weed abundance. RDM was estimated using a two methods: 1) ocular; and 2) clip plots. The use of both plot and ocular estimation methods provides a good estimation of actual RDM present (Guenther 1998). Ocular estimates consisted of visual estimated the biomass from 30 quadrats in each pasture. Ocular RDM estimates were based on the Wildland Solutions' *Residual Dry Matter Monitoring Photo-Guide* (Guenther 1998). This method stratifies RDM estimates into six reference classes:

1. More than 1,000 lbs./acre
2. 750-1000 lbs./acre
3. 500-750 lbs./acre
4. 250-500 lbs./acre
5. 125-250 lbs./acre
6. Less than 125 lbs./acre

Clip plot estimates entailed clipping all the vegetation within 15 plots per pasture to a stubble height of 6 mm and weighing the dried material for an estimate of biomass. Both techniques used a 35 x 35 cm quadrat frame. Materials from clip plots were placed into a labeled paper bags and transported to Chico State University laboratory for subsequent drying and weighing.

Clipped vegetation was dried in an electric oven at 70° C for at least one hour and the net weight per quadrat weighed to the nearest 10[th] of a gram, using a triple-beam balance analytical scale.

Residual dry matter (RDM) for the Preserve was collected in all monitoring years in each of the pastures except for the Wurlitzer pasture that was not monitored in 1997. RDM values are reported as pounds per acre (lbs/ac) as this is the standard unit used in annual grassland range management. RDM can be converted from lbs/ac to kilograms per hectare (kg/ha) using a conversion factor of 1.12 kg·ac / ha·lb.

No attempt to statically analyze fire and grazing effects of this pasture-wide data was conducted. However, descriptive statistics and general comparisons regarding species composition and richness, priority weed species, and thatch and bare ground were performed.

EXPERIMENTAL PLOT MONITORING

Experimental plot monitoring began in 1997 following the establishment of fenced livestock exclosures in each of the pastures (Figures 5-a and -b), with the exception of the Wurlitzer pasture, which remained ungrazed and therefore did not require an exclosure.

Monitoring of the experimental-plots consisted of collecting data on species composition and cover from randomized quadrats placed within paired grazed and ungrazed plots. The ungrazed plot was removed from livestock grazing by erecting enclosures consisting of barbwire fencing. Enclosures were established in each of the Preserve's four main pastures (Figure 5) during 1996.

To examine the effects of prescribed burning on upland and vernal pool vegetation, each of the experimental plots, was subdivided into adjacent subplots of approximately equal size where one of the subplots was randomly assigned to be protected from burning (control) and the other subplot allowed to burn (treatment) (Figures 5a and 5b). Table 7 shows the habitat types within each of the paired experimental plots and subplots and the plot sizes for each pasture.

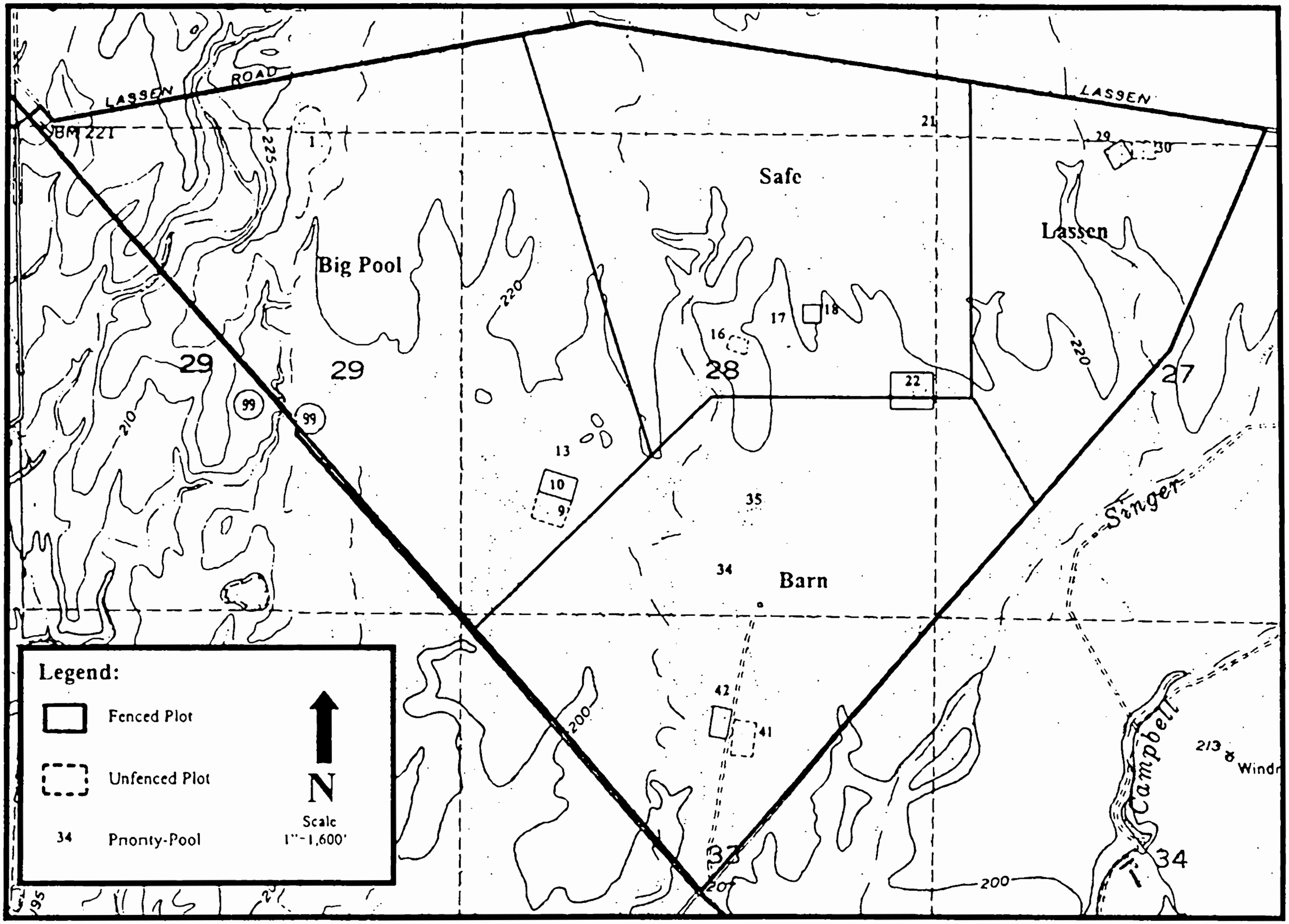


Figure 5-a. Experimental Plot and Priority-Pool Locations.

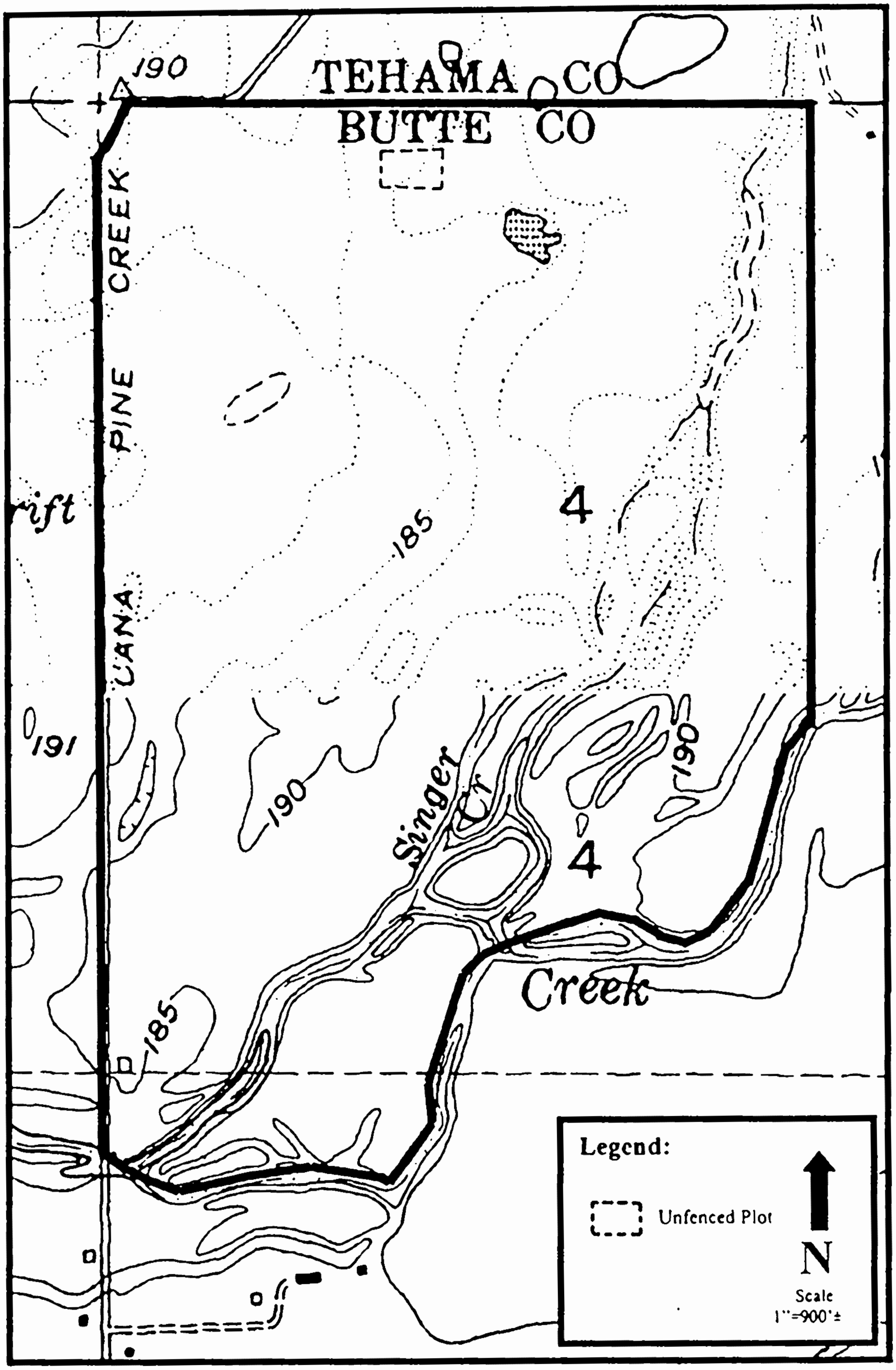


Figure 5-b. Experimental Plot – Wurlitzer Pasture.

Table 7. Habitat Types Contained Within Subplots of Paired Experimental Plots.

Pasture	Experimental Design		Habitat Types			
	Paired Plots	Subplot	Vernal Pool	Playa Pool	Vernal Swale	Upland
Barn	Fenced (43 x 70m)	A			X	X
		B	X		X	X
	Unfenced (35 x 50m)	A	X			X
		B	X			X
Big Pool	Fenced[1] (35 x 65m)	A			X	X
		B			X	X
	Unfenced (35 x 56m)	A	X		X	X
		B	X		X	X
Lassen	Fenced (50 x 70m)	A	X		X	X
		B	X		X	X
	Unfenced (50 x 70m)	A	X		X	X
		B	X		X	X
Safe	Fenced (60 x 70m)	A	X		X	X
		B	X		X	X
	Unfenced (36 x 70m)	A		X	X	X
		B		X	X	X
Wurlitzer	Unfenced	A	X		X	X
		B	X		X	X

[1] Enclosure was erected west of targeted vernal pool 13; however, the enclosure did encompass moist intermound areas and therefore was regarded as enclosing vernal swale habitat.

In Big Pool, Safe, and Barn pastures, one plot within a pair was randomly assigned to the grazing treatment and the other to the grazing control. In contrast, it was decided to exclude grazing from the west plot's pool in the Lassen pasture because water may flow downhill from the this pool into the east plot's playa pool via a narrow drainage. Hence, grazing effects on water quality (e.g., suspended sediments) would not contaminate the ungrazed control. Burning treatments within subplots are shown in Table 8.

Table 8. Burning Treatments of Subplots Within Paired Experimental Plots (fenced and unfenced)

Pasture	Experimental Design		Years		
	Paired Plot	Subplot	1997	1998	1999
Barn	Fenced	a			
		b			
	Unfenced	a			
		b	B		
		b			
Big Pool	Fenced	a			
		b		B	
	Unfenced	a			
		b		B	
		b			
Lassen	Fenced	a			B
		b			B
	Unfenced	a			
		b			
Safe	Fenced	a			
		b			
	Unfenced	a			
		b			
Wurlitzer	Unfenced	a	B		
		b	B		

B = Burned in late spring that year

To monitor vegetation composition and cover within the experimental plots eight quadrats (35 cm x 70 cm) ($0.25m^2$; Pollak and Kan 1996) were randomly placed within each plot (i.e., grazed and ungrazed) in 1997. In 1997 quadrats were not equally distributed among upland (e.g., annual grassland) and wetland habitats (e.g., vernal pool or swale). The number of quadrats was increased from eight to 16 for the 1998 and 1999 monitoring years. Sample-size analysis (Thompson 1992) of the first year's data (1997) was used to determine if quadrats needed to be added to subplots in the second year to improve precision. A rectangular shape was chosen to enhance precision (Salzer 1996). In addition, the relatively large quadrat dimension limits potential edge bias through a low perimeter ratio. Of the 16 quadrats sampled, eight were randomly placed in upland habitats and eight randomly placed in swale and/or swale pool habitats. Placement of quadrats was not stratified between subplots within a plot.

Quadrat placement randomization was accomplished by selecting a long-axis of each experimental plot (Figure 6) as a baseline and dividing it into eight equal length segments. Within each of the eight segments a sampling transect was extended perpendicularly into the plot from a randomly selected location within each baseline segment (Figure 6). Quadrats were then randomly positioned within each habitat along the sampling transects based on values derived from a random number table (Zar 1996).

The data collected regarding upland vegetation was the same as that collected for pasture wide monitoring. The only difference between the experimental plots and the pasture wide monitoring was the sampling design.

This paired experimental plot design allowed the following hypotheses to be tested:

H1. Prescribed burning increases the abundance of native species in the ungrazed experimental plots of Barn, Big Pool, Lassen, Safe, and Wurlitzer pasture

H2. Prescribed burning increases the abundance of native species in the grazed experimental plots of Barn, Big Pool, Lassen and Safe pastures.

H3. Cattle grazing increases the abundance of native species in the experimental plots in Barn, Big Pool, Lassen, and Safe pastures.

H4. Within Barn, Big Pool, Lassen, and Safe experimental plots, the increase in the abundance of native species under cattle grazing and prescribed burning in combination is greater than the sum of these practices' separate effects.

Because grazing controls and treatments were not randomly assigned to plots within the Lassen pasture, the data for grazing effects and grazing x burning effect could not be analyzed as if all assignments of grazing controls and treatments were random (i.e., we cannot infer to the larger population of all possible grazing control and treatment randomizations). So, rather than providing measures of statistical significance for plots within the Lassen pasture, means and standard deviations of %RCNS will be provided for the following:

- Grazed plots (burned and unburned combined),
- Ungrazed plots (burned and unburned combined),
- Burned grazed plots,

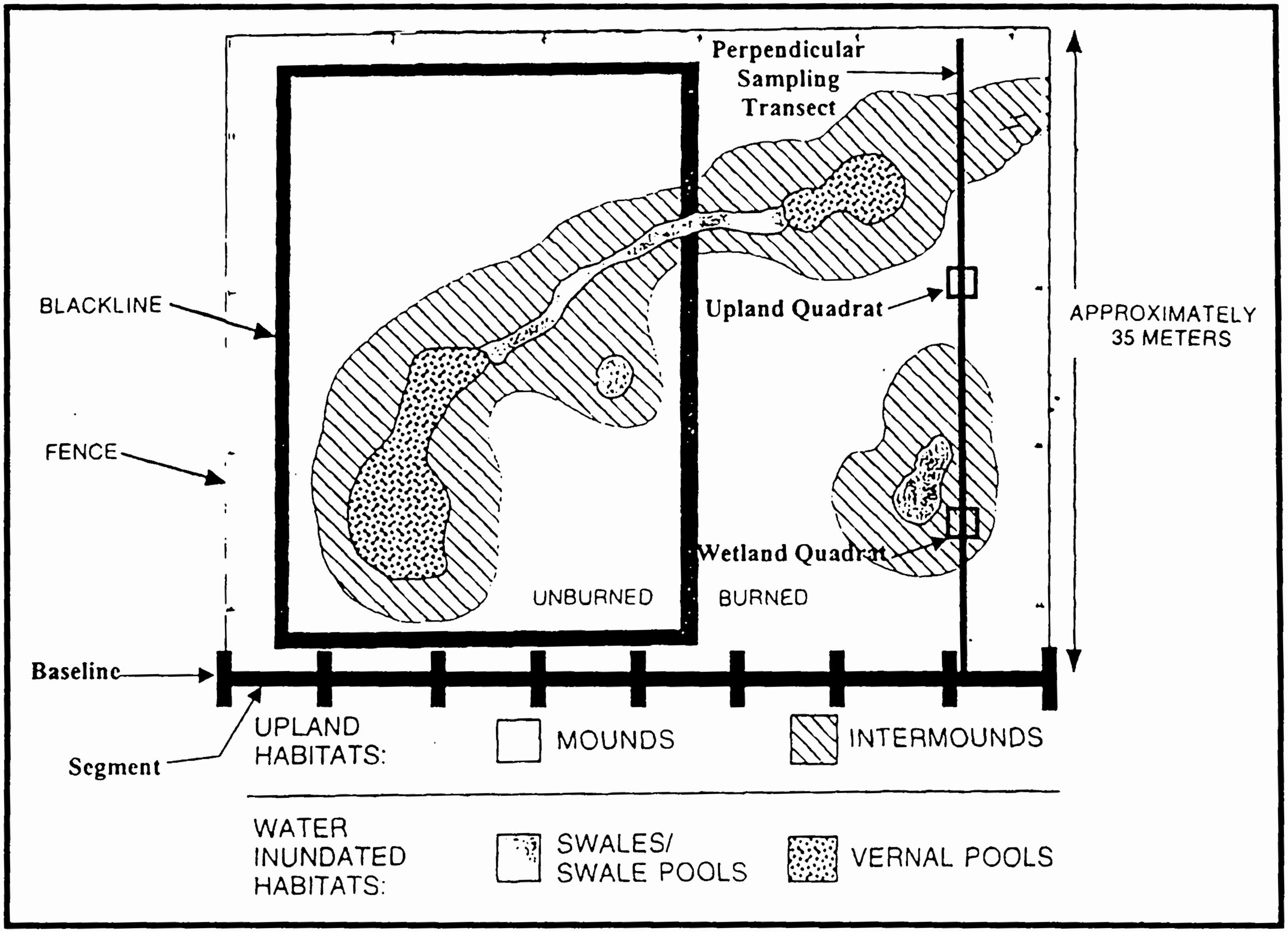


Figure 6. Experimental Plot sampling configuration at Vina Plains Preserve.

- Unburned grazed plots,
- Burned ungrazed plots, and
- Unburned ungrazed plots.

In contrast, burned and unburned conditions were randomly assigned to subplots, enabling specific hypotheses tests about burning effects (hypothesis H1, H2, and H4). The data on plant-species composition from the experimental subplots was analyzed across years and pastures as two separate, randomized complete fixed-block designs, one for the grazed plots and another for the ungrazed plots. Because prescribed burning was applied in a few preselected years and within a few pastures in different years (Table 8). This constraint has two consequences.

1. To examine burning specific effects, the change in %RCNS between consecutive pre-burn and post-burn spring surveys will serve as the dependent variable in the analyses.

2. In order to examine the impacts of late spring burning on the subsequent year's spring species composition, data from experimental plots burned in different years were analyzed. Four fixed-blocks are as follows (Table 8): 1) Barn unfenced experimental plot burned in 1997, 2) Lassen pasture's fenced experimental plot burned in 1999, 3) Big Pool pasture's experimental plots burned in 1998, and 4) Wurlitzer pasture's experimental plots burned in 1997. Burning treatments were not conducted in the Safe Pasture.

Contrary to common practice in ecological research, these blocks were treated as a fixed factor rather than as a random factor, because the pastures and years examined were not a random sample of pasture/burn-year combinations drawn from some larger, total population of pastures and years. Under this design configuration, all block x treatment interactions are assumed to be negligible. Data violating this assumption, will have inflated error terms, thus making hypothesis testing conservative.

During the 1997 survey season, all data regarding upland vegetation was directly entered into Lotus spreadsheets using Hewlett Packard palmtops in the field. Data was uploaded from palmtops to a desktop computer at the end of each day of field measurements. Data was printed out each day and checked for errors.

Field data collected from the 1998 and 1999 survey season regarding upland vegetation was recorded on standardized data sheets. Field data sheets were examined for errors before moving on to the next quadrat so that corrections could be made while on site. Field data was entered from field data sheets into a Lotus spreadsheet.

1997 surveys were conducted by Kathleen Berry-Garrett, Caroline Warren, and Garrett Gibson (independent consultants); 1998 and 1999 surveys were conducted by John Hale and Matt Gause of May Consulting Services.

Percent relative cover of native species (%RCNS) was calculated for each quadrat within a pasture and experimental plot as the sum of the cover estimates (using cover class midpoints shown in Table 5) of native species divided by the sum of the cover estimates for all species.

Residual dry matter (RDM) was estimated by converting the net dry weight in grams of clipped vegetation to kilograms per hectare of RDM. Range managers typically employ a 0.96 square foot circular frame within which to clip litter and vegetation for RDM sampling. The vegetation clipped from within the circular frame is then weighed, and its weight in grams and multiplied by 100 to arrive at pounds per acre RDM (Geunther 1998). This convenient empirical formula is widely utilized, therefore data collected at the Preserve using the 35 cm square frame was adjusted for the difference in area between the Preserve's sampling frame and a square foot frame. The following formula was used to arrive at pounds per acre RDM: dry net weight in grams x 0.729 x 100.

Descriptive statistics including means, medians, standard deviations, standard errors, and interquartile ranges regarding %RCNS, thatch, bareground, per pasture and plot were calculated using Microsoft Excel 2000 and Minitab release 12.2 statistical software package (Minitab Inc. 1998). Descriptive statistics for RDM were only calculated for pastures as a whole.

Treatment effects (i.e., burning and grazing) were tested across pastures using a fixed-block design and analyzed using the two-sample t-test or Mann-Whitney test (Minitab Inc. 1998). The Mann-Whitney test was used when normally distributed data could not be assumed (Daniel 1990, Edgington 1995).

Although multivariate techniques (e.g., MANOVA) could have been used, results would be more explicable if separate analyses are run for %RCNS, thatch, and bareground. Type I error rate was controlled at a =.10 across the four burning main-effect hypotheses using sequential Bonferroni adjustment (Holm 1977). Type I error rate will be set to 10% in order to improve the power of the analysis given that sample sizes are not large.

RARE PLANTS

Monitoring rare plants consisted of determining density measurement to estimate population size. Because density measurements are time consuming and playa pools are large, only a moderate number of pools could be sampled. Rare plant monitoring consisted of two types: 1) priority-pool monitoring and 2) experimental pool monitoring described below.

PRIORITY-POOL MONITORING

Four pools that appear to consistently support the largest populations of rare plants (Alexander and Schlising 1996) were chosen for priority-pool monitoring in 1997 (Table 9). Three additional pools were added and one deleted in 1998 and 1999 (Table 9)

Table 9 Pools Chosen for Priority-Pool Monitoring

Pasture	Pools Sampled 1997	1998 & 1999	Species Supported[1]
Safe	17	17	*Chamaesyce hooveri, Orcuttia pilosa*
Safe	21	21	*Tuctoria greenei*
Big Pool	1		*Chamaesyce hooveri, Orcuttia pilosa*
Lassen	29	29	*Orcuttia tenuis*
Safe/Barn		22	*Chamaesyce hooveri, Orcuttia pilosa, Tuctoria greenei*
Barn		34	*Chamaesyce hooveri, Orcuttia pilosa*
Barn		35	*Chamaesyce hooveri, Orcuttia pilosa, Tuctoria greenei*

[1] According to Alexander and Schlising (1996)

Priority pool monitoring varied among years as discussed below.

