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Vegetation Structure in Northern Mixed Chaparral as Affected by Trail Usage and Location

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by

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1998

This thesis is dedicated to the memory of Norman D. Hogg
July 24, 1947 – August 19, 1996

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ABSTRACT OF THE THESIS

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Professor Hartmut S. Walter, Chair

With the rise in visitation to parks and recreation areas nationwide, there is a growing need for research in the field of recreation ecology. A greater understanding of the relationship between recreational impacts and changes in the surrounding biotic communities is needed in order to provide effective management of those areas and to minimize those impacts.

This study looked at the changes in vegetation structure and species richness brought on by trail usage and location in the Santa Monica Mountains National Recreation Area (SMMNRA). Vegetation was sampled within 2x1m quadrats every 10 meters along a 50m transect placed 05.m, 5m and 20m from the trail edge. Species richness and growth form (herb, graminoid and shrubs) coverage were measured in order to determine the changes occurring with distance from the trail.

This study found an internal edge effect was found to be created by trails. In addition vegetation structure varied dramatically along trail edges and was dominated by herbs and graminoids. Trail usage was a greater influence in determining vegetation structure and species richness than trail location. A higher presence of exotics was measured, particularly along multiple use trails which form the majority of trails within the SMMNRA.

Chapter One

Introduction

Natural Areas

Natural Parks, wilderness areas, preserves, and semi-natural areas (referred to in this document as natural areas) serve the primary function of preserving and protecting areas of biological diversity and cultural significance. With a few exceptions, the majority of these natural areas are open to educational, research and recreational activities. The directive as stated by the U.S. National Public Service Act of 1916, was for national parks to not only "conserve the scenery and natural and historic objects and wild life herein", but also to "provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Recreational Visits

Tourism is one of the largest industries in the world. A changing shift in trends, partly due to increased environmental awareness and subsequent concern, has resulted in a specialized form of tourism known as ecotourism. Unlike traditional tourism (e.g. sightseeing of foreign cities or amusement parks, ecotourism is based on the enjoyment of natural areas. Contemporarily, there has also been a rise in outdoor sports such as hiking, rock climbing, and horseback riding. With the advent of mountain bikes, the use of natural areas for biking has also dramatically increased in the past decade (Flather and Cordell 1995). All these factors combined have resulted in a steady increase in visitors logged at natural parks and preserves. In 1946 U.S. National Park attendance was 22 million, today it exceeds 270 million (Weir 1996). Visitor days (defined as a 12 hour stay by one person) rose from 7 million in 1974 to over 20 million by 1993 (Cole 1994). The area of focus in this study, the Santa Monica Mountains National Recreation (hereafter referred to as SMMNRA), has similarly experienced an increase in visitors (fig 1.1).

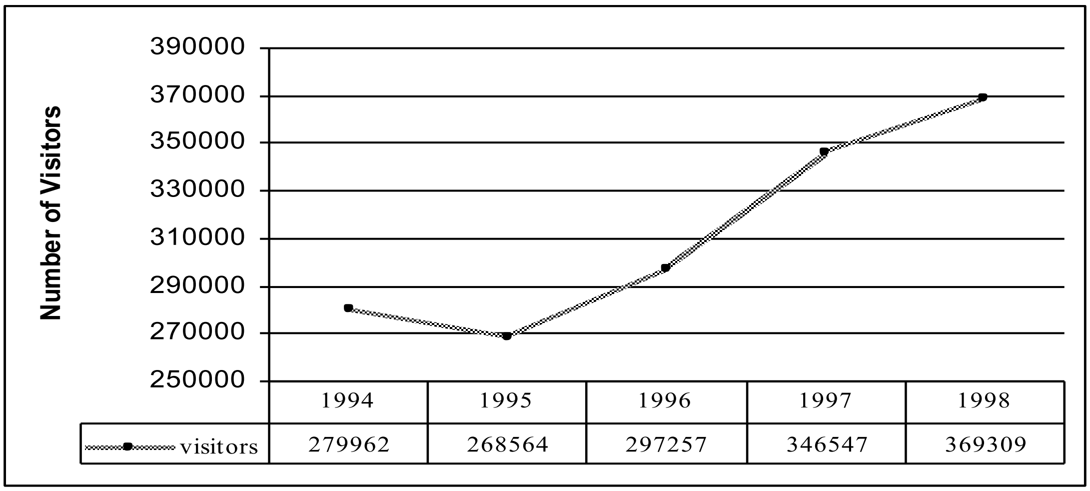


Fig. 1.1 – Number of year-to-date visitors to the Santa Monica Mountains National Recreation Area in July of each year (from monthly log reports, SMMNRA).

