Review of Historical and Current Land Use Practices, Characterization of Suitable Habitat, and Habitat Management Recommendations for the Endangered Ohlone Tiger Beetle, *Cicindela ohlone* (Coleoptera: Cicindelidae)

Photograph by : Richard A. Arnold

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INTRODUCTION

Pursuant to provisions of the Endangered Species Act, *Cicindela ohlone* (Coleoptera: Cicindelidae), commonly known as the Ohlone Tiger Beetle (OTB), was listed as an endangered species by the U.S. Fish & Wildlife Service (USFWS) in 2001 (USFWS 2001) only eight years after it was recognized as a new species (Freitag, Kavanaugh, and Morgan 1993). The OTB is associated with coastal prairies that occur on former marine terraces that are characterized by mima mound topography in and near the city of Santa Cruz (Santa Cruz County), California. A few of the 17 historical OTB sites (Figure 1) have been extirpated due to urbanization and agriculture. At other OTB sites, changes in land use practices and colonization by invasive weeds and annual grasses altered the plant species composition and structure (i.e., increased plant density, accumulation of thatch, and/or reduced amount of bare or sparsely-vegetated ground) of the coastal prairie habitat to the detriment of the OTB. Today the OTB occurs at only 8 of the 17 sites that historically supported the beetle. To manage habitat at remaining occupied sites to benefit the OTB, potentially restore degraded unoccupied sites, and ultimately recover this species, scientific information about compatible management activities and their effects on the OTB and its habitat is needed.

This report describes the results from our studies that focused on the following tasks:

1. Conducted a review of historical and current land uses, habitat conditions, and management activities at all formerly and currently occupied OTB sites;
2. Visited all known OTB sites to assess current habitat conditions and evaluate the potential for rehabilitation of unoccupied sites;
3. Interviewed property owners and land managers to identify historical management practices and evaluate the success of various land use activities for managing the OTB habitat;
4. Evaluated correlations between habitat management practices and site occupancy of the OTB; and
5. Investigated various physical properties of the soils and seasonal variation in vegetation characteristics of known OTB sites to characterize suitable habitat.

The section of this report titled, Current and Historical Management Study, describes the findings of the first four tasks, while the section titled, Suitable Habitat Characterization Study, describes the findings of the fifth task. Information from all five tasks of this study was synthesized into generalized habitat management guidelines and livestock operation guidelines that can be used by landowners to manage their properties to benefit the OTB.

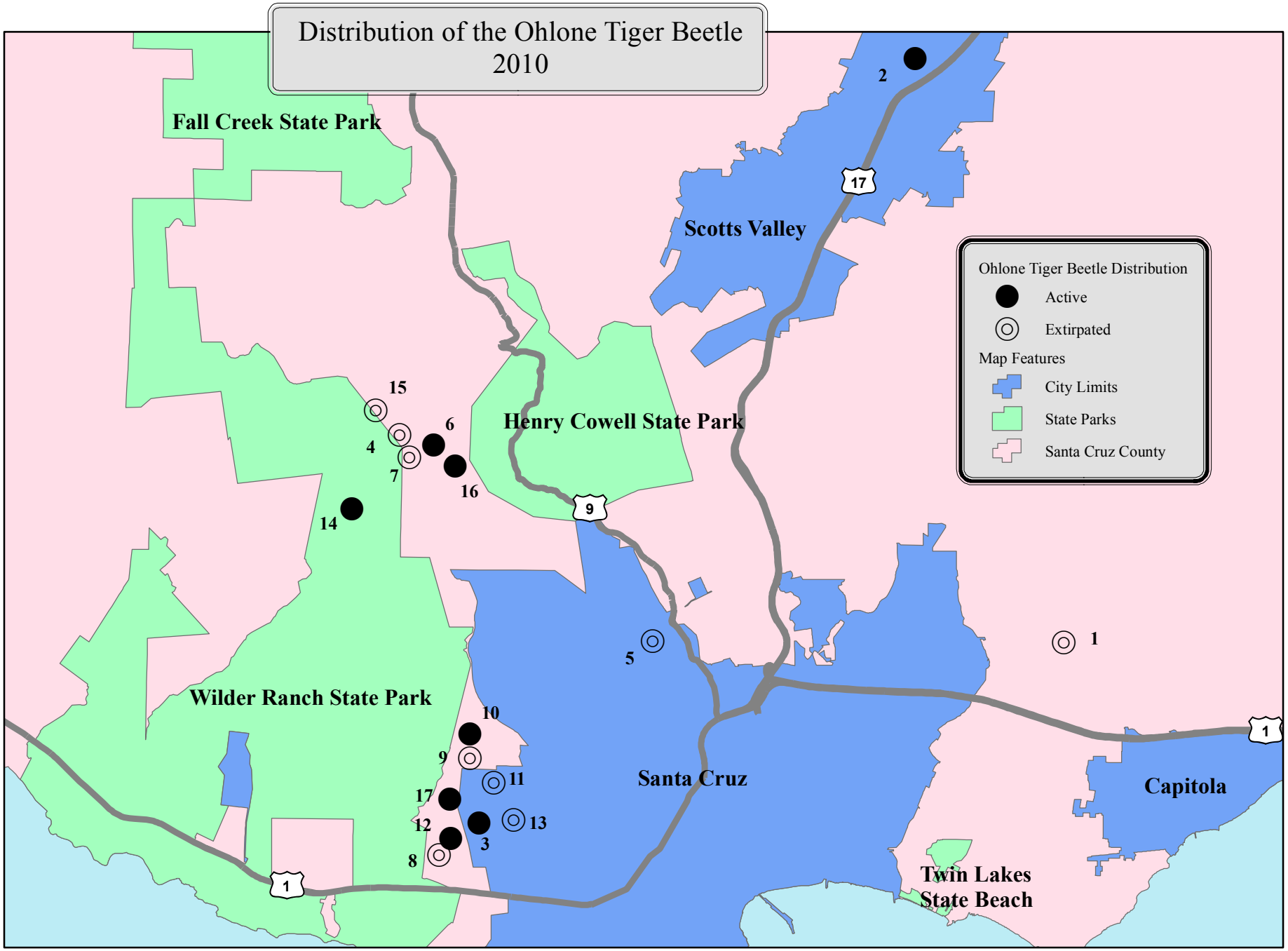


Figure 1

October 17, 2010
Entomological Consulting Services, Ltd.

Table 1 provides definitions for key terms used in this report.

Table 1. Glossary of Key Terms

OTB Site	The more general location, such as a meadow or area of a park or ranch, where breeding OTBs were previously or currently known to occur.
OTB Subsite	The more precise locations within the OTB sites that were either occupied or unoccupied by OTB (adults or larvae were observed or not found); the area sampled with transects for the Site Characterization Study.
Currently Occupied	OTB adults and larvae have been observed there in recent years.
Recently Extirpated	OTB that were present up to a few years ago, are now presumed to be no longer present there (OTB adults and larvae were observed during repeated surveys since first reported, and until recently, when none have been observed). At some recently extirpated sites, habitat management or restoration may improve conditions for natural recolonization by the OTB or possible reintroduction.
Historically Extirpated	OTB that were found during the first surveys, but not since, and are presumed to be no longer present there (i.e., no OTB adults or larvae have been observed in repeated surveys since first reported). At some historically extirpated sites, habitat management or restoration may improve conditions for natural recolonization by the OTB or possible reintroduction.
Historically Occupied	The 17 OTB sites shown in Figure 1 (including the currently occupied, recently extirpated, and historically extirpated sites).
Extensive Grazing	Grazing by "range" cattle or "range" horses in relatively large fields (not improved or irrigated pastures nor confined paddocks), with minimal if any cross-fencing to allow low density stocking rates and wide movements), trailing effects common, more structural heterogeneity of the herbaceous vegetation, the primary source of forage provided by the grassland and little if any supplemental feed, and a relatively high degree of forage choice.
Intensive Grazing	Grazing by cattle or horses in relatively smaller fields (possibly including irrigated or improved pastures), field boundary configurations or cross-fencing to support high-density stocking and frequent rotations between fields, trailing effects less common, less structural heterogeneity of the herbaceous vegetation, and a relatively low degree of forage choice.

BACKGROUND INFORMATION ON THE OTB

This section summarizes available information about the taxonomy, identification, distribution, habitat, biology, and conservation of the Ohlone Tiger beetle. Information from related species of tiger beetles is often discussed, particularly when specific information for the OTB is lacking.

Taxonomy
Tiger beetles are generally treated as a family, the Cicindelidae, in the insect order Coleoptera; however, some entomologists prefer to recognize tiger beetles as a subfamily (Cicindelinae) or tribe (Cicindelini) of the ground beetle family, Carabidae. Thus, all of these names are encountered in the entomological literature.

The Ohlone tiger beetle was recognized as an endangered species by the U.S. Fish & Wildlife Service in 2001 (USFWS 2001). As of December 2010, the beetle is known from only 8 sites. The Ohlone Tiger beetle was described in 1993 by Freitag, Kavanaugh, and Morgan (1993). Their description of this new species was based on specimens collected from three sites in west central Santa Cruz County between 1987 and 1992. Subsequent to the authors' submission of their paper, the beetle has been found at about 17 sites, which may represent distinct populations, or because of the proximity of several sites, may actually represent only a couple of metapopulations of the OTB.

Species Description
Adult tiger beetles possess elongate, cylindrical bodies. They are usually brightly colored, often with a metallic or iridescent sheen. Their eyes and sickle-shaped mandibles (i.e., jaws) are very prominent. Together, their eyes and head are wider than the thorax. They possess long, cursorial legs that are characterized by numerous spines. Adults are typically about 15-25 mm. in length.

Cicindela ohlone is most closely related to *C. purpurea*, which is commonly known as the Cow Path Tiger beetle because it is found along cattle trails in meadows of the Sierra Nevada (Pearson, Knisley, and Kazilek 2006). The OTB can be distinguished from this and related species by its overall size, the color and maculation patterns on its thorax and elytra, and its genitalic features. The OTB's body color is a brilliant green, with gold to bronze-colored maculations. Freitag, Kavanaugh, and Morgan (1993) illustrated the maculation pattern characteristic of *C. ohlone* and the diagnostic features of its genitalia. In addition, the winter-spring activity period of the OTB is distinctive, as most tiger beetles in coastal California are active in the spring and summer months (Nagano 1980).

Larvae of tiger beetles are much more uniform in appearance than adults. They have an eruciform (i.e., grub-like) appearance and live in an earthen tunnel or burrow. The head and pronotum are strongly chitinized, and the fifth abdominal segment possesses a pair of medial hooks that are used as anchors to secure the larvae as they reach out from the burrow in a jack-in-the-box like manner to ambush prey. The larvae of *C. ohlone* have not been described.

Distribution
Of the 109 species of tiger beetles that have been described in North America (Pearson, Knisley, and Kazilek 2006), *Cicindela ohlone* exhibits one of the most restricted geographic ranges. It has been reported at only 17 sites in central and western Santa Cruz County, California (Figure 1).

Although the potential exists for the OTB to occur in other locations in the county supporting suitable coastal prairie habitat, to-date the beetle has not been found at other similar sites that were checked. This species appears to be restricted to coastal terrace situations, at low to mid-elevations (less than 1,200 feet), located between the crest of the Santa Cruz Mountains and the Pacific Ocean.

Habitat
Cicindela ohlone inhabits coastal terrace prairies characterized by remnant stands of native perennial grassland. California oatgrass (*Danthonia californica*) and Purple needlegrass (*Nasella pulchra*) are two native grasses known to occur at all sites. Within these grasslands, the beetle has been observed primarily on level ground, where the vegetation is sparse or bare ground is prevalent. Adults are less frequently observed in the densely-vegetated grassland, but larval burrows have been observed in sparsely vegetated patches in otherwise dense grassland.

The substrate at each known beetle site consists of shallow, poorly drained clay or sandy clay soils that have accumulated over a layer of bedrock known as Santa Cruz Mudstone (Freitag, Kavanaugh, and Morgan 1993). According to the county's soil survey (Bowman *et al.* 1980) and supplemental soil analyses conducted by the Natural Resources Conservation Service (U.S. Department of Agriculture) at selected OTB sites, all known beetle sites are characterized by Watsonville Loams, although in a few cases the Watsonville Loams are an inclusion in another mapped soil.

Biology
Specific biological and life history information for *C. ohlone* is not well known. Similarly, the egg, larval, and pupal stages of *C. ohlone* have not been described. However, all tiger beetles share some general biological characteristics, which are summarized in this section.

The diurnally active adults and larvae of *C. ohlone* are associated with sunny areas of bare or sparsely vegetated ground. Adults run rapidly in and near the larval habitat. They are strong flyers at least for short distances. Because they are cold-blooded, are active during the winter and spring months, and favor microhabitats that are sparsely vegetated and whose temperatures can fluctuate dramatically during their activity period, adults and larvae may spend a considerable portion of their daily activity thermoregulating.

Collection records indicate that most adult *C. ohlone* are typically active from mid-January through mid-May (Arnold, personal observation). Both adults and larvae of tiger beetles are opportunistic, preying on smaller, soft-bodied insects and other types of invertebrates. Adults possess good visual acuity and are found on sunny glades of bare or sparsely vegetated soil, where they actively search for potential prey. In contrast, larvae remain in their burrows, and ambush prey that wander within their striking distance in a jack-in-the-box manner. Specific prey items of *C. ohlone* adults include ants, spiders, adult and larval flies (Diptera), tiny insects, small beetles, and earthworms (Arnold, personal observation). Larvae prey primarily on ants, including the introduced Argentine ant (*Iridiomyrmex humilis*).

Larvae of most tiger beetles occur in a narrower range of microhabitats than their adult stages, probably because they tolerate less variation in many physical factors, especially soil moisture, soil composition, particle size, and temperature (Pearson 1988; Shelford 1907 and 1909). All known larvae construct a tunnel-like burrow at sites where eggs were laid by the mother beetle. Larvae of other tiger beetle species that live in grasslands typically build their burrows at the edges of the bare or sparsely-vegetated portions of the grassland, where adult beetles are most commonly observed. The edge of the vegetation acts somewhat like a drift fence to funnel potential prey to the mouth of the beetle's larval burrow. The OTB generally follows a similar pattern, although some larval burrows occur at interior portions of bare or sparsely-vegetated patches.

Burrow depth of other tiger beetle taxa varies depending on the larval developmental stage, species, season, and substrate, but ranges from 15 to 200 cm (Pearson 1988; Willis 1967). Excavated burrows of mature OTB larvae were as deep as 15-20 cm. OTB larval burrow diameters (measured at the burrow mouth) range in size from ca. 1.5 - 6.5 mm. OTB larvae can complete their development within one year if they have sufficient food, but monitoring of marked burrows revealed that some larvae take two or possibly even three years to complete their development (Arnold, unpublished data).

Pupation takes place in the larval burrows. The upper portion of the larval burrow is usually sealed off by the larva with a soil plug when its molts between larval instars or when it pupates.

CURRENT AND HISTORICAL MANAGEMENT STUDY

Introduction

We identified the current, recent, and historical land uses and management activities that have occurred at each of the 17 OTB sites (Figure 1). This information was used to determine the efficacy of management activities to support OTB occupation at sites with seemingly suitable physical and vegetation characteristics, and identify the roles these activities may have played in causing extirpation of the OTB.

Methods

In order to determine current and historical land use and management activities, we completed site visits and interviews of current property owners and land managers at 14 of the 17 known OTB sites (Figure 1). The owner of one private property that supports three OTB sites would not allow access or agree to be interviewed. However, historical information from neighboring properties was assumed to apply to these sites, and thus was included in this analysis. The analysis included the following eight OTB sites (Figure 1) that are currently occupied: #2, #3, #6, #10, #12, #14, #16, and #17.

The analysis also included the following nine OTB sites (Figure 1) that were historically occupied (recorded in the surveys during and following listing as an endangered species), but are now considered recently or historically extirpated: #1, #4, #5, #7, #8, #9, #11, #13, and #15.

We prepared a questionnaire about several management characteristics of every OTB site: the grazing season(s); the kind of domesticated grazing animal, class (age/gender), and number of grazing animals; field size; grazing system (e.g. continuous, rotational); and other types of management activities. Responses for each question were given a numerical code in order to group similar responses between sites. In this qualitative analysis, we developed management categories, the most informative of which are shown in Table 2. The management categories proved to be more useful for this analysis than the coding system because the resulting pattern of qualitative correlation was found most distinctly in the current year management (refer to the results section). At each OTB site, these same questions were asked in reference to four different time periods: the current year, previous year, a typical year, and historically to obtain a sense of how habitat conditions may have changed over time due to different types of management. This historical management information was later sub-divided into five periods: Pre-Historical, Spanish-Mexican, 1840s-1940s, 1950-1980, and 1981-present. Survey data were obtained primarily through interviews of the current and former property owners, current land managers, and our professional familiarity with the 17 OTB sites. Additional information for some sites was acquired from management planning documents and other publications that describe land use history in the Santa Cruz area.

Data were entered into a spreadsheet (referred to as the management matrix) for analysis. Each row in the spreadsheet represented an OTB site and each column represented a management category in each time period that was identified from the surveys. The

management matrix identified the types of management activities that occurred throughout the aforementioned time periods for all OTB sites.

Results

Table 2 summarizes the data on management history. The OTB sites are color coded and grouped by OTB status:

- Green = currently occupied OTB sites;
- Yellow = recently extirpated OTB sites; and
- Pink = historically extirpated OTB sites.

The determination of OTB status was based on observations by Richard Arnold (unpublished data) between 1991 and 2010.

Management activities identified at the known OTB sites included:

- Extensive and intensive grazing with cattle or horses, as well as dairy cattle, sheep, and goats (for economic and recreational purposes, including meat and milk production, recreational horse keeping, horse stable facilities, and brush clearing);
- Mowing, haying, brush clearing, and burning (for economic, conservation, and recreational purposes, including road and trail maintenance, fire hazard reduction, habitat improvement, and hay production);
- Scraping and digging (for economic and conservation purposes, including construction, grazing operations, and OTB habitat improvement);
- Specialized weed-whacking (used at one site for OTB habitat improvement);
- Low and moderate trail use by hikers, bicyclists, and horse riders (for recreational purposes);
- Operation or maintenance vehicle traffic (for management operations and maintenance of roads); and
- Road and trail maintenance and graveling (for management operations and maintenance of roads).

The indigenous management activities that might have affected OTB habitat during prehistoric times were least known by our informants. The indigenous Californians focused such grassland management on their settlement areas, transport and migratory trails, burning, and other manipulations of the vegetation and soil for the improvement of conditions for plants and animals used as food, clothing, and tools, and the reduction of fire hazards (Anderson 2007). The prehistoric grassland vegetation was dominated by native species, apparently with more bare soil patches between plants than occur today because the aggressive annuals (that cover those spaces today) had not invaded yet. The bare patches were also due to the abundance of indigenous living areas within the grasslands, more manipulation of the grasslands by the indigenous managers, and more native animal herbivory and trailing than occurs today. At the time of indigenous occupation, the grasslands of this area provided habitat for large, but fluctuating populations of grazing mule deer, elk, bears, small mammals, and birds (Schiffman 2007). During the transition to the historic period, grassland grazing by large animals shifted from native wildlife to non-native livestock. This resulted in a shift in grazing

behaviors and effects on grassland vegetation (Shiffman 2005), and probably on the associated bare soil patches utilized by the OTB. The native grazing varied yearly and seasonally in response to weather fluctuations and other environmental differences on the landscape. These native grazers did not graze intensively in large herds, and were very selective of forage, whereas livestock graze the vegetation more thoroughly with less selectivity within confined fields. Our records of management activities at the OTB habitat sites during the historic periods shows a shift from beef cattle operations to beef cattle, oxen, and horses, and then to beef and dairy cattle operations, with increasing vehicle traffic, including motorized vehicle uses. Frequent recreational uses began in the later historical periods, and now are major objectives of land management. The management activities during recent years have been more diversified than during earlier years, but have focused mainly on beef cattle grazing and recreational horse keeping, hiking, and bicycling. Among the large native grazing animals of the prehistoric times, only deer remain in this area.

We speculate the OTB has persisted through these time periods where patches of bare ground were maintained on the appropriate sites of Watsonville Loam soil. During prehistoric times, habitat was available due to the combination of activities of the indigenous people, the suitable characteristics of the native plants, and the grazing effects of the native animals at the Watsonville Loam sites. During historic times, habitat was available in a smaller area due to conversion to agriculture and clearing for development, but the remaining potential habitat was maintained mainly by the combination of livestock grazing, including trailing, and moderately frequent traffic by vehicles, hikers, and bicyclists on dirt roads and trails.

During the current year and typical years, extensive cattle grazing occurred at four sites (Table 2, Sites #3, #10, #12, and #17) and extensive horse grazing occurred at one site (Table 2, Site #2). OTBs were present at all sites with extensive cattle or horse grazing. Moderate-frequency hiking and bicycling use during the current and typical year occurred at three sites where OTB were present (Table 2, Sites #6, #10, and #14). All unoccupied sites (Table 2, Sites #1, #4, # 5, #7, #8, #9, #11, #13, and #15) lacked extensive grazing by cattle or horses or moderate-frequency hiking and bicycling traffic. Similarly, the one site (Table 2, Site #8) with a horse stable facility and intensive horse grazing (added in 2009) in the current and typical year, no longer supports the OTB.