Rare plant monitoring in June 1997 focused on monitoring *Chamaesyce hooveri*, *Tuctoria greenei*, *Orcuttia tenuis* and *Orcuttia pilosa* in four pools (pools 1, 17, 21, and 29) using adaptive cluster sampling (Thompson 1992). Adaptive cluster sampling entailed establishing a baseline through the center of each pool at its greatest dimension. The baseline was then divided into four segments. Individual transects were then extended out perpendicularly, either to the right or left of the baseline segment, to the pool's perimeter. The position of each transect and its direction to the right or left was chosen randomly using a random number table. "Core quadrats" (dimensions of 10 x 35 cm) were positioned at randomly chosen distances along each transect from a random starting point on the baseline. The number of core quadrats was proportional to the length of the transect (one core quadrat per 5 meters of transect length). Whenever a core quadrat was found to contain a species designated for sampling in that pool (i.e., the "target" species), then eight additional quadrats were positioned contiguous with the core quadrat, as illustrated in Figures 7. In turn, if any one of the adjoining quadrats was found to contain the target species, then additional adjoining quadrats were added to completely surround the initial adjoining quadrats (Figure 8). This process was continued, forming a growing cluster of adjoining quadrats, until the no quadrat on the periphery of the cluster contains the pool's target species.

Rare plant monitoring in 1998 and 1999 was conducted in pools 17, 21, 22, 29, 34, and 35. These six pools were chosen for monitoring because they consistently supported the largest populations of rare plants (Alexander and Schlising 1996) (Figure 5).

Population estimates for *T. greenei* in pools 21, 22, and 35, consisted of conducting a walking reconnaissance in each pool to delineate the spatial distribution of populations of

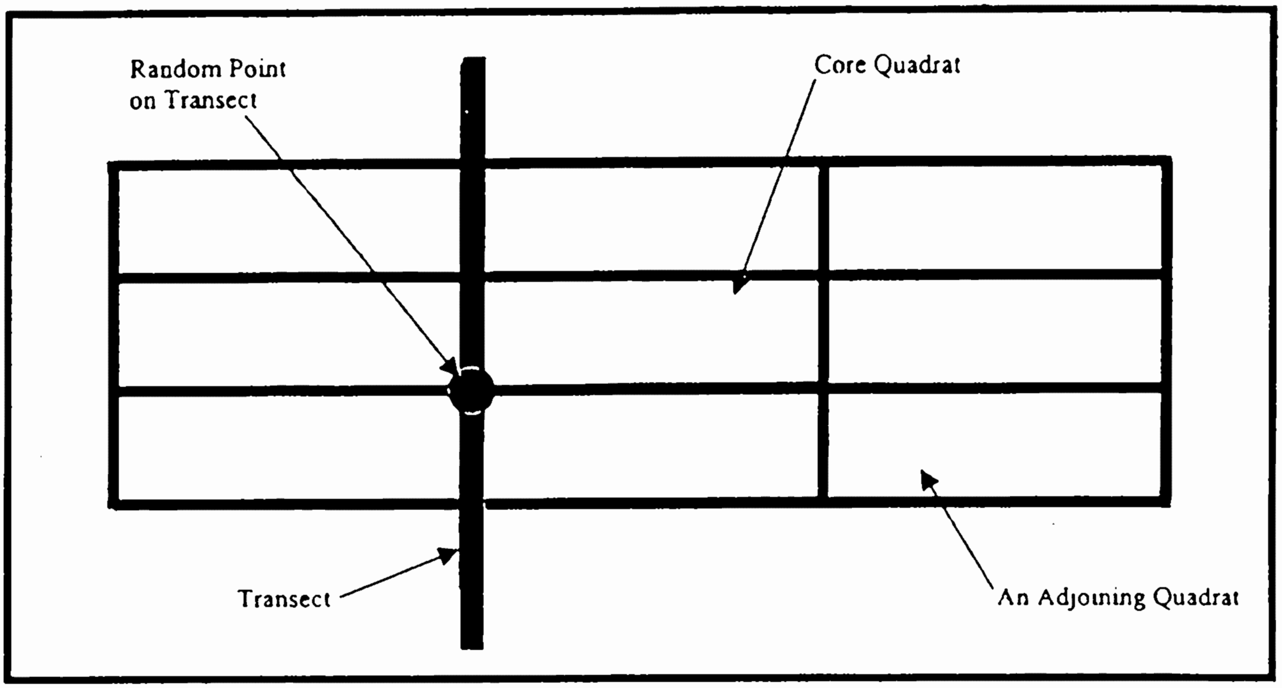


Figure 7. Basic adaptive cluster sampling quadrat arrangement.

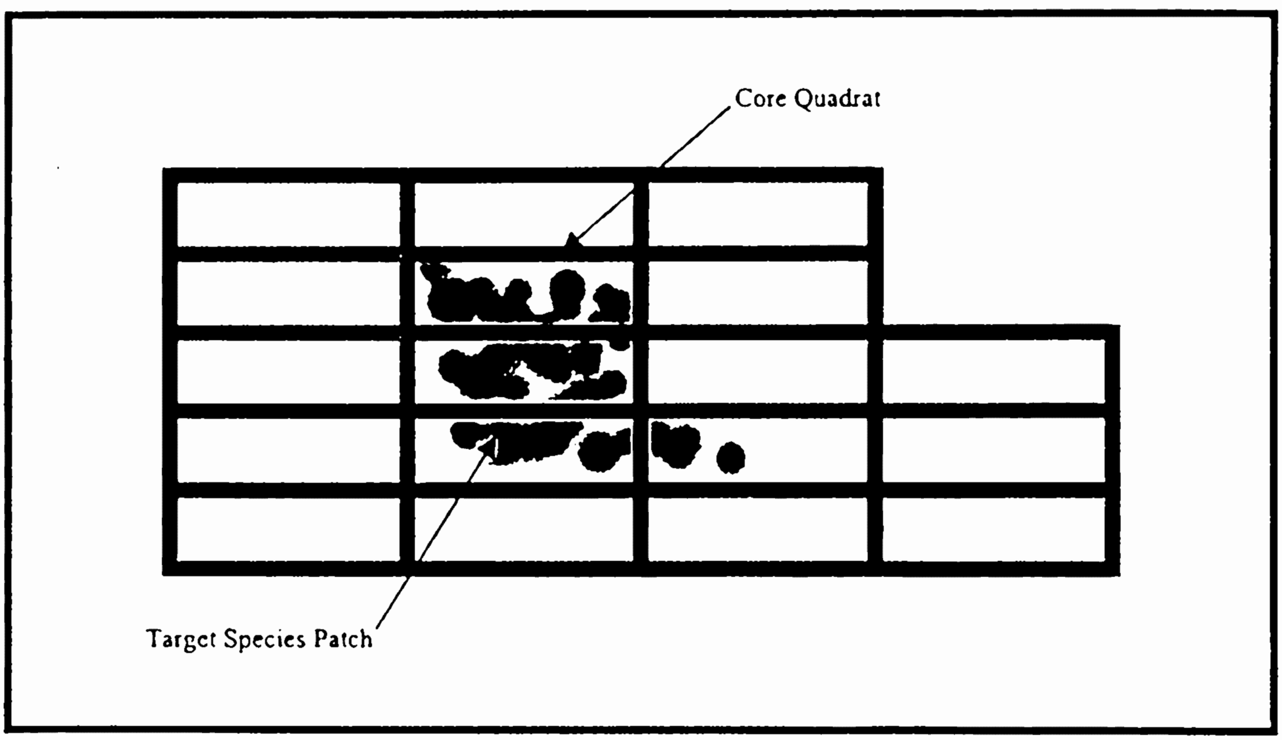


Figure 8. Formation of a complete cluster, using basic adaptive cluster sampling.

this species. A baseline was then laid out across the longest dimension and through the center of each population patch. Within each population, individual transects were then extended out perpendicularly, either to the right or to the left of each baseline, to the population's edge. Transect position along the baseline and its direction to the right or left was chosen randomly using a random number table. The lower left-hand corner of a single quadrat was then laid down at a random distance on each transect. The quart dimensions were 10 x 35 cm (350 sq cm) and was marked into eight equal portions (43.75 cm^2). Within each quadrat the number of *T. greenei* individuals was tallied until a count of 100 was achieved. The size of the area containing those 100 plants was then visually estimated to the nearest eighth of a quadrat and recorded on a standardized data sheet. For quadrats with fewer than 100 individuals, the total area of the quadrat (i.e., 350 cm^2) was recorded.

A modified adaptive cluster sampling (Thompson 1992) method was used to monitor populations of *C. hooveri* and *O. pilosa* in pools 17, 22, 34, and 35. This sampling technique was used because these rare species tend to be restricted to a few high-density clumps within a pool (Alexander and Schlising 1996). This method was generally the same as described for 1997 except quadrat clustering was modified to reduce the overall number of quadrats sampled. Unlike sampling in 1997 when a core quadrat was found to contain plants of *C. hooveri* or *O. pilosa* (i.e., the "target" species), two adjoining quadrats along the transect were positioned contiguous with the core quadrat, as illustrated in Figure 9. In turn, if any one of the adjoining quadrats was found to contain the target species, additional adjoining quadrats were added along the transect. This process was continued, forming a growing row of adjoining quadrats along the length of the transect, until the rare plant patch was spanned in both directions. Note that the two end quadrats lie beyond the edge of the patch.

A multi-stage design (Thompson 1992) was used to sample populations of *Orcuttia tenuis* in pool 29. This method was similar to adaptive cluster sampling, however, core quadrats were placed without the formation of clusters.

Quarats used in 1997, 1998 and 1999 for all three designs (i.e., adaptive cluster sampling, modified adaptive cluster sampling, and multi-stage design were the same. The dimensions of this quadrat were small enough to limit the amount of counting required per quadrat and the elongate shape increased sampling efficiency by increasing the likelihood that any given quadrat would contact a patch of rare plants.

1997 surveys were conducted by Kathleen Berry-Garrett, Caroline Warren, and Garrett Gibson (independent consultants); 1998 surveys were conducted by Mark Homrighausen formerly of The Nature Conservancy and 1999 surveys were conducted by John Hale and Matt Gause of May Consulting Services.

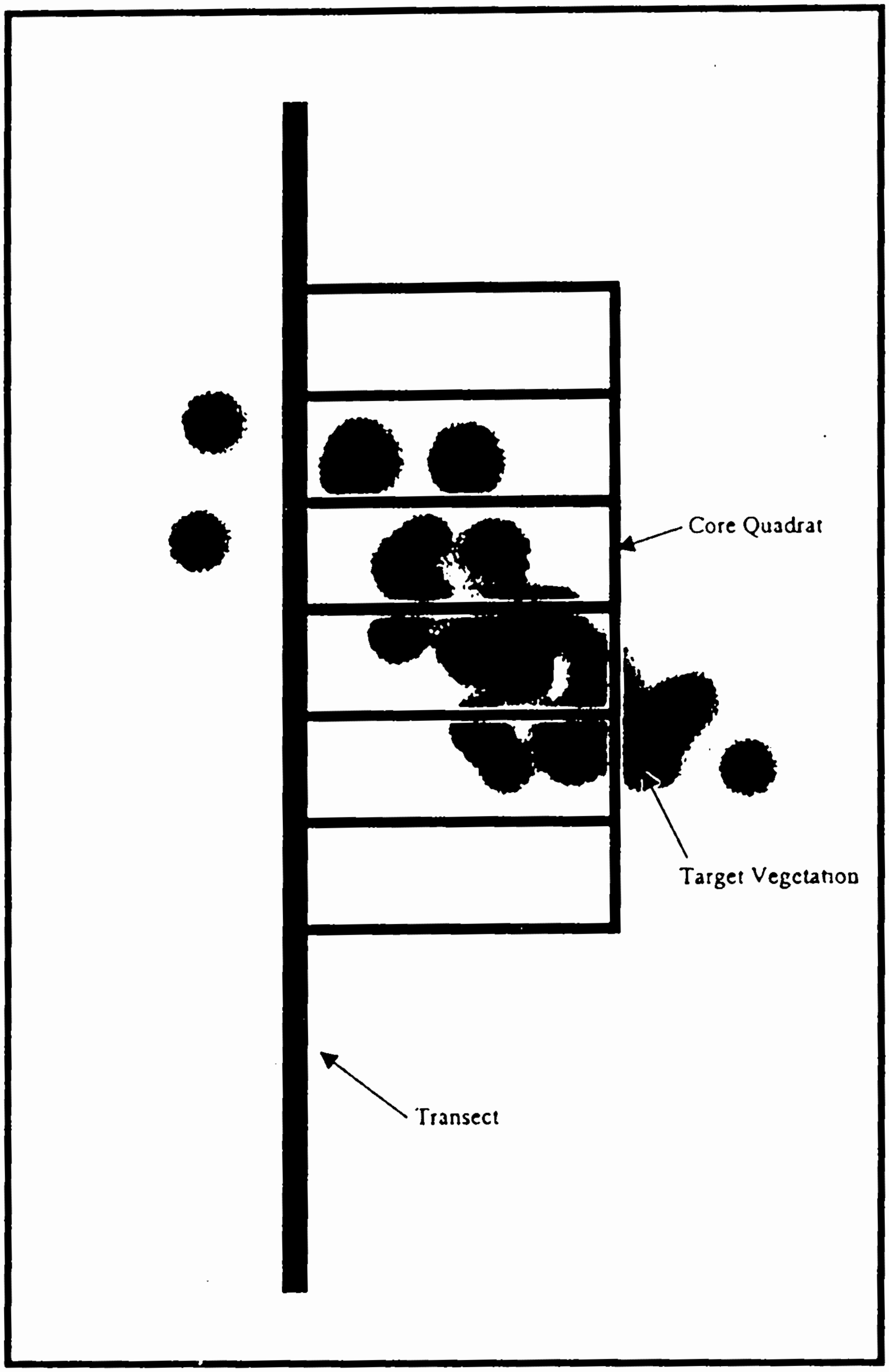


Figure 9. Belt Transect Modification of Adaptive Cluster Sampling.

Because the objective of priority pool monitoring was to investigate the population size of target rare plants through time, no attempt to analysis fire or grazing effects on these species was conducted. Hence, no hypotheses were statistically tested.

EXPERIMENTAL POOL MONITORING

In addition to priority pool monitoring, monitoring was conducted in several experimental pools (Figure 5 and Table 10).

Table 10. Pools Chosen for Experimental-Pool Monitoring

	Pools	
Pasture	Grazed	Ungrazed
Safe	22, 21, 17	none
Barn	34, 35	22
Lassen	none	29

Monitoring within the experimental pools followed the same methods as those described above for priority pools monitored in 1998 and 1999. Annual monitoring of these experimental plots did not allow any hypothesis testing effects of grazing or burning on rare plants.

Given an estimate of a rare species' mean density within a pool, estimation of the total population size that species within that pool required an estimate of that pool's area. Measurement error in the estimate of pool area (from two-axis grid method) [Cox 1976] was combined with the error in the density estimate through the standard formula for multiplicative propagation of error in order to accurately calculate the standard error for the population total (Beavington and Robinson 1992).

SWALE AND VERNAL POOL VEGETATION

Swale and vernal pool vegetation monitoring was conducted in the experimental plots described above for upland vegetation monitoring. Each of the experimental plots encompasses upland as well as swale and vernal pool habitat (Table 7).

In 1997, eight quadrats were randomly placed within each plot (i.e., grazed and ungrazed) and no attempt was made to stratify these quadrats among the habitat types. In contrast, during monitoring in 1998-1999 16 quadrats were utilized and stratified between wetland and upland habitat types within each plot.

Information collected for the swale and pool vegetation monitoring was the same as that collected for upland vegetation within experimental-plots and consisted of species composition and cover and cover of bareground and thatch.

The main objective of the swale and vernal pool monitoring was to compare the relative abundance of native species between the different burning and grazing treatment combinations. Sampling of swales and swale vernal pools within these subplots allowed testing of the following hypotheses.

H5. Prescribed burning increases the abundance of native species in the ungrazed experimental plots of Barn, Big Pool, Lassen, Safe, and Wurlitzer pastures.

H6. Prescribed burning increases the abundance of native species in the grazed experimental plots of Barn,.Big Pool, and Lassen pastures.

H7. Cattle grazing increases the abundance of native species in the experimental plots in Barn, Big Pool, and Lassen pastures.

H8. Within Barn, Big Pool, and Lassen pastures' experimental plots, the increase in the abundance of native species under cattle grazing and prescribed burning practices in combination is greater than the sum of these practices' separate effects.

LARGE BRANCHIOPODS

The main objective of the large branchiopod sampling was to evaluate the use of abundance estimates of federally listed large branchiopods (adults and cysts) as indicators for determining the effects of prescribed burning across a range of grazing conditions at the Preserve.

Large branchiopod monitoring involved both dry-season and wet-season sampling. Wet-season sampling involved sweep netting large branchiopods, counting, and promptly returning specimens to the pool. Capturing adult large branchiopods during the wet season requires repeated sampling because the timing of hatching depends on water temperature (Helm 1998, Lanway 1974). To avoid population impacts, less than 3% of the pool volume was wet-season sampled in any one month. Population estimates from wet-season sampling can be skewed by weather conditions.

In contrast to wet-season sampling, dry-season sampling involved collecting surface soil from the bottoms of dried wetlands and processing the soil to extract large branchiopods cysts for subsequent identification. To avoid population impacts, less than 0.3% of the pool surface area was dry-sampled. Tadpole shrimp cysts are the largest of those produced by large branchiopods (roughly 400 micrometers [μm] in diameter), followed by fairy shrimp cysts at approximately 200 μm and clam shrimp cysts at approximately 100 μm.

Dry-season sampling was forwarded as a method that could be used to estimate the overall "cyst" (i.e., large branchiopod embryonic egg) bank within a given pool, whereas wet-season sampling would be used to estimate the concentration of large branchiopods within a given pool in a season. Both methods are described below.

DRY-SEASON SAMPLING

Dry-season sampling was slated to begin prior to fall rains in 1996; however, because of delays in obtaining the required authorizations from the U.S. Fish and Wildlife Service, sampling was postponed until the summer of 1997.

Sampling within each pool was stratified random, with sampling allocation proportional to stratum area (Thompson 1992). Each pool was divided into four cardinal quadrants (northeast, northwest, southeast, southwest) by running a pair of north-south and east-west transect lines through the deepest point in the pool. A laser level was used to determine the maximum ponding depth of the pool to be sampled. The maximum ponding depth was divided by to two. The resulting number was used to subdivide each cardinal quadrant into two zones (i.e., shallow and deep) of equal elevational breadth, yielding a total of eight strata per pool. The two elevation zones (deep and shallow) were defined using the laser level. A minimum of two cores within each stratum was randomly taken

Random stratification enhanced dispersion of cores placement within strata to ensure accurate mean and variance estimates of cysts concentration.

Soil samples were taken with a standard T-bar coring device (cores were 2-centimeters [cm] in diameter and up to 35-cm long). A laser level was used to measure the elevation were each soil sample was taken. These measurements of the pool, two-axis grid, and stratum were documented and sketched on grid paper. Sketches were labeled with the appropriate scale, pool number, each cores location, and the direction of magnetic north.

Pools were permanently marked with three-inch-diameter washers secured to the ground with large 8-inch nails placed at each end of the two-axis grid (just outside the pool margin). A metal tag inscribed with the pool number was secured to one of the nails to allow positive identification of the pool and the axis orientation without requiring an obtrusive above-ground marker, which would be susceptible to damage by cattle.

Each soil core was placed in a 1-liter plastic freezer bag labeled with the pool number, core location within the pool, date of identification, and name of the person(s) who did the collection. Soil samples were transported to Jones & Stokes Associates' laboratory for storage and analysis. Each soil core was removed from the storage bag and the upper 1-cm was analyzed for cysts. Only cysts occurring near or at the soil-water interface have potential to contribute to the subsequent wet-season population. The rest of the core sample was stored for future analysis if funds become available. Future analysis of remaining soil may include total cyst population estimates, and an estimated of the proportion of cysts that occur at a depth at which hatching is prevented by burial.

Soil core samples were analyzed by placing the core section into a 500-micron-pore-sized brass sieve with stainless steel mesh (20-cm in diameter) that is stacked on top of two other sieves (300- and 150-micron pores, respectively, in descending vertical order). The soil was then loosened in lukewarm water by gently rubbing the soil against the sieve with a camel-hair brush. The soil retained from the 300-micron-pore and 150-micron-pore sieves was placed in a brine solution. All floating organic material, including cysts were retrieved from the solution and placed in a plastic petri dish for examination of cysts under a microscope.

Cysts were identified to genus or species. Cysts identification was accomplished by using scanning electron micrographs (Mura 1991, Gilchrist 1978) and Jones & Stokes Associates' reference collection of cysts specimens. A subset of cyst samples were archived for future verification of species identity. The samples were then be enumerated and placed in glass vials for storage.

Dry-season sampling was only conducted in 1997. Matt Gause and Daniel Burmeister both formerly of Jones & Stokes Associates performed soil sample collection and laboratory analysis of soil samples was conducted by Christopher Rogers of Jones & Stokes Associates.

Wet-Season Sampling

Wet-season sampling was conducted during the winters of 1996-1997, 1997-1998 and 1998-1999. Sampling methods in 1996-1997 differed from monitoring conducted in the following years and are described below.

Wet-sampling for large branchiopods in 1997-1998 was conducted in 10 vernal pools covering all pastures on the Preserve. Wet sampling methods used in 1997-1998 were the same as those described below for 1998-1999; however on average fewer dipnet samples were taken in each pool sampled in 1997-1998 than in the 1998-1999 monitoring year (Table 11).

Wet-season sampling for large branchiopods in 1998-1999 was conducted in 15 vernal pools covering all four pastures on the Preserve and one vernal pool located on the Wurlitzer pasture (Table 11).

Table 11. Wet-Season Sampling Design for Large Branchiopods

Pasture	Pool No.	No. of Samples (i.e., dipnets) in 1997	No. of Samples (i.e., dipnets) in 1998 and 1999
Barn	41	2	4
Barn	42	3	4
Barn	34	N/S	10
Barn	35	N/S	16
Safe	22	N/S	16
Safe	18	4	5
Safe	17	N/S	16
Safe	16	3	6
Big Pool	9	1	N/S
Big Pool	10	1	4
Big Pool	13	1	4
Big Pool	1	N/S	16
Safe	21	N/S	10 (14)
Lassen	29	4	8
Lassen	30	4	4
Wurlitzer		4	8

( ) = number of samples taken during the December 16, 1997, January 21, and February 16, 1998 survey dates
N/S = Not Sampled

Each pool was sampled four times each during the wet-season at roughly 30-day intervals. Sampling was random stratified and semi-quantitative. Each sample was taken at a random point determined from a randomly chosen distance and compass bearing from the center of the pool. Random numbers were obtained from a printed random number table (Zar 1996). After locating the appropriate sample start point, a dipnet was lowered into the pool and rested on the bottom and held in a vertical position. After a few seconds, allowing for the initial disturbance of the water to cease, the 80-µm mesh size dipnet was moved forward in the direction of the compass bearing and upward to the surface for a distance of approximately one-meter. Given the aperture of the dipnet of 0.025 m^2 and distance the net was moved, roughly 0.025 m^3 or 25 liters of the water column was sampled vertically and horizontally with each sweep of the net. Sampling allocation among pools was approximately proportional to pool volume (derived by multiplying average depth and pool surface area) (Table 11).

After the completion of each sample sweep, the contents of the net were emptied into an enamel pan. Identification and enumeration of all large branchiopod species and instar stage (or in the case with *Lepidurus packardi*, length of carapace) was preformed prior to being released back into the pool. Instar stage was grouped into four categories: >15 (adult), 10-15, 5-10, and 1-5. Carapace lengths of *Lepidurus packardi* were grouped as follows: >20 mm, 10-20 mm, 5-10 mm, and <5 mm. Determination of instar stages were derived from Heath (1924) for *Linderiella occidentalis* and Patton (1984) for *Branchinecta conservatio*.

Concentration estimates of large branchiopods were calculated as number of individuals per liter of water (= number of individuals/[net aperture area x length of sweep]). In those few cases when the water column was shallower than the net aperture height, the sweep was entirely horizontal and the net aperture calculated as the width of the net (25-cm) multiplied by the depth of water.

All data was recorded on standardized data sheets imprinted on Write-In-The-Rain™ paper.

Sampling was initiated at approximately 10:00 am and ended roughly 5:00 pm. Pools were sampled in the chronological order presented in Table 11. The first ten pools were accessed from the Barn Pasture, the next four pools were accessed from Lassen Road, and the Wurlitzer pool was accessed from the west along Haille Road.

The following hypotheses regarding fire impacts on large branchiopods across a spectrum of grazing were tested.

H9: population size per pool of *B. lynchi* is higher in burned than in unburned plots.

H10: population size per pool of L. *packardi* is higher in burned than in unburned plots.

H11: population size per pool of *B. conservatio* is higher in burned than in unburned plots.

Descriptive statistics regarding concentration estimates of large branchiopods were calculated using Microsoft Excel 2000 (Microsoft Software 1999) and Minitab release 12.2 statistical software package (Minitab Inc. 1998).

Data was analyzed as a randomized, complete fixed-block design. A separate ANOVA will be preformed for each species. Each one-sided hypothesis was tested using an a priori mean contrast between burned and unburned means. Type I error rate was controlled across contrast tests using Sequential Bonferroni adjustment (Holm 1978).

Wet-season sampling in 1996-1997 was conducted by Christopher Rodgers of Jones and Stokes Associates. Brent Helm and Matt Gause of May Consulting Services conducted wet-season sampling during 1997-98 and 1998-99.

WATER QUALITY

The main objective of the water quality monitoring was to monitor the effect of direct access by cattle on levels of nitrite and nitrate, dissolved oxygen (DO), pH, and temperature in vernal pools at the Preserve. Water quality monitoring compared vernal pools that were accessible to cattle (treatment) with those from which cattle were excluded by fencing (control). While excluded pools were subject to "watershed" effects from adjacent pasture, this effect was assumed to be minimal because direct overland flow makes a very small contribution to the water volume of vernal pools at the Preserve.

Excluded pools did not receive impacts associated with direct cattle access, such as trampling and deposit of feces in or immediately adjacent to them. Therefore, it was expected that water quality parameters would differ substantially between accessible and cattle-excluded pools. These differences could be compared with data on large branchiopods populations to provide insights on possible mechanisms by which livestock access to pools may affect large branchiopods.

Water quality parameters monitored included nitrite and nitrate, DO, pH, and water temperature. Nitrite, nitrate, and DO parameters were chosen because they are deemed most likely to be affected by direct access of cattle to vernal pools and to affect large branchiopods populations. Elevated nutrient levels caused by livestock feces have been associated with the timing and extent of algae growth. It was predicted that elevated nitrate and nitrite would shift the algae growth curve to earlier in the spring, and would in turn lead to lower levels of DO due to nighttime respiration of algae and more rapidly growing populations of algae-grazing organisms. There were no predicted effects of cattle access to pools on pH and water temperature. Measurements of pH were made because it is a critical component of biologic systems and may help the interpretation of other data. Temperature was monitored because it is strongly associated with the level of dissolved oxygen and is an important factor in large branchiopods life cycle (Helm 1998, Lanway 1974).

Levels of nitrite (NO_2), nitrate (NO_3), DO, pH, and water temperature ($^{\circ}$ C) were monitored at 7 pools (13, 16, 18, 29, 30, 41, 42) at the Preserve and in one pool in the Wurlitzer pasture once monthly in December 1997 - April 1998. DO measurements were made with a membrane electrode meter that had adjustments to correct for temperature and salinity. Temperature was measured with a standard full immersion mercury thermometer. Measurements of pH were made with a meter calibrated daily against two buffers of appropriate pH. The pH instrument did not deviate by more than 0.1 pH from the buffers. Electrodes were kept in the buffer solution, washed with distilled water, and dried between measurements.

Monitoring information and sampling data were recorded on standardized field data sheets. Special conditions, such as the presence of cattle in a pool, at the time of sampling were noted

Water samples were collected in glass or polyethylene bottles and preserved with sulfuric acid (H_2SO_4) at a pH of less than 2 and returned to the laboratory at California State University, Chico for nitrate and nitrite analysis.

Laboratory studies for water quality were limited to the analysis of water samples for nitrite and nitrate concentrations. Analysis of water samples for Nitrite and Nitrate concentrations used the Hydrazine Reduction method (American Public Health Association 1992, 4500-NO_3^-H)

In order to reduce confounding effects of rain and wind on water quality, sampling took place at least three days after a rainfall and not during periods of winds over 32 km/h (20 mph). In each monitoring period, all seven pools at the preserve were sampled as close together in time as possible between 10:00 a.m. and 2:00 p.m. Paired pools in each pasture were sampled in succession, and all pools were sampled in the same order on each sampling date.

The following hypotheses were examined.

H12. Direct access to pools by livestock increases levels of total nitrite and nitrate.

H13. Direct access to pools by livestock decreases levels of DO.

Descriptive statistics including means, medians, standard deviations, standard errors, and interquartile ranges regarding nitrate, nitrite, DO, and water temperature per pasture and plot were calculated using Microsoft Excel 2000 and Minitab release 12.2 statistical software package (Minitab Inc. 1998).

Grazing effects were tested across pastures using a fixed-block design and analyzed using the two-sample t-test or Mann-Whitney test (Minitab Inc. 1998). The Mann-Whitney test was used when normally distributed data could not be assumed (Daniel 1990, Edgington 1995).

Although multivariate techniques (e.g., MANOVA) could have been used, results would be more explicable if separate analyses are run for nitrate, nitrite, DO, and water temperature. Type I error rate was controlled at α =.10 across the two grazing main-effect hypotheses using sequential Bonferroni adjustment (Holm 1977). Type I error rate will be set to 10% in order to improve the power of the analysis given that sample sizes are not large.

RESULTS

UPLAND VEGETATION

PASTURE-WIDE MONITORING

SPECIES COMPOSITION AND COVER

Prior to the initiation of this study in 1996 (before livestock grazing was reintroduced to Barn, Big Pool, Lassen, and Safe pastures), the total number of species varied slightly among pastures (Table 12) with the Big Pool pasture supporting the greatest number of species and the Lassen pasture supporting the least number (Dittes and Guardino 1996). The total number of species in most grazed pastures increased in 1997, but declined steadily in all but the Lassen pasture in subsequent years (Table 12). The Wurlitzer pasture, which remained ungrazed for the duration of this study, experienced the greatest decline in total number of species.

Table 12. Total number of vascular plant species within upland habitats, by pasture.

Pasture	Total Number of Species				Percent Change from 1996 to 1999
	1996[a]	1997	1998	1999	
Barn	55	49	46	44	- 20
Big Pool	67	69	61	44	- 34
Lassen	49	54	38	53	+ 8
Safe	63	no data[b]	38	46	- 27
Wurlitzer	61	66	33	35	- 43

[a] source. Dittes and Guardino (1996)
[b] data collected but lost

In regards to the number of native plant species, in 1996 the Big Pool pasture supported the greatest number of native plant species while the Lassen pasture supported the fewest native species (Table 13). The number of native species within the pastures remained relatively unchanged between 1996 and 1997. (i.e., there was no significant difference in the number of native species within each pasture between 1996 and 1997. In 1997-1998, the number of native species in all the pastures began to decline (Table 13); with the Wurlitzer pasture suffering the greatest reduction (- 43 %).

Table 13. Number of native species within upland habitats, by pasture.

Pasture	Number of Native Species				Percent Change Form 1996 to 1999
	1996[a]	1997	1998	1999	
Barn	35	31	30	27	- 23
Big Pool	47	47	42	30	- 36
Lassen	34	37	25	36	+ 6
Safe	39	no data[b]	20	33	- 15
Wurlitzer	43	42	33	23	- 46

[a] source: Dittes and Guardino (1996)
[b] data collected but lost

Similar to the number of native species, the number of non-native species similarly declined in all pastures over the duration of the study (1997-1999), with the exception of the Lassen pasture (Table 14).

Table 14. Number of non-native species within upland habitats, by pasture.

Pasture	Number of non-native species				Percent Change From 1996 to 1999
	1996[a]	1997	1998	1999	
Barn	20	18	16	17	- 15
Big Pool	20	22	19	14	- 30
Lassen	15	17	13	17	+ 13
Safe	24	no data[b]	18	13	- 46
Wurlitzer	16	24	18	12	- 25

[a] source: Dittes and Guardino, 1996
[b] data collected but lost

Although the total number of native and non-native species declined from 1996 to 1999 in nearly all the pastures, the relative proportion of native species to non-native species within each pasture remained relatively unchanged (Table 15).

Table 15. Percent of Plant Taxa That Are Native By Pasture; 1996-1999

Pasture	1996[a]	1997	1998	1999
Barn	64	63	65	61
Big Pool	70	68	69	68
Lassen	69	68	66	68
Safe	61	no data[b]	52	71
Wurlitzer	70	64	65	65

[a] source: Dittes and Guardino, 1996
[b] data collected but lost

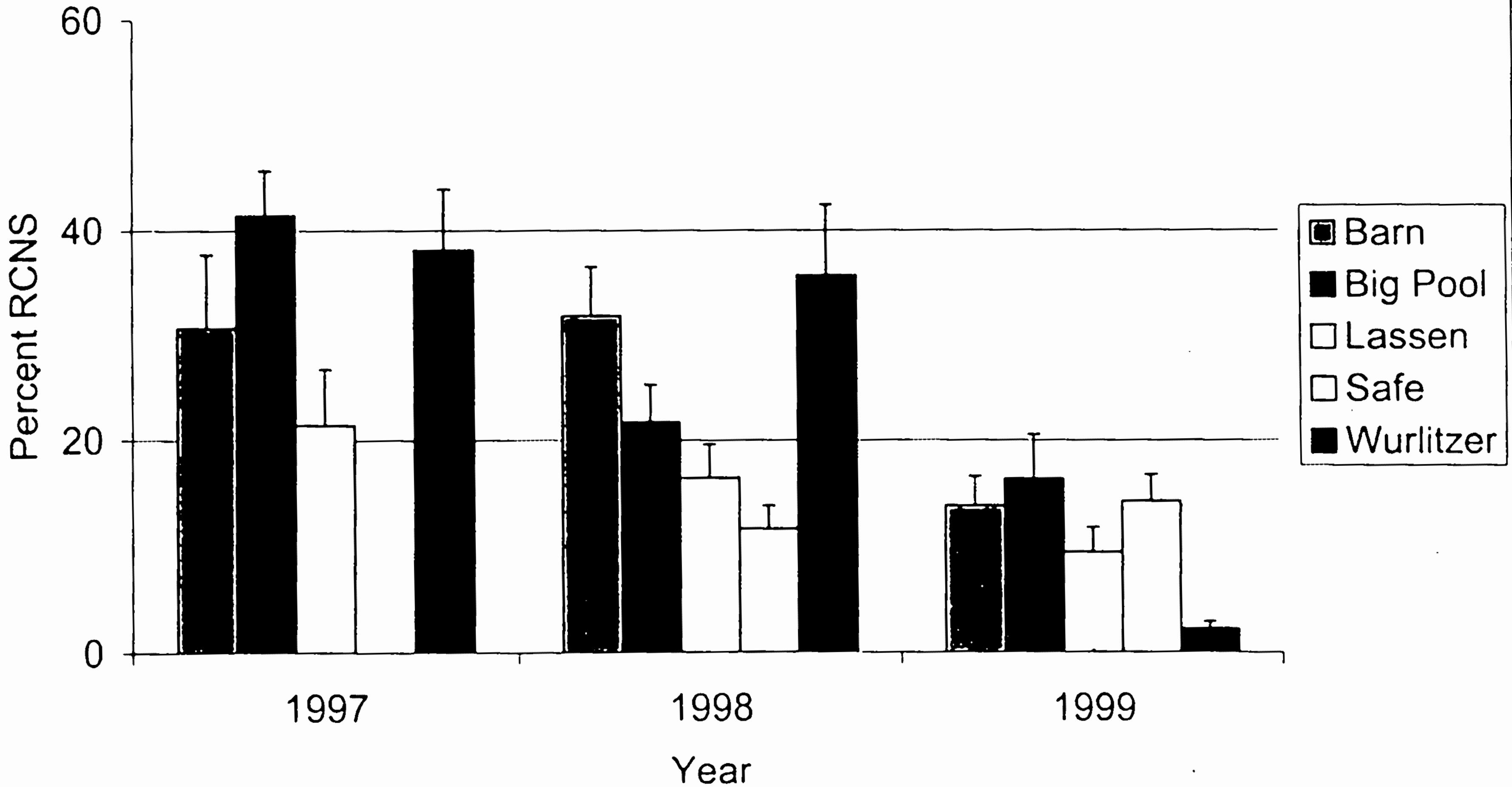
Although %RCNS has varied among pastures within the same year and the same pastures among years, it has declined in all pastures over the course of the study with the exception of the Safe pasture where %RCNS increased slightly in 1999 (Table 16, Figure 10).

Table 16. Descriptive statistics regarding %RCNS of upland habitats obtained from pasture wide sampling.

Year	Pasture	Mean	Median	TrMean	StDev	SEMean	25th Percentile	75th Percentile
1997	Barn	30.63	23.15	28.50	29.06	7.05	7.09	44.72
	Big Pool	41.80	43.05	40.99	26.78	4.53	19.89	60.00
	Lassen	21.40	6.79	19.20	28.02	5.30	1.91	27.87
	Safe	--	--	--	--	--	--	--
	Wurlitzer	38.75	27.79	37.40	32.20	5.88	6.75	64.67
1998	Barn	31.84	27.61	30.10	22.35	4.66	11.11	48.40
	Big Pool	21.69	19.59	20.80	17.72	3.54	8.36	31.63
	Lassen	16.41	13.62	14.82	17.26	3.20	3.30	20.50
	Safe	11.58	11.02	11.10	10.27	2.19	0.92	18.67
	Wurlitzer	35.65	24.20	34.61	34.52	6.77	5.99	73.11
1999	Barn	13.76	4.72	12.69	14.57	2.80	2.45	27.16
	Big Pool	16.93	8.11	13.99	20.58	4.29	5.78	21.35
	Lassen	8.57	6.77	7.12	9.33	1.70	1.93	10.76
	Safe	13.95	14.59	12.93	13.47	2.55	1.79	22.20
	Wurlitzer	2.24	0.98	1.74	3.33	0.67	0.45	3.81

The %RCNS between 1997 and 1998 within pastures were similar with the exception of the Big Pool pasture which experienced a significant decline in %RCNS (Table 16 and Table 17). However, between 1998 and 1999 all pastures, with the exception of the Big Pool and Safe pastures, experienced significant declines in %RCNS (Table 17). Over the

Figure 10. Upland Habitat %RCNS by Year Obtained from Pasture-Wide Sampling



course of the study, all pastures with the exception of the Lassen pasture experienced significant reductions in %RCNS.

Table 17. Results of Mann-Whitney Tests for % RCNS within Pastures

	P_{adj} Values[1]		
Pasture	1997 vs. 1998	1997 vs. 1999	1998 vs. 1999
Barn	0.4601	*0.0283	**0.0007
Big Pool	**0.0031	**0.0002	0.1293
Lassen	0.8294	0.2830	*0.0462
Safe	N/A	N/A	0.5001
Wurlitzer	0.8373	**0.0000	**0.0000

[1] See Table 16 for medians, sample numbers, and definitions

N/A = Not Applicable

* Significant difference at α= 0.10

** Highly significant difference α= 0.01

The results of statistical testing of %RCNS between pastures within the 1997, 1998, and 1999 monitoring years are shown in Tables 18, 19, and 20.

Table 18. Results of Mann-Whitney Tests for % RCNS between Pastures collected in 1997

	P_{adj} Values[1]		
Pasture	Wurlitzer	Big Pool	Barn
Safe			
Lassen	*0.0131	**0.0025	0.1114
Wurlitzer		0.6404	0.4384
Big Pool			0.1233

[1] See Table 16 for medians, sample numbers, and definitions

* Significant difference at α= 0 10

** Highly significant difference α= 0.01

Table 19. Results of Mann-Whitney Tests for % RCNS between Pastures collected in 1998

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		0.4081	*0.0106	*0.0417	**0.0004
Lassen			*0.0414	0.1816	**0.0042
Wurlitzer				0.3913	0.6095
Big Pool					0.0987

[1] See Table 16 for medians, sample numbers, and definitions

* Significant difference at α= 0 10

** Highly significant difference α= 0.01

Table 20. Results of Mann-Whitney Tests for % RCNS between Pastures collected in 1999

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		0.1783	**0.0001	0.5766	0.8597
Lassen			**0.0002	0.0583	0.3925
Wurlitzer				**0.0000	**0.0001
Big Pool					0.2932

[1] See Table 16 for medians, sample numbers, and definitions

* Significant difference at α= 0 10

** Highly significant difference α= 0.01

Overall, it appears that thatch cover increased in all pastures between 1997 and 1998 and declined slightly in 1999. The cover of bare ground decreased significantly between 1997 and 1998 (Table 27) in all pastures that corresponds with the increased thatch cover mentioned above.

Descriptive statistics regarding cover of thatch and bare ground within each pasture over the period from 1997-1999 are shown in Tables21 and 22.

Table 21. Descriptive Statistics for Pasture-Wide Thatch Obtained from Pasture-Wide Sampling.

Year	Pasture	Mean	Median	TrMean	StDev	SEMean	25th Percentile	75th Percentile
1997	Barn	20.88	15.00	19.14	19.48	4.87	6.00	32.25
	Big Pool	7.53	0.50	5.09	14.97	2.61	0.25	3.00
	Lassen	29.11	15.00	28.92	25.00	4.72	3.00	63.00
	Safe[1]	--	--	--	--	--	--	--
	Wurlitzer	4.14	0.25	3.00	10.32	1.95	0.00	0.50
1998	Barn	32.30	38.00	30.62	20.40	4.25	15.00	38.00
	Big Pool	37.52	38.00	36.43	19.96	3.99	15.00	50.50
	Lassen	34.83	38.00	33.22	23.06	4.28	15.00	38.00
	Safe	39.09	38.00	38.60	27.35	5.83	15.00	63.00
	Wurlitzer	29.33	26.50	29.12	18.97	3.72	15.00	38.00
1999	Barn	22.44	15.00	20.57	21.51	4.30	9.00	38.00
	Big Pool	36.52	38.00	35.81	23.41	4.88	15.00	63.00
	Lassen	13.30	15.00	12.19	10.07	1.84	3.00	15.00
	Safe	22.50	15.00	21.69	18.63	3.52	15.00	38.00
	Wurlitzer	9.86	15.00	9.04	8.65	1.73	3.00	15.00

[1]Data collected but lost

Table 22 Descriptive Statistics for Pasture-Wide Bare Ground Obtained from Pasture-Wide Sampling.

Year	Pasture	Mean	Median	TrMean	StDev	SEMean	25th Percentile	75th Percentile
1997	Barn	24.76	15.00	23.67	20.37	4.94	15.00	38.00
	Big Pool	28.48	15.00	27.21	24.64	4.29	9.00	50.50
	Lassen	20.00	15.00	19.00	18.74	3.54	3.00	32.25
	Safe[1]	--	--	--	--	--	--	--
	Wurlitzer	16.82	15.00	15.69	16.16	3.05	3.00	32.25
1998	Barn	0.83	0.50	0.74	0.86	0.18	0.50	0.50
	Big Pool	0.70	0.50	0.61	0.69	0.14	0.50	0.50
	Lassen	0.74	0.50	0.69	0.79	0.15	0.50	0.50
	Safe	0.61	0.50	0.50	0.53	0.11	0.50	0.50
	Wurlitzer	0.69	0.50	0.60	0.68	0.13	0.50	0.50
1999	Barn	0.57	0.50	0.50	0.49	0.10	0.50	0.50
	Big Pool	0.50	0.50	0.50	0.00	0.00	0.50	0.50
	Lassen	0.50	0.50	0.50	0.00	0.00	0.50	0.50
	Safe	0.59	0.50	0.50	0.47	0.09	0.50	0.50
	Wurlitzer	0.50	0.50	0.50	0.00	0.00	0.50	0.50

[1]Data collected but lost

Statistical testing regarding thatch and bare ground both among and between pastures are presented in Tables 23 through 31, below.

Table 23. Results of Mann-Whitney Tests for Cover of Thatch within Pastures

	P_{adj} Values[1]		
Pasture	1997 vs. 1998	1997 vs. 1999	1998 vs. 1999
Barn	*0.0354	0.8831	*0.0442
Big Pool	**0.0000	**0.0000	0.8204
Lassen	0.2638	*0.0699	**0.0000
Safe			*0.0293
Wurlitzer	**0.0000	**0.0000	**0.0001

[1] See Table 21 for medians, sample numbers, and definitions

* Significant difference at α= 0.10

** Highly significant difference α= 0.01

Table 24. Results of Mann-Whitney Tests for Cover of Thatch Between Pastures, 1997

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe					
Lassen			**0.0000	**0.0000	0.5048
Wurlitzer				*0.0393	**0.0000
Big Pool					**0.0002

[1] See Table 21 for medians, sample numbers, and definitions

* Significant difference at α= 0.10

** Highly significant difference α= 0.01

Table 25. Results of Mann-Whitney Tests for Cover of Thatch Between Pastures, 1998

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		0.7097	0.2710	0.9377	0.5309
Lassen			0.4378	0.4646	0.7654
Wurlitzer				0.1432	0.6511
Big Pool					0.3092

[1] See Table 21 for medians, sample numbers, and definitions

Table 26. Results of Mann-Whitney Tests for cover of thatch between Pastures collected in 1999

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		*0.0590	**0.0040	*0.0266	0.8120
Lassen			0.1383	**0.0001	0.1384
Wurlitzer				**0.0000	*0.0121
Big Pool					*0.0242

[1] See Table 21 for medians, sample numbers, and definitions

* Significant difference at α= 0 10

** Highly significant difference α= 0.01

As mentioned previously the cover of bare ground in 1998 was highly significantly different from the values collected in 1997 (Table 27); however, values between 1998 and 1999 remained relatively unchanged (Table 22).

Table 27. Results of Mann-Whitney Tests for cover of Bare Ground within Pastures

	P_{adj} Values[1]		
Pasture	1997 vs. 1998	1997 vs. 1999	1998 vs. 1999
Barn	**0.0000	**0.0000	0.1497
Big Pool	**0.0000	(2)	(2)
Lassen	**0.0000	(2)	(2)
Safe	--	--	0.8856
Wurlitzer	**0.0000	(2)	(2)

[1] See Table 22 for medians, sample numbers, and definitions

[2] See Tables 28 regarding these relationships

* Significant difference at α= 0.10

** Highly significant difference α= 0.01

Table 28. Results of Wilcoxon Signed Rank Tests for cover of bare ground within Pastures

Pasture	N	N for test	Wilcoxon Statistic	p	Est. Median
Big Pool 1997 vs. 1999	23	23	0.00	**0.0000	0.5
Lassen 1997 vs. 1999	30	30	0.00	**0.0000	0.5
Wurlitzer 1997 vs. 1999	25	25	0.00	**0.0000	0.5

[1] See Table 22 for medians, sample numbers, and definitions

* Significant difference at α= 0.10

** Highly significant difference α= 0.01

Statistical testing (i.e., Sign Test for Median [Minitab 1998]) did not reveal any significant differences between bare ground cover values between 1998 and 1999 within the Big Pool, Lassen, and Wurlitzer Pastures (Table 22).

Table 29. Results of Mann-Whitney Tests for Cover of Bare Ground Between Pastures, 1997

Pasture	P_{adj} Values[1]				
	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe					
Lassen			0.4661	0.2472	0.3101
Wurlitzer				*0.0702	0.1117
Big Pool					0.8889

[1] See Table 22 for medians, sample numbers, and definitions

* Significant difference at α = 0.10

Table 30. Results of Mann-Whitney Tests for Cover of Bare Ground Between Pastures, 1998

Pasture	P_{adj} Values[1]				
	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		0.7820	0.6749	0.6505	0.3335
Lassen			0.9627	0.9366	0.5648
Wurlitzer				0.9839	0.5538
Big Pool					0.5851

[1] See Table 22 for medians, sample numbers, and definitions

Table 31. Results of Mann-Whitney Tests for Cover of Bare Ground Between Pastures collected in 1999

Pasture	P_{adj} Values[1]				
	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		N/A	N/A	N/A	0.8333
Lassen			N/A	N/A	N/A
Wurlitzer				N/A	N/A
Big Pool					N/A

[1] See Table 22 for medians, sample numbers, and definitions

N/A – Statistical test not applicable-medians equivalent

Several relationships between pastures in 1999 could not be tested (i.e., Lassen vs. Safe, Wurlitzer vs. Safe, Wurlitzer vs. Lassen, Big Pool vs. Safe, Big Pool vs. Lassen, and Big Pool vs. Wurlitzer) using available methods (i.e., Mann-Whitney Test, Wilcoxon Signed Rank Test, or Sign Test for Median) because either the data was similar between pastures or collected values for bare ground were identical for all samples. Table 31 above demonstrates that values for bare ground within the Lassen, Wurlitzer, Big Pool, and Safe pastures were very similar in 1999.

DATA HANDLING

The 1997 data collected from the Safe pasture regarding relative percent cover of native species was overwritten while on computer disk and lost prior to analysis. As a result of this loss, the data collection and archiving process was modified to ensure that the data collected exists both in hardcopy and electronic format. Upland vegetation monitoring for species richness and %RCNS was successfully completed during the spring of 1998 and 1999.