SUMMARY OF SITE MANAGEMENT HISTORY AND OTB STATUS

	Current Year																			Typical Year															Historically														
	Grazing					Other Uses/Management														Grazing				Other Uses/Management													Grazing		Other Uses/Management											
OTB Status / OTB Site Numbers	Horse--Extensive	Horse--Stable Facility	Cattle--Extensive	Cattle--Intensive Rotation	None	Hiking--Moderate Frequency Use	Hiking--Low Frequency Use	Biking--Moderate Frequency Use	Biking--Low Frequency Use	Horse Riding--Moderate Frequency Use	Horse Riding--Low Frequency Use	Vehicle Driving--Moderate Frequency Use	Vehicle Driving--Low Frequency Use	Mowing	Flaming/Burning	Scraping/Digging/Tilling/Disking/Pig Rooting	Weed Whacking	Gravel Present on Dirt Road		Horse--Extensive	Horse--Stable Facility	Cattle--Extensive	None	Hiking--Moderate Frequency Use	Hiking--Low Frequency Use	Biking--Moderate Frequency Use	Biking--Low Frequency Use	Horse Riding--Moderate Frequency Use	Horse Riding--Low Frequency Use	Vehicle Driving--Moderate Frequency Use	Vehicle Driving--Low Frequency Use	Mowing	Flaming/Burning	Scraping/Digging/Tilling/Disking/Pig Rooting	Gravel Present on Dirt Road		Horse--Extensive	Cattle--Extensive	Hiking--Moderate Frequency Use	Hiking--Low Frequency Use	Biking--Moderate Frequency Use	Biking--Low Frequency Use	Horse Riding--Moderate Frequency Use	Horse Riding--Low Frequency Use	Vehicle Driving--Moderate Frequency Use	Vehicle Driving--Low Frequency Use	Flaming/Burning	Scraping/Digging/Tilling/Disking/Pig Rooting	Gravel Present on Dirt Road
CURRENTLY OCCUPIED																																															
#2,3,6,10,12,14,16, 17	1	0	4	0	3	3	2	3	1	0	5	0	7	4	0	3	1	2		1	0	4	3	3	2	3	1	0	5	0	7	4	1	1	2		3	8	3	8	3	1	0	6	0	8	8	5	2
RECENTLY EXTIRPATED																																															
#1,5,8	0	1	0	1	2	0	2	0	0	1	0	1	0	2	0	0	0	1		0	1	0	2	0	2	0	0	1	0	1	0	2	0	1	1		2	3	0	3	0	1	0	0	0	2	3	2	0
HISTORICALLY EXTIRPATED																																															
#4,7,9,11,13,15	0	0	0	0	6	0	4	0	3	0	4	0	4	6	0	0	0	3		0	0	0	6	0	4	0	3	0	4	0	4	5	0	0	3		3	6	0	6	0	3	0	4	0	6	6	2	3

Discussion and Conclusions

We confronted several challenges to obtain complete and accurate management information for all OTB sites and time periods and to categorize the information, including:

- In some cases we received inconsistent information from different sources for the same OTB site. For example, a few current owners and land managers were not familiar with historical land management activities at their properties. Therefore, some management data is not as precise or accurate as we had intended.
- We were not able to interview all property owners, notably the owner of OTB Sites #9, #12, and #17). In spite of reviewing available historical documents, for a few OTB sites we were not able to find management information (e.g. information about OTB Site #5). In those cases we made assumptions about what impacts might have occurred based on the historical info we were able to gather (e.g. at OTB Site #5 we assumed there was wagon traffic associated with historic industry operations).
- It was a challenge to categorize the different types and circumstances of recent and historical management to provide a meaningful explanation of current OTB presence or absence. By distinguishing the degree of intensity of grazing and the type of grazing operation (extensive versus intensive), and the degree of frequency of traffic of hikers and bicyclists (low versus moderate), we found those categories were correlated closely with the status of OTB.

Two main kinds of current management activities appear to be most associated with maintenance of habitat conditions beneficial for OTB persistence—extensive cattle or horse grazing and moderate-frequency hiking and bicycling traffic (Table 2):

- A traditional extensive beef cattle grazing operation with minimal cross fencing, some light to moderate-use recreational trails, and grazing operation vehicle use (Table 2, OTB Sites #3, #10, #12, and #17).
- Extensive horse grazing (not a horse stable facility) where the primary source of forage is provided by the grassland with little supplemental feed, and a goal of the grazing management is focused on maintaining and improving OTB habitat (Table 2, OTB Site #2).
- Moderate-frequency recreational (foot and bicycle) traffic and maintenance vehicle traffic on unimproved dirt roads and trails with no grazing (Table 2, OTB Sites #6 and #16), and with seasonal mowing along trail shoulders and/or periodic controlled burns (Table 2, OTB Site #14). Sites that currently no longer support beetles have no extensive grazing or moderate-frequency hiking or bicycling traffic (Table 2, OTB Sites #1, #4, #5, #7, #8, #9, #11, #13, and #15).
- Based on changes in habitat management that we have observed at extirpated OTB sites (Table 2, OTB Sites #1, #4, #5, #7, #8, #9, #11, #13, and #15), if the current management practices were to be discontinued at the currently occupied OTB sites (Table 2, OTB Sites #2, #3, #6, #10, #12, #14, #16, and #17), we expect the beetle would be extirpated. Although it seems reasonable that effective management at one site would work at another site, we would proceed with caution before changing management at any site where the beetle currently occurs

because of the possibility of an accident or unanticipated factor(s) that cause(s) extirpation. However, adding a complementary management type would likely improve the sustainability of the habitat (e.g. adding cattle grazing at OTB Site #14). If the kind of management was altered or ceased, we would expect the subsites of occupation by the beetle would change or be extirpated as has been observed at some OTB sites (Arnold, personal observation). For example if management switched from grazing to moderate-frequency hiking or bicycling traffic, occupation might switch from the grazed open grassland habitat areas to the recreational trails. Each of these kinds of management is associated with a different kind and quality of beetle habitat that it creates and could be added to current management or could be a substitute for current management.

- All 17 OTB sites were historically grazed by cattle (Table 2). At all of the recently extirpated OTB sites (Table 2, OTB Sites #1, #5, and #8), grazing was either removed or the grazing regime was changed, and lacked moderate-frequency hiking, bicycling, or horse riding. OTBs are no longer found at a recently extirpated site (#8) where there was a switch from extensive horse grazing on the entire site to a horse stable facility with several smaller pastures. The OTB prefers sites with patches of bare to sparsely-vegetated Watsonville Loam soils. Prehistorically, factors such as periodic wildfires, grazing by large and small mammals, burrowing animals, and herbivorous insects created and maintained patches of bare ground suitable for OTB occupation. Today coastal terrace prairie habitats have been colonized to varying degrees by invasive weeds and annual grasses, wild fires are generally controlled more quickly, and many of the native grazers and burrowing animals have been displaced. Thus sufficient bare and sparsely-vegetated ground does not persist at sites after management activities that contributed to their creation and maintenance cease.
- Extensive grazing and moderate-frequency recreational hiking or bicycling traffic are management activities that create and maintain bare or sparsely-vegetated ground suitable to support OTB populations. One or both of these management activities are appropriate to maintain an OTB population. A combination of these management activities may be necessary to insure long-term occupancy of an OTB population. For example, if grazing is removed, OTB might still persist on dirt trails where there is moderate-frequency hiking and bicycling traffic (however, at each of the grazed currently occupied OTB sites, there is little or no hiking or bicycling use). Each of the currently occupied sites has only one key management activity and all are particularly vulnerable.
- The use of both extensive grazing and moderate-frequency hiking and/or bicycle traffic may be the optimum habitat management strategy to protect the OTB because of the possibility that one or the other management activity might be suspended. OTB sites that have only moderate-frequency hiking or bicycling lack grazing, and vice versa. If hiking and bicycling diminished or was removed, it would take time to develop a grazing program. If grazing ceased at a currently occupied OTB site, it would take time to encourage moderate-frequency hiking or bicycle use, and a few private property owners might not cooperate. A related concern is that recreational hiking and bicycling activities have increased dramatically in the greater Santa Cruz area since the OTB was recognized as

endangered. The beetle has not been observed at locations with suitable habitat characterized by high-frequency foot and bicycle traffic, such as the central campus areas of the University of California Santa Cruz, presumably because the frequency of human activity disrupts beetle behavior, life stages of the beetle are harmed, and intensive use may cause erosion or other problems.

- Continued future grazing in Santa Cruz County is not guaranteed. If the cattle grazing industry disappeared or became infeasible, or the horse-keeping community shifted from extensive grazing to stable facilities, and high-frequency recreational traffic use on the OTB sites was inadequate to create and maintain sufficient bare to sparsely-vegetated ground, the beetle would probably be extirpated. Thus, private properties without extensive grazing or appropriate recreation seem to be most vulnerable.

Our analysis of historical and recent management activities for the recently extirpated OTB sites suggest that the cessation of grazing or a change from extensive to intensive grazing resulted in the reduction of suitable habitat, namely bare or sparsely-vegetated ground, that could be occupied by the beetle. Although coastal terrace prairie remnants that are currently occupied by the OTB are characterized by a mixture of native and non-native plants, the extensive grazing or moderate-frequency recreational activities are the management activities that seem to best maintain sufficient bare ground for the beetle to persist.

Potential explanations for the recent extirpation of OTB include:

- At Site #11 cattle grazing ceased earlier in this decade and within a couple of years bare ground was colonized and overgrown by herbaceous vegetation that displaced the OTB.
- At Site #1 the area of occupied habitat was very small and low-frequency hiking and bicycling were the primary management activities. More recently, excavation to create water pits and ramps by the mountain bikers occurred within the primary OTB breeding area. Concurrently, the amount of bare ground has substantially decreased with the spread of French broom and various annuals, notably *Erodium*, in the grasslands.
- At Site #5 the primary habitat management activity since the OTB was recognized as endangered has been low-frequency hikers. Previously, a small number of horses grazed extensively at this site. The cessation of grazing, prevention of bicycle access, and low-frequency hiking have not maintained sufficient bare or sparsely-vegetated ground to support the OTB.
- At Site #8 the OTB were extirpated after land use changed from extensive horse grazing to intensive horse grazing with supplemental feeding as part of a new horse stable operation with a few, smaller pastures. The primary areas of bare soil were the intensively trampled paddocks, in some cases covered by moving layers of decomposing hay and manure, and riding arenas; however, neither were suitable for OTB occupation due to the high-frequency of use and imported soil in the arena. Dirt roads that were formerly occupied by the beetle were re-aligned and portions were covered with gravel to make them suitable for use by ranch

vehicles during adverse weather. Additional dirt roads and trails were created, but OTBs have yet to be observed using them.

Additional management activities to benefit OTB include:

- Supplemental management activities to create bare patches of ground, such as scraping (removal of the top layers of vegetation and sod) and flaming (using a propane torch to burn away the vegetation) have been tried at several OTB sites, but their beneficial effects typically persist for only a couple of years. Thus their benefit to the OTB has been short term, and they can be costly due to the intensive labor.
- Monitoring of the grazing and recreational traffic and plans for adaptation of the management plans to assure attainment of the required habitat conditions would increase the effectiveness of the management and stability of the habitat. Formal plans for monitoring and adaptive management would also reduce the vulnerability of the habitat to changing management personnel.

SUITABLE HABITAT CHARACTERIZATION STUDY

Introduction

Our habitat characterization study attempted to identify key general and specific site features associated with current OTB occupation and the effects of habitat management that favor beetle occupation. Specifically, it had two objectives:

- to describe the physical features characteristic of occupied sites; and
- to describe the vegetation characteristics of currently occupied sites.

Ideally, we would have preferred to characterize habitats at currently occupied sites and compare them to recently extirpated sites, but budget constraints and lack of cooperation from all property owners caused us to use the aforementioned study design.

Field Methods

We investigated habitat characteristics at five currently occupied OTB sites, contrasting those characteristics at subsites that were currently occupied at the time of our surveys versus subsites that were not currently or recently occupied based on recent population monitoring surveys by Arnold (unpublished data). The five currently occupied OTB sites were #2, #3, #6, #14, and #16.

The owner of a fifth property, which supports currently occupied OTB sites #12 and #17, would not allow us access, so no habitat studies could be undertaken there.

The survey design was based on our preliminary understanding of the key information needed to discern the likelihood of maintaining, losing, and rehabilitating habitat suitable for sustainable occupation by the OTB, and other key information about OTB. Our previous observations identified the primary habitat characteristics associated with use by females for oviposition and by larvae in establishment and maintenance of burrows. These characteristics include areas of Watsonville Loam soil with good drainage and infiltration, flat to slightly sloping topography, exposure to warming sunlight (and unshaded by overhanging woody vegetation), and abundant patches of bare to sparsely-vegetated soil in grassland or bare dirt roads and trails (refer to "Habitat Management Model Context" in the Guidelines for OTB Habitat Management section below).

For this study, we defined suitable habitat characteristics in two categories: physical site and vegetation. Measurement of physical characteristics included percent cover of soil, loose sand, stones, bedrock, small mammal burrows, human digging, and other-1. Measurement of vegetation characteristics included percent cover of annual grass, perennial grass, legumes, other forbs, litter, manure, and other-2, plus herbaceous height (inches) and combined herbaceous mass (lbs./acre). In addition, soil samples were collected in 4-inch deep cores for each transect and sent to ANR Analytical Lab at the University of California, Davis for analysis of pH, Total N, Total C, Bray-P, texture (derived from sand, silt, and clay proportions).

Transects were established in four different zones (sample units) at each study site to compare OTB occupied versus unoccupied subsites and dirt roads/trails versus grasslands:

- Roads/trails-occupied (RTO);
- Roads/trails-unoccupied (RTU);
- Grasslands-occupied (GO); and
- Grasslands-unoccupied (GU).

A total of 18 transects were established. Two supplemental transects were established at OTB Site #14, bringing the total number of transects there to six, whereas we had four transects at the other sites. During the spring sampling we discovered that OTB occupation at a couple of the designated subsites might have been mis-labeled, so we improved certainty by adding two distinct subsites.

Physical and vegetation characteristics were measured along each transect at three times of the year:

- Winter 2009, after first rains and herbaceous green-up;
- Late spring 2010, while adult OTB were active; and
- Fall 2010 at the end of the growing season and at the beginning of the first rains.

OTB occupied and unoccupied subsites were randomly selected using maps prepared by Arnold that illustrated locations of OTB occurrence in recent years at each study site. We used a ¼ meter by ¼ meter quadrat to measure vegetation and habitat characteristics in 20 quadrats, spaced 3 meters apart on each road/trail and grassland transect. Quadrats were thus arranged linearly, along the length of each road/trail segment and were placed at the edge of the trail tread with a 10 cm overlap of the trail tread's edge. In grasslands, quadrats were arranged in a zigzag or spiral pattern. All vegetation and habitat data collected from the transects and the three sampling times were entered into a database using Microsoft Access.

Photodocumentation of Habitat Conditions

Photographs were taken along all transects to illustrate and document the habitat conditions observed during our habitat characterization field work, the variation between quadrats along each transect during the same sampling period, and the seasonal differences within and between transects. During the winter sampling, we took photos showing each transect plus a few representative quadrats. During the spring and autumn sampling, we took photos of each transect and each quadrat. Representative photos of transects and quadrats are presented in Appendix 1.

Each photo page in Appendix 1 illustrates habitat conditions for one transect. To illustrate representative habitat conditions in different seasons there are 4 photos for each transect during each measurement period. The first photo shows the entire transect. The next three photos show quadrats with a relatively low amount of vegetation, relatively moderate amount of vegetation, then relatively high amount of vegetation for that transect in that season. Therefore, for transects with a varied amount of vegetation, there are photos with distinctively low, moderate, and high amounts of vegetation. Conversely, for transects that consistently had a substantial amount of vegetation, the photos will show what appears to be similar amounts of vegetation in the three quadrat photos. The variable for total standing herbaceous matter (combination of percent cover of annual

grass, perennial grass, legumes, and other forbs) was used to select the low, moderate, and high vegetation for the winter and spring photos. The variable for total standing herbaceous matter variable plus the variable for litter were used to select the low, moderate, and high vegetation for the autumn photos. We included litter for autumn because a substantial amount of the vegetated portion of some quadrats was litter during that season. The low, moderate, and high vegetation categories used for the photos are not associated with any categories used in the statistical analysis.

Statistical Methods

The Site Characterization Study was conducted at four properties with a total of 18 transects sampled during the Winter 2009, Spring 2010, and Fall 2010 as described above. Transects were located in areas occupied or unoccupied by OTB, and further separated into grassland or roads/trails.

To determine if the subsite transects could be quantitatively classified based on vegetation, environmental factors, management, soil characteristics, or presence or absence of OTB, we subjected the data set to Detrended Correspondence Analysis (DCA) using PC-Ord (MJM Software). DCA is an ordination procedure that simplifies complex multivariate data sets into graphs that can help in evaluating patterns in the data. Axes in ordination space can often be interpreted as environmental gradients. DCA grouped the subsites along the axes with more similar features plotted closer together and subsites that are more different plotted farther apart. DCA is commonly used for classification of complex ecological data and is best thought of as a quantitative descriptive method valuable for generating hypotheses (for further study) rather than a statistical test. The DCA using all three sample dates showed a high correlation between measures for Winter 2009 and Fall 2010. Difficulty identifying the occupied versus unoccupied transects in Winter 2009 at OTB Site #14, resulted in some missing data for that date. When we re-ran DCA using all of the subsites and data from Spring and Fall 2010, the classification was unchanged, so the Spring and Fall 2010 results are reported here. Subsite transect codes and variables used in the analysis are listed and described in Tables 3 and 4.

Table 3 lists the codes used to identify each transect in the results graphs shown below.

Table 4 lists the codes used to identify each variable, plus descriptions of each variable included in the DCA. Codes ending in "S" were measured Spring 2010; codes ending in "F" were measured Fall 2010. Variables were included only if they occurred in at least two transects in each sample period.

In Fall 2010 we found active burrows in eleven quadrats. We used a t-test to determine significant differences among the variables for quadrats with and without visible OTB burrows in Fall 2010. No active burrows were observed in the quadrats during the other two sampling periods.

Table 3. Codes for Transects Used in DCA Analysis.

Code	OTB Site Identifier and Description of Transect
a11	#2 Grassland Occupied
a22	#2 Grassland Unoccupied
a33	#2 Road/Trail Occupied
a44	#2 Road/Trail Unoccupied
a51	#16 Grassland Occupied
a62	#6 Grassland Unoccupied
a73	#6 Road/Trail Occupied
a84	#6 Road/Trail Unoccupied
a91	#3 Grassland Occupied
a102	#3 Grassland Unoccupied
a113	#3 Road/Trail Occupied
a124	#3 Road/Trail Unoccupied
a132	#14 Grassland Unoccupied
a143	#14 Road/Trail Occupied
a153	#14 Road/Trail Occupied
a163	#14 Road/Trail Occupied
a171	#14 Grassland Occupied
a184	#14 Road/Trail Unoccupied

Table 4. Codes for Variables Used In DCA Analysis.

Code	Description of Habitat Feature Variable
TNVS	total non-vegetated -- the sum of soil-1, soil-2 (wet), loose sand, stones, bedrock, mammal burrow (not ground squirrel), human digging, and other-1
Soil1S	bare ground
LoosS	sand that easily moves when touched
StonS	small rocks
BedS	bedrock
MamS	mammal burrowing that occurred within the season during which we took measurements (does not include ground squirrel mounds
TSHS	sum of ann. grass, perennial grass, legumes, and other forbs
AGS	annual grass
PGS	perennial grass
LegS	legumes
OFS	other forbs
LittS	anything that is not attached, from this year or last year – includes deer droppings; does not include woody plant leaves or stems (if oak leaves were present, we estimated % cover of what was underneath them)
ManuS	cattle or horse manure
HtS	average vegetation height
MassS	weight of standing herbage
TNVF	total non-vegetated -- the sum of soil-1, soil-2 (wet), loose sand, stones, bedrock, mammal burrow (not ground squirrel), human digging, and other-1.
Soil1F	bare ground
LoosF	sand that easily moves when touched
StonF	small rocks
MamF	mammal burrowing that occurred within the season during which we took measurements (does not include ground squirrel mounds
OthF	any other non-vegetated surface (we only used this column for what appeared to be cryptogamic crust.)
TSHF	sum of annual grass, perennial grass, legumes, and other forbs
AGF	annual grass
PGF	perennial grass
LegF	legumes
OFF	other forbs
LittF	anything that is not attached, from this year or last year – includes deer droppings; does not include woody plant leaves or stems (if oak leaves were present, we estimated % cover of what was underneath them)
ManuF	cattle or horse manure
HtF	average vegetation height
MassF	weight of standing herbage

Results

DCA explained about 81% of the total variation in the data with 79% explained by the first axis (Figure 2). Explanations of site codes are shown in Table 3. Group A consists of grassland subsite transects exclusive of OTB Site #2; Group B consists of OTB Site #2 grassland transects; and the widely dispersed Group C consists of road/trail transects.

Figure 3 displays results of DCA for all of the variables. Axis 1 explains nearly all of the variation and represents a gradient of amount of vegetation from high cover and biomass on the left to very low on the right. Explanations of environmental variable codes are shown in Table 4.

There are three distinct groups of subsite transects identified from ordination in Figure 3: the compact Group A on the extreme left of axis 1 includes the grassland transects; Group B on the lower end of axis 2 includes both grassland transects of OTB Site #2; and the very dispersed Group C in the upper right quadrant, extending into the lower left quadrant, contains the remaining road/trail transects. Axis 2 explains very little of the variation, but two of the grassland transects at OTB Site #2 are grouped lower on that axis primarily due to high legume content coupled with intermediate biomass and other measures of plant abundance on axis 1.

DCA for the soil chemical and physical characteristics revealed only one significant relationship: an association of very low phosphorus (P) with the Group A grassland transects (Figure 4). Refer to Appendix 2 for more details on soil analyses. Size of the triangles represents phosphorus concentration in the soil of the transect.

Figure 5 displays the results of DCA for perennial grass cover. The Group A grassland transects with low P also tended to have more perennial grasses. Size of the triangles represents percent perennial grass cover on the transect.

We derived a management variable incorporating notes for current grazing use and human impacts. Unfortunately this variable had no association with the ordination.