PRIORITY WEED MONITORING

Overall, weed abundance decreased in all pastures between 1998 and 1999 (Tables 32 through 41). Wild lettuce (*Lactuca serriola*) abundance plummeted between 1998 and 1999 in the Lassen, Safe, and Wurlitzer pastures and was absent within Barn and Big Pool pastures in 1999. Yellow starthistle (*Centaurea solstitialis*) abundance also decreased in all of the pastures between 1998 and 1999. Weed abundance data was not collected in 1997.

Table 32. Barn Pasture Priority Weed Distribution, Percent of Quadrats in each class, 1998[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	0	20	73	0	7
Centaurea solstitialis	0	0	27	10	63
Lactuca serriola	0	0	20	0	80
Sonchus asper asper	0	0	83	0	17

[1] See Table 4 For number of quadrats sampled per pasture

Table 33. Barn Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1999[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	3	25	59	3	9
Centaurea solstitialis	0	0	19	0	81

[1] See Table 4 For number of quadrats sampled per pasture

Table 34. Big Pool Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1998[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	16	39	42	0	3
Centaurea solstitialis	0	0	23	3	74
Lactuca serriola	0	0	55	0	45
Sonchus asper asper	0	0	0	3	97
Sonchus oleraceus	0	0	23	0	77
Rumex crispus	0	0	6	10	84

[1] See Table 4 For number of quadrats sampled per pasture

Table 35. Big Pool Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1999[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	0	0	94	0	6

[1] See Table 4 For number of quadrats sampled per pasture

Table 36. Lassen Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1998[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	28	50	19	0	3
Centaurea solstitialis	0	3	56	22	19
Lactuca serriola	0	0	100	0	0
Sonchus oleraceus	0	0	38	6	56
Sonchus asper asper	0	0	3	0	97
Convolvulus arvensis	0	0	3	0	97

[1] See Table 4 For number of quadrats sampled per pasture

Table 37. Lassen Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1999[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	38	47	16	0	0
Centaurea solstitialis	0	3	44	0	53
Lactuca serriola	0	0	6	0	94
Sonchus asper asper	0	0	38	0	63
Convolvulus arvensis	0	0	3	0	97

[1] See Table 4 For number of quadrats sampled per pasture

Table 38. Safe Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1998[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	19	30	48	4	0
Centaurea solstitialis	0	7	30	7	56
Lactuca serriola	0	4	63	0	33
Sonchus asper asper	0	0	15	0	85
Sonchus oleraceus	0	0	19	4	78
Rumex crispus	0	0	11	0	89
Conium maculatum	0	0	4	0	96
Convolvulus arvensis	0	0	4	4	93

[1] See Table 4 For number of quadrats sampled per pasture

Table 39. Safe Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1999[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	28	50	22	0	0
Centaurea solstitialis	0	0	25	3	72
Lactuca serriola	0	0	9	0	91
Sonchus asper asper	0	0	3	6	91
Sonchus oleraceus	0	0	3	0	97
Rumex crispus	0	0	6	3	91
Xanthium strumarium	0	0	3	0	97
Convolvulus arvensis	0	0	6	3	91

[1] See Table 4 For number of quadrats sampled per pasture

Table 40. Wurlitzer Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1998[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	0	6	63	13	19
Centaurea solstitialis	0	3	66	9	22
Lactuca serriola	0	0	84	6	9
Sonchus oleraceus	0	0	19	6	75
Rumex crispus	0	0	16	0	84

[1] See Table 4 For number of quadrats sampled per pasture

Table 41. Wurlitzer Pasture Priority Weed Distribution, Percent of Quadrats in Each Class, 1999[1]

Species	Dominant	Common	Occasional	Occurred nearby	Absent
Taeniatherum caput-medusae	0	9	69	16	6
Centaurea solstitialis	0	0	34	3	63
Convolvulus arvensis	0	0	6	0	94
Lactuca serriola	0	0	25	3	72
Rumex crispus	0	0	3	0	97
[1] See Table 4 For number of quadrats sampled per pasture					

Abundance and frequency results were similar. In general, (as with abundance data) the frequency of yellow starthistle and medusa-head decreased between 1996 and 1999 (Table 42). Although infrequently encountered within the pasture-wide sampling quadrats from 1996-1998, yellow starthistle did not occur in any of the pasture-wide quadrats in 1999.

Table 42. Yellow starthistle (*Centaurea solstitialis*) and Medusa-head grass (*Taeniatherum caput-medusae*) Frequency in Pasture-wide Sampling Quadrats (1996-1999) (sample size in parentheses)

Pasture	Target Species	Percent of sample quadrats containing target species				Change in Frequency (1996-1999)
		1996	1997	1998	1999	
Barn	medusahead	93 (n=29)	17 (n=17)	48 (n=23)	56 (n=27)	40% reduction in frequency
	starthistle	7 (n=29)	17 (n=17)	---	---	100% reduction in frequency
Big Pool	medusahead	86 (n=29)	55 (n=33)	92 (n=25)	65 (n=23)	21% reduction in frequency
	starthistle	---	3 (n=33)	12 (n=25)	---	100% reduction in frequency
Lassen	medusahead	90 (n=30)	57 (n=28)	76 (n=29)	93 (n=28)	3% increase in frequency
	starthistle	---	11 (n=28)	3 (n=29)	---	100% reduction in frequency
Safe	medusahead	90 (n=30)	no data	77 (n=22)	96 (n=28)	6% increase in frequency
	starthistle	27 (n=30)	no data	6 (n=22)	---	100% reduction in frequency
Wurlitzer	medusahead	87 (n=30)	46 (n=28)	42 (n=26)	36 (n=25)	51% reduction in frequency
	starthistle	3 (n=30)	32 (n=28)	8 (n=26)	---	100% reduction in frequency
--- : not observed						

Residual Dry Matter

Descriptive statistics regarding RDM data collected over the period from 1997 to 1999 are shown in Table 43 below.

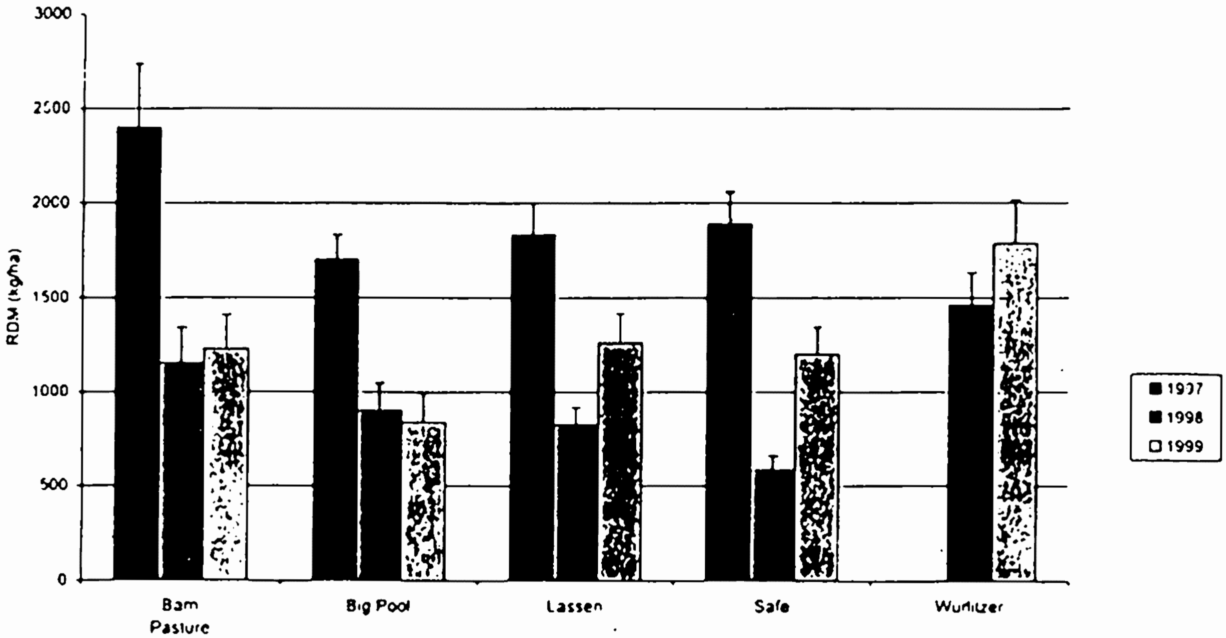
Table 43. Descriptive Statistics for Pasture-Wide Residual Dry Matter (kg/ha).

Year	Pasture	Mean	Median	TrMean	StDev	SEMean	25th Percentile	75th Percentile
1997	Barn	2401.0	1799.0	2214.0	1440.0	339.0	1550.0	3149.0
	Big Pool	1680.0	1552.0	1595.0	630.0	149.0	1273.0	1905.0
	Lassen	1838.0	1663.0	1813.0	680.0	165.0	1308.0	2100.0
	Safe	1898.0	1687.0	1870.0	718.0	169.0	1420.0	2399.0
	Wurlitzer[1]							
1998	Barn	1151.0	980.0	1080.0	732.0	189.0	525.0	1216.0
	Big Pool	902.0	794.0	880.0	564.0	146.0	381.0	1320.0
	Lassen	825.2	704.6	801.8	349.4	90.2	548.7	1139.0
	Safe	581.1	554.4	558.8	307.9	79.5	308.6	723.4
	Wurlitzer	1460.0	1199.0	1400.0	667.0	172.0	888.0	1775.0
1999	Barn	1226.0	1159.0	1182.0	706.0	182.0	568.0	1971.0
	Big Pool	840.0	723.0	802.0	610.0	157.0	234.0	1418.0
	Lassen	1258.0	1104.0	1180.0	602.0	155.0	747.0	1376.0
	Safe	1198.0	983.0	1172.0	566.0	146.0	798.0	1547.0
	Wurlitzer	1787.0	1648.0	1763.0	877.0	226.0	1158.0	2496.0

[1] RDM data not collected in 1997

RDM levels were very high in 1997 (Figure 11, Table 43) exceeding 1500 kg/ha in all pastures sampled. RDM was reduced significantly in 1998; however, values increased again in nearly all pastures in 1999 (Figure 11).

Figure 11   Mean Residual Dry Matter (RDM). 1997-1999 (bar represents one Standard Error)



Pasture-wide RDM levels changed appreciably between 1997 and 1998 (Table 44) with levels dropping significantly between 1997 and 1998.

Table 44. Results of Mann-Whitney Tests for Residual Dry Matter Within Pastures

	P_{adj} Values[1]		
Pasture	1997 vs. 1998	1997 vs. 1999	1998 vs. 1999
Barn	**0.0007	**0.0036	0.5897
Big Pool	**0.0016	**0.0010	0.6187
Lassen	**0.0000	**0.0082	*0.0251
Safe	**0.0000	**0.0014	**0.0057
Wurlitzer[2]			0.2998

[1] See Table 43 for medians, sample numbers, and definitions

[2] RDM data not collected in 1997

* Significant difference at α= 0.10

** Highly significant difference at α= 0.01

RDM values were fairly consistent between pastures in 1997 with the only significant difference in RDM being between the Barn and Big Pool Pastures (Table 45).

Table 45. Results of Mann-Whitney Tests RDM Between Pastures, 1997

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer[2]	Big Pool	Barn
Safe		0.8301		0.3346	0.3038
Lassen				0.5415	0.2548
Wurlitzer[2]					
Big Pool					*0.0738

[1] See Table 43 for medians, sample numbers, and definitions

[2] RDM data not collected in 1997

* Significant difference at α= 0.10

** Highly significant difference at α= 0.01

In 1998, RDM values began to diverge between pastures with the Wurlitzer Pasture having significantly different values (Table 46) from all but the Barn pasture.

Table 46. Results of Mann-Whitney Tests RDM Between Pastures, 1998

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		*0.0344	**0.0001	0.2134	*0.0128
Lassen			**0.0032	0.8682	0.3615
Wurlitzer				*0.0421	0.1354
Big Pool					0.4068

[1] See Table 43 for medians, sample numbers, and definitions

* Significant difference at α= 0 10

** Highly significant difference at α= 0.01

The ungrazed Wurlitzer pasture continued to have significantly different RDM values from the rest of the pastures in 1999. RDM values in the grazed pastures were fairly homogenous in 1999.

Table 47. Results of Mann-Whitney Tests RDM Between Pastures, 1999

	P_{adj} Values[1]				
Pasture	Safe	Lassen	Wurlitzer	Big Pool	Barn
Safe		0.9010	*0.0620	0.1150	0.8035
Lassen			*0.0680	*0.0745	0.5897
Wurlitzer				**0.0042	*0.0745
Big Pool					0.1585

[1] See Table 43 for medians, sample numbers, and definitions

* Significant difference at α= 0 10

** Highly significant difference at α= 0 01

EXPERIMENTAL PLOT MONITORING

%RCNS within upland habitat varied considerably among the four grazed and exclosure plots during sampling in 1997 (Figure 12 and Tables 48 and 49. However, %RCNS within grazed plots in 1997 closely resembled %RCNS data gathered for the corresponding pasture (see Table 16) where the plot was located. Similar to the drop in %RCNS for the pastures as a whole in 1998 (see previous section), the %RCNS also decreased in all exclosure plots except for the Barn exclosure in 1998 (Figure 12).

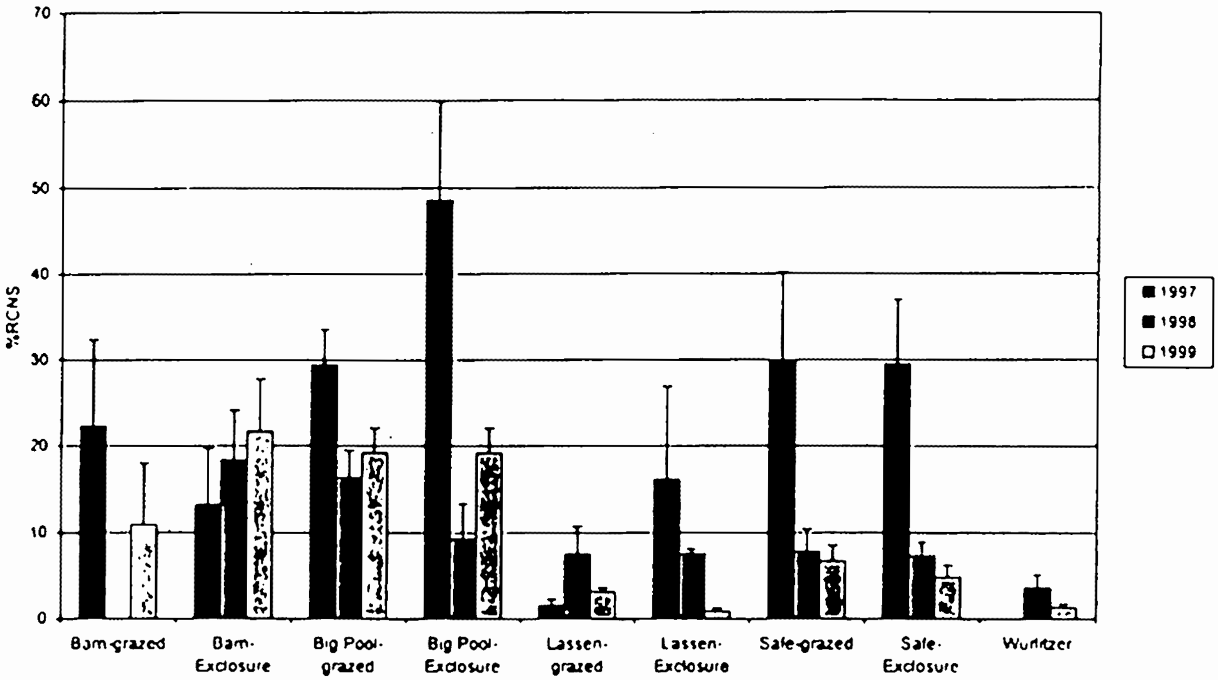
Table 48 Descriptive Statistics Regarding %RCNS for Grazed Experimental Plots

			Mean		Median		TrMean		StDev		SEMean		25th Percentile		75th Percentile	
Year	Pasture	Habitat	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned
1997	Barn	pool/swale		27 20		27 20		27.20		34.10		24 10		16.70		30 12
	Big Pool	pool/swale														
	Lassen	pool/swale														
	Safe	pool/swale														
	Wurlitzer	pool/swale														
	Barn	upland		21.92		16.25		21 92		24 10		9 84		0 57		44.08
	Big Pool	upland		23.50		22 45		23.50		8.21		2.90				
	Lassen	upland		1 53		0 85		1 53		1.87		0 66		0.50		2 30
	Safe	upland		29.80		18 00		29.80		29.30		10.30		3 90		57 40
	Wurlitzer	upland														
1998	Barn	pool/swale	7.90		6.00		7.90		5.84		2.61			3 70		13.05
	Big Pool	pool/swale		55 00		56 70		55.00		38.70		13.70		12.50		95 80
	Lassen	pool/swale		97.40		99.50		97 40		5.35		1.89		97.08		100 00
	Safe	pool/swale		100.00		100 00		100.00		0 00		0.00		100 00		100 00
	Wurlitzer	pool/swale														
	Barn	upland														
	Big Pool	upland		16.24		10.80		16 24		12.90		4 88		6.10		26 50
	Lassen	upland		7.46		4.50		7.46		8 98		3.18		0.62		14 30
	Safe	upland		7.84		4 40		7 84		7.26		2 57		1 57		16 55
	Wurlitzer	upland														
1999	Barn	pool/swale	100.00		100 00		100 00		0.00		0 00		100 00		100 00	
	Big Pool	pool/swale		33.50		18.00		33.50		33 70		11.90		7.80		60.30
	Lassen	pool/swale		100.00		100 00		100.00		0 00		0 00		100 00		100.00
	Safe	pool/swale		100.00		100.00		100.00		0.00		0.00		100.00		100 00
	Wurlitzer	pool/swale														
	Barn	upland		10 94		4 30		10 94		20.04		7.09		1 25		8 58
	Big Pool	upland	13.62		6.80		13.62		15.35		5.43		4 35		17 48	
	Lassen	upland		3.11		3 25		3.11		1 34		0.48		1.73		4 15
	Safe	upland		6 67		4.95		6.67		5 21		1 84		2 55		10 23
	Wurlitzer	upland														

Table 49 Descriptive Statistics Regarding %RCNS for Ungrazed Experimental Plots

			Mean		Median		TrMean		StDev		SEMean		25th Percentile		75th Percentile	
Year	Pasture	Habitat	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned	Burned	Unburned
1997	Barn	pool/swale														
	Big Pool	pool/swale														
	Lassen	pool/swale		50.00		50.00		50.00		15.40		10.90		*		*
	Safe	pool/swale														
	Wurlitzer	pool/swale														
	Barn	upland														
	Big Pool	upland		49.30		40.80		49.30		32.10		11.30		21.60		86.40
	Lassen	upland		16.10		4.50		16.10		26.50		10.80		0.00		31.90
	Safe	upland		27.40		20.10		27.40		20.07		7.10		17.82		29.85
	Wurlitzer	upland														
1998	Barn	pool/swale		100.00		100.00		100.00		0.00		0.00		4.87		29.72
	Big Pool	pool/swale		22.89		15.55		22.89		22.92		8.10		4.75		43.68
	Lassen	pool/swale		96.80		99.10		96.80		5.87		2.07		96.57		100.00
	Safe	pool/swale		100.00		100.00		100.00		0.00		0.00		100.00		100.00
	Wurlitzer	pool/swale	34.90		26.00		34.90		31.50		11.20		9.30		68.40	
	Barn	upland		18.35		13.05		18.35		16.50		5.83		4.87		29.72
	Big Pool	upland		9.26		6.50		9.26		10.84		4.10		2.20		13.50
	Lassen	upland		1.59		0.85		1.59		1.83		0.65		0.13		2.93
	Safe	upland		7.29		5.60		7.29		4.57		1.62		3.65		11.75
	Wurlitzer	upland	3.59		1.75		3.59		4.22		1.49		0.98		5.35	
1999	Barn	pool/swale		99.95		100.00		99.95		0.14		0.05		100.00		100.00
	Big Pool	pool/swale	55.90		60.50		55.90		41.30		14.60		13.30		96.60	
	Lassen	pool/swale		99.90		100.00		99.90		0.28		0.10		100.00		100.00
	Safe	pool/swale		100.00		100.00		100.00		0.00		0.00		100.00		100.00
	Wurlitzer	pool/swale	23.55		21.75		23.55		12.67		4.48		18.82		24.82	
	Barn	upland	21.68		19.95		21.68		17.39		6.15		7.05		30.35	
	Big Pool	upland		19.15		21.15		19.15		9.26		3.27		13.48		24.35
	Lassen	upland		0.80		0.50		0.80		1.26		0.45		0.00		0.90
	Safe	upland		4.81		3.30		4.81		3.85		1.36	0.50	2.10	1.85	7.40
	Wurlitzer	upland														

Figure 12. Experimental Plot Mean %RCNS for Upland Habitat, 1997-1999



Grazed plots also experienced a decrease in %RCNS between 1997 and 1998, except for the Lassen pasture plot which experienced a slight increase in %RCNS over the extremely low value recorded in 1997. In 1999, %RCNS values for the exclosure plots declined further from the values recorded in 1997 (Figure 12) except for the Barn and Big Pool plots which increased slightly. With the exception of the Big Pool pasture plot, grazed plots in 1999 showed a similar decrease in %RCNS from the previous years' values (Figure 12).

Because quadrats were not stratified between burned and unburned subplots within a plot it was not possible to compare burned vs. unburned vegetation conditions within a year. Therefore, hypothesis testing on the effects of burning within a plot was limited to testing between, and not within years (Table 50). The consequence of testing burning effects between years is that climate related effects on vegetation composition cannot be disregarded and therefore causation cannot be substantiated.

The results of statistical testing regarding %RCNS for upland habitats both among and between years and grazing treatments are shown below in Tables 50 and 51.

Table 50. Results of Mann-Whitney Tests Regarding %RCNS Medians Within Upland Habitats of Experimental Plots Between Years

Pasture	Treatment	P_{adj} Value		
		1997 vs. 1998	1997 vs. 1999	1998 vs. 1999
Barn	UB & UG vs. UB & G	Data lost	Data lost	NA
Barn	UB & UG vs. B & UG	Data lost	Data lost	0.6365
Big Pool	UB & UG vs. UB & UG	**0.0065	*0.0406	*0.0933
Big Pool	UB & G vs. UB & G	0.3253	NA	NA
Lassen	UB & UG vs. UB & UG	0.6056	0.3886	0.3355
Lassen	UB & G vs. UB & G	0.1383	*0.0312	0.5632
Safe	UB & UG vs. UB & UG	**0.0019	**0.0013	0.1146
Safe	UB & G vs. UB & G	0.1275	0.1279	0.9580

B = Burned
G = Grazed
UB = UnBurned
UG = UnGrazed
NA = Not Applicable
* Significant difference at $\alpha = 0.10$
** = Highly significant difference at $\alpha = 0.01$

Table 51. Results of Mann-Whitney Tests Regarding %RCNS Medians Within Upland Habitats of Experimental Plots Within Years

Date	Pasture	Treatments P_{adj} Value		
		UB & G vs. UB & UG	UB & G vs. B & UG	UB & UG vs. B & G
1997	Barn	NA	NA	NA
1997	Big Pool	0.1278	NA	NA
1997	Safe	0.7469	NA	NA
1997	Lassen	0.6742	NA	NA
1998	Barn[1]	NA	NA	NA
1998	Big Pool	0.3067	NA	NA
1998	Safe	0.1264	NA	NA
1998	Lassen	0.7132	NA	NA
1999	Barn	NA	*0.0661	NA
1999	Big Pool	NA	NA	0.1563
1999	Safe	**0.0052	NA	NA
1999	Lassen	0.4945	NA	NA

B = Burned
G = Grazed
UB = UnBurned
UG = UnGrazed
NA = Not Applicable
* Significant difference at α= 0.10
** = Highly significant difference at α= 0.01
[1] Data not collected in 1998 for Barn Pasture

Burning effects on %RCNS was statistically tested for upland habitat in both the Barn and Big Pool pastures under ungrazed and grazed conditions, respectively, between 1998 and 1999, (Table 52). In summary, no significant differences in %RCNS were found.

Table 52. Results of Mann-Whitney Tests for Upland Habitat %RCNS Between Years Following a Prescribed Burn

Pasture	Burn Timing	Grazing Treatment	P_{adj} Values[1] 1998 vs. 1999
Barn	Late Spring 1998	Ungrazed	0.6365
Big Pool	Late Spring 1998	Grazed	0.4519

[1] See Tables 48 and 49 for medians, sample numbers, and definitions

RARE PLANTS

PRIORITY POOL MONITORING

With the exception of Pool 1 that was removed from the study in 1998, Priority Pool monitoring was conducted in the same pools using the same methods as Experimental Pool Monitoring. Therefore, the results of priority pool monitoring are combined with the results of Experimental Pool Monitoring, presented below.

EXPERIMENTAL POOL MONITORING

Four pools (1, 17, 21, and 29) were monitored in 1997 resulting in 1256 quadrats being sampled along 113 transects. The population estimates of the target rare plant species in the four pools in 1997 are shown in Table 53.

Table 53. Target rare plant species populations (± one standard error) in monitored vernal pools in 1997

Pool	*Chamaesyce hooveri*	*Tuctoria greenei*	*Orcuttia tenuis*	*Orcuttia pilosa*
1	893,377 ±65,347	not present	not present	4,122,886 ±191,907
17	not present	not present	not present	9,376,417 ± 452,261
21	not present	1,910,533 ±1,024,963	not present	not present
29	not present	not present	1,482,964 ±366,277	not present

As described in the "Methods" section, the extreme level of effort expended during 1997 rare plant monitoring necessitated a change in the monitoring procedure to reduce the overall monitoring effort while still providing meaningful data. Additionally, in 1998 the number of pools sampled was increased to six so that all rare plants (except *Orcuttia tenuis*, which occurs in only one pool at the Preserve) were sampled in both grazed and ungrazed pools. Pool #1 in the Big Pool pasture was dropped from the study because of the inordinate amount of effort expended during rare plant monitoring during the 1997 monitoring year

Population estimates could not be determined from the data collected in 1998 due to problems encountered with the implementation of the modified procedure. However, several observations made in 1998 warrant reporting. *Orcuttia pilosa* was found in only one of the pools monitored (pool 17) (Table 54). Additionally, *Orcuttia tenuis* was not present in pool 29 during monitoring. However, *Chamaesyce hooveri* was observed in pool 17 where it was not observed during monitoring in 1997 (Table 54).

During monitoring in 1999, the modified sampling method was implemented successfully. However, because of the patchy nature of the rare plant occurrences, it was not possible to sample enough transects within a pool to stabilize the cumulative sample mean density across transects to ±10%, as was stipulated in the original experimental design. Additional sampling transects were added to attempt to stabilize the cumulative mean density for the target rare plants, however, collecting the additional data resulted in trampling of the rare plants. Because it was not possible to reach an adequate sample size in the time available and without trampling the target vegetation, the standard error for the estimates of population size were by necessity excessively large, essentially rendering the data useless for the purposes of the study. As a result, population estimates for rare plants in 1999 are not presented. However, more qualitative observations of the target species' populations and occurrences within the pools monitored were recorded for this sampling year.

Rare plant data was inconsistent from year to year. For example, the *Orcuttia tenuis* population in pool 29 during 1999 was much smaller than the same population size recorded in 1997 (i.e. approximately 300 individuals observed in 1999 versus greater than one million in 1997). Additionally, *Chamaesyce hooveri* reappeared in pool 17 in 1999 (visual estimate of > 1.0×10^6 individuals) from where it was reported absent in 1997, and where only two plants were observed in 1998.

Table 54. Target rare plant species presence in monitored pools; 1997-1999

Pool	Species	1997	1998	1999
1	*Chamaesyce hooveri*	Present	NM	NM
	Orcuttia pilosa	Present	NM	NM
17	*Chamaesyce hooveri*	Absent	Present	Present
	Orcuttia pilosa	Present	Present	Present
21	*Tuctoria greenei*	Present	Absent	Present
22	*Chamaesyce hooveri*	NM	Absent	Present
	Orcuttia pilosa	NM	Absent	Absent
	Tuctoria greenei	NM	Absent	Present
29	*Orcuttia tenuis*	Present	Absent	Present
34	*Chamaesyce hooveri*	NM	Present	Present
	Orcuttia pilosa	NM	Absent	Present
35	*Chamaesyce hooveri*	NM	Present	Present
	Orcuttia pilosa	NM	Absent	Present
	Tuctoria greenei	NM	Present	Present
NM = Not Monitored				

SWALE AND VERNAL POOL VEGETATION.

For the 1997 data collection, eight quadrats (35 cm x 70 cm in size) were randomly placed within grazed and ungrazed plots. However, the number of quadrats sampled in swale and vernal pool habitats within a pasture was not large enough (e.g., sample size of n=2 for each pasture) to provide reliable data. Further, because quadrats were randomly placed, often no quadrats fell within swale or vernal pool habitats (i.e., Big Pool and Safe Pastures). Therefore, 1997 data regarding swale and vernal pool vegetation does not yield results indicative of conditions within swale or vernal pool habitats, and therefore is not discussed further.

For sample year 1998, %RCNS within swale and vernal pool habitat was consistently greater than that for the adjacent upland habitat for the grazed and exclosure plots (Figure 13 and Tables 48 and 49).

Vernal pool and swale habitat data from the Big Pool and Wurlitzer pastures had relatively low %RCNS when compared to other pastures. This result may be attributed to vegetative differences between vernal pools and swales. Wetland habitats within these pastures are comprised primarily of swale habitat (Table 7), a habitat that naturally supports a few species of hydrophytic non-native annual grasses such as Italian ryegrass (*Lolium multiflorum*) and Mediterranean barley (*Hordeum marinum* ssp. *gussoneanum*). In contrast, vernal pools are typically dominated by native annual and native herbaceous perennial species, so therefore inherently have higher %RCNS than swales. In contrast to the Big Pool and Wurlitzer experimental plots, the Lassen and Safe experimental plots (both grazed and ungrazed) contain a large proportion of vernal pool area in relation to swales, hence the high %RCNS observed in both grazed and ungrazed plots in 1998. The Barn pasture's ungrazed plot (i.e., exclosure) consists primarily of vernal pool habitat with a relatively small proportion of swale habitat while the corresponding grazed plot consists of a mix of vernal pool and swale habitat.

Because sampling of the wetland habitats within the experimental plots was not stratified between swales and vernal pools, the data collected represents the %RCNS condition for vernal pools, swales, or a combination of these two habitats. The resulting changes in %RCNS between and among years therefore may not accurately portray conditions in either vernal pool or swale habitats.

Furthermore, because quadrats were also not stratified between burned and unburned subplots within vernal pools and swales, burning effects within a single year and within a single habitat type could not be compared. Burned and unburned effects could be compared between years (Table 55), however, climatic effects on vegetation compositions could not be disregarded (and therefore the causation between years could not be substantiated).

Figure 13   Experimental Plot Mean %RCNS for Swale and Pool Habitat, 1998-1999

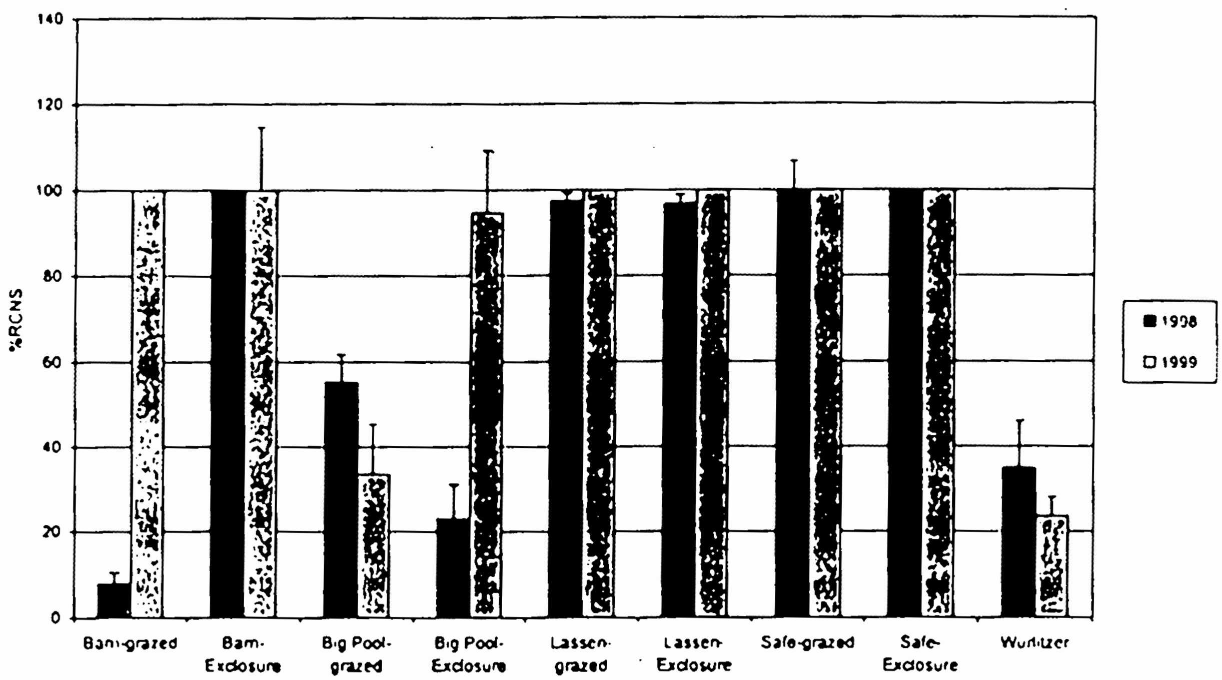


Table 55. Results of Mann-Whitney Tests for Pool and Swale Habitat %RCNS Medians Between Years Following a Prescribed Burn

Pasture	Burn Timing	Grazing Treatment	P_{adj} Values[1]
Barn	Late Spring 1997	Grazed	0.8465
Big Pool	Late Spring 1998	Ungrazed	*0.0831

[1] See Tables 48 and 49 for medians, sample numbers, and definitions

* Significant difference at α= 0.10

However, within any year hypothesis testing of %RCNS between the grazed and burned treatment; the ungrazed and unburned treatment; and the grazed and unburned treatment was possible (Table 56).

Table 56. Results of Mann-Whitney Tests Regarding %RNCS Medians Within Pool/Swale Habitats of Experimental Plots Within Years

		Treatments P_{adj} Value		
Date[1]	Pasture	UB & G vs. UB & UG	UB & G vs. B & UG	UB & UG vs. B & G
1998	Barn	NA	NA	**0.007
1998	Big Pool	0.1278	NA	NA
1998	Safe	0.9141	NA	NA
1998	Lassen	1.000	NA	NA
1999	Barn	NA	NA	1.000
1999	Big Pool	NA	0.3442	NA
1999	Safe	1.000	NA	NA
1999	Lassen	1.000	NA	NA

B = Burned

G = Grazed

UB = UnBurned

UG = UnGrazed

NA = Not Applicable

** = Highly significant difference at α = 0.01

[1] Quadrats were not randomly stratified among habitat types (i.e., uplands and pool/swale) and therefore wetlands were not adequately sampled. Hence, statistical analysis could not be preformed.

Statistical testing within pastures and between years for consistent combinations of treatments are shown in Table 57. Pool and swale %RCNS did not differ significantly between 1998 and 1999 under grazed or ungrazed conditions in all plots except the ungrazed plot in the Lassen Pasture %RCNS. However, the change in mean %RCNS (+3.1%) (Table 49) in the ungrazed Lassen plot between 1998 and 1999 is biologically insignificant.

Table ?. Results of Mann-Whitney Tests regarding %RCNS medians within pool/swale habitats of experimental plots between years

Pasture	Treatment	P_{adj} Value		
		1997 vs. 1998	1997 vs. 1999	1998 vs. 1999
Barn	UB & UG vs. UB & UG	NA	NA	1.000
Barn	B & G vs. B & G	NA	NA	1.000
Big Pool	UB & G vs. UB & G	NA	NA	0.3442
Lassen	UB & UG vs. UB & UG	*0.0474	*0.0160	*0.0402
Lassen	UB & G vs. UB & G	NA	NA	1.000
Safe	UB & UG vs. UB & UG	NA	NA	1.000
Safe	UB & G vs. UB & G	NA	NA	1.000

B = Burned
G = Grazed
UB = UnBurned
UG = UnGrazed
NA = Not Applicable
* = Significant difference at $\alpha = 0.10$

Large Branchiopods

DRY SEASON SAMPLING

Dry-season sampling in the summer of 1997 was performed with limited success. Specificially, *Linderiella occidentalis* cysts were found in four pools (16, 18, 42, and W) out of the nine pools that were sampled. *Lepidurus packardi* cysts were found in three pools (29, 30, and W), and cysts belonging to genus *Branchinecta* were found in six pools (16, 18, 29, 30, 41, and W).

Descriptive statistics for large branchiopod cyst concentrations collected in 1997 (expressed as number of cysts per cubic centimeter [cm^3] of soil) are presented in Tables 58, 59, and 60.

Table 58 Descriptive Statistics Regarding Concentration (No. of Individuals per cm^3) of *Linderiella occidentalis* Cysts

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
16	8	0.0	1.0	0.125	0.00	0.125	0.354	0.125
18	8	0.0	7.0	1.125	0.00	1.125	2.475	0.875
42	8	0.0	5.0	0.625	0.00	0.625	1.768	0.625
W	8	0.0	1.0	0.125	0.00	0.125	0.354	0.125

Table 59. Descriptive Statistics Regarding Concentration (No. of Individuals per cm^3) of *Lepidurus packardi* Cysts

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
29	8	0.0	2.0	0.375	0.00	0.375	0.744	0.263
30	8	0.0	1.0	0.125	0.00	0.125	0.354	0.125
W	8	0.0	12.0	2.25	1.00	2.25	4.06	1.44

Table 60. Descriptive Statistics Regarding Concentration (No. of Individuals per cm^3) of *Branchinecta* sp. Cysts

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
16	8	0.0	2.0	0.750	1.00	0.750	0.707	0.250
18	8	0.0	1.0	0.250	0.00	0.250	0.463	0.164
29	8	0.0	6.0	1.50	0.00	1.50	2.330	0.824
30	8	0.0	2.0	0.375	0.00	0.375	0.744	0.263
41	8	0.0	2.0	0.375	0.00	0.375	0.744	0.263
W	8	0.0	2.0	0.375	0.00	0.375	0.744	0.263

Based on the limited value of the data collected in 1997 (i.e., very few cysts were obtained), the extraordinary effort expended in collecting the data, and the fact that sampling was not conducted prior to the first year of the wet-season sampling, it was decided that dry-season sampling be abandoned in its entirety.

WET SEASON SAMPLING

In summary, six of the nine pools sampled using the wet-season methods during the 1996/97 sampling period supported large branchiopods (Table 61).

Descriptive statistics of large branchiopod concentrations for the 1996/1997 sampling season (expressed as number of individuals per 0.025 cubic meter [m^3] of water) are presented in Tables 62 through 88 and Figures 14-19 in Appendix A.

During the 1996/1997 sampling season, as stated earlier, six of the nine pools wet-season sampled in 1996/97 were found to support large branchiopods (Table 61). During the first sampling event on December 6, 1996, no large branchiopods were found in any of the 10 pools sampled. During this sampling event, Pool 13 did not have open water (and therefore was not sampled) and the Wurlitzer pool (W) was not sampled. During the second sampling event on January 30, 1997, *Linderiella occidentalis* was found in five pools (Table 61) and *Lepidurus packardi* was found in three pools (Table 61). During the third sampling event conducted on February 21, 1997, only *Lepidurus packardi* was found in five pools (Table 61). Pools 9, 10, and 13 were dry during this sampling date. Except for Pool 29, all of the pools sampled during the fourth and final sampling round in 1997 were dry or there was not enough water to conduct sampling. Hence, no large branchiopods were observed during the fourth and final sampling event.

Table 61. Results of Large Branchiopod Wet-Season Sampling, 1997-1999

Pool No	Survey Dates: 1996/1997				1997/1998				1998/1999			
	Dec 6, 1996	Jan 30, 1997	Feb 21, 1997	Mar 13, 1997	Dec 16 1997	Jan 21, 1998	Feb 26, 1998	Mar 19, 1998	Dec 18, 1998	Feb 4, 1999	Feb 26 1999	Apr 1, 1999
41	—	LIOC, LEPA	—	—	LIOC, LEPA	LIOC, LEPA	LIOC, LEPA	LEPA	LIOC	—	—	—
42	—	LIOC, LEPA	—	—	LIOC, BRLY, LEPA	LIOC, LEPA	LIOC, LEPA	LEPA	LIOC	—	—	—
34	NS	NS	NS	NS	LIOC, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO	LIOC, BRCO	LIOC, BRCO, LEPA	LIOC, BRCO
35	NS	NS	NS	NS	LIOC, BRCO	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA
22	NS	NS	NS	NS	BRCO	BRCO, LEPA	LIOC, BRCO	LIOC, BRCO	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA
18	—	—	—	—	LIOC	LIOC	—	—	LIOC	—	LEPA	—
17	NS	NS	NS	NS	BRCO	BRCO, LEPA	BRCO	BRCO, LEPA	BRCO, LEPA	BRCO, LEPA	BRCO, LEPA	BRCO, LEPA
16	—	—	LEPA	—	LIOC, BRCO, LEPA	BRCO, LEPA	LIOC, BRCO	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LIOC, BRCO, LEPA	LEPA
13	—	—	—	—	LIOC	LEPA	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—
1	NS	NS	NS	NS	BRCO, LEPA	BRCO, LEPA	BRCO, LEPA	BRCO, LEPA	BRCO	BRCO, LEPA	BRCO, LEPA	BRCO, LEPA
21	NS	NS	NS	NS	LIOC	LIOC	LIOC, LEPA	LIOC, LEPA	LIOC, LEPA	LIOC	LIOC	LIOC
29	—	LIOC	LEPA	—	LEPA	—	LEPA	LEPA	—	—	LEPA	—
30	—	LIOC	LEPA	—	LIOC, LEPA	—	—	—	BRLY, LEPA	LEPA	LEPA	—
W	—	LEPA	LEPA	—	LIOC	LIOC, LEPA	—	—	—	—	—	—

NS = Not Sampled
LIOC = *Linderiella occidentalis*
LEPA = *Lepidurus packardi*
BRCO = *Branchinecta conservatio*
BRLY = *Branchinecta lynchi*

During the 1997/1998 and 1998/1999 sampling seasons, 14 of the 15 pools sampled in 1997/1998 and 12 of the 15 pools sampled in 1998/1999 were found to support large branchiopods (Table 61). Seven of the pools sampled (pools 1, 16, 17, 21, 22, 34, 35) in 1997-1998 and 1998-1999 monitoring years, consistently supported at least one, and frequently two, species of large branchiopods during each of the monitoring visits (Table 61). Pools 1, 16, 17, 22, 34, and 35 most consistently supported populations of both *Branchinecta conservatio* and *Lepidurus packardi*. Pool 10, within the Big Pool pasture, only supported *Lepidurus packardi* during the January 21, 1998 monitoring visit. Similarly, Pool 13 supported *Linderiella occidentalis* and *Lepidurus packardi* during only two monitoring visits (Table 61). Similar to the pools in the Big Pool pasture, the Wurlitzer Pool was found to support large branchiopods only during the early winter surveys of 1997-1998. Pools 41 and 42 in the Barn pasture supported populations of both *Linderiella occidentalis* and *Lepidurus packardi* during the El Niño winter of 1997-1998, but were only found to support *Linderiella occidentalis* during one visit in the winter of 1998-1999. The vernal pool fairy shrimp, *Branchinecta lynchi*, was only recorded twice during the study on the December 16, 1997 in Pool 42 and on December 18, 1998 in Pool 30.

Peak mean concentrations of *Linderiella occidentalis* during 1997-1998 were recorded during the first monitoring visit on December 16, 1997 with the highest concentration occurring in pool 34 (1528±273 individuals/ m^3) (Figure 14). Following the first monitoring visit, mean concentration of *Linderiella occidentalis* declined in all of the pools (Figure 14). Like the 1997-1998 monitoring period, peak mean concentrations for *Linderiella occidentalis* in the 1998-1999 monitoring period were recorded on the first monitoring visit (December 18, 1998), with the exception of pool 34 which recorded its peak mean concentration on the February 4, 1999 (Figure 15). Pool 42 supported the highest mean concentration of *Linderiella occidentalis* (800±362 individuals/m^3 of water) in the 1998-1999 monitoring period, recorded on December 18, 1998.

Branchinecta conservatio also typically recorded peak concentrations during the first monitoring visit (i.e., December 16, 1997) of the 1997-1998 monitoring period (Figure 16) with the exception of the populations in pools 22 and 35 which recorded their peak concentration of the species on the second monitoring visit (i.e., January 21, 1998). The maximum mean concentration for the species (2584±540 individuals/m^3) (Figure 16) was recorded in pool 22 on the December 16, 1997. Peak mean concentrations for *Branchinecta conservatio* in the 1998-1999 monitoring period were also recorded during the first monitoring visit on December 18, 1998 (Figure 17) with the maximum mean concentration recorded in pool 35 (1038±176 individuals/m^3). Mean concentration of *Branchinecta conservatio* fell steadily following the initial monitoring visit in the 1998-1999 monitoring period.