The current presence or absence of OTB also showed no separation among the groupings; occupied and unoccupied subsites for the same property were within the same groupings. OTB occupied and unoccupied transects spanned the range of vegetation parameters. We did compare individual quadrats observed to have OTB burrows in Fall 2010 to the overall means for Fall 2010. Eleven quadrats had at least one OTB larval burrow; the occupied grassland transect at OTB Site #2 had the most. The plant and soil surface values on quadrats with burrows did not differ significantly from the overall sample means, although the number of samples with visible burrows is small. Comparisons of the differences in seasonal soil and plant characteristics in individual quadrats revealed no significant relationship to burrow occurrence and a wide range of values on occupied quadrats. For example, Total Non-Vegetative cover ranged from 10-60% on grassland subsite quadrats with burrows in Fall 2010 and ranged from 20-75% on road/trail

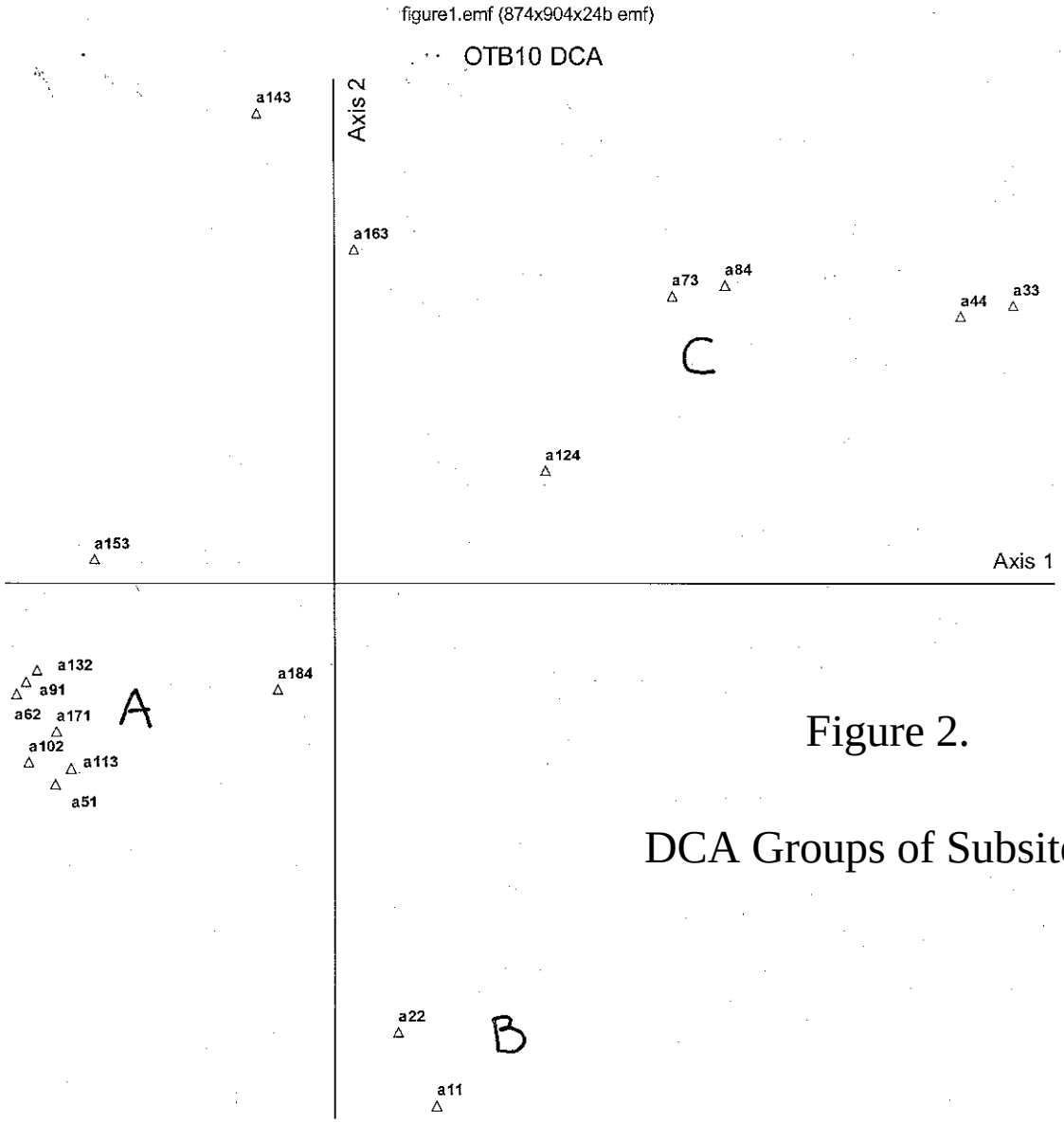
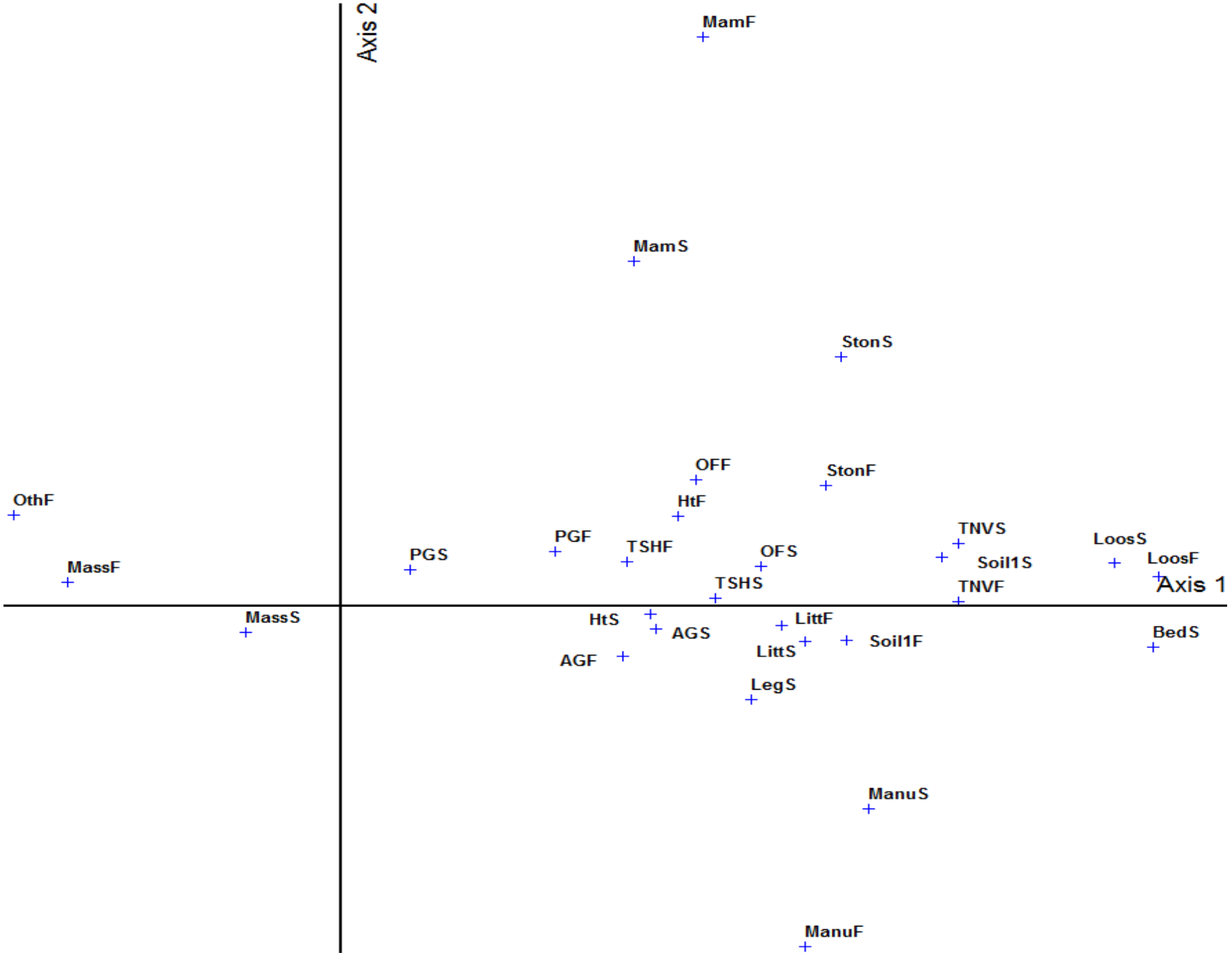


Figure 2.

DCA Groups of Subsites.

Figure 3. Groupings of Environmental Variables (+).



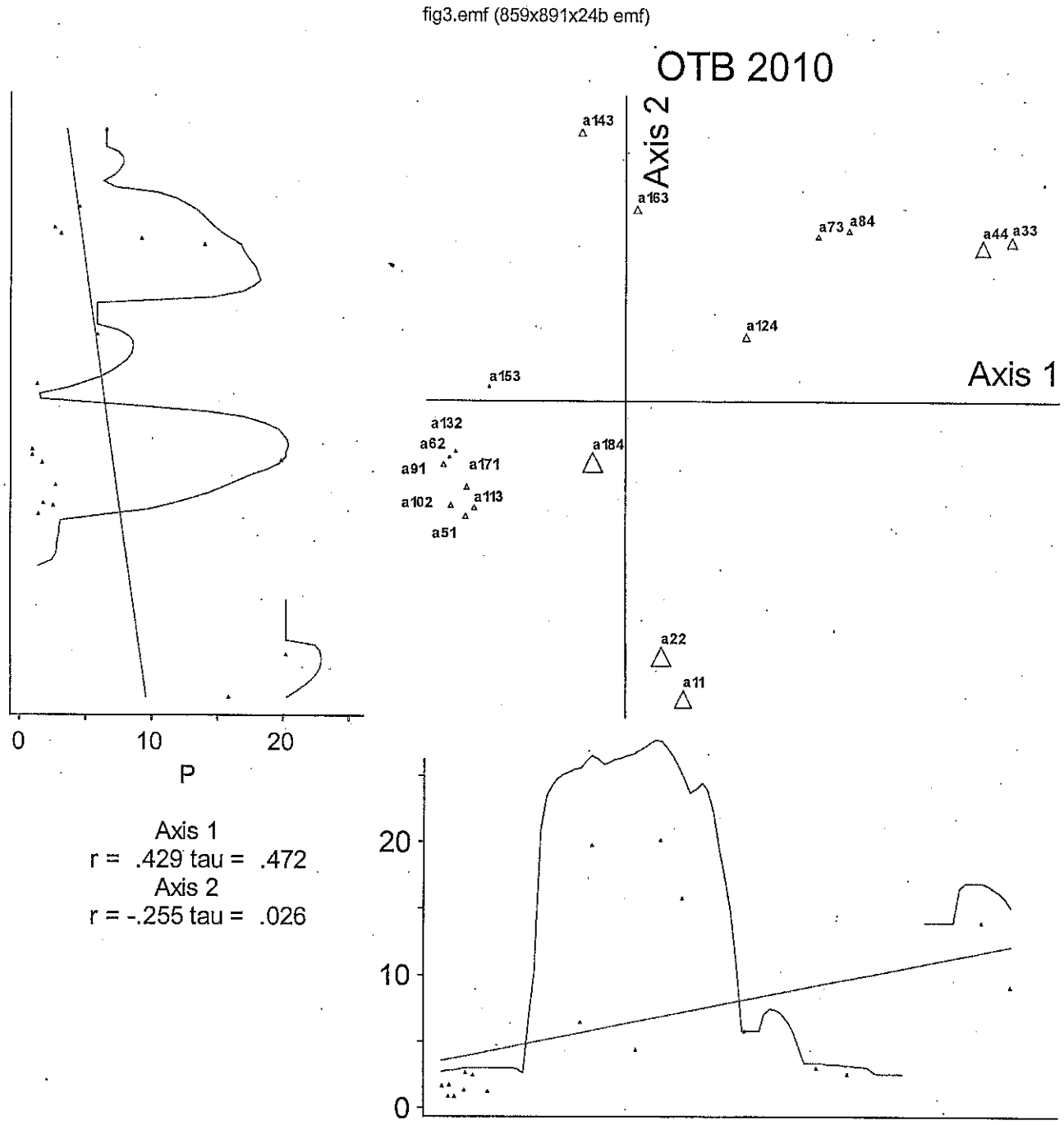


Figure 4.

Biplot of Soil Phosphorous (Bray ppm) and Subsites on Axes 1 (lower graph) and 2 (upper left graph).

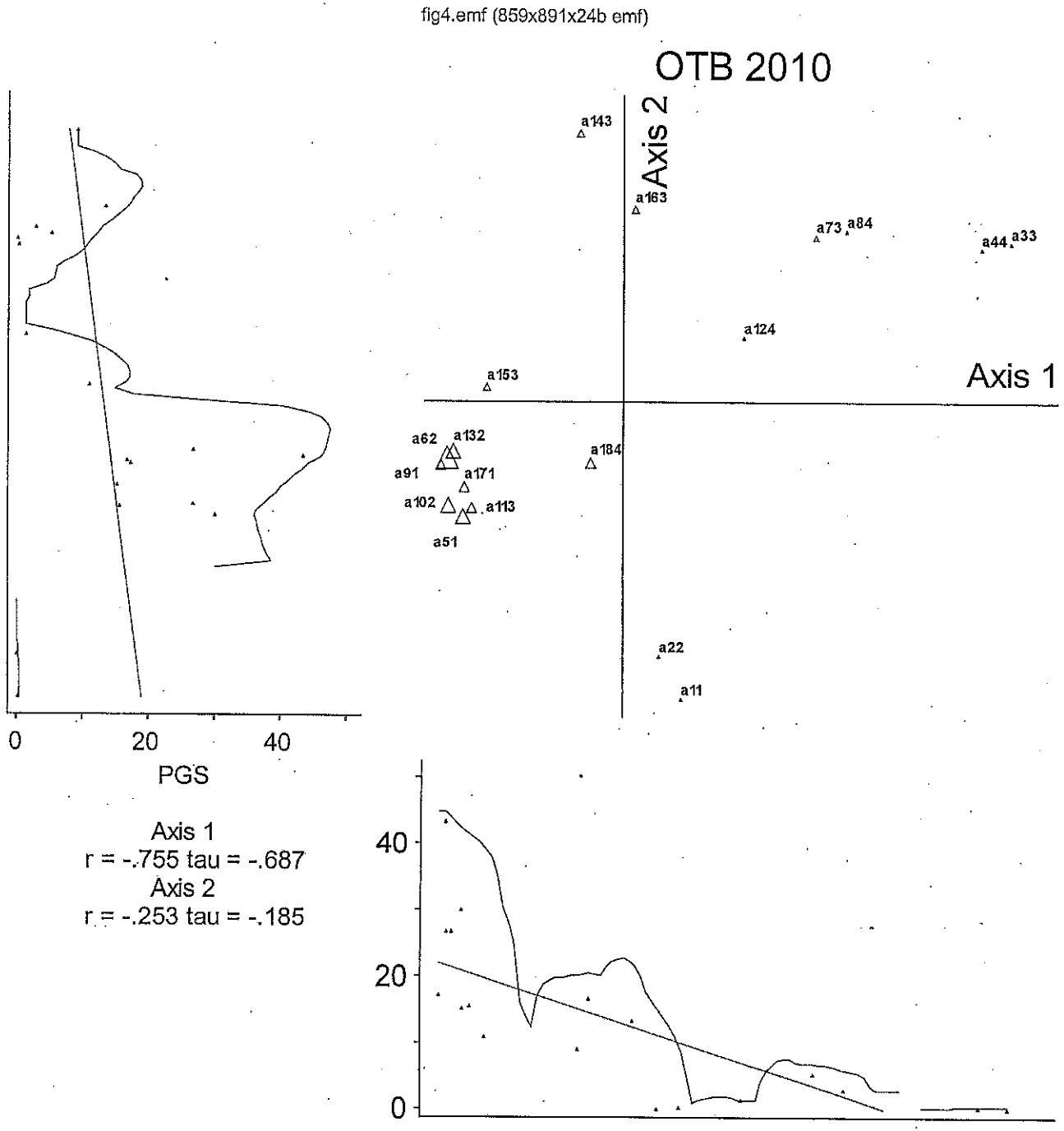


Figure 5.

Biplot of Percent Cover for Perennial Grasses and Subsites on Axes 1 (lower graph) and 2 (upper left graph).

subsite quadrats. The values for Total Standing Vegetation showed a similar range, with 5-80% cover on grassland quadrats with burrows and 15-65% on road/trail quadrats. Refer to Appendix 3 for summary statistics on the values of each variable measured by subsite transect category.

Discussion and Conclusions

Our attempts to characterize and classify subsites based on occupation and habitat met with limited success. We found:

- No differences between occupied and unoccupied transects were noted, but differences were observed between grassland and road/trail subsites. We are planning a second phase of this study to determine the characteristics of oviposition sites selected by adult females.
- More precise comparisons of the micro-sites occupied by OTB burrows with those not occupied, or to sites where OTB was recently extirpated might reveal some differences.
- Such differences might not be important as it appears there is high variation of characteristics among the occupied areas and among the unoccupied areas in both the grassland and road/trail habitats. This suggests OTB can tolerate the variation, and perhaps opportunistically take advantage of a wide range of conditions, or restricts its use to suitable subsites when the habitat conditions are favorable.

Characteristics of occupied and unoccupied OTB subsites based on the data collected on the transects:

- The two kinds of OTB habitat (grassland and road/trail) that we observed and used as parameters in this study were in fact quite different, primarily based on amount of bare ground and vegetative cover.
- All currently occupied OTB sites have had both occupied and unoccupied subsites based on observations of OTB adults and larval burrows in recent years.
- Among the grassland subsite transects and among the road/trail subsite transects, the vegetation and physical characteristics did not differ significantly between the occupied and unoccupied OTB subsites, nor between the grazed and ungrazed sites.
- There is a substantial variation in vegetation and bare soil conditions that can be occupied by OTB. Cessation of grazing and absence of or lower-frequency of recreational uses are habitat management actions shared by the recently and historically extirpated OTB sites.
- OTB use of different subsites in either the grassland or road/trail habitats is dynamic over time as changes in habitat conditions occur.

Suitable OTB habitat can be created through management:

- Although our data were not able to separate habitat characteristics from occupied versus unoccupied subsites, we believe that suitable OTB habitat characteristics can be created through a variety of livestock and human management means. Livestock will likely be more efficient and effective than mowing or other human activities at creating large-scale areas of habitat within the grassland. Human

management of recreational uses, such as hiking, bicycling, or vehicle driving, can create appropriate road/trail habitat as long as that use is sufficient to maintain some bare ground, but not so busy to increase injury and mortality of the OTB and damage the soils.

Additional site information that might be useful in determining how management influences the presence of OTB:

- Measuring micro-habitat characteristics immediately surrounding specific OTB burrow locations as opposed to measuring habitat in the general subsite of occurrence, and comparing these micro-habitat conditions with those at unoccupied sites might reveal some differences. This also would tell us more specifically what habitat requirements are required for successful burrow locations and their immediate surroundings, which is where OTB larvae spend all of their time during this stage of life.
- Investigating if there are other factors at work that affect OTB site use, occupation, and extirpation from sites. Is there a population biology threshold, such as source/sink phenomena, proximity to sources and sinks, size of the sub-populations, size of the meta-property "clusters", barriers, or fragmentation phenomena? Is there a threshold of flexibility due to loss of options for occupation? Of the four "clusters" on the map of the 17 originally occupied sites, two of the extirpated sites are outliers, and the extirpated sites in the other two clusters had grazing ceased, and have relatively low-frequency recreational traffic. We might be able to use Arnold's census data for the sites to determine whether there are any apparent correlations of burrow abundance to the vegetation and physical differences between the grassland and road/trail habitat types.
- Observational studies on OTB larvae and adults might reveal management effects. The following are questions that might be asked in such studies. How and where do OTB adults forage? Are they only hunting in bare ground areas? Is bare ground under the vegetation canopy suitable habitat or does the bare ground need to be free from overhanging vegetation? How large does the bare ground area need to be? Can they hunt in areas with low growing vegetation? Do larvae and adults need different amounts of bare ground? Maybe larvae need smaller areas of bare ground immediately around their burrows, whereas adults might need larger bare ground areas to forage. It would also be interesting to study areas where eggs are laid and watch them throughout the year. Do the areas ever get covered over with vegetation? If so, does that prevent the larvae from being able to survive? If the areas do become covered in vegetation, will that vegetation (*Erodium* for example) eventually die and get blown away allowing the area to continue being suitable to the beetle?
- The influence of weather on presence of OTB at different subsites might be important. For example, above-normal precipitation years often produce more herbaceous vegetation, and thus less bare soil patches (especially in grassland habitat). This effect fluctuates between years. But management might not change on the same schedule, and thus road /trail habitat might remain more constant. Would such a dynamic vegetation effect influence whether OTB use grassland or road/trail habitat?

- Understanding the bare ground threshold below which a site is not suitable habitat would add to our ability to make management recommendations as well.

GUIDELINES FOR OTB HABITAT MANAGEMENT

The recommended guidelines presented here are a synthesis of our conclusions from the qualitative management history study and the quantitative habitat characterization study, plus qualitative observations, a review of the recommendations of other experts, and our expert opinions based on experience studying and planning for OTB habitat management in the region. The management history study results show the key difference between currently occupied sites and formerly occupied sites was management that included either extensive grazing by cattle or horses or moderate-frequency hiking and bicycling use on trails. The habitat characterization study results confirmed the differences between the grassland and trail habitats, but found no significant indicator of the differences between the occupied and unoccupied transects within the occupied OTB sites. This latter result might be because few or no real differences in potential habitat quality exist between the occupied and unoccupied areas within an occupied site. This result could also be because both grassland and trail habitats are suitable for occupation so long as the suitable site conditions occur to a sufficient degree (refer to the Habitat Management Model section), whether or not grazed or used for moderate-frequency recreational hiking and bicycling traffic. This result might also have been because our sampling focused at a scale too coarse to detect those differences. Our 2011 study will compare soil features of OTB oviposition subsites with unoccupied subsites.

Recent and historical extirpation at nine OTB sites indicates that habitat quality can deteriorate rapidly, and result in extirpation of the OTB from those sites. Thus, active management is critical for maintenance of the remaining active OTB populations and management based on these recommendations is essential until further research or contrary indications are available.

Habitat Management Model Context

A Habitat Management Model for OTB was developed to provide context for designing our studies, interpreting results of the studies, and defining the management guidelines recommended in this section (Tables 5-9). This conceptual modeling exercise included distinguishing subsites currently occupied and unoccupied by OTB (within the currently occupied OTB sites), and identification of management activities and parameters that have apparently worked to provide the appropriate habitat conditions at the eight sites where active OTB remain (of the 17 known OTB sites). A summary of the most critical management activities is provided below.