In contrast to *Linderiella occidentais* and *B. conservatio*, *Lepidurus packardi* mean concentration in both the 1997-1998 and 1998-1999 monitoring periods peaked later in the season, typically in January or February (Figures 18 and 19). The maximum mean concentration for the species recorded for the 1997-1998 monitoring period occurred in pool 17 (73±18 individuals/m^3) on the January 21, 1998. The maximum mean

Figure 14. Mean Concentraton of *Linderiella occidentalis* 1997-1998

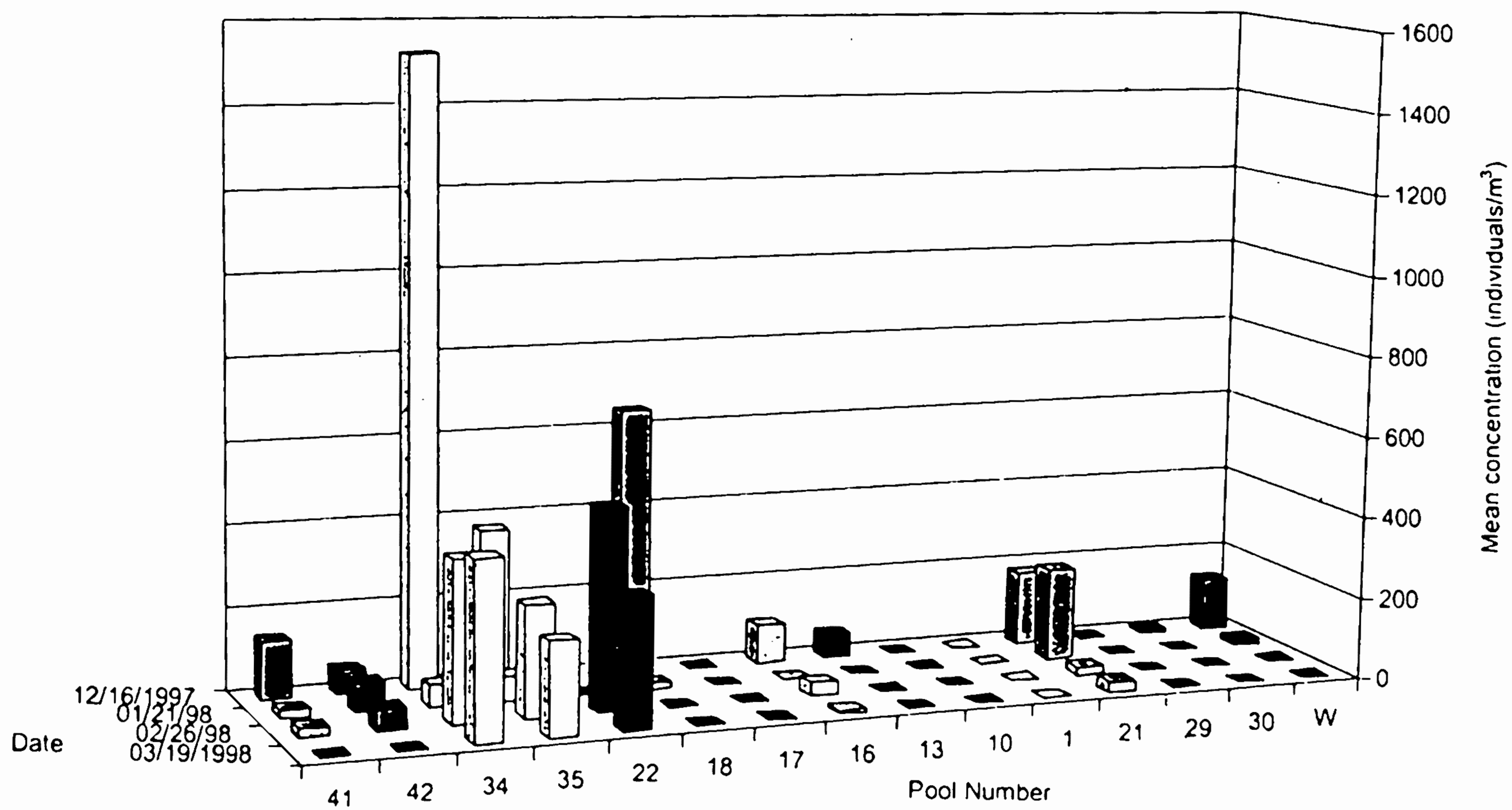


Figure 15. Mean Concentration of *Linderiella occidentalis*, 1998-1999

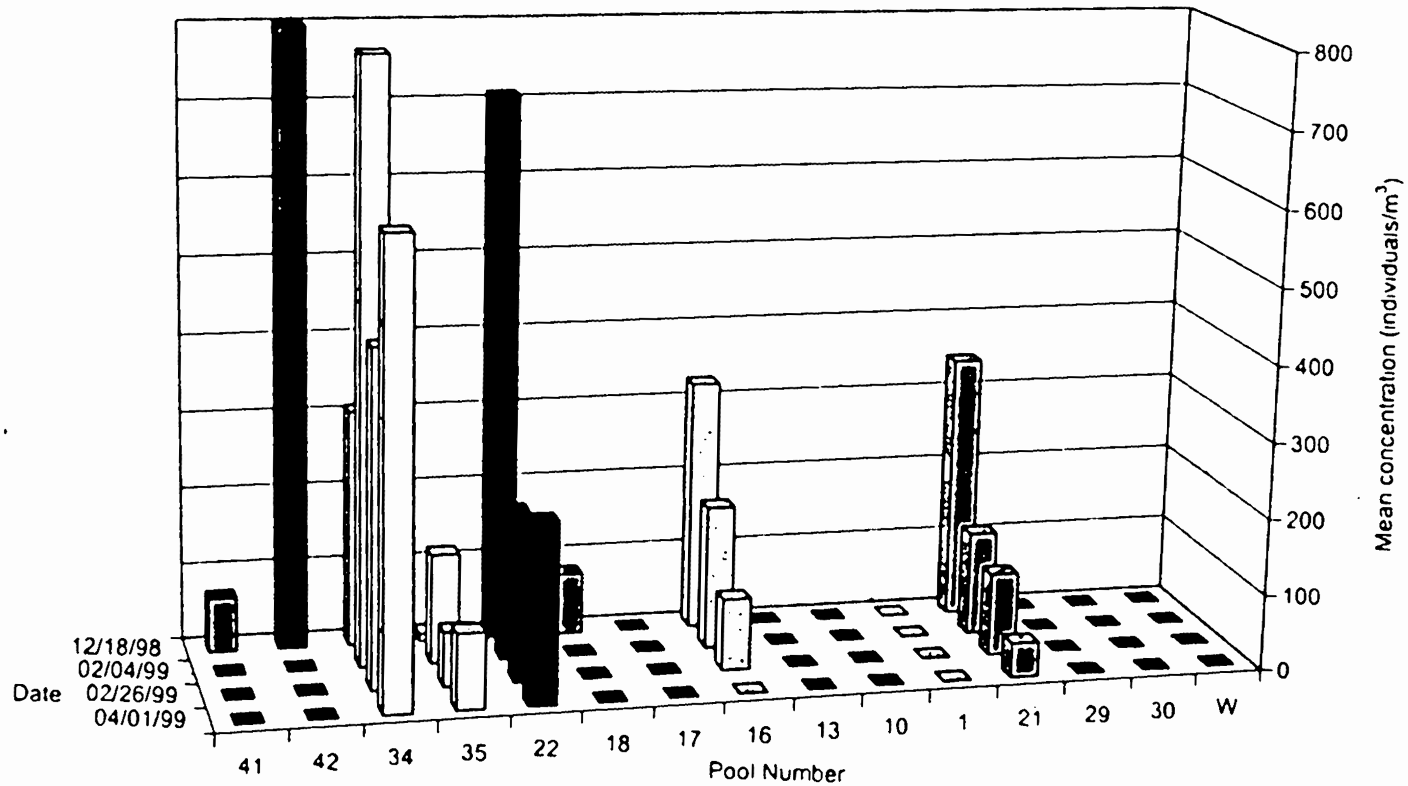


Figure 16. Mean Concentration of *Branchinecta conservatio* 1997-1998

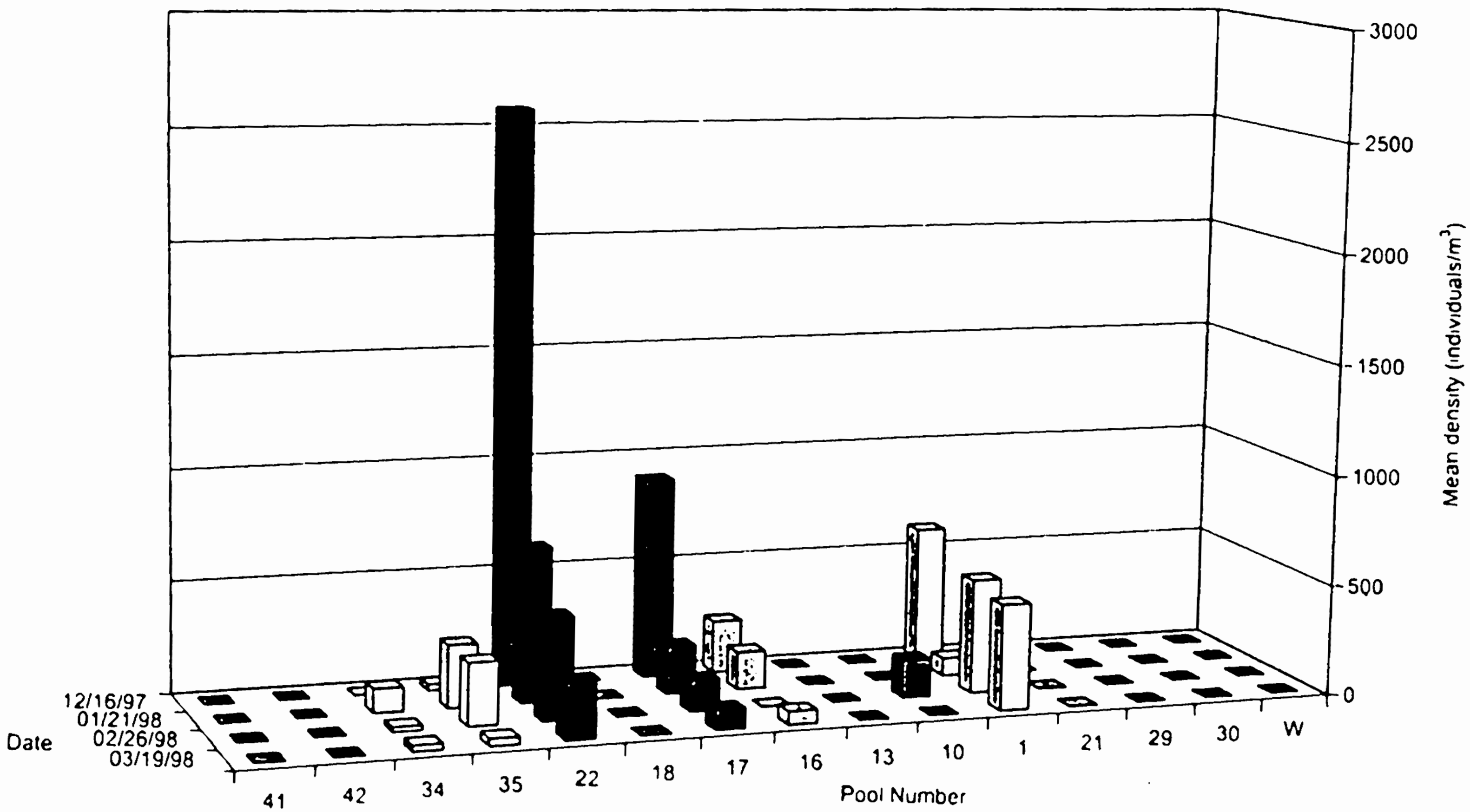


Figure 17. Mean Concentration of *Branchinecta conservatio*, 1998-1999

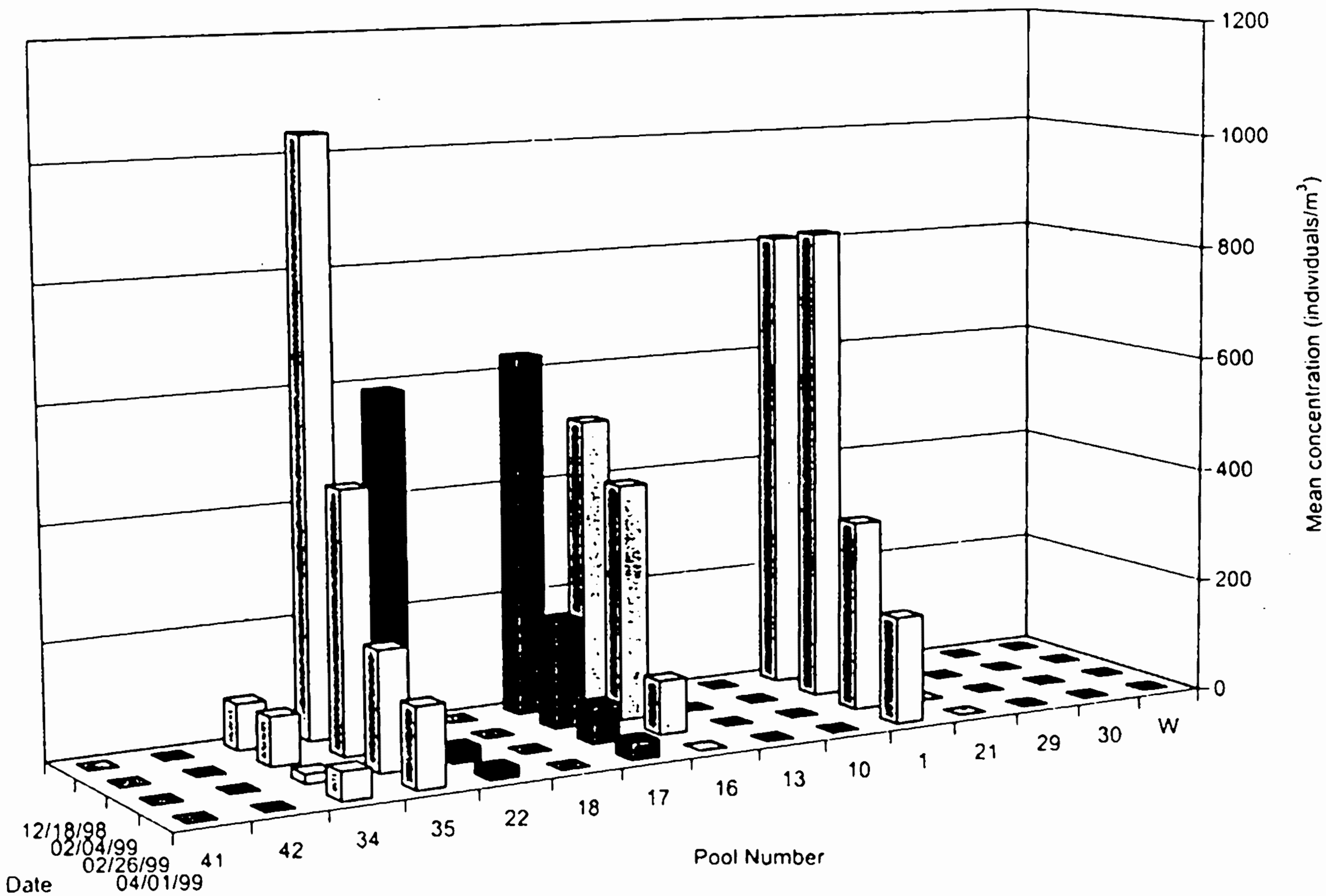


Figure 18. Mean Concentration of *Lepidurus packardi*, 1998-1999

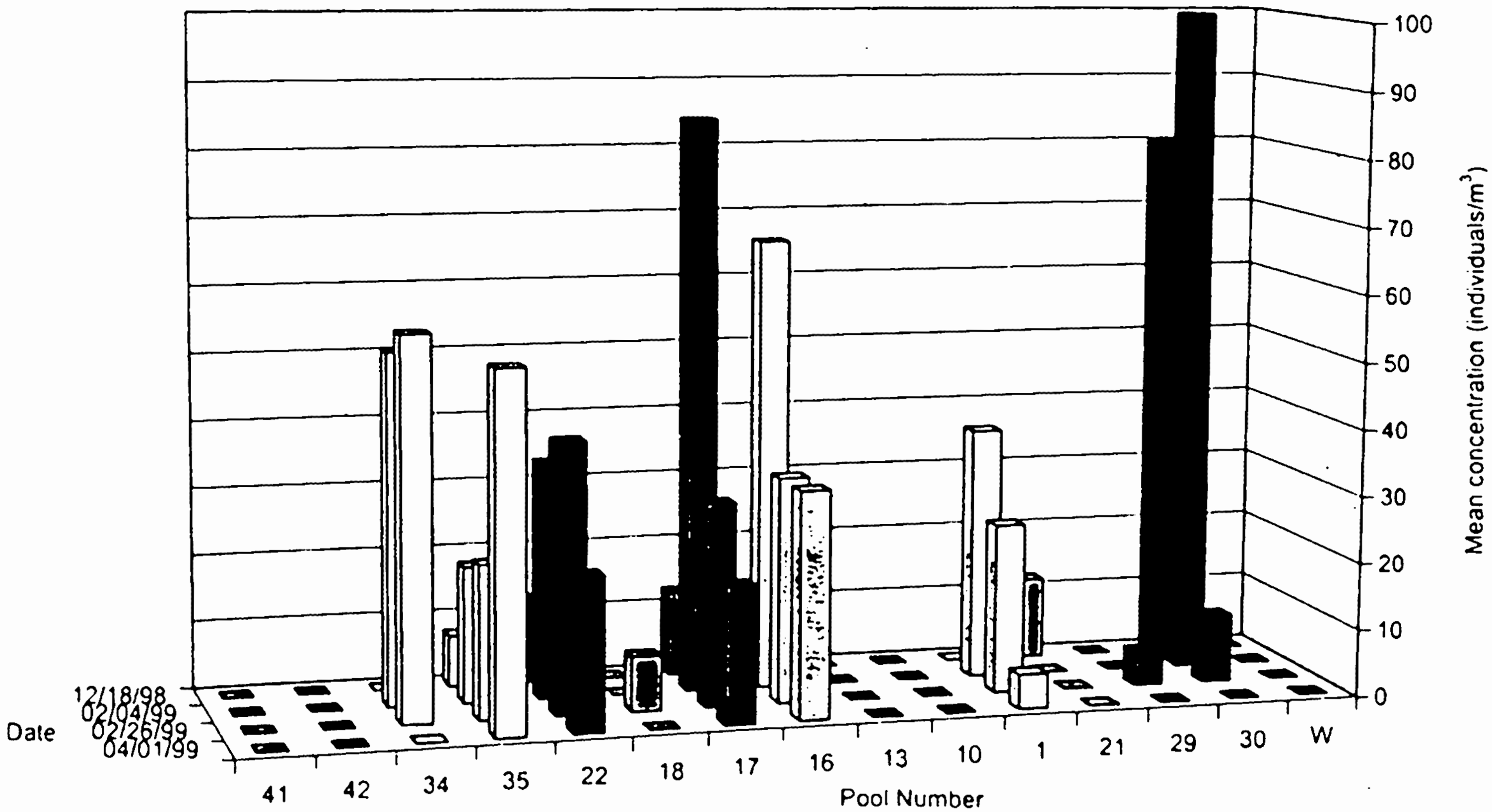
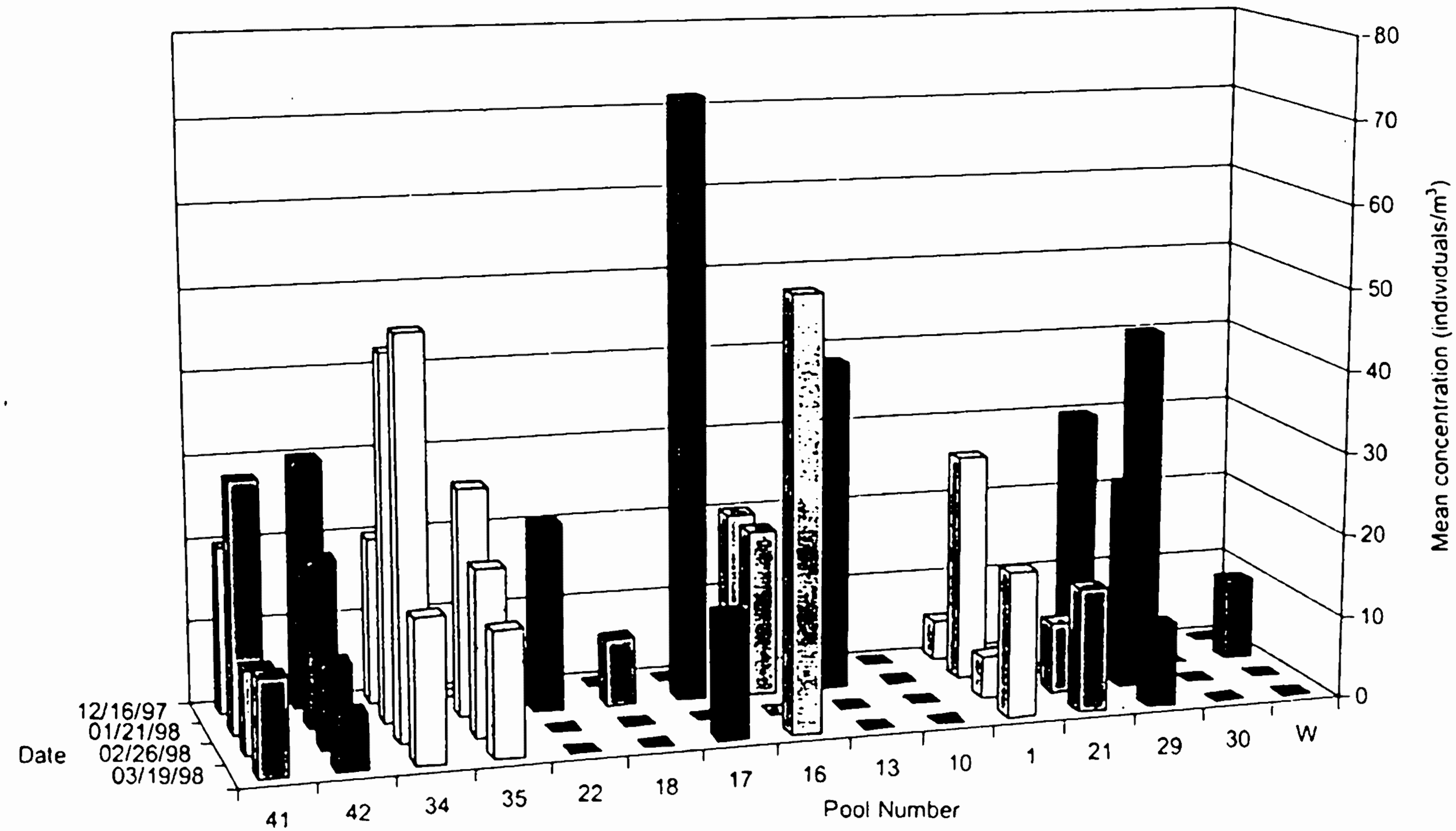


Fig 19. Mean Concentration of *Lepidurus packardi* 1997-1998



concentration for *Lepidurus packardi* (100±20 individuals/m^3) recorded for the 1998-1999 monitoring period was recorded on the February 4, 1999 in pool 30 (Figure 19).

Although the intent of the sampling design was to allow comparisons of large branchiopods populations under differing grazing and burning regimes within 4 pair pools (42 & 41; 9 &10; 16 &18; and 29 & 30) (Figure 5), implementation of the sampling design only allowed for the comparison of four pools, 42 & 41, and 29 & 30. Pools 42 and 41 were similar in size, depth, species composition, and soil substrate and mostly likely were originally the same pool until a road was built through the middle of the pool, bisecting it in two. Likewise, Pools 29 and 30 are similar in size, depth, and soil substrates.

In contrast, Pool 16 is a playa pool (with Anita Clay substrates) supporting *B. conservatio*, *L. occidentalis*, and *L. packardi*; while its paired ungrazed Pool 18 is a vernal pool (with Tuscan loam substrates) supporting only *L. occidentalis* and occasionally *L. packardi*. Pool 10 was never enclosed and seldom ponded water and therefore did not allow for comparisons with Pool 13.

Furthermore, the data collected for large branchiopods during the 1996/1997 wet-season was supposed to represent baseline data from which the 1997/98 and 1998/99 data could be compared. Unfortunately, the data presented for 1996/97 is of minimal use since few large branchiopods were recorded (Table 61).

There was not enough data collected to test the hypothesis that population size per pool of *B. lynchi*, *L. occidentalis*, and *L. pakardi* differs between burned and unburned plots.

In regards to populations of *L. packardi*, the recorded abundance of these benthic (bottom) dwellers was likely underestimated as a result of sampling methods. Wet-season sampling protocol for this species in deep and shallow pools required a sampling distance of 1 meter horizontal distance. Because of this sampling protocol, more deep-water habitat (favored by the species) was sampled in shallow pools, and conversely, less deep water habitat was sampled in deep pools, possibly skewing the data towards under-representing the number of *L. packardi* in deep vernal pools.

WATER QUALITY

On the first sampling date on December 19, 1997, the ground around the pools was at or near saturation and the pools were constantly flushed with rainfall. This condition persisted through February and ended in the beginning of March, when approximately three weeks of dry weather occurred prior to the March 20, 1998 sampling date. Pool volumes were reduced by the April 27, 1998 sampling date and all of the pools were dry on the final sampling date except for pool 16 in the Safe Pasture.

The pH of the ponds was neutral or slightly acidic in December 1997.

Samples were not collected in February 1998 due to the continuing high rainfall and saturated conditions of the watershed. By mid-May 1998, the water levels in the pools had either fallen below levels necessary for sampling or the pools had gone dry.

Complete summaries of the field-measured physical parameters are presented in Tables 89 and 90.

Table 89. Summary of Field-Measured Physical Parameters

Pasture	Pool[1]	Sample Date	Temp. (°C) 1	Temp. (°C) 2	Temp. (°C) 3	D.O. (mg/L) 1	D.O. (mg/L) 2	D.O. (mg/L) 3	pH 1	pH 2	pH 3
Big Pool	**10**	12/19/97	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.
		01/21/98	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.
		03/20/98	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
		04/27/98	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	13	12/19/97	10.6	10.2	9.1	11.0	11.2	10.8	7.15	7.27	7.25
		01/21/98	13.0	13.5	13.8	14.1	13.5	14.5	8.47	7.17	8.19
		03/20/98	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
		04/27/98	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Safe	16	12/19/97	7.7	7.7	7.6	11.1	11.5	11.9	6.87	7.04	6.87
		01/21/98	14.1	10.8	9.9	11.1	11.0	10.4	7.13	7.33	6.81
		03/20/98	24.5	24.8	24.9	10.6	10.6	10.5	8.67	8.36	7.78
		04/27/98	30.4	28.1	24.1	9.2	9.5	9.6	8.14	8.42	7.55
	18	12/19/97	8.2	8.1	8.1	11.2	11.8	11.8	6.82	7.04	7.02
		01/21/98	13.2	11.2	13.7	14.4	13.2	15.2	8.41	8.26	8.24
		03/20/98	27.3	26.3	25.9	10.8	11.3	11.5	8.45	8.56	8.71
		04/27/98	30.9	28.7	29.3	9.6	10.6	10.9	8.90	8.72	8.90
Lassen	**29**	12/19/97	5.2	6.8	6.2	13.6	14.1	13.1	7.15	7.34	7.28
		01/21/98	7.7	7.2	7.1	11.5	11.1	9.7	6.94	7.12	6.88
		03/20/98	24.7	24.2	22.3	10.9	11.2	11.8	8.05	8.61	9.15
		04/27/98	24.4	23.8	23.5	9.3	8.6	10.6	7.67	7.77	7.99
	30	12/19/97	6.8	7.3	7.2	13.6	12.6	14.6	7.46	7.18	7.44
		01/21/98	8.3	7.3	7.8	11.4	11.8	10.8	7.31	7.28	7.29
		03/20/98	23.6	22.9	23.0	12.9	12.2	12.6	8.70	7.72	8.40
		04/27/98	23.6	23.2	22.1	9.6	9.8	11.4	8.04	8.13	8.11
Barn	41	12/19/97	7.4	7.4	7.9	12.4	12.2	12.2	7.06	7.07	7.06
		01/21/98	9.2	8.7	8.1	12.0	11.4	11.2	7.16	7.06	7.03
		03/20/98	23.1	24.2	23.3	10.6	11.4	10.8	7.63	7.98	8.48
		04/27/98	29.1	27.0	26.9	10.3	9.3	9.7	9.03	8.69	7.85
	42	12/19/97	8.1	7.8	7.9	12.2	12.7	12.5	6.96	7.12	7.11
		01/21/98	11.5	8.7	9.1	12.0	10.8	10.8	7.07	6.91	6.83
		03/20/98	25.5	24.6	25.0	11.7	10.9	11.1	7.46	8.13	8.10
		04/27/98	27.3	29.2	28.5	13.2	10.4	10.9	9.70	9.01	8.85
Wurlizter		12/20/97	7.3	6.5	6.6	11.2	10.8	10.4	6.60	6.38	6.45
		01/21/98	11.7	11.7	14.2	15.1	16.0	18.0	8.90	8.93	9.67
		03/20/98	26.6	26.1	25.0	10.9	9.8	10.7	8.29	9.16	8.40
		04/27/98	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.