Table 5. Plant Growth Schedule in California Annual Grassland

Plant Growth Stage	Dry/Green	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	OTB Management Concerns and Recommendations
Dormant	Dry graying annuals	X	X								X	X	X	Native perennial grasses are favored as livestock forage while annuals lose palatability; exclude or temporarily remove grazing as needed to avoid harm (including reduced reproduction) to native perennial grasses due to excess livestock utilization by exclusion.
Slow Winter Growth	Green			X	X	X	X							Seedlings invade and establish in bare patches and trails; *Erodium* cover can dominate bare patches; control seedlings before establishment with weed-whacking of trails (prior to Jan 15 only), livestock herbivory and traffic in trails and grassland, and recreational traffic in trails; further control the herbaceous cover by using grazing and recreational traffic to compact the soils in trails and bare soil patches; avoid excess utilization of perennial grasses by excluding livestock unless no other control means is feasible; avoid traffic and compaction impacts to eggs on surface and young larvae in shallow burrows by ceasing weed-whacking by Jan 15, minimizing grazing during the late fall and early winter, and temporarily removing livestock during and shortly after heavy precipitation.
Rapid Spring Growth	Green							X	X	X				Annuals can accumulate high phytomass, reproduce abundantly, compete with natives for moisture, sunlight, and nutrients, and cover bare patches with live stems, thatch, and litter; control of herbaceous establishment and growth imperative in bare patches and trails as above; avoid excess accumulation of phytomass and summer thatch by increasing livestock numbers; avoid erosion and compaction impacts to eggs on surface and young larvae in shallow burrows by temporarily removing livestock during and shortly after heavy precipitation.
Peak Phytomass; End of Annual Growth	Green									X	X			Annual plants die with depletion of soil moisture; perennials continue growth and reproduce later than annuals; maintain phytomass >470 lbs/acre now to allow decomposition through summer to assure fall RDM minimum of 300 lbs/acre. Optimal if maximum is <1200 lbs/acre.
Growth of Summer Annuals and Perennials	Dry yellow annuals & green-gray perennials									X	X	X		Reduce excess spring mass and height and control summer weeds and brush encroachment by continuing grazing as needed; native perennial grasses are favored as livestock forage while annuals lose palatability; avoid harm (including reduced reproduction) to native perennial grasses due to excess livestock utilization by exclusion after mid to late summer.

Table 6. Weather Schedule (1893-2009 Santa Cruz, CA, Western Regional Climate Center 2010).

Average	Units	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	OTB Management Concerns
Max. Temp.	F	76.1	73.0	66.7	61.2	60.3	62.4	64.6	67.9	70.5	74.0	74.7	75.1	General surface activity is potentially vulnerable from Oct-Mar during episodes of ≥53.
Min. Temp.	F	49.8	46.6	42.2	39.0	38.8	40.9	41.9	43.3	46.1	48.8	51.1	51.4	Larvae are in deeper burrows and inactive from Oct-Jan during times of <53, and are thus less vulnerable.
Total Precipitation	Inches	0.43	1.34	3.34	5.21	6.16	5.46	4.31	1.90	0.81	0.23	0.06	0.07	Burrows are vulnerable to compaction, erosion, scraping when soils are saturated by episodes of heavy rain.

Table 7. OTB Life Stages Schedule (Note: times indicated are approximate as some individuals will take longer to mature).

OTB Life Stage	Location	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	OTB Management Concerns
Egg	Immediately below soil surface						X	X	X					Ovipositing female vulnerable on soil surface and egg can be dislodged from burrow.
Instar 1	Burrow ≤1 inch deep							X	X	X	X	X		Vulnerable in shallow burrow.
Instar 2	Burrow ≤2-3 inches deep								X	X	X	X	X	Vulnerable in shallow burrow.
Instar 3	Burrow ≤6-8 inches deep	X	X	X						X	X	X	X	Less vulnerable to surface disturbance in deep burrow.
Pupae	Burrow ≤6-8 inches deep; plugged and diameter increased		X	X	X	X								Least vulnerable to surface disturbance in deep burrow.
Adult	In burrow or on surface at night or during cold weather; scurry on surface to forage, mate, and deposit eggs					X	X	X	X	X				Vulnerable on surface when sluggish due to cold temperature.

Note that question marks (?) are used in Tables 8 and 9 to indicate uncertainty whether the management tool has an important effect or should be applied, due to the expected fluctuations of seasonal weather conditions or lack of scientific information.

Table 8. OTB Habitat Area Management Options and Schedule.

Tool	Application	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	OTB Management Recommendations
Grazing by Cattle or Range Horses (not horses from stable facility)	Heavy grazing (adjustable high stocking rates); extensive grazing fields with minimal cross-fencing; separate OTB fields if other fields are needed for distribution, flexibility, or stock placement during other seasons or temporary removals; place watering and mineral/molasses licks strategically to cause trailing; horses incompatible with public recreation.					?	?	?	X	X	X	?		Moderate to heavy grazing (herbivory and traffic effects) in OTB habitat fields to control establishment and growth of annual vegetation and to create and maintain bare patches; temporarily remove grazing during episodes of saturated soil (to minimize compaction and scraping); when excluding grazing from OTB habitat fields at end of growing season (July) assure at least 470 lbs./acre average heterogeneous phytomass remains (to allow decomposition through summer to assure fall RDM minimum of 300 lbs/acre); exclude grazing in OTB habitat fields during late summer, fall, and early winter when native grasses are more vulnerable, and excess grazing might cause increases of pest plants; move cattle or horses to non-OTB habitat fields as needed during exclusions.
Weed-Whacking	Clip defined area of trail treads weekly or alternate weeks from start of rains through Jan 15 only.		X	X	X	X								Clip plants weekly at ground level in trail tread only with minimal impact to soil; supplements grazing to control establishment of annuals in trails and bare patches; commence clipping with first germination of grass seedlings, and terminate January 15 (i.e., before the first OTB adults are observed); Tables 2 and 3 suggest least vulnerability of OTB during periods of air temperature <53^{o} F; appears to be useful substitute for hiking and bicycling effects.
Hiking	Light to moderate frequency traffic on bare-dirt trails with no surfacing, especially during growing season.	X	X	X	X	X	X	X	X	X	X	X	X	Light to moderate traffic to control establishment of annuals and to create and maintain bare trails within OTB habitat areas; temporarily suspend hiking within OTB habitat areas during episodes of saturated soil, if feasible.
Bicycling/ Vehicle Driving	Light to moderate frequency traffic on bare-dirt trails and roads with no surfacing, especially during growing season.	X	X	X	X	X	X	X	X	X	X	X	X	Light to moderate frequency traffic to control establishment of annuals in trails and roads and to create or maintain bare ground during herbaceous growing season within OTB habitat areas; temporarily suspend vehicles and biking within OTB habitat areas during episodes of saturated soil; require smooth tires

Tool	Application	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	OTB Management Recommendations
														on vehicles during wet seasons; Tables 2 and 3 suggest least vulnerability of OTB during early summer through fall and when air temperatures are <53^{o} F.
Burning	Burn grasslands with a prescription to reduce mass and cover of annual grasses and forbs, including thatch, and to favor native perennial grasses.	X	X								X	X	X	Tables 2 and 3 suggest least vulnerability of OTB during summer through fall during periods of air temperature <53^{o} F.
Other	Scraping, hot-flaming, sheet solarization, hole digging, and single-event disturbances that exposes fresh soil in small areas.			X	X	X								Use as emergency supplements to above tools; best applied during early and mid growing season; avoid at sites currently or recently occupied by OTB; test at currently and recently unoccupied sites only.

Table 9. Suitable OTB Habitat Characteristics.

Habitat Factor	Description	Characteristics	Critical	Mng. Tools Affecting It						
				Graze	Whack	Mow	Hike	Bike/Veh	Burn	Other
Substrate	Suitable for OTB adult females to recognize and deposit eggs, adults to recognize and find mates, larvae to dig and maintain burrows; suitable for use by appropriate prey; road and trail treads, or patches between plants in open grassland.	Bare, uncovered soil surface	X	X	X		X	X	X	X
		No excess amounts of litter, loose sand, stones/rocks, hay/manure dust, cuttings, or woody debris on surface	?	X	X	X			X	
		Not bedrock	X							
		Not where ground water rises to surface or surface water pools; not wetland; rapid drainage and infiltration	X							
		Compacted	?	X			X	X		
		Watsonville Loam	X							
		Chemical and physical properties	?						X	
		Minimal surface erosion	X	X			X	X		
		Freshly exposed soil from single-event disturbance (gophers, not gr. squirrels, digging) in small areas	?							X
Herbaceous Vegetation	Suitable for OTB adult hopping, recognition of bare patches,	Heterogeneity with abundant bare soil patches	X	X	X				X	X
		Low Cover		X	X	X			X	

Habitat Factor	Description	Characteristics	Critical	Mng. Tools Affecting It						
				Graze	Whack	Mow	Hike	Bike/Veh	Burn	Other
	and within-species interactions.	Low Crown Height	X	X	X	X	X	X		
		Low Mass	?	X	X	X				
		Low Thatch	X	X	X	X	X	X	X	X
Woody Vegetation	Unsuitable if nearby.	No woody plant encroachment that results in shading, allelopathy, or root encroachment	?	X					X	
Prey Availability	Prey for both adults and larvae (smaller invertebrates).	Bare zones near burrows	?	X	X		X	X	X	X
Predators	Potential predators of OTB (birds, other invertebrates, small mammals?).	?	?	?	?	?	?	?	?	?
Landscape Arrangement	Proximity of sub-population to other sub-populations in meta-population.	Fragments of habitat nearby	?							

We recommend that planners and managers responsible for OTB habitat consider the following additional management:

- Map potential OTB habitat sites based on records of observations and suitable habitat characteristics.
- Distinguish OTB habitat sites from non-habitat areas, and separate as needed for flexibility in the control of grazing and other specialized treatments.
- For grazing management, integrate non-habitat areas for alternate forage, improved distribution, flexibility of stocking rate, or stock placement during other seasons or temporary removals, and management of the other special resources.
- Consider the potential effects of alternative management tools and activities on other special resources and recreation.

Critical Management to Maintain OTB Habitat Quality

As described in the study results sections above, the recent history of management activities is more important than older history to explain current persistence of OTB among the 17 sites originally occupied. This is because the current and recent management activities can influence either the extirpation or persistence of OTB at sites with the same physical conditions and potential for OTB occupancy. Thus current and recent decisions about management of OTB habitat and active management to benefit OTB are critical to maintain OTB occupancy. For example, at the nine sites where OTB were recently extirpated, the property managers either discontinued extensive livestock grazing, discontinued moderate frequency recreational hiking or bicycling, or converted the habitat to other land uses. Where the recent and historical management has included continuation of extensive livestock grazing or moderate frequency recreational hiking or bicycling, OTB have persisted.

We assume that habitat management practices similar to those used at currently occupied OTB sites would be likely to restore habitat conditions suitable for OTB (a few sites, such as OTB Sites #1 and #5 might need reintroductions of OTB because of the distances to the nearest occupied OTB site, possibly farther than the OTB's dispersal capability) at the recently extirpated OTB sites. The most critical management planning decisions are about continuation of extensive grazing and moderate-frequency recreational hiking and bicycling traffic. Clearly, the underlying physical site conditions that support OTB habitat must be present, including Watsonville Loam soil, good drainage and infiltration (no ground water rising to the surface or surface water pooling), flat to slightly sloping topography, exposure to warming sunlight (and unshaded by overhanging woody vegetation), and abundant patches of bare to sparsely-vegetated soil in grassland or bare dirt trails and roads. Higher soil phosphorus, among other micro-site conditions, seems to vary across the known geographic range of OTB within the known sites, and appears to be related to the occurrence of native perennial grasses and indirectly to the cover of bare soil. The potential vegetation composition and structure (and corresponding degree and arrangement of bare soil) of each grassland area are thus most significantly influenced by these physical conditions, plus interaction with the growth effects of annual weather (Huntsinger, Bartolome, and D'Antonio 2007). Where these physical conditions exist and when the recent weather has been favorable enough (including above-normal amount of precipitation, consistent precipitation, and relatively warmer growing season)

to increase the herbaceous vegetation cover, the OTB habitat manager should make use of prescribed grazing, recreational hiking and bicycling traffic, and maintenance vehicle traffic to reduce the vegetation cover, increase and maintain bare patches and trails, and thus improve OTB habitat quality. This implies that when the weather is drier than normal and otherwise below optimal, the continuation of grazing might not be necessary to maintain the quality of the grassland habitat. However, such a change in management should be made only with careful monitoring and preparations to continue grazing if needed. Also, it is likely that in all but the driest years, the moderate frequency recreational hiking and bicycling should be continued. Conducting both management treatments together is not necessary, but at least one is necessary. In our opinion, both would provide the greatest management flexibility, and greatest chance of sustaining the OTB populations.

There are nine sites where OTB have been extirpated. They were historically or recently grazed by range cattle or range horses, then had such grazing terminated or replaced by other activities, and have relatively low-frequency or no recreational traffic. The extirpated OTB sites #4, #7, and #15 have not been grazed in decades and have relatively low-frequency recreational traffic. If any negative effects of restricted meta-population dynamics and fragmentation are at work, then the loss of OTB at the formerly occupied sites would likely have a multiplying effect, and add to the risk of extirpation at one or more of the eight currently occupied OTB sites.

Recovery of this endangered species, and the counter-acting of any restrictive meta-population dynamics and fragmentation might be possible by restoring optimal habitat conditions as thoroughly as possible at the sites where OTB have been recently extirpated (assuming OTB populations can be re-introduced). Continuing research to test such restoration or enhancement of habitat quality is needed.

Guidelines for Management Planning and Assessment of Alternative Treatments

Tables 10 and 11 summarize the recommended management planning for OTB habitat, including maintenance of existing OTB populations and restoration of habitat conditions at recently extirpated sites for future re-occupation by OTB, and guidance to assess and prescribe the alternative management treatments. Appendix 4 provides the recommended outline of a management plan for OTB habitat. The plan should address management of any other special resources and special management concerns present or expected at any subject property, the typical rangeland ecosystem elements, and the basic sustainability of the ecosystem and management operations, based on the best available science and expert opinion.

Table 10. OTB Habitat Management Planning Goals, Objectives, and Desired Effects

Management Goal / Objective:	Desired Effects
Goal 1. Maintain rangeland vegetation conditions conducive to the long-term persistence of the desired habitat qualities.	
Obj. 1a. Maintain grassland herbaceous vegetation structure to benefit habitat quality for the OTB.	**Effect 1a**. Maintain target minimum and maximum cover of herbaceous vegetation, litter (and decomposing hay and manure), and bare soil surface in grasslands and trails; maintain target minimum OTB population size and demographics.
Obj. 1b. Maintain grassland herbaceous vegetation structure to benefit habitat quality for other special-status animals, special-status plants, special natural communities (native grasses, oaks, wildflowers, riparian zones, and wetlands), and biodiversity generally.	**Effect 1a**, plus **Effect 1b**. Maintain target minimum and maximum herbaceous phytomass/RDM, height, and height heterogeneity; maintain targets for other habitat qualities (such as limited trampling at defined life stages, limited browsing of riparian woody plants, and structural heterogeneity); maintain target minimum special species population size and demographics, and target area of special natural communities.
Goal 2. Maintain the health of the rangeland ecosystem, including soil integrity and water quality.	
Obj. 1b, plus **Obj. 2a**. Control soil erosion at priority sites where current grazing and other management activities are contributing to significant sediment movement and where erosion is active.	**Effect 1b**, plus **Effect 2a**. Maintain occurrences of significant new erosion or significant expansions of existing eroded sites associated with grazing and related management activities at current or reduced width and depth.
Obj. 2b. Control water pollution due to sediments, pathogens, and nutrients at priority sites where current grazing and other management activities are contributing to significant water pollution.	**Effects 1b** and **2a**, plus **Effect 2b**. Maintain water quality associated with grazing and related management activities during non-flood periods, measured at the base of watersheds on the property, at current or better levels.
Goal 3. Reduce the fire hazards associated with the mass of dry herbaceous vegetation in the grasslands during the summer and autumn seasons, and with the mass of woody fuels in scrub and woodlands.	
Obj. 1b, plus **Obj. 3**. Limit woody fire hazard to a low level to the extent feasible using grazing and related methods.	**Effect 1b**, plus **Effect 3**. Maintain the woody fuel load at current or reduced levels.
Goal 4. Minimize the impacts of invasive non-native "pest" plants.	
Obj. 4. Avoid and control the introduction and expansion of invasive non-native pest plants in grasslands associated with the grazing program and operations. This can be done by maintaining a rapid deployment capability in the management agency to control new introductions associated with grazing and related management activities.	**Effect 4**. Maintain the extent and patch size of infestations at current or reduced area.
Goal 5. Maintain recreational access and enjoyment by the public, if public access is allowed.	
Obj. 5. Avoid conflicts between recreational users and grazing program operations.	**Effect 5**. Maintain sensitive trail zone protections; maintain a program of public consultation as well as signage and education about the management activities; maintain occurrence of complaints from

Management Goal / Objective:		Desired Effects
		recreationists at current or reduced levels.
Goal 6. Maintain the quality of forage, infrastructure, and other conditions to sustain use by healthy livestock and a sustainable livestock operation.		
	Objs. 1b, **2b**, and **4**, plus **Obj. 6**. Install and assure maintenance of adequate conditions of the grazing infrastructure to support the effectiveness and efficiency of the livestock grazing operation.	**Effects 1b, 2b, 4 and 5**, plus **Effect 6**. Maintain effective infrastructure of adequate quality and functional condition as needed for grazing and other management activities.
Goal 7. Provide the working conditions for the Landowner and Livestock Operator to maintain a cooperative and productive relationship.		
	Obj. 7. Provide reasonable opportunity and flexibility for the livestock operation to function profitably; and facilitate communications between the Landowner and Livestock Operator.	**Effects 1b, 2b, 4, 5 and 6**, plus **Effect 7**. Assure that efficient means are in place to cooperate effectively and promptly on information collection, decision-making, and implementation of the management plan.

Table 11 provides the basic guidelines and identifies the kinds of additional detail needed to choose the most appropriate of the alternative treatments available.

Table 11. Recommended Management Treatments and Assessment for OTB Habitat Sites

Management Treatment	Description, Opportunities, and Limitations	Examples, Additional Details
Cattle Grazing	• Extensive winter-spring seasonal grazing by "range" cattle during the herbaceous growing period; larger fields with minimal cross-fencing; separated habitat and non-habitat fields for flexibility. • Spring grazing should occur at adjustable stocking rates, high enough to achieve herbaceous mass, height, and cover reduction objectives and to compact the bare soil in trails and grasslands. • Extend seasonal grazing into early summer as needed to reduce excess herbaceous growth and to control weeds and woody plant invasion. • Manipulate watering and mineral lick locations or herding to maximize trailing. • Terminate grazing by early summer and exclude during late summer, fall, and early winter to minimize damage to any native perennial grasses and allow effective reproduction. • Avoid erosion and compaction impacts to OTB eggs on surface and young larvae in shallow burrows by temporarily removing the cattle from the OTB habitat field to a non-habitat field during	• OTB site #3 is a model for the traditional extensive cattle grazing with minimal cross fencing that has maintained beetle habitat for decades. Extensive winter and spring cattle grazing at a moderate intensity would provide the most benefit with the least amount of impact on the beetle and on the surrounding environment; public recreational hiking is low- to moderate-frequency; there is no bicycling use. • We assume that year-round extensive cattle grazing historically occurred at all sites originally occupied by OTB, which suggests that year-round cattle grazing at a moderate intensity is also compatible with OTB so long as the herbaceous mass is minimized

Management Treatment	Description, Opportunities, and Limitations	Examples, Additional Details
	periods when the soils are very wet from rains, and when the growth of forage has been too low to maintain the cattle or the minimum phytomass; livestock traffic on the trails is preferred over weed-whacking during the winter and spring due to less impact at the surface. • Conduct sufficient outreach and education of the neighboring public and recreationists to assure safety and compatibility.	during the growing period.
Horse Grazing	• Same as for range cattle (above), with the following exceptions: • Extensive "range" horse grazing where the primary source of forage is provided by the grassland with little supplementation, no shelter is provided, and management of the OTB site is primarily for habitat; horse stable facilities usually do not allow horses to graze the natural forge adequately to maintain beetle habitat. • Year-round grazing might be necessary for a viable horse operation, but is not preferred because of the potential impacts of their traffic and herbivory when the soils are saturated (scraping and compaction risks at burrow sites) and in general during non-growing seasons (trampling risks, and not necessary for vegetation management); exclude horses from OTB habitat areas (separated OTB habitat field) when horse impacts would not be beneficial. • Allow use of the OTB habitat field during times otherwise excluded only if necessary to provide an alternative pasture to avoid horse foundering (due to unusually high growth during above-normal precipitation year, and abundance of "sweet" forage in the other pastures).	• OTB site #2 is a model for an appropriate range horse grazing operation (since 1982) to maintain OTB habitat; grazing occurs year-round with a specific OTB field; during the winter and spring (when soils are not too wet) horses are confined to the OTB field so they will consume the vegetation and maintain trails; during the rest of the year, the gates between all of the fields are left open and horses are allowed to graze where they choose; there is no public recreational use.
Recreational Hiking and Bicycling	• Provide access and establish a network of hiking and bicycling trails through suitable OTB habitat sites. • Assure moderate-frequency use of the trails by hikers and bicyclists; plan the trail routes to link to other trails, thus adding traffic; concentrate the trails to assure the treads are free of vegetative cover and relatively wider than a low to moderately used trail, and to compact the bare soil at the surface of the trail treads (to minimize the germination and establishment of plants in the trail tread); avoid too much dispersal and duplication of trails, which could lead to insufficient traffic effects. Do not cover dirt trails with gravel or other materials to make them all-weather trails.	• OTB sites #6, #14, and #16 are models for appropriate moderate-frequency recreational hiking and bicycling use to maintain OTB habitat; there is no livestock or horse grazing. • OTB have persisted at these sites without livestock grazing for decades, but with maintenance vehicle traffic on roads; the moderate-frequency recreational traffic use at OTB site #14 trails began after acquisition in 1996, but before

Management Treatment	Description, Opportunities, and Limitations	Examples, Additional Details
	• Avoid erosion and compaction impacts to OTB eggs on surface and young larvae in shallow burrows by temporarily closing trails through the OTB habitat during periods when the soils are very wet from winter and spring rains, and where the trails occur on highly compactable soils. • Conduct sufficient outreach and education of the neighboring public and recreationists to assure safety and compatibility. • Horses are very dangerous and likely to be incompatible with recreational use, especially if the grazing fields are small (increased chances of contact) or the horses are attracted to people, especially during the seasons (fall and winter) when natural forage quality is low; where recreational use is necessary, separate horses from recreationists in space (designated grazed versus recreational use fields) or time (designated open and closed seasons).	then at OTB sites #6 and #16.
Vehicle Driving	• Vehicle driving on designated dirt roads should be slow, but moderate-frequency for the greatest benefit to OTB habitat; however we found that vehicle traffic was less important than hiking and bicycling. • Vehicle driving should be for land maintenance, species and habitat monitoring, or livestock or horse operations purposes only, not public access for recreational vehicles; the latter would be likely to cause soil erosion, excessive compaction, and harm to OTB. • Vehicles driving in OTB habitat areas should be equipped with wide and smooth-surfaced tires during the wet seasons to avoid pitting and rutting.	• There is little vehicle driving at most of the sites, and it is primarily maintenance vehicles. • The most harmful practices associated with vehicle roads in OTB habitat are road re-routing, scraping, surfacing, and adjacent mowing that leaves cut material as litter.
Mowing, Brush Clearing, and Weed-Whacking	• Mowing should not be used for management of grassland habitat because of the impacts of machinery, accumulation of litter, and impact on OTB larvae and adults; mowing of trail sides and weed-whacking of trail treads should be conducted only infrequently and as a supplement to livestock or recreational traffic if needed to minimize herbaceous vegetation mass and height with little or no accumulation of cuttings; mowing of trail sides should occur at the beginning of the growing season, but then suspended from mid-January through May when the OTB adults emerge and look for oviposition sites, and are thus vulnerable to such severe surface disturbance; mowing of trail edges may then occur again if needed at the end of the growing season. Any cuttings should be carefully removed without disturbing the soil surface, and	• Infrequent mowing of trail sides is practiced regularly at OTB sites #6 and #16, but not at the neighboring OTB site #14. • A trial of weed-whacking was begun in 2010 at OTB site #2 (by the authors); the preliminary results appear effective and promising to maximize the trail habitat on existing horse trails, but it has not been fully assessed yet.

Management Treatment	Description, Opportunities, and Limitations	Examples, Additional Details
	disposed of away from the OTB habitat areas. • Weed-whacking appears to be a useful tool to maintain the bare soil on trail treads based on trials at OTB site #2; it provides flexibility to supplement horse or cattle trailing and traffic effects, particularly during the beginning of the fall growing season, when native perennial grasses can be vulnerable to grazing; during this time, the OTB larvae and pupae are least vulnerable in their deep burrows. In addition to the guidelines above, any weed-whacking should be suspended when the soil is wet and when OTBs are active. • Brush clearing (by manual means) in areas with appropriate soils and micro-topography might increase OTB habitat area.	
Herbicides and Pest Plant Management	• The effects of herbicides on OTB are unknown, but likely to be harmful if in direct contact; as a precaution, both insecticides and herbicides should be prohibited in the proximity of known or potential OTB habitat. • Invasive plants are of concern in OTB habitat; herbaceous and woody plants that grow tall and dense are of concern because they cover bare ground areas. • Pest plants should be monitored in OTB habitat to determine whether a problem develops; if so, then manual clipping should be tested.	• Two native "pest" plants occur in OTB habitat at OTB site #2 --the summer annuals turkey mullein (*Croton setigerus*) and vinegar weed (*Trichostema lanceolata*); both are abundant (but patchy) and could reach densities that cover OTB habitat.
Haying and Forage/Hay Improvements	• OTB habitat fields should not be used for hay production, planted to improve hay or forage quality, fertilized, or mowed for hay collection; these practices are inappropriate for OTB habitat since the improvement plants grow dense and tall during much of the year, involve tractor traffic, and leave residue after harvest that can cover the bare soil.	• None of the formerly occupied sites have been subject to haying or improvements in recent decades, with the possible exception of one site where OTB has been extirpated.
Burning and Flaming	• Burning and flaming reduce biomass and can open up areas of bare ground; however, herbaceous vegetation can quickly re-colonize burned areas, and some burns (particularly late fall burns) do not remove the thatch and litter close to the ground, thus leaving the soil surface covered; burning could be used to initially reduce cover of tall grass plus thatch and litter if prescribed for that, and thus to enhance OTB habitat, but another management tool will be needed to maintain that low vegetation and bare ground during the growing season. • Flaming refers to burning of a small patch of grassland using a propane torch to clear the herbaceous vegetation, including litter and thatch,	• Prescribed burning of some portion of the meadows at OTB site #14 is typically conducted every year; the most recent burn of the OTB habitat meadows was in October 2010. • Flaming was tested for one year at OTB site #8, where the beetle was extirpated, and has not been fully assessed. Flaming was also tested at OTB site #2 where the flamed areas were quickly re-

Management Treatment	Description, Opportunities, and Limitations	Examples, Additional Details
	and expose bare soil; it can be used repeatedly in small areas at any time of year, including during the growing season; two significant problems with this method are gaining permission from the fire management authorities, and difficulty and cost of propane to completely burn green vegetation.	colonized by vegetation.
Soil Disturbance	• Soils should not be disturbed by scraping, digging, construction or other soil disturbance activity in areas where OTB occur; however, like burning and flaming, soil disturbance such as scraping and digging can open up areas of bare ground that OTB colonize; it is important any soil disturbance activities for habitat enhancement occur in areas of appropriate habitat, but that are currently unoccupied by the beetle (to avoid harm); it will be important to prevent vegetation from moving into the created bare ground area by some non-disturbance means, such as grazing.	• Scraping has been conducted effectively by UC Santa Cruz researchers and Arnold as a means to increase OTB habitat (Vasey, Cornelisse, and Holl 2010) at OTB sites #2, #3, #5, #6, #10, #14, and #16.

Combinations of management treatments should be practiced to maintain and enhance OTB habitat quality:

- A combination of grazing plus moderate-frequency hiking and bicycling traffic would provide duplication of the two most effective means to maintain OTB habitat quality; such combination would also reduce extirpation vulnerability due to reductions of one or the other management action.
- Current management activities at the eight sites still occupied by OTB (Table 2, Sites #2, 3, 6, 10, 12, 14, 16, and 17) should be continued; if these management activities were to be discontinued, habitat conditions would likely deteriorate, thus increasing the likelihood of extirpating the OTB.
- Combining grazing and moderate-frequency recreational bicycling and hiking traffic would be likely to increase the effectiveness and sustainability of the beetle habitat.

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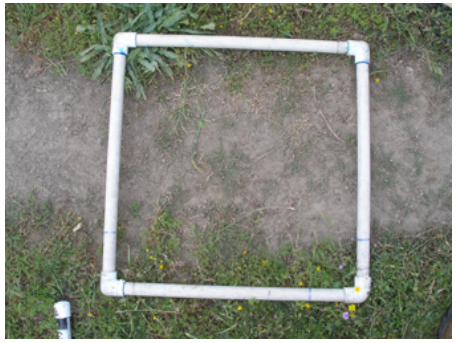
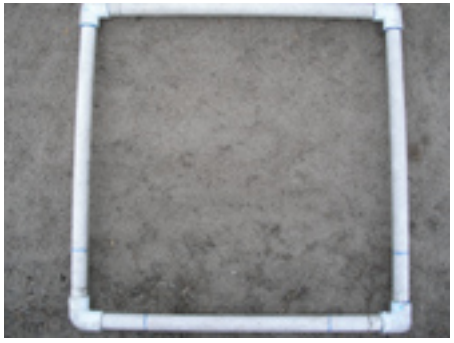
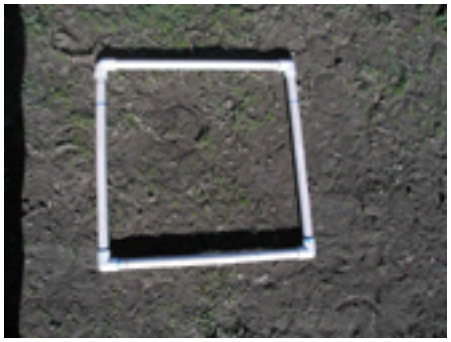
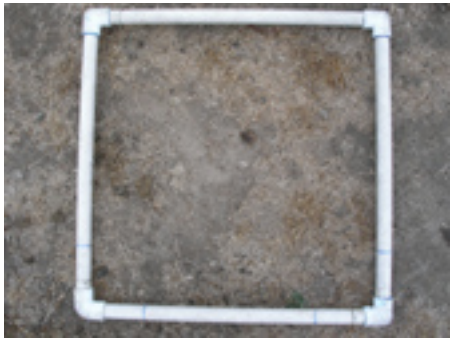
APPENDIX 1:

Photos of Transects and Quadrats from the Habitat Characterization Study

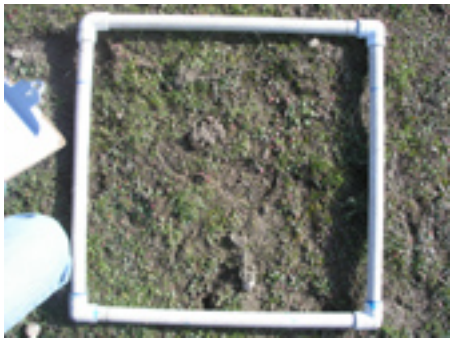
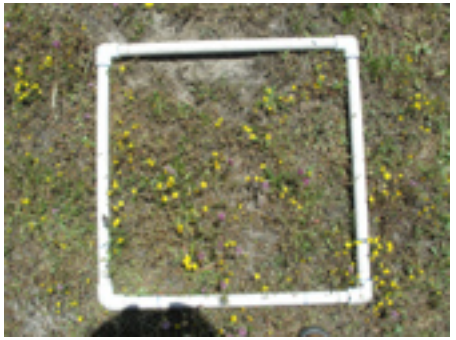
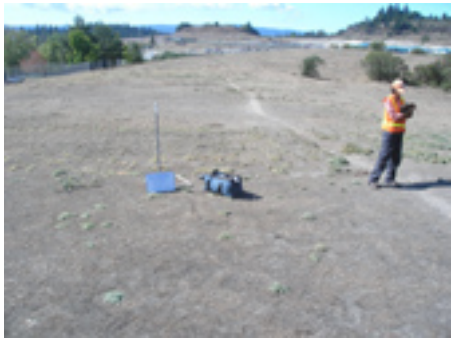
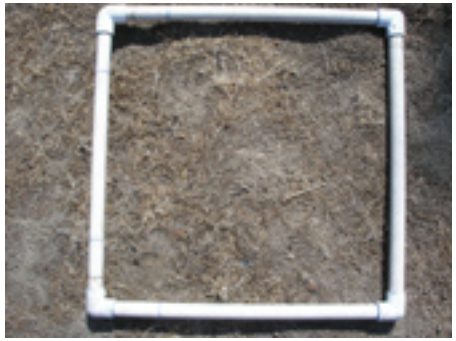
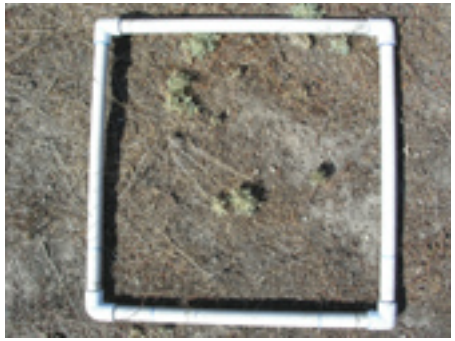
Site #2– RTO

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter - 12/23/2009				
Spring - 5/14/2010				
Autumn - 10/18/2010				

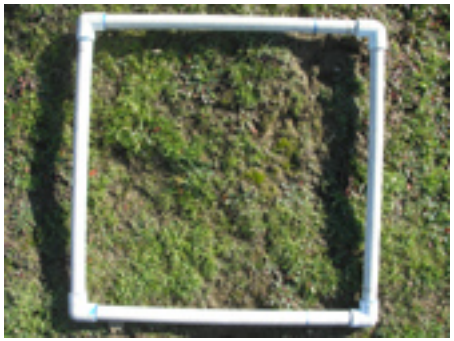
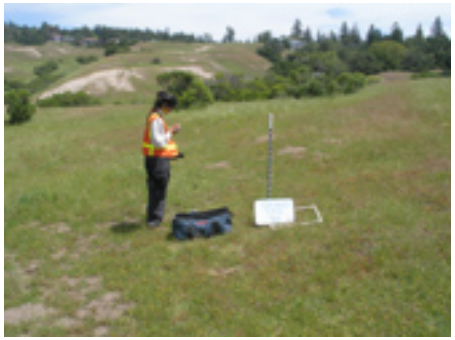
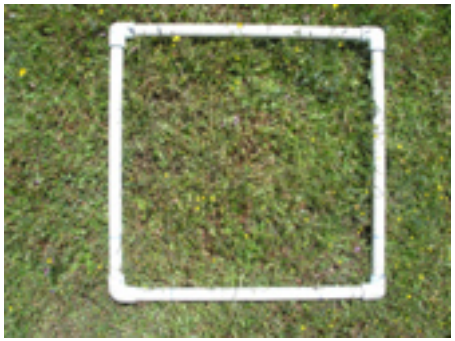
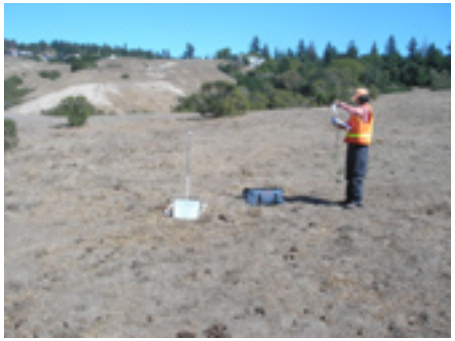
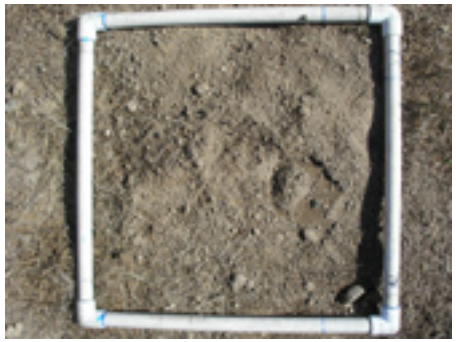
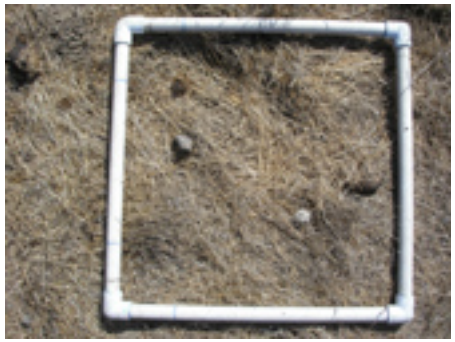
Site #2 – RTU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/23/2009				**No Photo**
Spring – 5/14/2010				
Autumn – 10/18/2010				

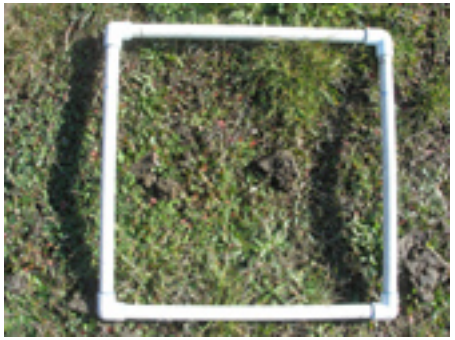
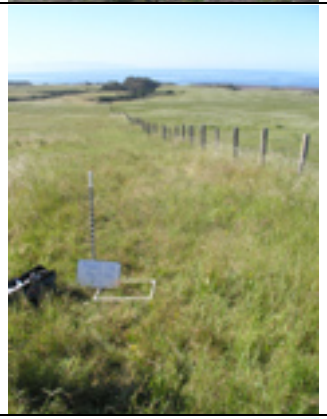
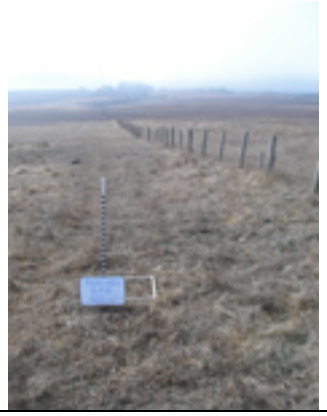
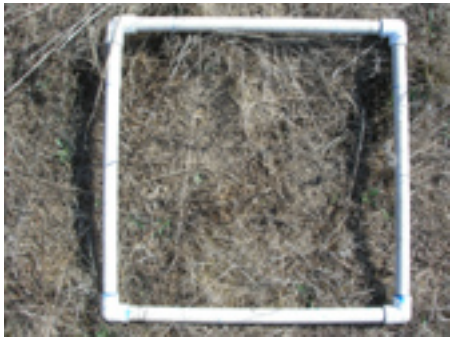
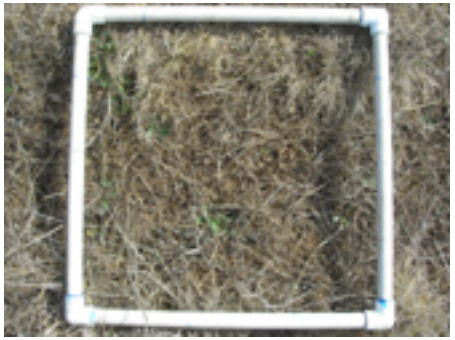
Site #2 – GO

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/24/2009		**No Photo**		
Spring – 5/14/2010				
Autumn – 10/18/2010				

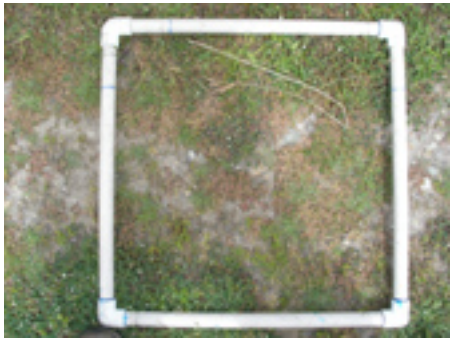
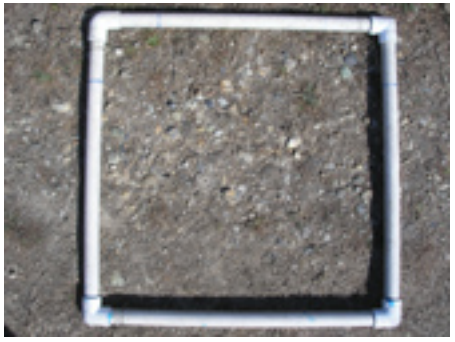
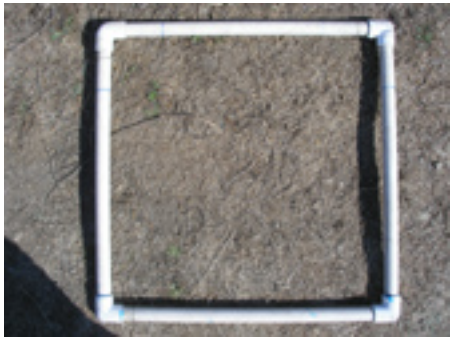
Site #2 – GU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/24/2009		**No Photo**		
Spring – 5/14/2010				
Autumn – 10/18/2010				

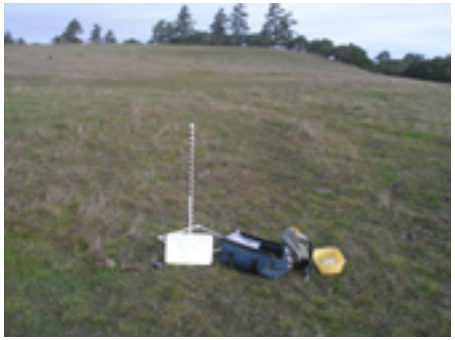
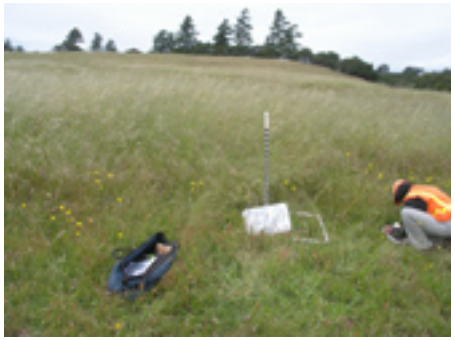
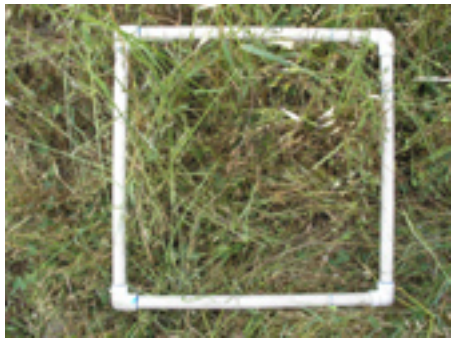
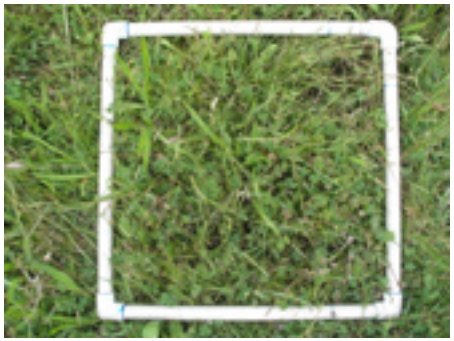
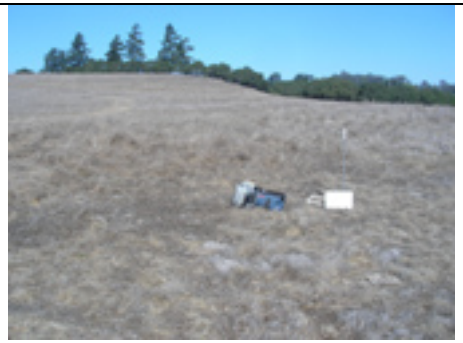
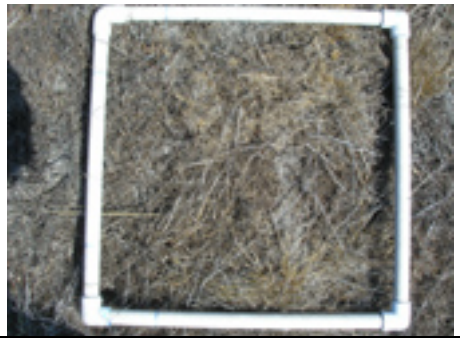
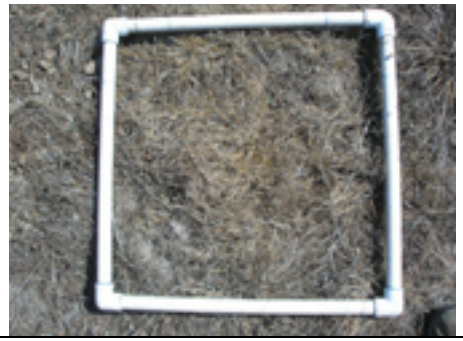
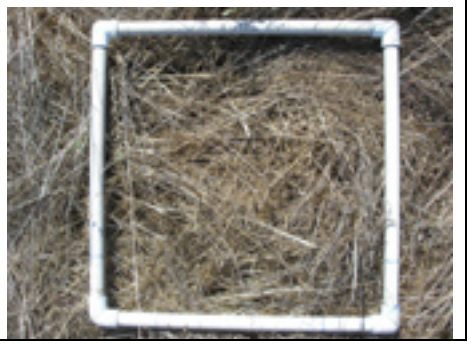
Site #3 – RTO