[1]Bold number indicates fenced pool (i.e., ungrazed).

I.D. Insufficient pool depth to sample.

N.S. Pool not sampled, removed from sampling program.

Table 90 summarizes the laboratory analysis of nitrogen concentration data from 1997-1998.

Table 90. Pool Water Nitrite-N and Nitrate-N Concentrations (mg/L) at Vina Plains Preserve; 1997-1998

	Sampling Dates			
Pool No.	Dec. 19, 97	Jan. 21, 98	Mar. 20, 98	Apr. 27, 98
29 (ungrazed)	0.030	0.041	<0.003	0.007
30	0.041	0.066	<0.019	0.028
41	0.038	0.055	<0.021	0.018
42 (ungrazed)	0.035	0.057	<0.023	0.038
16	0.051	0.244	<0.030	0.037
18 (ungrazed)	0.020	0.077	<0.022	0.038
Wurlitzer	0.052	0.037	<0.007	--

Water quality monitoring was not conducted during the 1998-1999 monitoring period. There were no detectable differences that could be attributed to fencing of some pools. The small number of samples precludes meaningful statistical analyses. Dissolved oxygen was at or near saturation for all stations. There was no detectable difference between fenced and unfenced pools. Although turbidity was not measured quantitatively, fenced pools appeared to be less turbid the unfenced pools on a fairly consistent basis. Generally, the unfenced pools tended to have higher concentrations of nitrites and nitrates than the fenced pools, but the differences were very slight. Barn 41 and 42 were about the same concentration of nitrites and nitrates throughout, so fencing did not appear to have an effect at this site.

Because of the potentially high spatial and temporal variation of parameters to be measured and the limited project budget, it was not possible to adequately determine livestock-induced effects on water quality of the vernal pools monitored.

DISCUSSION

The use of grazing management for the enhancement of native wildflowers and vernal pool plant species in California's annual grasslands is a relatively new concept. This study is the first to examine the effects of fire and grazing on the various habitat types occurring within a vernal pool grassland landscape. Much of the research in the field of grazing management has been conducted in the Great Basin and Great Plains, providing management information that isn't applicable to California's annual grassland ecosystems. The majority of work that has been done on annual grassland systems focuses on the effect of grazing livestock on forage quantity and quality (George 1994, Pitt and Heady 1979). The remaining studies have focused on California's historic (and prehistoric) plant composition (Edwards 1992, Blumler 1992) and attempts to convert annual grassland to a system dominated by perennial bunchgrasses (Sanders 1992). Some attention has also been given to the effects of grazing annual grassland on oak seedling establishment and oak woodland overstories (Adams *et. al* 1992, Ratliff *et. al* 1991). Barry (1998) did initial work of the effects of grazing on vernal pools. . She found that grazing to reduce residual dry matter (RDM) around vernal pools prior to fall germination was effective in the enhancement of vernal pool margin species.

Prescribed fire has been shown to be effective in the reduction of medusahead and the establishment of native species. McKell *et. al* (1962) and Pollak and Kan (1998) found that burning medusahead after the stems and leaves begin to dry and before the seeds reach full maturity (i.e. seed moisture greater than 30%) can be very effective in the reduction of medusahead. Theses authors found there to be very little medusahead seed carryover from year to year, therefore one properly timed burn was highly effective in reducing the overall seed bank. Pollak and Kan also found a significant increase in the percent cover of native species from prescribed fire.

Direct comparisons of results of Pollak and Kan study to this one has limitations. For instance, in Pollak and Kan's study, grazing was not included as a treatment effect and only grasslands and vernal swale habitats were included for study.

UPLAND VEGETATION

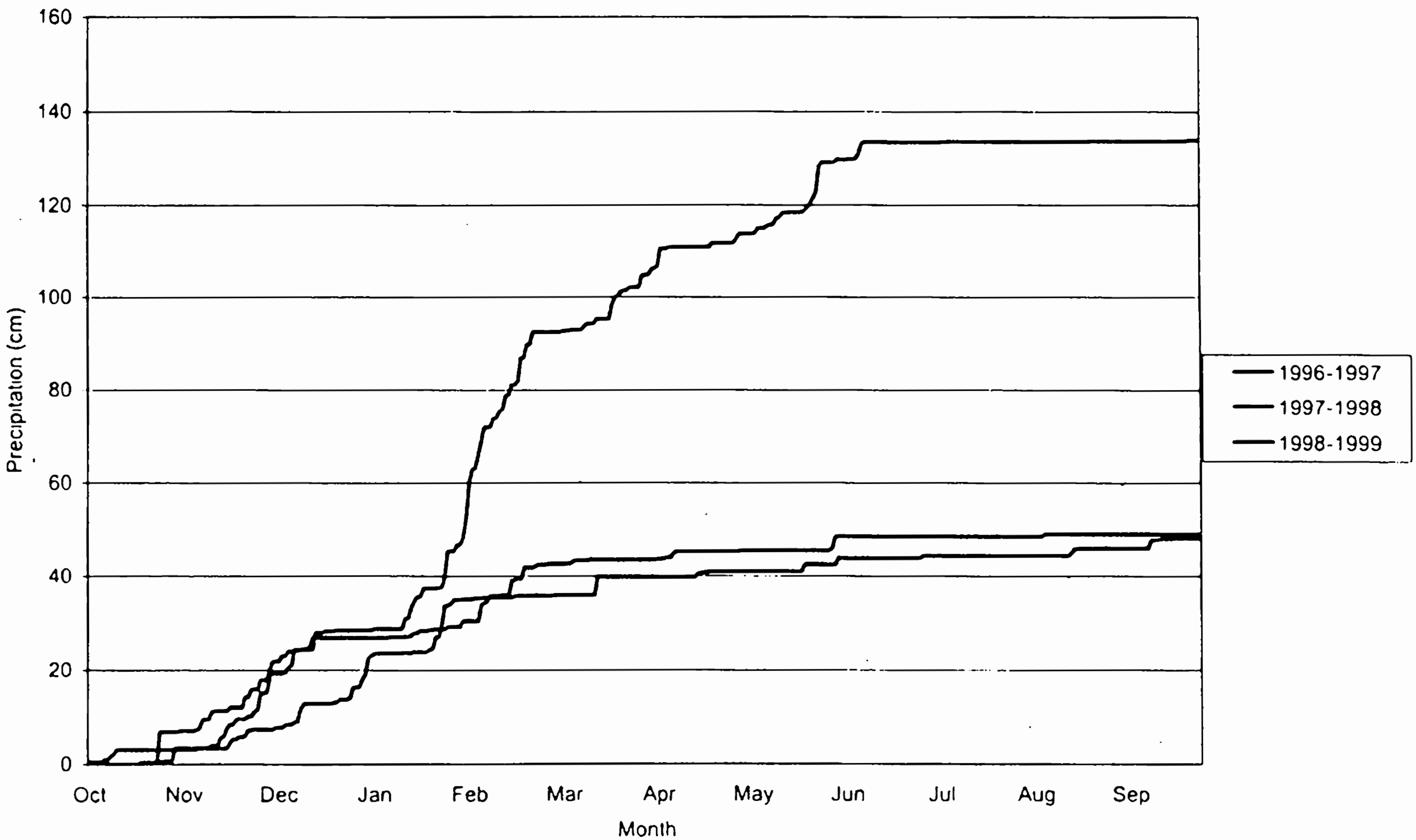
PASTURE-WIDE MONITORING

The pasture-wide monitoring effort at the Preserve was relatively successful over the course of the study. Among all of the data collected for this study, the information regarding upland vegetation collected from pasture-wide monitoring provides the best picture of the pastures from fire and grazing treatments. Nonetheless, analysis of this data was hampered to some extent due to lost data (Safe pasture in 1997), data not collected (weed abundance in 1997), and small sample sizes (the sample size per pasture using the systematic sampling grid were less than the sample size estimated to be needed [See Table 3]). Novel approaches in biological field data collection (i.e., palmtop computers) resulted in the loss of data for one of the pastures in 1997; however, this was rectified in 1998 by the return of standardized field data forms. The systematic sampling grid, although somewhat labor intensive, allowed for complete and random sampling within each pasture while being easy to implement. Additionally, because the habitat types present and their distribution, species composition, and abundance differs amongst the pastures, the effects of fire and grazing between pastures could not be analyzed. For example, Lassen pasture occurs at the highest elevation and unlike the other pastures studied, it is readily drained by a incised arm of Singer Creek. Hence, the Lassen pasture is less mesic in comparison to the other pastures and therefore supports at different compliment of plant species typical of the surrounding grazed area (e.g. less *Lolium multiflorum*).

The outcome of pasture-wide monitoring at the Preserve brings to light several important points for annual grassland land managers throughout the Central Valley. The apparent trend of a decline in upland %RCNS in the Barn, Big Pool, Lassen, and Wurlitzer pastures over time appears at first to be disturbing, and the initial response may be to look at management activities (i.e., grazing and prescribed fire) as a possible cause. However, the apparent trend of a decline in % relative cover of native species (RCNS) over time within each of the pastures as a whole was also apparent in the data collected for upland habitat in the experimental plots regardless of grazing treatment or lack of grazing (Figure 12) over the same time period. This suggests that grazing alone is not responsible for the decline in the cover of native plant species. Closer investigation of the data collected (i.e., species cover contribution and top four dominant species) and an investigation of the growing conditions (i.e., precipitation, air temperature, wind, etc.) during the course of the study suggests that a number of factors discussed below may have contributed to the decline.

The growing conditions of the Spring of 1998 were heavily influenced by the warm water El Niño current in the Pacific Ocean. The El Niño effect resulted in exceptionally heavy precipitation throughout Northern California coupled with milder than normal winter air temperatures. Precipitation recorded at Gerber in Tehama County in the winter of 1997-1998, approximately 4.8 km to the west of the Preserve, was greater than twice the amount recorded in either 1996-1997 or 1998-1999 (Figure 20) and far greater than the average precipitation experienced in the region over the previous ten years (University of California 2000). Additionally, substantial precipitation (for the purposes of this study greater than 2.5 cm) had fallen by the beginning of the second week of October in 1997; whereas, substantial precipitation did not occur until the beginning of November in 1996 (University of California 2000). Substantial precipitation early in fall when air temperatures are moderate favor the germination and growth of the cool-season exotic annual grasses that dominate the pastures at the Preserve . During the winter of 1997-1998 temperatures were moderated by the warm moist maritime air masses borne by the El Nino current further enhancing the growing conditions for the exotic annual grasses. Furthermore, rainfall during the El Niño influenced rainy season persisted well into mid-June, whereas, substantial precipitation typically ceases by February or March (Figure 20). The substantial precipitation and moderate temperatures of the fall, winter, and spring of 1997-1998 combined to produce growing conditions ideal for the exotic annual grasses dominating the Preserve.

Figure 20. Cumulative Annual Precipitation at Gerber, Tehama County



The data also suggests that the decrease in %RCNS is related to an increase in the cover of exotic annual grasses (i.e., soft chess [*Bromus hordeaceus*], Italian ryegrass [*Lolium multiflorum*]) and grass-like species (i.e., toad rush [*Juncus bufonius*]). For instance, Italian ryegrass contributed a negligible amount of cover (less than 5% relative cover) in the upland habitats in all pastures in 1997; however, in 1998 Italian ryegrass was among the four most dominant plant species in all but the Lassen and Wurlitzer Pastures (recall that Lassen Pasture is more well drained than the other pastures and the Wurlitzer Pasture was not grazed but was burned all three years of the study). Similarly, relative cover of toad rush was very negligible (less than 1% relative cover) in all pastures in 1997 but was among the top four dominant species in all pastures in 1998 frequently exceeding 10% cover. Relative cover of both Italian ryegrass and toad rush returned to negligible, or near negligible values, in 1999.

Monitoring observations at the Preserve during in the winter of 1997-1998 and spring 1998 suggest that the increase in cover of these exotic species are two-fold. First, the extremely wet conditions and mild temperatures favored exotic grass species with a tolerance for saturated soil (e.g., Italian ryegrass). Secondly, the ground disturbance from livestock (i.e., hoof action) during the winter months created a substantial amount of bare ground that was colonized by toad rush. The degree in which the ground was disturbed by livestock was probably exacerbated by the past exclusion of livestock for nearly ten years. In the absence of trampling by livestock, fossorial animals (i.e., pocket gophers, moles, earthworms, and other ground dwelling invertebrates) reduce compaction by soil churning. Observations of other vernal pool grasslands where direct comparisons of grazed and ungrazed conditions were possible (i.e., Beale Air Force Base in Yuba County, Rancho Seco Park and Mather Air Force Base in Sacramento County) revealed the presence of compacted soils in grazed areas and soft friable soils in areas that have not been grazed within the last ten years. The presence of humans within the ungrazed areas during the wet-season caused major disturbances to uplands and the bottoms of vernal pools (i.e., deep foot prints, turbidity, reduction of plant cover, and burial of plant seedlings). The soil disturbance was exacerbated at the Preserve because the uncompacted soil (i.e., ungrazed for nearly 10 years) collapsed easily under the weight of a cow or bull when the soil was saturated thoroughly punching the terrain.

Except for the Wurlitzer pasture that has been consistently dominated by filaree (*Erodium brachycarpum*), soft chess was either the dominant, or co-dominant, plant species in all pastures during all years. Similar to Italian ryegrass and toad rush, soft chess became more prevalent in 1998 in nearly all the pastures and continued to increase in cover in 1999. From the perspective of a livestock operator, an increase in soft chess is beneficial because it is a valuable forage species being palatable and of good nutritional value to livestock (Heady 1977).

Initial interpretations of the declines in %RCNS and the total number of plant species (i.e., species richness) in all but the Lassen pasture between 1996 and 1999 (Table 12) may lead one to believe that the declines were from treatment effects. However, we offer several explanations why this conclusion may be erroneous. First, the timing of field

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Initial interpretations of the declines in %RCNS and the total number of plant species (i.e., species richness) in all but the Lassen pasture between 1996 and 1999 (Table 12) may lead one to believe that the declines were from treatment effects. However, we offer several explanations why this conclusion may be erroneous. First, the timing of field sampling; and secondly, the prevailing weather conditions had a profound effect on species that were observed. In general, all fieldwork for pasture-wide sampling was conducted during the period when the dominant grasses species were readily sight identifiable (i.e., flowering). The 1997 sampling coincided with the period when the majority of native forb species were flowering. In contrast, 1998 sampling occurred when many of the native forb species had flowered and senesced (Late May) perhaps resulting in a under representation of the percent cover of native species.

The delay in field sampling until late-May of 1998 was a result of the exceptionally wet 1997-1998 winter that also caused a prolonged growing season for annual grasses. We surmise that the luxuriant growth of annual grasses observed in the spring of 1999 resulted from the extended growing season of the annual grasses that allowed for an above average annual grass seed production that year. The luxuriant growth of annual grasses cover greatly outweighed the cover of native forbs for that year and possible obscuring views of natives. Because of the favorable growing conditions derived from El Nino effects certain exotic grass species such as Italian ryegrass and soft chess grass cover increased and possibly also obscuring the observers' view of subdominant exotic species. Hence, the reduction of natives plants and total reduction of species at the preserve may be attributed to the El Nino effects. Evidence on the effect of El Nino were lesst apparent at the Lassen pasture which is well drained and contain less clay substrates.

The results of priority weed monitoring suggest that the abundance of many of the priority weeds at the Preserve decreased over the course of the study and reaffirmed the fact that medusa-head grass is abundant at the Preserve and that it can be controlled through the use of prescribed fire. For example, within the Big Pool pasture in 1998, medusa-head grass occurred in the dominant abundance class within 16% of the quadrats and the common abundance class in 39% of the quadrats (see Table 6 for definitions of abundance classes) (Table 34). Yet, in the year following a prescribed burn (1998) in the Big pool pasture, medusa-head grass did not occur in either the dominant or the common abundance classes (Table 35). Pasture-wide sampling data, collected within the Big Pool pasture, also revealed a trend in the reduction of medusa-head grass from a mean relative cover of 26.6% to only 0.87% cover. This reduction in medusa-head grass further reinforces the role prescribed fire has in controlling this invasive exotic grass.

Explanations for the observed decrease in the abundance of yellow-starthistle are less apparent then that of the medusa-head grass, because the abundance of this species decreased in all pastures regardless of treatment or combinations thereof (i.e., grazing or burning) (Tables 32 through 41).

The possible causes for the appreciably decrease in the frequency of yellow starthistle (collected from pasture-wide sampling quadrats) (Table 42) from 1996 and 1998, and the species altogether disappearing in 1999, are many. One explanation could be that yellow starthistle, being a xerophyte, did poorly during the relatively moist conditions occurring on site during the 1997/1998 and 1998/99 growing seasons. (See discussions on possible El Nino effects above). Similarly, successive years of prescribed fire alone or fire in combination with grazing has been shown by DiTomaso (1998) to greatly reduce yellow starthistle density. Lastly, it is possible that the starthistle was obscured from the investigators view from the luxuriant grass growth. Yellow starthistle is a warm-season species, that in the northern Central Valley, does not begin to bolt and flower until after the majority of annual grasses have senesced. Nonetheless, yellow starthistle could have been in a basal rosette form during the timing of field sampling. Hence, surveys to assess the abundance of late-season weed species should probably have been conducted a a later date and separately from spring surveys.

In regards to RDM, the high values (i.e., >1,500 kg/ha.) at the Preserve (derived from a long period of thatch buildup resulting from a lack of grazing and fire), began to decrease as anticipated, following the reintroduction of fire and grazing. However, the resulting RDM values were still within the range considered adequate to protect the Preserve's soils from erosion (i.e., 500–750 kg/ha.) (Soil Conservation Service 1967). The RDM values reported here cannot be interpreted as a measure of resource utilization (i.e., grazing pressure) or rangeland health (i.e., forage production) at the Preserve unless it can be compared with the same year's forage production values. Forage production was not monitored at the Preserve as a part of this study.

EXPERIMENTAL PLOT MONITORING

The reason why upland vegetation data collected from the experimental plots yielded little information on the effects of grazing and fire is mainly due to the experimental design and the implementation of the design. Although an attempt was made, in hindsight it is clear that the experimental plots did not include the same types of habitats (i.e., vernal pools, vernal swales, clay flat, and playa pool). The experimental plots needed to encompass the same geologic surfaces and the physical parameters of each habitat needed to be similar. For instance, vernal pools chosen for study within the experimental plots should have exhibited similar maximum ponding depths, surface areas, and volumes, etc.). For example, pool 16 is a playa pool and it's paired fenced pool (18) is a vernal pool [see Introduction section for a discussion on the major differences of these two pool types]). Furthermore, habitat types and extent were not equally distributed within plots and subplots within a plot. For example, the fenced plot in Safe pasture, encompasses a greater amount of vernal pool (18) habitat, in comparison to upland habitats. Additionally, within a subplot, sampling effort in 1997 was not equally distributed among habitat types present. Hence, some habitat types were over sampled and others were under sampled. Additionally, burning treatments were not contained within a subplot (as designed) and usually the prescribed burn treatment burned the majority of both portions of the subplot within a plot. This did not allow direct comparisons of burning treatments on habitats types present between subplots.

Concerning, grazing treatments, enclosure fencing did not always exclude cattle. For example, the loose barbwire fencing around pools 18 and 28 allowed calves access to the plots. Lastly, data was lost and in some instances not collected at all. For example, data was not collected during the spring of 2000 even though burning treatments were conducted in 1999 and portions of the experimental plot data collected in 1997 and 1998 were lost.

Nonetheless, statistical testing did reveal significant differences between %RCNS for grazed vs. ungrazed plots. For instance, the 1999 data for the Safe pasture exhibited a significant difference in %RCNS between grazed (6.67 % RCNS) and ungrazed (4.81 %RCNS) (Tables 48 and 49) plots. Yet, the difference between 4 and 6 percent is small and is probably not biologically significant.

RARE PLANTS

The data collected from rare plant monitoring yielded the least amount of information on fire and grazing effects. Not only was the sampling method complicated and difficult to implement in a timely fashion, but also the sample size requirements resulted in an excessive number of quadrats (thousands) and still the cumulative mean variance didn't stabilize. In addition, this sampling method was very disruptive to the pool flora (i.e., quadrat placement, transect placement, and kneeling of the investigators trampled large ares of the pool). Similar to upland vegetation monitoring in the experimental plots many of the experimental pools were not fenced or paired. For example, pools 34 and 35 were not fenced and pool 29 supporting *Orcuttia tenuis* was not paired with a pool also supporting this species. What could be concluded from rare plant monitoring was that the populations of these rare plant species fluctuate greatly from year to year. This conclusion is similar to other investigators studying grasses in the tribe Orcuttiae (Stone *et al.* 1988, Vollmar pers. comm.).

SWALE AND VERNAL POOL VEGETATION

Swale and pool vegetation sampling results suffered from similar problems in the sampling design or its implementation discussed above for upland vegetation using experimental plot sampling. However, data from 1998 and 1999 does suggest that regardless of treatment (i.e., grazed or ungrazed, burned or unburned) the %RCNS in vernal pools will remain relatively unchanged. Yet, this study did not gather data on absolute vegetative cover that can be diminished in some vernal pools through trampling by livestock.

LARGE BRANCHIOPODS

The number of individual large branchiopods within a given pool, in a given sampling time and year varied greatly and one could not deduce population effects of burning and grazing from sampling a small portion of the habitat. Weather conditions that influence the temperature of water during the first inundation of a pool is extremely important. The large branchiopods occurring at the Preserve are known to hatch at temperatures around 10° C (50° F) (Helm 1998). If the pool is first inundated with rainwater that is a few degrees higher or lower that 10° C (i.e., less than optimal conditions [Lanway 1974]) a smaller subset of the cyst pollution will hatch. This in return will contribute to a smaller number of the cysts being replaced (i.e., cyst bank). Besides a low number of hatching, the contribution to the cyst bank on a given year could also be affected by heavy predation of adults (usually from water fowl and shore birds) or false starts. False starts happen when pools shallowly inundate and rapidly dry out (due to lack of back-to-back storm events and warm weather conditions) thus killing the immature large branchiopods. False starts usually occur at the beginning or at the end of the raininy season.

The life history of large branchiopods, (with the presence of a cyst bank potentially representing multiple generations), further complicates the process of estimating population sizes. The number of mature adults present in the wet season is a complex function of the number of cysts available to hatch as well as the current year's environmental conditions (affecting both hatching and survival rates). In contrast, the number of cysts in the soil at the end of the season is a function of the number of adults which reached maturity, the number of cysts produced by those adults, and the number of cysts left over from previous cohorts which did not hatch but remained viable. Thus, there are lags (or buffers) between potential impacts to these population and any eventual numerical effects.

Dry-season sampling has the greatest potential to yield the most information regarding the population size of large branchiopods within a given pool. Unlike wet sampling that yields data on only that portion of the population present during the time of survey, dry-sampling cuts through the environmental conditions which are so important for hatching of the cysts and looks at the potential for hatching within the cyst bank. Unfortunately, this method was time consuming and its success depended on survey timing. The coring device needed to be used when the soil was still moist but not saturated or dry so that an intact "plug" could be obtained. Additionally, the sample size was too small and needed to be increased substantially to yield useful information. Other problems with technique stem from its utilization in the large playa pools that are uniformly flat making stratification of elevational gradients problematic.