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/29/2009				
Spring – 5/19/2010				
Autumn – 10/19/2010				

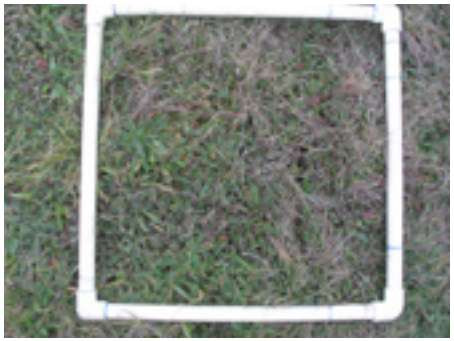
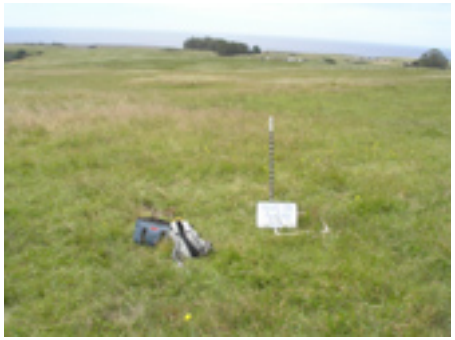
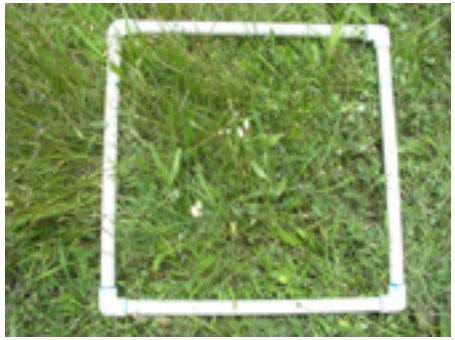
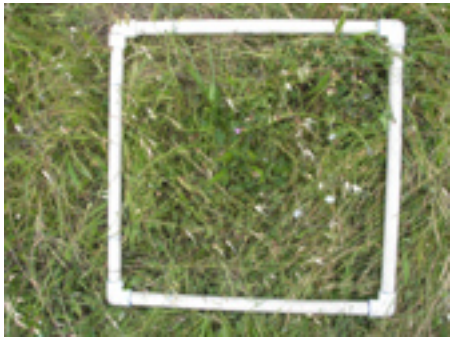
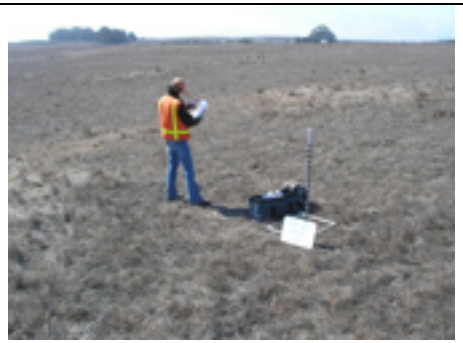
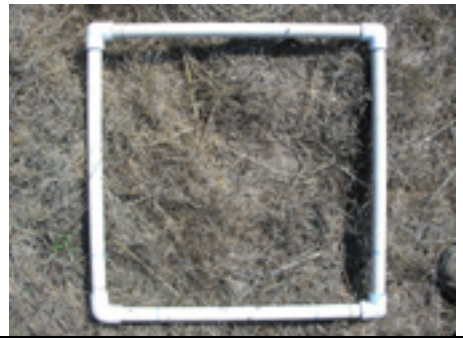
Site #11 – RTU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/29/2009				
Spring – 5/19/2010				
Autumn - 10/19/2010				

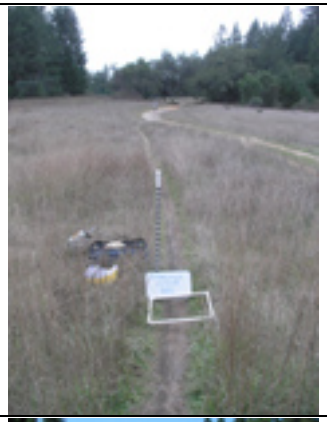
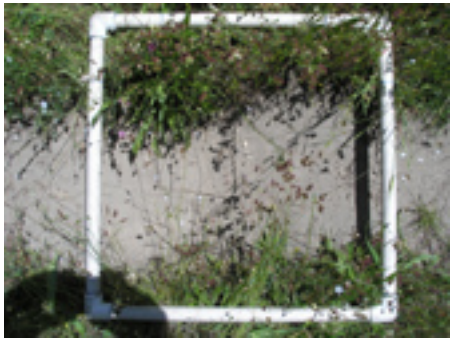
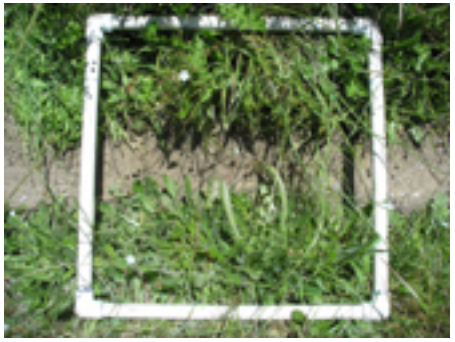
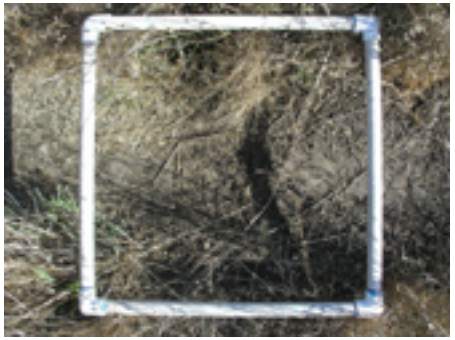
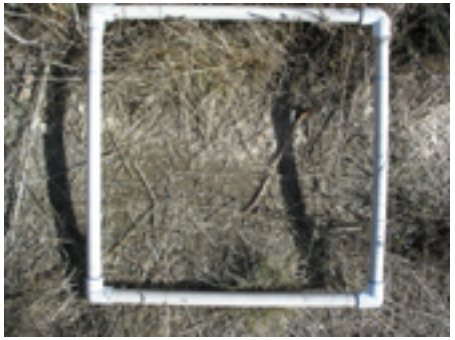
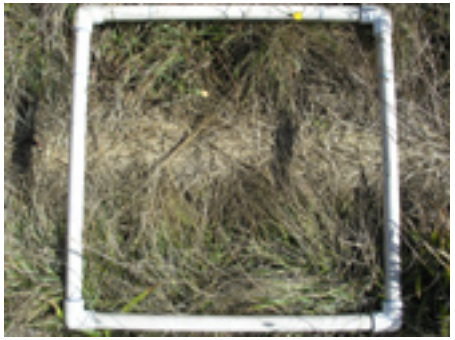
Site #3 – GO

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/31/2009		**No Photo**	**No Photo**	
Spring – 5/19/2010				
Autumn - 10/19/2010				

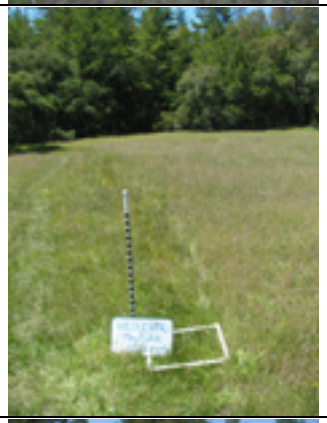
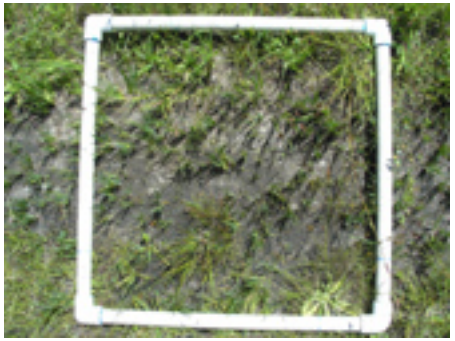
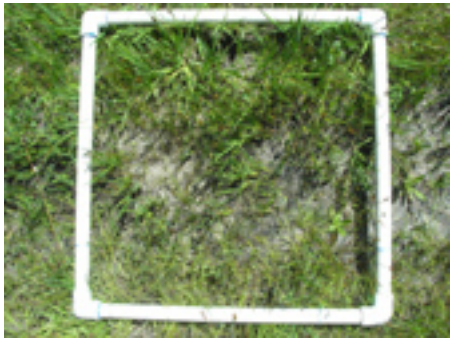
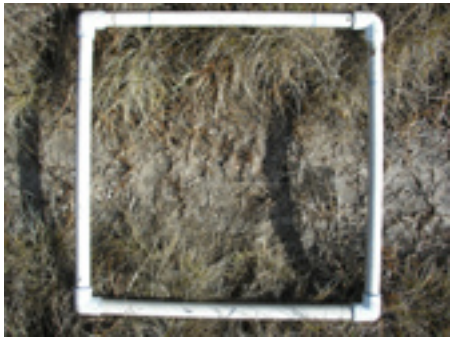
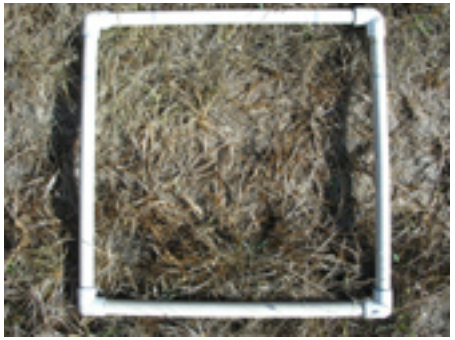
Site #3 – GU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/29/2009		**No Photo**	**No Photo**	
Spring – 5/19/2010				
Autumn - 10/19/2010				

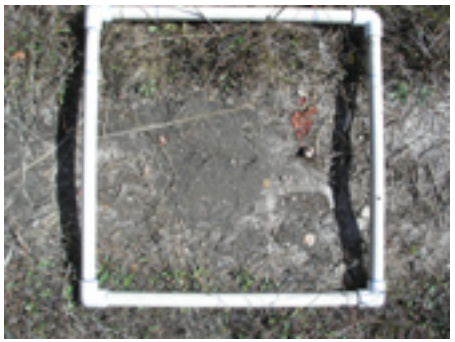
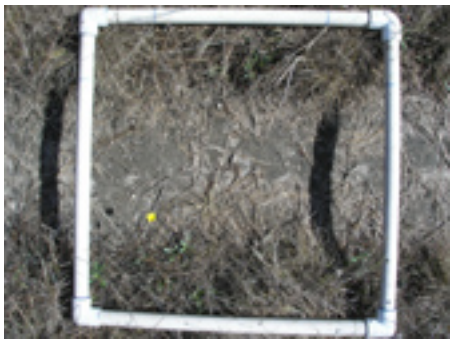
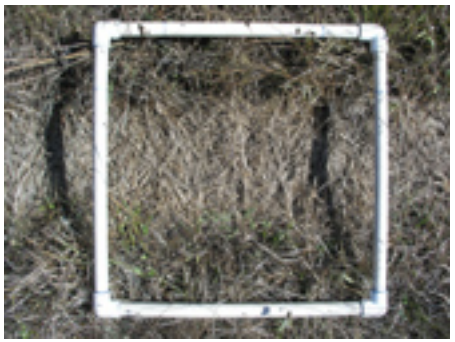
Site #14 – RTO1

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/31/2009				
Spring – 5/20/2010				
Autumn – 10/25/2010				

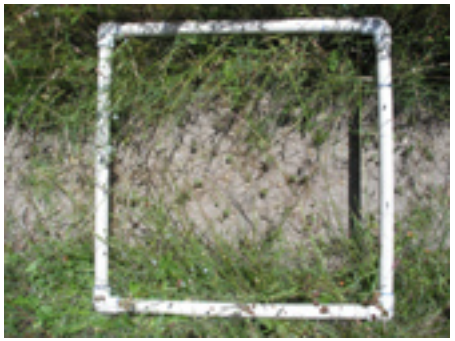
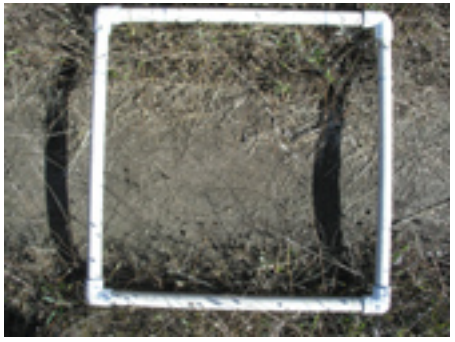
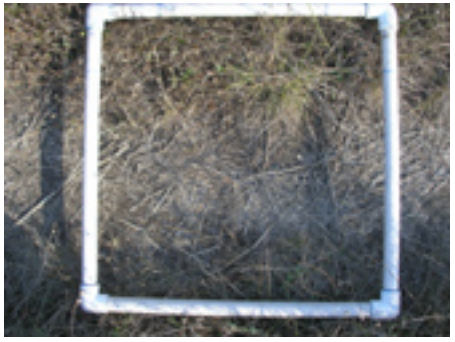
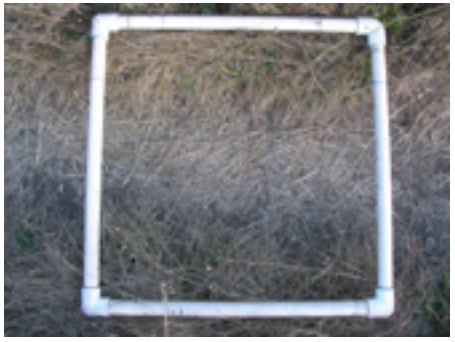
Site #14 – RTO2

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/31/2009				
Spring – 5/20/2010				
Autumn - 10/25/2010				

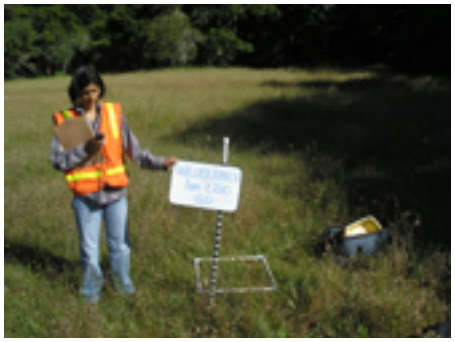
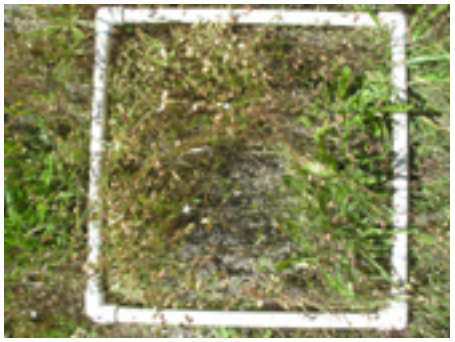
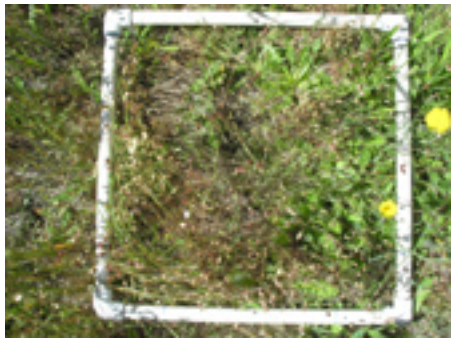
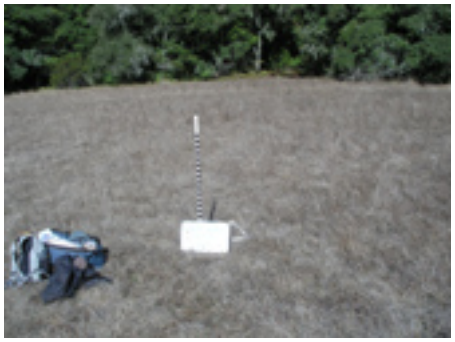
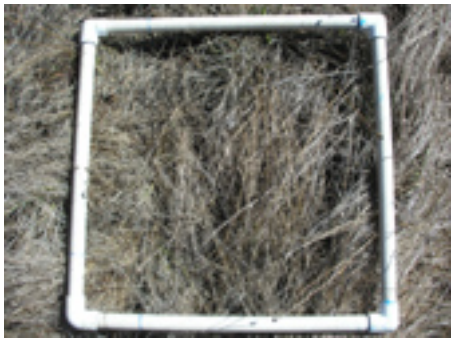
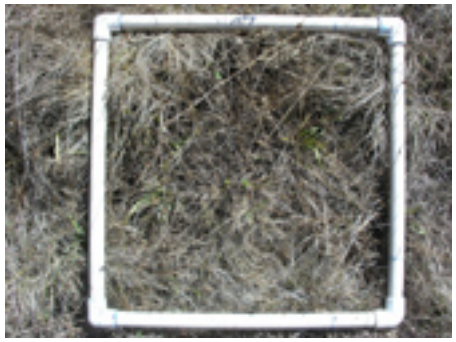
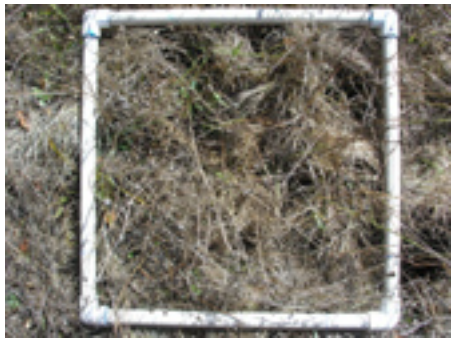
Site #14 – RTO3

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – N/A	**N/A**	**N/A**	**N/A**	**N/A**
Spring – 5/20/2010				
Autumn - 10/25/2010				

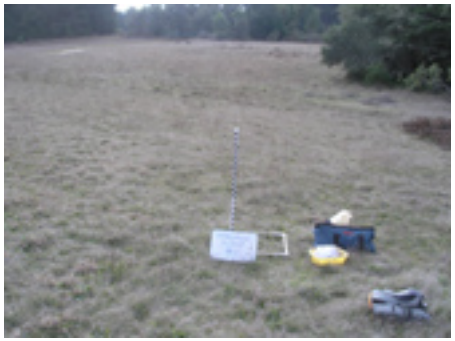
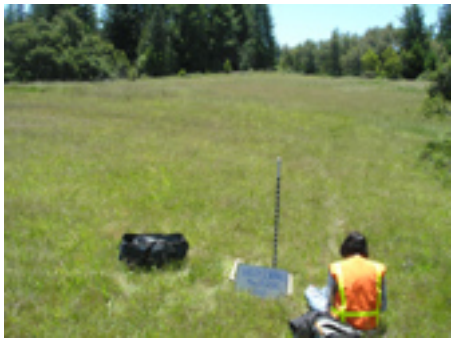
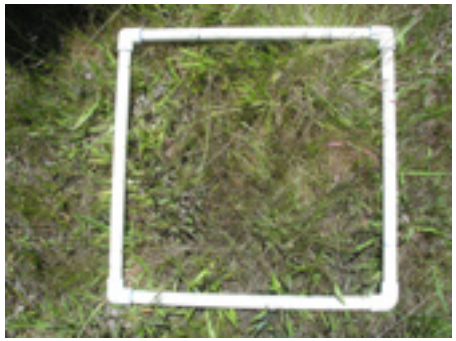
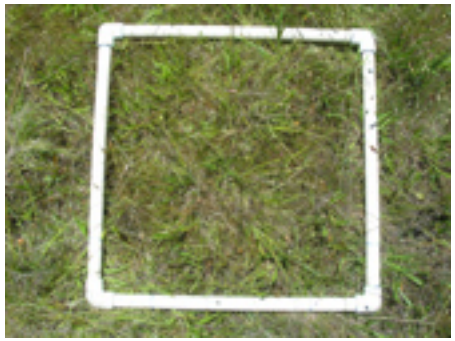
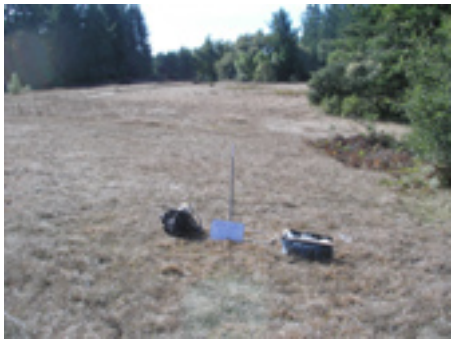
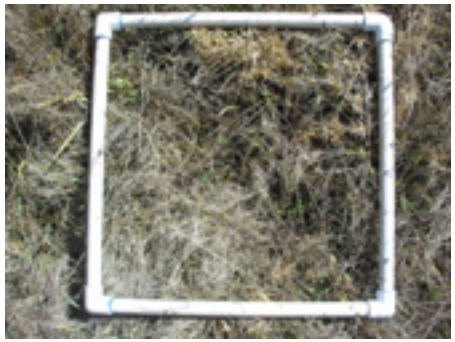
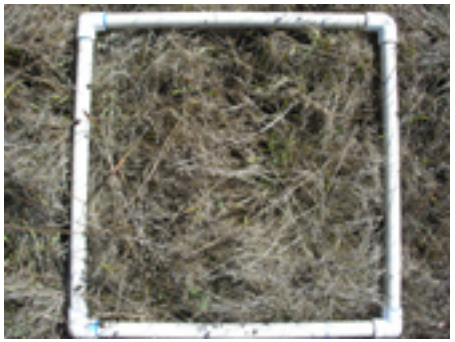
Site #14 – RTU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – N/A	**N/A**	**N/A**	**N/A**	**N/A**
Spring – 6/7/2010				
Autumn - 10/25/2010				

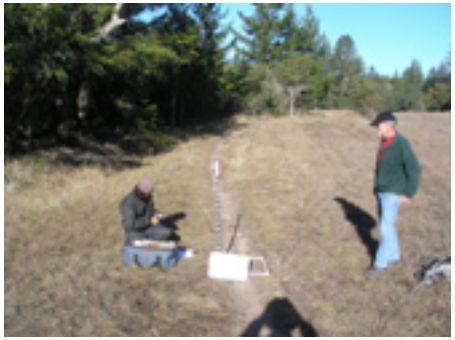
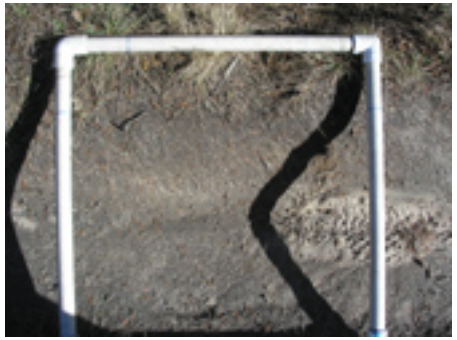
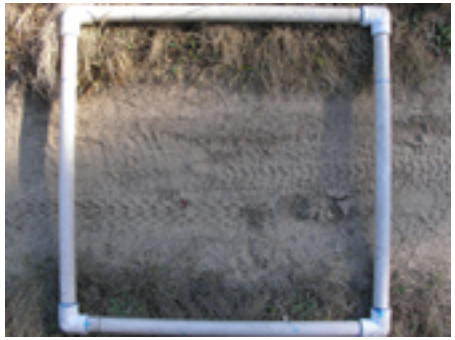
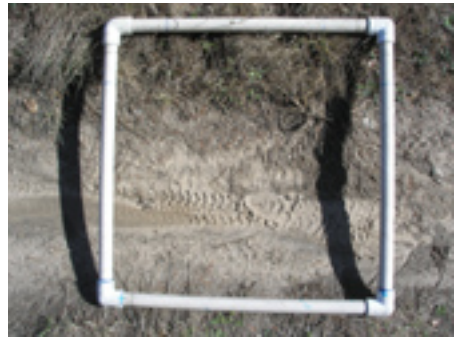
Site #14 – GO

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – N/A	**N/A**	**N/A**	**N/A**	**N/A**
Spring – 6/7/2010				
Autumn - 10/25/2010				

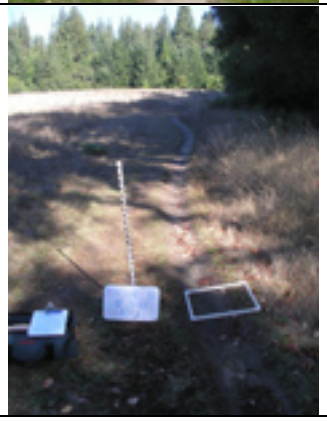
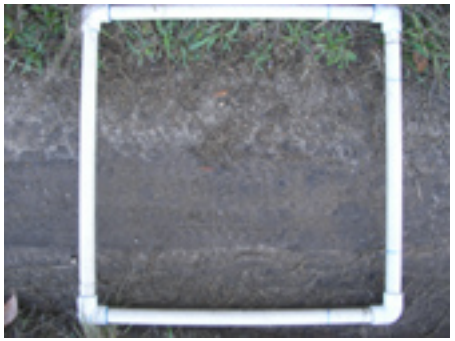
Site #14 – GU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 12/31/2009		**No Photo**		
Spring – 5/20/2010				
Autumn - 10/25/2010		**No Photo**		

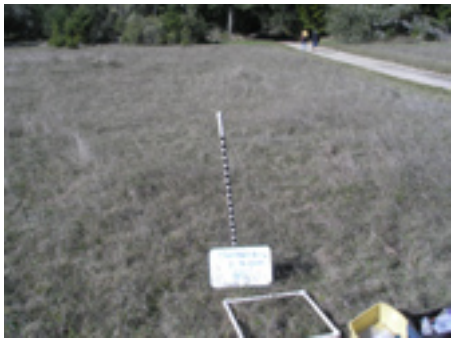
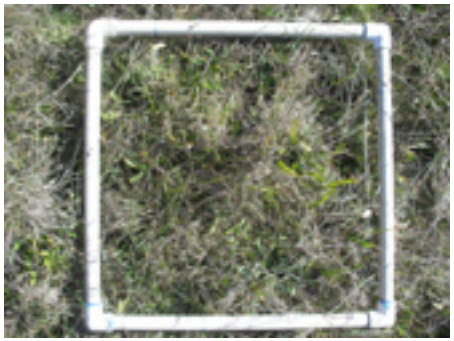
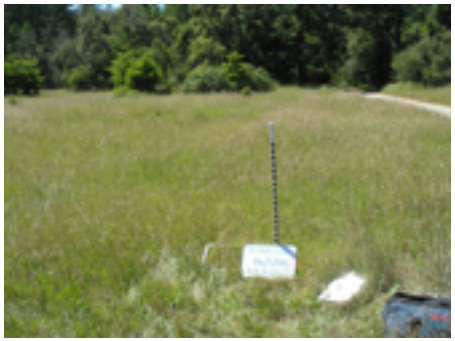
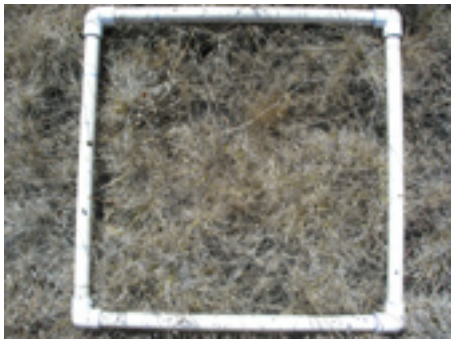
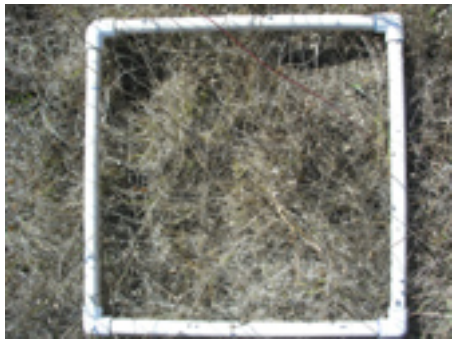
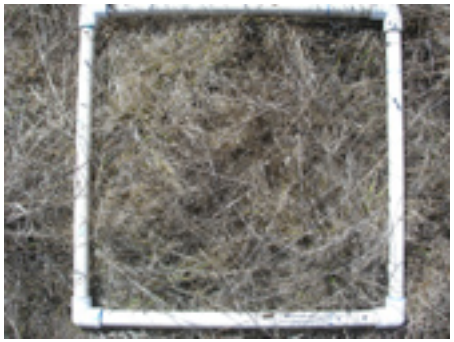
Site #6 – RTO

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 1/4/2010			**No Photo**	**No Photo**
Spring – 5/24/2010				
Autumn – 10/26/2010				

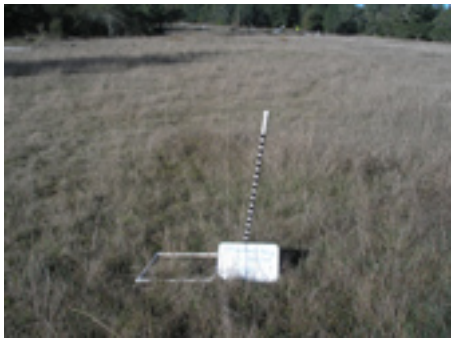
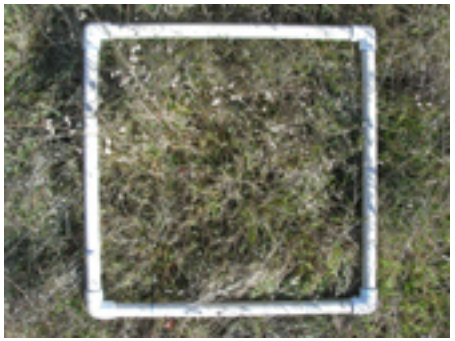
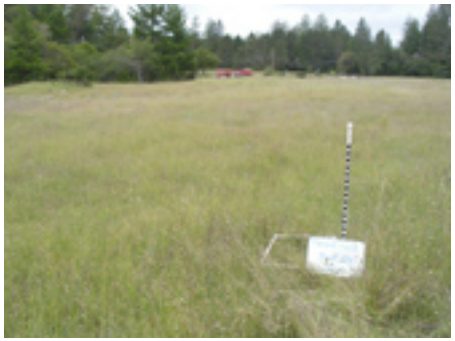
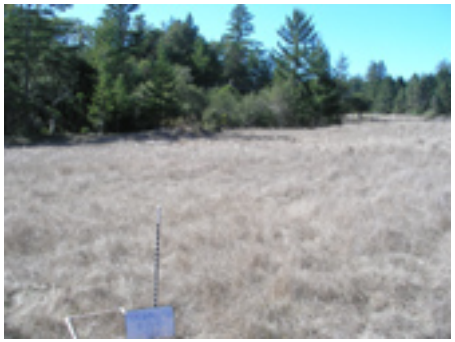
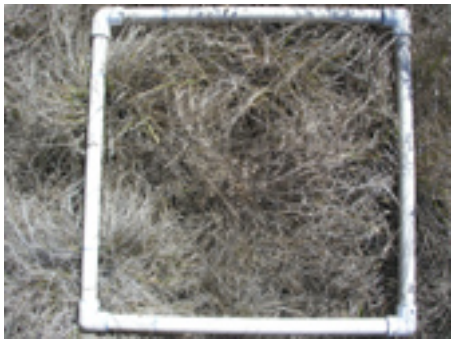
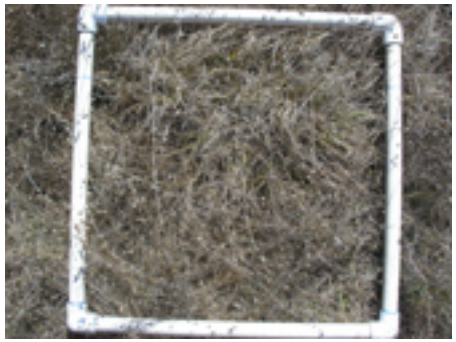
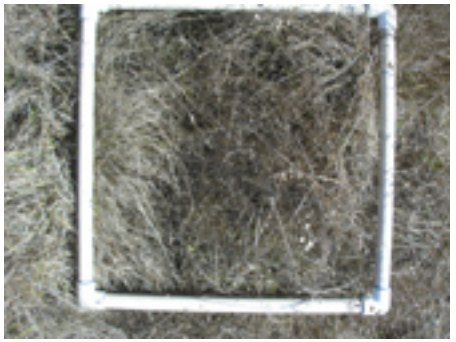
Site #6 – RTU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 1/4/2010			**No Photo**	**No Photo**
Spring – 5/24/2010				
Autumn - 10/26/2010				

Site #16 – GO

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 1/4/2010		**No Photo**	**No Photo**	
Spring – 5/24/2010				
Autumn - 10/26/2010				

Site #6 – GU

	Transect	Low Vegetation	Moderate Vegetation	High Vegetation
Winter – 1/4/2010		**No Photo**	**No Photo**	
Spring – 5/24/2010				
Autumn - 10/26/2010				

APPENDIX 2:

Soils Analysis Data

Raw Soils Data

OTB Study Site and Survey Date	pH [SOP 205.02]	N (Total) [SOP 320.03] %	C (Total) [SOP 320.03] %	Bray-P [SOP 355.02] ppm	Sand [SOP 470.03] %	Silt [SOP 470.03] %	Clay [SOP 470.03] %
Site #2 RTO Dec 23, 2009	4.8	0.221	2.06	9.2	65	22	13
Site #2 RTU Dec 23, 2009	5.1	0.214	2.17	14.0	58	24	18
Site #2 GO Dec 24, 2009	4.7	0.274	2.54	15.8	61	24	15
Site #2 GU Dec 24, 2009	4.6	0.227	2.16	20.2	65	20	15
Site #3 RTO Dec 29, 2009	5.2	0.157	1.67	2.5	64	21	15
Site #3 RTU Dec 29, 2009	5.2	0.184	1.80	5.8	71	18	11
Site #3 GO Dec 31, 2009	4.8	0.197	2.01	1.7	64	25	11
Site #3 GU Dec 29, 2009	5.2	0.192	2.05	1.8	68	19	13
Site #14 RTO1 Dec 31, 2009	4.8	0.194	2.28	6.5	68	15	17
Site #14 RTO2 Dec 31, 2009	4.9	0.152	1.69	1.3	68	19	13
Site #14 RTO3 June 7, 2010	5.1	0.066	0.83	4.4	77	14	9
Site #14 RTU, June 7, 2010	5.4	0.153	1.94	19.8	60	22	18
Site #14 GO, June 7, 2010	5.1	0.081	1.08	2.7	81	10	9
Site #14 GU Dec 31, 2009	5.2	0.142	1.63	0.9	70	19	11
Site #6 RTO Jan 4, 2010	5.0	0.070	0.80	3.1	73	15	12
Site #6 RTU Jan 4, 2010	5.3	0.195	2.31	2.6	58	23	19
Site #16 GO Jan 4, 2010	5.5	0.148	1.76	1.4	59	22	19
Site #6 GU Jan 4, 2010	5.2	0.090	1.06	0.9	68	17	15

APPENDIX 3:

Summary Statistics for Habitat Feature Variables Measured by Subset Transect Category

SUMMARY STATISTICS FOR HABITAT FEATURES

Number of Observations

Time of Year	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009	60	80	60	20	20		60	300
Summer 2010	80	80	60	20	20	20	80	360
Fall 2010	80	80	60	20	20	20	80	360
Total	220	240	180	60	60	40	220	1,020

Total Non Vegetated

Time of Year Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	5.7	4.9	58.6	58.8	41.3		68.7	34.6
Standard Error	0.9	0.6	3.9	2.2	2.3		2.5	1.9
Standard Deviation	7.3	5.7	29.9	10.0	10.5		19.7	32.9
Confidence Level (95.0%)	1.9	1.3	7.7	4.7	4.9		5.1	3.7
Summer 2010								
Mean	3.4	3.7	46.2	38.0	27.8	29.0	48.1	25.2
Standard Error	0.5	0.6	4.0	2.0	3.8	2.5	2.9	1.4
Standard Deviation	4.1	5.1	30.8	8.8	16.8	11.1	25.8	27.3
Confidence Level (95.0%)	0.9	1.1	8.0	4.1	7.9	5.2	5.7	2.8
Fall 2010								
Mean	12.3	13.1	55.8	22.3	19.5	28.3	48.8	29.7
Standard Error	1.7	1.9	3.8	2.8	2.9	3.1	2.9	1.5
Standard Deviation	15.1	17.1	29.1	12.3	13.1	14.0	25.7	27.6
Confidence Level (95.0%)	3.4	3.8	7.5	5.8	6.1	6.5	5.7	2.9
Total								
Mean	7.3	7.2	53.5	39.7	29.5	28.6	54.0	29.5
Standard Error	0.7	0.7	2.3	2.4	2.1	2.0	1.7	0.9
Standard Deviation	10.9	11.6	30.3	18.2	16.2	12.5	25.8	29.4
Confidence Level (95.0%)	1.4	1.5	4.4	4.7	4.2	4.0	3.4	1.8

Soil 1

Time of Year Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	4.0	4.8	53.3	58.5	32.5		62.2	31.3
Standard Error	0.5	0.6	3.8	2.2	2.0		3.5	1.8
Standard Deviation	3.5	5.7	29.4	9.9	9.1		27.3	31.9
Confidence Level (95.0%)	0.9	1.3	7.6	4.6	4.3		7.0	3.6
Summer 2010								
Mean	3.4	3.6	36.1	32.8	12.5	21.5	36.2	19.3
Standard Error	0.5	0.6	3.7	2.3	2.3	2.9	2.8	1.2
Standard Deviation	4.0	5.1	28.6	10.1	10.3	12.8	24.6	23.0
Confidence Level (95.0%)	0.9	1.1	7.4	4.7	4.8	6.0	5.5	2.4
Fall 2010								
Mean	11.8	13.1	15.7	18.5	13.0	21.0	29.3	17.6
Standard Error	1.7	1.9	2.7	2.0	1.7	2.9	2.6	1.0
Standard Deviation	15.2	17.1	20.6	9.0	7.7	13.0	22.9	19.0
Confidence Level (95.0%)	3.4	3.8	5.3	4.2	3.6	6.1	5.1	2.0
Total								
Mean	6.6	7.2	35.0	36.6	19.3	21.3	40.8	22.2
Standard Error	0.7	0.7	2.3	2.5	1.7	2.0	1.9	0.8
Standard Deviation	10.4	11.6	30.5	19.2	13.0	12.7	28.1	25.4
Confidence Level (95.0%)	1.4	1.5	4.5	5.0	3.4	4.1	3.7	1.6

SUMMARY STATISTICS FOR HABITAT FEATURES

Soil 2

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	-	-	0.2	-	-		-	0.0
Standard Error	-	-	0.2	-	-		-	0.0
Standard Deviation	-	-	1.3	-	-		-	0.6
Confidence Level (95.0%)	-	-	0.3	-	-		-	0.1
Summer 2010								
Mean	-	-	-	-	-	-	-	-
Standard Error	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Confidence Level (95.0%)	-	-	-	-	-	-	-	-
Fall 2010								
Mean	-	-	-	-	-	-	-	-
Standard Error	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Confidence Level (95.0%)	-	-	-	-	-	-	-	-
Total								
Mean	-	-	0.1	-	-	-	-	0.0
Standard Error	-	-	0.1	-	-	-	-	0.0
Standard Deviation	-	-	0.7	-	-	-	-	0.3
Confidence Level (95.0%)	-	-	0.1	-	-	-	-	0.0

Loose Sand

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	-	-	4.5	0.3	8.3		1.8	1.8
Standard Error	-	-	0.9	0.3	0.8		0.3	0.2
Standard Deviation	-	-	6.6	1.1	3.7		2.4	4.1
Confidence Level (95.0%)	-	-	1.7	0.5	1.7		0.6	0.5
Summer 2010								
Mean	-	-	7.9	2.3	0.3	4.5	10.4	4.0
Standard Error	-	-	2.0	1.3	0.3	0.8	2.4	0.7
Standard Deviation	-	-	15.5	5.7	1.1	3.6	21.2	12.7
Confidence Level (95.0%)	-	-	4.0	2.7	0.5	1.7	4.7	1.3
Fall 2010								
Mean	-	-	39.9	1.5	4.0	5.0	16.1	10.8
Standard Error	-	-	4.5	0.6	0.9	0.6	3.2	1.3
Standard Deviation	-	-	34.9	2.9	4.2	2.8	28.5	24.3
Confidence Level (95.0%)	-	-	9.0	1.3	2.0	1.3	6.3	2.5
Total								
Mean	-	-	17.4	1.3	4.2	4.8	10.2	5.8
Standard Error	-	-	2.0	0.5	0.6	0.5	1.5	0.5
Standard Deviation	-	-	27.4	3.8	4.6	3.2	22.1	16.8
Confidence Level (95.0%)	-	-	4.0	1.0	1.2	1.0	2.9	1.0

SUMMARY STATISTICS FOR HABITAT FEATURES

Stones

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	0.2	0.1	-	-	0.5		4.7	1.0
Standard Error	0.1	0.1	-	-	0.3		1.1	0.2
Standard Deviation	0.9	0.6	-	-	1.5		8.4	4.2
Confidence Level (95.0%)	0.2	0.1	-	-	0.7		2.2	0.5
Summer 2010								
Mean	0.1	-	0.5	-	0.8	3.0	1.4	0.6
Standard Error	0.1	-	0.2	-	0.5	0.6	0.3	0.1
Standard Deviation	0.6	-	1.5	-	2.4	2.5	2.9	1.9
Confidence Level (95.0%)	0.1	-	0.4	-	1.1	1.2	0.6	0.2
Fall 2010								
Mean	-	-	0.2	-	0.5	2.3	3.4	0.9
Standard Error	-	-	0.1	-	0.3	0.7	0.8	0.2
Standard Deviation	-	-	0.9	-	1.5	3.0	7.6	3.9
Confidence Level (95.0%)	-	-	0.2	-	0.7	1.4	1.7	0.4
Total								
Mean	0.1	0.0	0.2	-	0.6	2.6	3.0	0.8
Standard Error	0.0	0.0	0.1	-	0.2	0.4	0.4	0.1
Standard Deviation	0.6	0.3	1.0	-	1.9	2.8	6.7	3.4
Confidence Level (95.0%)	0.1	0.0	0.2	-	0.5	0.9	0.9	0.2