In regards to wet-season sampling, although reported to occur in pools 18, 37, and 38 (Alexander and Schlising 1996) the vernal pool fairy shrimp, *Branchinecta lynchi*, was only recorded once during the study on the December 18, 1998 monitoring visit in pool 30. Survey timing (i.e., too late) of the first sampling data most likely precluded its detection. *Branchinecta lynchi* is susceptible to warm water conditions (Helm 1998). Because wet-season sampling was only conducted once a month, underestimation of occurrences and populations sizes of short-lived large branchiopod species, such as the *Branchinecta lynchi*, occurred.

WATER QUALITY

These data and those of others points out that in general water quality data is not meaningful unless put in light of other pool parameters (Helm 1998). The sample size and frequency of water quality collection was not adequate to determine livestock induced effects. Nonetheless, possible explanations of water quality parameters observed are discussed. The neutral or slightly acidic pH of the ponds observed in December 1997 may have been due to the decomposition of organic matter. Initially, vernal pools are a detrital-based system, and early invertebrate inhabitants are mostly surviving and last years plant growth (Helm 1999). Yet, the neutral or slightly acidic pH observed may have been due to dilution and buffering effects of the above average rainfall (approximately doubling the long-term annual average of 63.5 cm.) during November and December from El Nino effects. The slightly basic pH observed in some pools during January could be due to attached photosynthesis actions of the burgeoning periphyton algae on last years plant growth (.e., carbon dioxide is removed from the water column during photosynthesis which increases water pH). The increased in pH as spring progressed was mostly likely a function of the increase of photosynthesis activities of the ever-increasing biomass of the vascular plant species spawned by the warm weather conditions. The values of DO appeared to be a function of temperature and wind speed.

CONCLUSIONS

As with many biological field studies, the conclusions of this study are clouded by the many biotic and abiotic variables, which could not be isolated. Yearly fluctuation in surface weather condition (precipitation, wind, air temperature) can and will greatly influence species composition in annual grasslands. El Nino had a profound effect on the abundance of plant species. In summary, the final goal of this study was to design a program sufficiently flexible, affordable, and feasible to be applied as a standard monitoring tool for use by The Nature Conservancy, various public agencies, and private landowners to grasslands and vernal pools throughout the region. In accordance, the following section (titled Recommendations) sets forth possible suggestions for a more repeatable, cost effective, and executable experimental design then used in this study. Ultimately, through the facilitation of cooperative development, a broad scale monitoring plan will arise for the use of grazing and burning as means of enhancing the health of the northern Valley's grassland and vernal pool ecosystems.

MONITORING RECOMMENDATIONS

Monitoring at the Preserve, as well as at other vernal pool preservation sites throughout the state, should be geared towards gathering two major information sets. First, monitoring should provide information that helps the manager make short-term decisions on day-to-day management activities such as grazing and weed control efforts. Second, monitoring should inform managers about the long-term trends of key indicators of ecosystem health. The following discussion outlines the types of data, which could be collected to efficiently service these to needs.

Monitoring designs for the Preserve should be 1) cost effective, 2) executable, and 3) repeatable. The framework for monitoring the Preserve, described below, was developed under the following assumptions:

- The goal is to adaptively manage the Preserve for native species diversity;
- Data collection will require approximately 10 person days per year;
- Investigators conducting the monitoring will vary in plant identification skills, ocular aerial cover interpretation skills; and
- Data analysis and report production will require approximately 10 person days per year.

UPLAND ANNUAL GRASSLAND MONITORING

Annual grassland monitoring should focus on sampling the plant species composition during the spring and mulch in late summer (i.e., RDM). Given the time limitations for annual monitoring and reporting, a series of permanently located point-intercept transect are recommended. Monitoring transect locations should be stratified by soil type. The number of transects placed on a given soil type should be based on the relative area of each pasture occupied by that soil type according to field observations and soil maps (Soil Conservation Service 1967). Transects should be oriented perpendicular to the topography to capture natural variation in the vegetative community. Transects should be between 30 and 50 meters long and permanently marked in the field. Transect endpoints should be marked at ground level to reduce effects of cattle using above ground markers as scatting posts. Colored plastic surveying monument caps, re-bar, and metal spikes driven flush with the ground have proven to last several years within livestock areas. Metal T-posts offset from the actual endpoints by 10 meters should be used to facilitate transect relocation. In addition, compass readings of transect bearing should be recorded to facilitate relation in the event that one or more t-post are removed.

Vegetation data will be collected using a point-intercept method. Surveys should be initiated when the majority of wildflowers are in bloom. This roughly corresponds to the time at which California goldfields (*Lasthenia californica*) are in peak flower. A vertical ocular projection will be made every 10 cm on the right side of the measuring tape and the first contact recorded (e.g., plant species, thatch, soil, rock, fecal matter, etc.). This translates to 499 data points/transect for a 50-meter transect. Using this method, relative species frequency and vegetative cover can be estimated. Each transect should also be photographically documented during each monitoring visit.

MULCH MONITORING

Each vegetation transect will have an associated randomly placed clip plot to measure RDM levels at the end of the grazing season. RDM can be used as surrogate for mulch thickness. RDM clip plot measurements should follow standard empirical range management practices and be made by clipping the plant material within each of the plots to ¼ in stubble height. A 0.96 ft^2 hoop for a plot size is commonly used as a standard device in California. The clipped plant material (from a 0.96 ft^2 hoop) is placed in a drying oven for at least 24 hours prior to weighing to the nearest gram and multiplied by 100 to arrive at pounds/acre RDM. RDM plots should be clipped once all the annual vegetation has senesced and dried. RDM plots should be moved annually.

If desired, additional RDM estimates can be visually determined using an appropriate guide such as the Wildland Solutions' *Residual Dry Matter Monitoring Photo-Guide*. The use of clip plots and ocular estimation methods provide a good estimation of actual RDM present. If desired, RDM can be compared to past production estimates to arrive at defensible conclusions regarding grazing pressure and future stocking rates.

WETLAND MONITORING

Two methods of vegetation monitoring are proposed for wetlands: 1) relevè and 2) point intercept. The relevè method (Braun-Blanquet 1928 cited in Mueller-Dombois and Ellenberg 1974) gives an ocular estimate of species aerial cover and a floristic inventory of species richness. The relevè is intended to provide a broad-brush overview of plant species occurrence and relative cover during an individual monitoring season. Point-intercept method entails monitoring of vegetation along two permanent transects collecting data at regular intervals similar to that described above for upland habitats. Depending on the extent of the target habitat, a minimum of 100 data points should be collected per wetland. One axis should be placed along the longest dimension of the wetland habitat thereby bisecting it into two approximately equal portions. The second transect will bisect the first at a right angle through the deepest portion of the wetland dividing the wetland into four quadrants (i.e., two-axis grid). Point intercept intends to detect changes in vegetation composition and species relative cover over time. Linear habitats such as swales or drainages may require additional transects spanning their width to ensure that a minimum of 100 points are sampled.

Wetland types should be determined based on plant species composition and hydrologic features. Wetland habitat designated as vernal pools or vernal swales should be those supporting plant species that are endemic to these habitat types, as was discussed above. Vernal pools and swales should not be treated as a single habitat type within the annual grassland matrix. Data regarding any excessive erosion and severe disturbances by cattle or humans will be noted. In addition, color photographs of each monitored wetland will be taken in April of each monitor year from a point one meter south from the wetland southern edge. The distance and orientation (sunlight from behind) should ensure adequate repeatable photographs. Photographic monitoring stations should be permanent so that comparisons of photographs through time can be accomplished.

RARE PLANT MONITORING

Because rare plant population sizes can experience significant fluctuations from year to year, monitoring should be geared towards assessing presence or absence on an annual basis while looking for trends in population extent. However, data analysis on species population trends without consideration of the species natural history reveals little on why the population is fluctuating or not and how to manage for a declining pollution. At best, species absence within a known site for two-consecutive years should trigger a response on why it is absent.

WEED MAPPING

Priority weed species abundance should be qualitatively assessed and mapped whenever the Preserve manager is conducting routine Preserve maintenance inspections. Additionally, concentrations of weeds should be noted during spring botanical composition monitoring and also when RDM is measured in the fall. Fall is a particularly useful season for observing yellow starthistle and medusahead in the field. If time and resources allow weed abundance transects as described in the Methods section should be initiated if a pasture is found to have a significant infestation.

POOL INVERTEBRATES

Monitoring of rare large branchiopods can be accomplished through an assessment of macroscopic (i.e., greater than 2 mm in length) aquatic invertebrate assemblages using semi-quantitative sampling methods. The dipnet should be lowered vertically into the deepest portion of the pool (usually the center) and rested on the bottom. The dipnet is then moved forward in the direction of the longest axis of the pool for approximately one-meter. In instances where half of the pool length is less then one meter in length, the net should be repositioned in the deepest portion of the pool and moved in the opposite direction for the remainder of the one-meter sample. After the completion of each sample sweep, the contents of the net should be examined for macroscopic invertebrates. All macroscopic aquatic invertebrates should be identified to the lowest justifiable taxon in the field, and recorded on standardized data sheets (Figure 21).

The relative numbers of individuals observed within each taxonomic group is then recorded in one of five categories: rare (<2 individuals), not common (3-10 individuals), common (11-50 individual), and abundant (>1000 individuals) (Figure 21). This method allows for the relative abundances and richness of aquatic invertebrates to be compared between and among wetlands through time. Additionally, this method allows for concentration estimates of invertebrates to be calculated as number of individuals per liter of water (= number of individuals/net aperture area x length of sweep).

Date

Investigator(s)

Weather Conditions

Habitat Types:
VP = Vernal Pool
SP = Stock Pond
VS = Vernal Swale
SW = Seasonal Wetland

Habitat Modifiers:
(b) = bermed
(a) = artificially created
(p) = plowed
(r) = road rut

Abundance: R = Rare (<2 individuals)
NC = Not Common (3-10 individuals)
C = Common (11-50 individuals)
VC = Very Common (50-100 individuals)
A = Abundant (>100 individuals)
X = Present but not observed in 1 meter sample

Pool No.	Habitat Type	Max. Depth (m)	Large Branchiopods				[illegible]	Copepods		[illegible]	Coleoptera				Hemiptera		[illegible]	Odonata		Diptera		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]		Calanoida	Cyclopoida	Cladocera	Dytiscidae	Hydrophilidae	Berosus sp.	[illegible]	Notonectidae	Corixidae	Ephemeroptera	Zygoptera	Anisoptera	Culicidae	Chironomidae	[illegible]	Physidae	Planorbidae	[illegible]	

Figure 21. Standardized Field Data Form

If rare large branchiopods are not detected during the semi-quantified sampling method, additional sweeps should be made with the net. Additional taxonomic groups of aquatic invertebrates detected using this alternative method should be noted as present by on an "X" on the standardized field data sheet. After the taxonomic identification and enumeration are completed, the contents of the net shall placed back into the pool from which they were collected. The data collected here is intended to simply determine presence or absence of a rare taxon in years where population sizes are not large.

Additional information collected from each wetland should include the type of habitat (vernal pool, vernal swale, play pool, seasonal wetland), the weather conditions (i.e., cloud cover, precipitation type, and ambient air temperate), and the greatest ponding depth during each field visit.

INTENSITY AND TYPE OF DATA COLLECTION

In this study, much energy was dedicated to experimentation using novel monitoring methods while attempting to sample intensively enough to produce rigorous data. Collecting data that is statistically "sound" is a necessity of modern science. However, from a land management perspective, the effort dedicated to the sampling design and implementation to collect biological data should not outweigh the effort to actually manage the land for those resources.

As land managers and biologists we should keep in mind that the landscapes that we are often working in and with evolved over millennia with a myriad of weather conditions (e.g., climatic warming or cooling), anthropogenic disturbances (i.e., fire by Native Americans) and grazing pressure (e.g., Pleistocene megafauna [such as wooly mammoth, mastodon, giant ground sloth), and Holocene native ungulates [such as elk and pronghorn]) and that these landscapes are fairly resilient.

Managers of annual grassland and vernal pools face unique challenges to management because the condition of the landscape can vary considerably from year-to-year depending on weather conditions as seen in the results of this study. Unfortunately, the land manager typically must make management decisions based on what he or she has observed over a relatively short timeframe (i.e., several years) and these observations may or may not reflect the actual long-term trend or condition of the site. When the land becomes substantially different than what is targeted (e.g., native plants disappearing etc.) the manager's first impulse is to substantially alter management (e.g., introduce prescribed fire, increase or decrease stocking rate, lengthen or shorten grazing period, or perhaps remove grazing altogether etc.) in hopes that target will return in sight. Perhaps, the response should be to gradually introduce new management tools or modify existing ones, so that changes can be more readily apparent and cause and effect relationships determined.

The results of this study demonstrated that observer effects from extensive monitoring can be harmful and the data collected not always helpful. For example, the data concerning rare plant populations, although extensive, yielded little information concerning the population size and even less on how to manage for them. Yet, from a visual standpoint, the human trampling of the rare plants from the massive sampling effort was far greater then the effects of fire or cattle grazing on the vernal pools. Similarly, the amount of energy and funds expended in monitoring the resources is often at the expense of managing the resources. For example, when personnel are expending the majority of their time collecting, entering, and analyzing monitoring data they are no longer free to conduct frequent real-time assessments of the resources such as inspecting fences, moving livestock, assessing forage availability, or maintaining range improvements (i.e., supplemental feed stations, salt blocks, watering areas, etc.). Such observations can allow for rapid changes in management before resource damage or degradation can occur. For example, forage may be depleted prior to scheduled livestock removal and prior to vegetation monitoring. This early detection may prevent irreversible resource degradation.

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Appendix A. Results of Large Branchiopod Wet Sampling 1997-1998 and 1998-1999 – Tables and Figures

Table 62. Descriptive Statistics Regarding Concentration (No. of Individuals per $0.025m^3$) of *Linderiella occidentalis* (January 30, 1997)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	2	1.0	1.0	1.0	1.0	1.0	0.00	0.00
42	3	1.0	1.0	1.0	1.0	1.0	0.00	0.00
16	3	1.0	1.0	1.0	1.0	1.0	0.00	0.00
29	4	0.0	1.0	0.75	1.0	0.75	0.50	0.25
30	4	0.0	1.0	0.25	0.00	0.25	0.50	0.25

Table 63. Descriptive Statistics Regarding Concentration (No. of Individuals per $0.025m^3$) of *Lepidurus packardi* (January 30, 1997)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	2	1.0	2.0	1.50	1.50	1.50	0.707	0.500
42	3	3.0	3.0	3.00	3.00	3.00	0.00	0.00
W	4	2.0	2.0	2.00	2.00	2.00	0.00	0.00

Table 64. Descriptive Statistics Regarding Concentration (No. of Individuals per $0.025m^3$) of *Lepidurus packardi* (February 21, 1997)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
18	4	0.0	2.0	0.50	0.00	0.50	1.00	0.50
16	3	2.0	2.0	2.00	2.00	2.00	0.00	0.00
29	4	0.0	2.0	1.00	1.00	1.00	1.155	0.577
30	4	0.0	2.0	0.50	0.00	0.50	1.00	0.50
W	5	0.0	2.0	1.20	2.00	1.20	1.095	0.490

Table 65. Descriptive Statistics Regarding Concentration (No. of Individuals per $.025m^3$) of *Lepidurus packardi* (Dec. 16, 1997)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	2.00	0.50	0.00	0.50	1.00	0.50
42	4	0.00	3.00	0.75	0.00	0.75	1.50	0.75
34	10	0.00	3.00	0.50	0.00	0.25	1.08	0.34
35	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00

18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	0.00	2.00	0.50	0.00	0.50	0.84	0.34
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	2.00	0.13	0.00	0.00	0.50	0.13
21	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	3.00	0.75	0.00	0.75	1.17	0.41
30	4	0.00	3.00	1.00	0.50	1.00	1.41	0.71
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 66. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Lepidurus packardi* (Jan. 21, 1998)

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	2.00	0.75	0.50	0.75	0.96	0.48
42	4	0.00	1.00	0.50	0.50	0.50	0.58	0.29
34	10	0.00	5.00	1.10	0.50	0.75	1.60	0.50
35	16	0.00	3.00	0.69	0.00	0.57	1.01	0.25
22	16	0.00	2.00	0.56	0.00	0.50	0.73	0.18
18	5	0.00	1.00	0.20	0.00	0.20	0.45	0.20
17	16	0.00	5.00	1.81	1.00	7.71	1.76	0.44
16	6	0.00	2.00	0.50	0.00	0.50	0.84	0.34
13	4	0.00	2.00	1.00	1.00	1.00	0.82	0.41
10	4	0.00	1.00	0.25	0.00	0.25	0.50	0.25
1	16	0.00	2.00	0.69	1.00	0.64	0.70	0.18
21	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	1.00	0.25	0.00	0.25	0.46	0.16

Table 67. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Lepidurus packardi* (Feb. 26, 1998)

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	1.00	0.25	0.00	0.25	0.50	0.25
42	4	0.00	1.00	0.25	0.00	0.25	5.00	0.25
34	10	0.00	4.00	1.20	0.50	1.00	1.55	0.49
35	16	0.00	2.00	0.50	0.00	0.43	0.63	0.16
22	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00

10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	1.00	0.13	0.00	0.07	0.34	0.09
21	14	0.00	2.00	0.21	0.00	0.08	0.58	0.16
29	8	0.00	2.00	0.63	0.50	0.63	0.74	0.26
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 68. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Lepidurus packardi* (Mar. 19, 1998)

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
41	7	0.00	1.00	0.29	0.00	0.29	0.49	0.18
42	6	0.00	1.00	0.17	0.00	0.17	0.41	0.17
34	14	0.00	4.00	0.43	0.00	0.17	1.09	0.29
35	16	0.00	2.00	0.38	0.00	0.29	0.62	0.16
22	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	1.00	0.38	0.00	0.36	0.50	0.13
16	10	0.00	5.00	1.30	1.00	1.00	1.57	0.50
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	3.00	0.44	0.00	0.29	0.81	0.20
21	8	0.00	1.00	0.38	0.00	0.38	0.52	0.18
29	8	0.00	1.00	0.25	0.00	0.25	0.46	0.16
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 69. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Branchinecta conservatio* (Dec 16, 1997)

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	16	0.00	10.00	0.69	0.00	0.07	2.50	0.62
22	16	18.00	199.00	64.60	46.50	58.30	54.10	13.50
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	4.00	41.00	22.50	21.00	22.50	9.76	2.44
16	6	0.00	12.00	5.83	4.00	5.83	5.00	2.04
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	4.00	28.00	15.25	16.00	15.14	6.84	1.71
21	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 70. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Branchinecta conservatio* (Jan. 21, 1998)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	0.00	8.00	2.70	0.00	2.38	3.53	1.12
35	16	0.00	22.00	7.00	4.50	6.43	7.10	1.77
22	16	1.00	46.00	17.25	15.50	16.36	12.82	3.20
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	13.00	5.31	3.50	5.14	3.84	0.96
16	6	0.00	13.00	4.17	2.00	4.17	4.96	2.02
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	10.00	2.00	1.00	1.57	2.85	0.71
21	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 71. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Branchinecta conservatio* (Feb. 26, 1998)

Pool	Samp	Range						
			Max					
No.	No.	Min		Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	0.00	4.00	0.50	0.00	0.13	1.27	0.40
35	16	0.00	21.00	7.00	4.00	6.50	7.15	1.79
22	16	0.00	45.00	11.44	7.00	9.86	12.10	3.02
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	1.00	10.00	3.50	3.00	3.21	2.31	0.58
16	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	6	0.00	9.00	4.17	4.00	4.17	3.19	1.30
1	16	1.00	21.00	12.81	14.50	13.07	6.35	1.59
21	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 72. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Branchinecta conservatio* (Mar. 19, 1998)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	14	0.00	2.00	0.64	0.00	0.58	0.84	0.23
35	16	0.00	3.00	0.81	1.00	0.71	0.91	0.23
22	16	0.00	15.00	6.19	5.00	6.00	5.09	1.27
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	7.00	2.25	2.00	2.07	1.98	0.50
16	10	0.00	4.00	1.50	1.00	1.38	1.65	0.52
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	7.00	16.00	11.81	12.50	2.64	2.64	0.66
21	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 73. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Linderiella occidentalis* (Dec. 16, 1997)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	9.00	3.50	2.50	3.50	4.04	2.02
42	4	0.00	3.00	1.50	1.50	1.50	1.29	0.65
34	10	5.00	75.00	38.20	34.50	37.75	21.61	6.83
35	16	1.00	19.00	9.31	9.50	9.21	4.77	1.19
22	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	5	6.00	32.00	16.20	12.00	16.20	10.16	4.54
17	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	1.00	4.00	2.33	2.00	2.33	1.03	0.42
13	4	0.00	3.00	1.50	1.50	1.50	1.29	0.65
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	14	0.00	10.00	4.50	4.00	4.42	2.77	0.74
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	1.00	0.25	0.00	0.25	0.50	0.25
W	8	0.00	8.00	3.25	3.50	3.25	2.44	0.86

Table 74. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Linderiella occidentalis* (Jan. 21, 1998)

Pool	Samp	Range						

30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 83. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Branchinecta conservatio* (Feb. 26, 1999)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	0.00	1.00	0.40	0.00	0.38	0.52	0.16
35	16	2.00	10.00	5.13	5.00	5.00	1.86	0.46
22	16	0.00	3.00	0.63	0.00	0.50	0.89	0.22
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	4.00	1.63	2.00	1.57	1.15	0.29
16	6	1.00	4.00	2.33	2.50	2.33	1.21	0.49
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	5.00	15.00	8.31	7.00	8.07	2.75	0.69
21	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 84. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Branchinecta conservatio* (Apr. 1, 1999)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	0.00	3.00	1.20	1.00	1.13	1.23	0.39
35	16	0.00	6.00	3.44	3.50	3.50	1.59	0.40
22	16	0.00	2.00	0.44	0.00	0.36	0.73	0.18
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	3.00	0.75	1.00	0.64	0.86	0.21
16	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	1.00	8.00	4.63	5.00	4.64	2.13	0.53
21	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 85. Descriptive Statistics Regarding Concentration (No. of

Individuals per .025m^3) of *Linderiella occidentalis* (Dec. 18, 1998)

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	3.00	1.75	2.00	1.75	1.26	0.63
42	4	3.00	41.00	20.00	18.00	20.00	18.07	9.04
34	10	1.00	19.00	7.70	5.50	7.13	6.78	2.15
35	16	0.00	2.00	0.25	0.00	0.14	0.58	0.14
22	16	7.00	41.00	17.75	15.50	16.86	8.61	2.15
18	5	0.00	5.00	2.00	2.00	2.00	1.87	0.84
17	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	0.00	19.00	8.17	7.00	8.17	6.52	2.66
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	10	4.00	17.00	8.60	6.50	8.12	4.84	1.53
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 86. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Linderiella occidentalis* (Feb. 4, 1999)

Pool No.	Samp No.	Range Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	5.00	27.00	19.50	19.50	20.37	6.69	2.11
35	16	2.00	8.00	3.56	3.00	3.36	1.63	0.41
22	16	0.00	17.00	4.87	3.50	4.36	5.19	1.30
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	1.00	8.00	4.67	5.00	4.67	2.42	0.99
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	8	1.00	7.00	3.38	3.50	3.38	2.07	0.73
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 87. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Linderiella occidentalis* (Feb. 26, 1999)

Pool	Samp	Range						

No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	5.00	23.00	10.90	10.00	10.12	5.88	1.86
35	16	0.00	4.00	1.75	1.50	1.71	1.48	0.37
22	16	0.00	8,00	3.31	3.00	3.21	2.02	0.51
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	0.00	4.00	2.33	2.50	2.33	1.63	0.67
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	10	0.00	5.00	2.70	3.00	2.75	1.42	0.45
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 88. Descriptive Statistics Regarding Concentration (No. of Individuals per .025m^3) of *Linderiella occidentalis* (Apr. 1, 1999)

Pool	Samp	Range						
No.	No.	Min	Max	Mean	Median	TrMean	StDev	SEMean
41	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	10	1.00	27.00	14.90	16.00	15.13	7.56	2.39
35	16	0.00	5.00	2.44	3.00	2.43	1.41	0.35
22	16	0.00	15.00	5.87	5.00	5.64	4.50	1.12
18	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	9	0.00	3.00	1.11	0.00	1.11	1.36	0.46
29	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00