Bedrock

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	-	-	0.6	-	-		-	0.1
Standard Error	-	-	0.6	-	-		-	0.1
Standard Deviation	-	-	4.5	-	-		-	2.0
Confidence Level (95.0%)	-	-	1.2	-	-		-	0.2
Summer 2010								
Mean	-	0.1	0.8	-	-	-	0.1	0.2
Standard Error	-	0.1	0.8	-	-	-	0.1	0.1
Standard Deviation	-	0.6	6.5	-	-	-	0.8	2.7
Confidence Level (95.0%)	-	0.1	1.7	-	-	-	0.2	0.3
Fall 2010								
Mean	-	-	0.1	-	-	-	-	0.0
Standard Error	-	-	0.1	-	-	-	-	0.0
Standard Deviation	-	-	0.6	-	-	-	-	0.3
Confidence Level (95.0%)	-	-	0.2	-	-	-	-	0.0
Total								
Mean	-	0.0	0.5	-	-	-	0.0	0.1
Standard Error	-	0.0	0.3	-	-	-	0.0	0.1
Standard Deviation	-	0.3	4.5	-	-	-	0.5	1.9
Confidence Level (95.0%)	-	0.0	0.7	-	-	-	0.1	0.1

SUMMARY STATISTICS FOR HABITAT FEATURES

Mammal Burrow

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	1.5	-	-	-	-		-	0.3
Standard Error	0.7	-	-	-	-		-	0.1
Standard Deviation	5.2	-	-	-	-		-	2.4
Confidence Level (95.0%)	1.3	-	-	-	-		-	0.3
Summer 2010								
Mean	-	-	0.8	3.0	-	-	-	0.3
Standard Error	-	-	0.7	1.1	-	-	-	0.1
Standard Deviation	-	-	5.3	4.7	-	-	-	2.5
Confidence Level (95.0%)	-	-	1.4	2.2	-	-	-	0.3
Fall 2010								
Mean	0.1	-	-	2.3	-	-	-	0.2
Standard Error	0.1	-	-	1.6	-	-	-	0.1
Standard Deviation	0.8	-	-	7.0	-	-	-	1.7
Confidence Level (95.0%)	0.2	-	-	3.3	-	-	-	0.2
Total								
Mean	0.5	-	0.3	1.8	-	-	-	0.3
Standard Error	0.2	-	0.2	0.6	-	-	-	0.1
Standard Deviation	2.8	-	3.1	4.9	-	-	-	2.2
Confidence Level (95.0%)	0.4	-	0.5	1.3	-	-	-	0.1

Human Digging

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	-	-	-	-	-		-	-
Standard Error	-	-	-	-	-		-	-
Standard Deviation	-	-	-	-	-		-	-
Confidence Level (95.0%)	-	-	-	-	-		-	-
Summer 2010								
Mean	-	-	-	-	-	-	-	-
Standard Error	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Confidence Level (95.0%)	-	-	-	-	-	-	-	-
Fall 2010								
Mean	-	-	-	-	-	-	-	-
Standard Error	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Confidence Level (95.0%)	-	-	-	-	-	-	-	-
Total								
Mean	-	-	-	-	-	-	-	-
Standard Error	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Confidence Level (95.0%)	-	-	-	-	-	-	-	-

SUMMARY STATISTICS FOR HABITAT FEATURES

Other 1

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	-	-	-	-	-		-	-
Standard Error	-	-	-	-	-		-	-
Standard Deviation	-	-	-	-	-		-	-
Confidence Level (95.0%)	-	-	-	-	-		-	-
Summer 2010								
Mean	-	-	-	-	14.3	-	-	0.8
Standard Error	-	-	-	-	4.1	-	-	0.3
Standard Deviation	-	-	-	-	18.3	-	-	5.3
Confidence Level (95.0%)	-	-	-	-	8.6	-	-	0.6
Fall 2010								
Mean	0.4	-	-	-	2.0	-	-	0.2
Standard Error	0.3	-	-	-	0.8	-	-	0.1
Standard Deviation	2.4	-	-	-	3.4	-	-	1.4
Confidence Level (95.0%)	0.5	-	-	-	1.6	-	-	0.1
Total								
Mean	0.1	-	-	-	5.4	-	-	0.3
Standard Error	0.1	-	-	-	1.6	-	-	0.1
Standard Deviation	1.4	-	-	-	12.3	-	-	3.3
Confidence Level (95.0%)	0.2	-	-	-	3.2	-	-	0.2

Total Standing Herb Matter

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	89.3	90.4	39.3	36.0	53.5		30.3	61.9
Standard Error	1.1	0.7	3.8	2.0	2.4		2.6	1.8
Standard Deviation	8.5	6.2	29.3	9.0	10.5		20.2	31.8
Confidence Level (95.0%)	2.2	1.4	7.6	4.2	4.9		5.2	3.6
Summer 2010								
Mean	94.4	93.1	51.3	58.3	72.3	70.3	49.1	72.3
Standard Error	0.6	0.6	3.9	2.1	3.8	2.6	2.9	1.4
Standard Deviation	5.0	5.5	30.2	9.2	16.8	11.5	26.3	27.4
Confidence Level (95.0%)	1.1	1.2	7.8	4.3	7.9	5.4	5.9	2.8
Fall 2010								
Mean	67.9	72.1	28.3	52.8	69.5	53.3	29.5	52.1
Standard Error	3.2	2.6	3.0	1.8	2.5	2.3	1.7	1.5
Standard Deviation	28.8	23.1	23.0	8.0	11.1	10.3	15.3	28.7
Confidence Level (95.0%)	6.4	5.1	5.9	3.8	5.2	4.8	3.4	3.0
Total								
Mean	83.4	85.2	39.6	49.0	65.1	61.8	36.8	62.1
Standard Error	1.5	1.1	2.2	1.7	2.0	2.2	1.6	1.0
Standard Deviation	21.6	16.9	29.1	12.8	15.4	13.8	23.0	30.4
Confidence Level (95.0%)	2.9	2.2	4.3	3.3	4.0	4.4	3.1	1.9

SUMMARY STATISTICS FOR HABITAT FEATURES

Annual Grass

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	16.7	22.1	5.8	7.5	2.5		6.2	12.3
Standard Error	2.3	2.6	0.6	1.1	0.7		0.6	1.0
Standard Deviation	18.0	23.5	5.0	5.0	3.0		5.0	16.6
Confidence Level (95.0%)	4.6	5.2	1.3	2.3	1.4		1.3	1.9
Summer 2010								
Mean	26.6	24.3	6.7	10.3	3.8	3.3	8.2	15.2
Standard Error	2.2	1.9	0.5	1.6	0.5	0.8	0.8	0.8
Standard Deviation	19.9	17.4	3.8	7.0	2.2	3.4	7.2	16.0
Confidence Level (95.0%)	4.4	3.9	1.0	3.3	1.0	1.6	1.6	1.7
Fall 2010								
Mean	29.3	28.9	5.8	11.0	0.5	6.8	8.0	16.7
Standard Error	2.6	2.1	1.2	2.5	0.3	1.3	0.7	1.0
Standard Deviation	23.0	19.2	9.4	11.3	1.5	5.7	6.6	18.9
Confidence Level (95.0%)	5.1	4.3	2.4	5.3	0.7	2.7	1.5	2.0
Total								
Mean	24.9	25.1	6.1	9.6	2.3	5.0	7.6	14.9
Standard Error	1.4	1.3	0.5	1.1	0.3	0.8	0.4	0.5
Standard Deviation	21.1	20.3	6.5	8.2	2.7	4.9	6.5	17.3
Confidence Level (95.0%)	2.8	2.6	1.0	2.1	0.7	1.6	0.9	1.1

Perennial Grass

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	17.6	30.9	5.5	8.3	29.8		2.3	15.8
Standard Error	2.9	3.2	0.8	1.3	2.3		0.5	1.2
Standard Deviation	22.1	28.6	6.0	5.9	10.1		4.2	21.6
Confidence Level (95.0%)	5.7	6.4	1.6	2.8	4.7		1.1	2.5
Summer 2010								
Mean	15.7	24.2	6.9	9.0	11.0	13.3	5.3	13.0
Standard Error	1.8	2.4	1.1	1.6	1.7	1.5	1.0	0.8
Standard Deviation	16.2	21.9	8.5	7.2	7.7	6.7	8.7	15.8
Confidence Level (95.0%)	3.6	4.9	2.2	3.4	3.6	3.2	1.9	1.6
Fall 2010								
Mean	25.1	33.4	11.6	22.5	34.5	19.8	10.9	21.6
Standard Error	2.7	2.7	1.5	1.9	1.6	2.0	1.4	1.1
Standard Deviation	23.8	24.4	11.5	8.7	7.2	9.0	12.6	20.2
Confidence Level (95.0%)	5.3	5.4	3.0	4.1	3.4	4.2	2.8	2.1
Total								
Mean	19.6	29.5	8.0	13.3	25.1	16.5	6.5	16.9
Standard Error	1.4	1.6	0.7	1.3	1.7	1.3	0.7	0.6
Standard Deviation	21.2	25.3	9.3	9.8	13.2	8.5	10.1	19.6
Confidence Level (95.0%)	2.8	3.2	1.4	2.5	3.4	2.7	1.3	1.2

SUMMARY STATISTICS FOR HABITAT FEATURES

Legumes

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	10.5	3.9	4.8	0.3	5.8		4.5	5.4
Standard Error	2.0	0.8	0.9	0.3	1.6		0.7	0.5
Standard Deviation	15.7	7.1	6.7	1.1	6.9		5.6	9.4
Confidence Level (95.0%)	4.1	1.6	1.7	0.5	3.2		1.4	1.1
Summer 2010								
Mean	15.5	16.9	13.2	0.8	5.8	12.3	11.8	13.1
Standard Error	1.9	1.9	1.7	0.4	0.7	1.6	1.6	0.8
Standard Deviation	16.9	16.9	13.2	1.8	2.9	7.3	14.2	14.8
Confidence Level (95.0%)	3.8	3.8	3.4	0.9	1.4	3.4	3.2	1.5
Fall 2010								
Mean	-	0.1	-	-	-	-	-	0.0
Standard Error	-	0.1	-	-	-	-	-	0.0
Standard Deviation	-	0.8	-	-	-	-	-	0.4
Confidence Level (95.0%)	-	0.2	-	-	-	-	-	0.0
Total								
Mean	8.5	7.0	6.0	0.3	3.8	6.1	5.5	6.2
Standard Error	1.0	0.8	0.8	0.2	0.7	1.3	0.7	0.4
Standard Deviation	14.7	12.8	10.1	1.3	5.1	8.0	10.4	11.5
Confidence Level (95.0%)	1.9	1.6	1.5	0.3	1.3	2.6	1.4	0.7

Other Forbs

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	44.6	33.6	23.1	20.0	15.5		17.3	28.3
Standard Error	4.1	3.4	2.6	2.2	2.1		2.0	1.5
Standard Deviation	31.6	30.6	20.2	10.0	9.6		15.8	26.3
Confidence Level (95.0%)	8.2	6.8	5.2	4.7	4.5		4.1	3.0
Summer 2010								
Mean	36.6	27.8	24.6	38.3	51.8	41.5	23.9	31.0
Standard Error	1.8	1.6	2.0	3.1	3.8	3.0	1.6	0.9
Standard Deviation	16.1	14.7	15.8	14.1	17.1	13.4	14.6	17.0
Confidence Level (95.0%)	3.6	3.3	4.1	6.6	8.0	6.3	3.2	1.8
Fall 2010								
Mean	13.6	9.6	10.8	19.3	34.5	26.8	10.6	13.8
Standard Error	1.3	1.0	1.2	2.6	2.5	3.7	0.9	0.6
Standard Deviation	11.3	8.8	9.3	11.8	11.0	16.4	8.1	12.0
Confidence Level (95.0%)	2.5	2.0	2.4	5.5	5.1	7.7	1.8	1.2
Total								
Mean	30.4	23.6	19.5	25.8	33.9	34.1	17.3	24.1
Standard Error	1.6	1.5	1.3	1.9	2.5	2.6	1.0	0.6
Standard Deviation	24.1	22.6	16.8	14.8	19.6	16.6	14.1	20.4
Confidence Level (95.0%)	3.2	2.9	2.5	3.8	5.1	5.3	1.9	1.3

SUMMARY STATISTICS FOR HABITAT FEATURES

Litter

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	3.7	4.4	1.3	5.3	5.3		1.0	3.1
Standard Error	0.4	0.4	0.3	0.4	0.3		0.3	0.2
Standard Deviation	3.3	3.4	2.2	2.0	1.1		2.0	3.2
Confidence Level (95.0%)	0.9	0.8	0.6	0.9	0.5		0.5	0.4
Summer 2010								
Mean	2.0	2.9	2.1	3.8	-	0.8	2.4	2.2
Standard Error	0.3	0.4	0.3	0.5	-	0.4	0.3	0.1
Standard Deviation	2.6	3.2	2.5	2.2	-	1.8	2.5	2.7
Confidence Level (95.0%)	0.6	0.7	0.6	1.0	-	0.9	0.6	0.3
Fall 2010								
Mean	19.6	13.6	14.7	25.0	11.0	18.5	21.6	17.7
Standard Error	1.7	0.9	1.3	2.2	1.0	1.8	1.8	0.7
Standard Deviation	15.4	7.8	10.0	10.0	4.5	8.1	15.8	12.7
Confidence Level (95.0%)	3.4	1.7	2.6	4.7	2.1	3.8	3.5	1.3
Total								
Mean	8.9	7.0	6.0	11.3	5.4	9.6	9.0	7.9
Standard Error	0.8	0.5	0.6	1.5	0.7	1.7	0.9	0.3
Standard Deviation	12.6	7.1	8.6	11.4	5.2	10.7	13.6	10.7
Confidence Level (95.0%)	1.7	0.9	1.3	2.9	1.4	3.4	1.8	0.7

Manure

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	1.3	0.3	0.8	-	-		0.1	0.5
Standard Error	0.3	0.2	0.3	-	-		0.1	0.1
Standard Deviation	2.6	1.5	2.6	-	-		0.6	1.9
Confidence Level (95.0%)	0.7	0.3	0.7	-	-		0.2	0.2
Summer 2010								
Mean	0.2	0.3	0.4	-	-	-	0.2	0.2
Standard Error	0.2	0.2	0.2	-	-	-	0.1	0.1
Standard Deviation	1.7	1.7	1.4	-	-	-	1.0	1.3
Confidence Level (95.0%)	0.4	0.4	0.4	-	-	-	0.2	0.1
Fall 2010								
Mean	0.1	1.2	1.3	-	-	-	0.1	0.5
Standard Error	0.1	0.4	0.4	-	-	-	0.1	0.1
Standard Deviation	0.8	3.2	3.1	-	-	-	0.6	2.1
Confidence Level (95.0%)	0.2	0.7	0.8	-	-	-	0.1	0.2
Total								
Mean	0.5	0.6	0.8	-	-	-	0.1	0.4
Standard Error	0.1	0.1	0.2	-	-	-	0.1	0.1
Standard Deviation	1.8	2.3	2.5	-	-	-	0.7	1.8
Confidence Level (95.0%)	0.2	0.3	0.4	-	-	-	0.1	0.1

SUMMARY STATISTICS FOR HABITAT FEATURES

Other 2

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	-	-	-	-	-	-	-	-
Standard Error	-	-	-	-	-		-	-
Standard Deviation	-	-	-	-	-		-	-
Confidence Level (95.0%)	-	-	-	-	-		-	-
Summer 2010								
Mean	-	-	-	-	-	-	0.1	0.0
Standard Error	-	-	-	-	-	-	0.1	0.0
Standard Deviation	-	-	-	-	-	-	0.8	0.4
Confidence Level (95.0%)	-	-	-	-	-	-	0.2	0.0
Fall 2010								
Mean	-	-	-	-	-	-	-	-
Standard Error	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Confidence Level (95.0%)	-	-	-	-	-	-	-	-
Total								
Mean	-	-	-	-	-	-	0.0	0.0
Standard Error	-	-	-	-	-	-	0.0	0.0
Standard Deviation	-	-	-	-	-	-	0.5	0.2
Confidence Level (95.0%)	-	-	-	-	-	-	0.1	0.0

Height

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	2.2	2.7	1.0	1.0	1.0		1.0	1.7
Standard Error	0.2	0.2	-	-	-		-	0.1
Standard Deviation	1.6	1.5	-	-	-		-	1.3
Confidence Level (95.0%)	0.4	0.3	-	-	-		-	0.1
Summer 2010								
Mean	8.2	7.1	2.7	10.1	4.8	3.7	4.9	6.0
Standard Error	0.7	0.5	0.2	1.0	0.3	0.3	0.7	0.3
Standard Deviation	6.1	4.2	1.8	4.5	1.3	1.2	6.4	5.3
Confidence Level (95.0%)	1.4	0.9	0.5	2.1	0.6	0.6	1.4	0.5
Fall 2010								
Mean	3.5	4.3	1.2	13.4	2.4	2.0	3.2	3.6
Standard Error	0.3	0.4	0.1	0.9	0.2	0.2	0.5	0.2
Standard Deviation	2.4	3.3	1.0	4.1	0.8	0.8	4.4	4.0
Confidence Level (95.0%)	0.5	0.7	0.2	1.9	0.4	0.4	1.0	0.4
Total								
Mean	4.8	4.7	1.6	8.2	2.7	2.8	3.2	3.9
Standard Error	0.3	0.2	0.1	0.8	0.2	0.2	0.3	0.1
Standard Deviation	4.8	3.7	1.4	6.3	1.8	1.3	4.9	4.3
Confidence Level (95.0%)	0.6	0.5	0.2	1.6	0.5	0.4	0.7	0.3

SUMMARY STATISTICS FOR HABITAT FEATURES

Mass

Time of Year / Statistical Measures	Subsite Transect Category							
	GO	GU	RTO	RTO1	RTO2	RTO3	RTU	Total
Winter 2009								
Mean	1,271.7	1,717.5	165.0	225.0	240.0		100.0	796.3
Standard Error	138.1	130.3	12.5	19.0	15.2		-	60.0
Standard Deviation	1,069.6	1,165.4	97.1	85.1	68.1		-	1,039.0
Confidence Level (95.0%)	276.3	259.3	25.1	39.8	31.9		-	118.0
Summer 2010								
Mean	3,336.3	3,493.8	1,235.0	390.0	1,800.0	395.0	431.3	1,963.1
Standard Error	250.4	259.9	192.8	44.1	179.2	24.6	46.3	112.6
Standard Deviation	2,239.5	2,324.2	1,493.1	197.1	801.3	109.9	414.5	2,136.2
Confidence Level (95.0%)	498.4	517.2	385.7	92.2	375.0	51.4	92.2	221.4
Fall 2010								
Mean	2,176.8	2,444.7	718.0	653.1	1,421.2	408.6	198.4	1,328.7
Standard Error	183.8	178.0	139.5	63.8	131.0	40.2	17.5	78.7
Standard Deviation	1,644.4	1,592.0	1,080.5	285.4	585.7	180.0	156.8	1,494.0
Confidence Level (95.0%)	365.9	354.3	279.1	133.6	274.1	84.2	34.9	154.9
Total								
Mean	2,351.6	2,552.0	706.0	422.7	1,153.7	401.8	256.2	1,396.0
Standard Error	131.0	122.6	85.5	34.8	113.1	23.3	20.2	53.6
Standard Deviation	1,943.6	1,899.0	1,146.6	269.6	876.1	147.4	299.9	1,712.3
Confidence Level (95.0%)	258.3	241.5	168.6	69.6	226.3	47.1	39.9	105.2

APPENDIX 4:

Recommended Outline for a Grazing or Resource Management Plan for Habitat of the Ohlone Tiger Beetle and Other Special Resources

Recommended Outline of Grazing or Resource Management Plan for
Habitat of Ohlone Tiger Beetle and Other Special Resources

1. Introduction (summaries only)
    a. Site Description
    b. Ownership
    c. History of Land Use and Management and Grassland Habitats (summary focused on effects on the current landscape and targeted special resources)

2. Summary of Current Conditions Affected by Grazing or Other Management (summaries only--related to known or potential sites and characteristics [of habitats and physical sites] necessary for occurrence [or persistence or continuation of values], and management effects, based on new and existing assessments)
    a. Fauna, Flora, Vegetation, including Special-Status Species and Natural Communities and Encroachment of Woody and Pest Plants
        i. Occupied and potential OTB habitat
    b. Geology, Special Physical Features, Soil, and Erosion
    c. Hydrology, Surface Water Drainage, and Water Quality
    d. Grazing Capacity
    e. Fire Hazard
    f. Infrastructure
    g. Special Management Areas and Hazards

3. Management Goals, Objectives, and Performance Standards
    a. Ecosystem Health
    b. Special Habitat or Feature Characteristics
        i. OTB habitat
        ii. Other special habitat
    c. Cooperation with the Livestock Operator, Neighbors, Management Stakeholders, and Resource Users

4. Predicted Effects and Desired Conditions (how grazing, related management, non-grazing management, and operations affect the special resources described in Section 2; potential for occupation by OTB; comparison of relative costliness and effectiveness of alternatives for effective management [including the current management] to improve and maintain habitat quality for the OTB, and to maintain ecosystem health and other special resources)
    a. Grazing and Related Management of Special Resources (including effects of grazing removal or continuation without grazing)
    b. Non-Grazing Management of Special Resources
    c. Alternative feasible management scenarios, including type of grazing animals, mowing/weed-whacking, recreation, and maintenance operations
        i. Potential conflicts and compatibility of livestock with recreation
    d. Timeline of Management Requirements of Special Resources Affected by Grazing

5. Grazing and Other Management Prescriptions (recommended alternatives, and management activities to avoid because of potential harm to the OTB or other special resources)
    a. Recommended Grazing Alternatives
    b. Grazing and Other Management Units
    c. Grazing and Other Management Prescriptions—general and special
    d. Other Management and Restrictions Related to Grazing and Cattle Operations
    e. Infrastructure Condition and Improvements Needed (including specifications for wildlife-friendly fencing and water troughs; requirements to initiate grazing)

6. Guidelines, Incentives, and Contingencies for Operations (for flexibility to adapt to extreme events and changing conditions)

7. Monitoring of Conditions and Planned Effects on Resources Related to Grazing
    a. Monitoring Variables, Methods, and Schedule
    b. Evaluation Standards and Analysis
    c. Adaptation of Management Actions
    d. Testing, Research, and Learning Needs
    e. Reporting

8. Implementation Schedule, Personnel, and Responsibilities

9. Assumptions and Recommended Supplementary Planning

10. Literature Cited