Effects of Recreational Use

Recreational activities are considered non-consumptive outdoor recreation because they don't involve the removal of wildlife or plants unlike hunting or collecting. Formerly thought benign (Miller et al 1998), increasing evidence indicates that these activities are affecting individuals, populations and wildlife communities (Knight and Cole 1995). A review by Boyle and Samson (1985) concluded that 81% of studies conducted on nonconsumptive outdoor recreation had found a negative effect on wildlife and plants. Unrestricted recreational use of natural areas tends to damage the plant communities which have been selected for preservation and protection. Recent increase in the use of these areas has accelerated this destruction and created an urgent need for ecological research designed to understand and minimize this conflict between recreational use and preservation (Cole 1978).

Trails are the major transportation system and the facility most commonly found in protected areas. The obvious effects of trails are noticeable to the eye. The first and foremost is the presence of denudation. With the exception of a few hardy stragglers, vegetation is completely removed from the trail, leaving the soil exposed. Combined with a short, but often intense rainy season, landslides resulting from exposed soil are common. Soil erosion is compounded by soil exposure and rough usage of the terrain. Visual surveys of trails, especially those that allow multiple usage (hikers, bikes, and horses) often show moderate to deep crevices etched into the trail path by water erosion (e.g. figure 1.2).

Objective

The objective of this thesis is to determine to what degree and in what way trail disturbance affects the surrounding northern mixed chaparral communities in the Santa Monica Mountains National Recreation Area. Based on previous studies and empirical evidence, my hypothesis is that trailside vegetation differs significantly in species richness and composition from off-trail vegetation. Furthermore, I predict that heavy use trails (as denoted by multiple trail use) tend to have more signs of disturbance resulting in the presence of more exotics and a greater difference in species composition than trails which are restricted to hikers only.

I further wish to determine from these findings if trails function as disturbance corridors; I would like to ascertain whether or not trail presence can correlate with a higher occurrence of exotic plant species. I hope to show which species are sensitive to trailside disturbance and therefore are most likely to be absent or in reduced numbers near trails. Looking at the comparisons between different trails, I would also like to determine if trail usage affects the species composition of trailside vegetation.

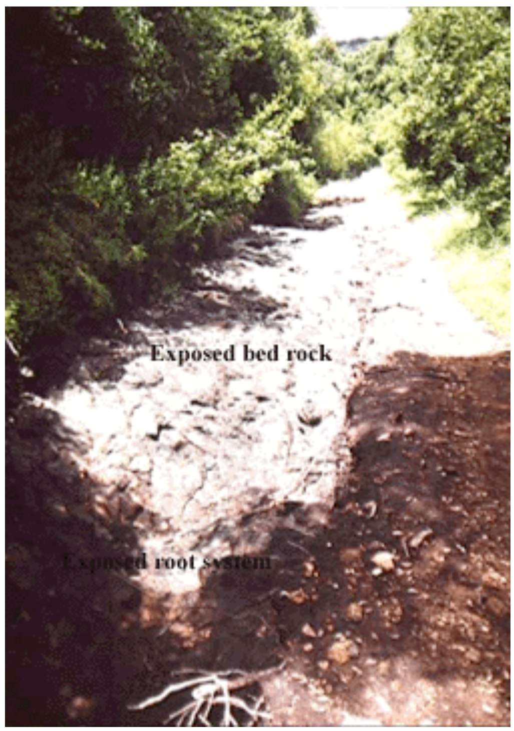


Fig 1.2 – Severe trail erosion along Bulldog Road, Malibu Creek State Park.

Chapter Two

Disturbance

Conservation management

A great deal of the focus on conservation management in natural areas adjacent to highly developed land has been centered around the theory of island biogeography, metapopulation dynamics and their related concepts concerning habitat fragmentation. These theories fail to address the impacts on biota caused by degradation of habitat quality within the natural fragments.

Inter-habitat fragmentation has been shown through several studies, one of which was conducted in the Santa Monica Mountains National Recreation Area (SMMNRA) (Buechner and Sauvajot 1996), to not always be the most significant factor affecting animal populations and species richness. What can be more significant is intra-habitat disturbance and change in habitat quality caused by anthropogenic activities. Studies of habitat quality found that while proximity to urban edges did not affect rodent population dynamics, the amount of disturbance within the habitat produced significant changes (Dunstan and Fox 1996, Buechner and Sauvajot 1996). This is in accordance with the species flow principle (Forman and Godron 1986). This principle states that species distribution and landscape structure are linked in a feedback loop. It then follows that natural or human disturbances that change or form landscape elements can therefore cause less resilient species to decrease in distribution or population. In fact, most studies of the ecological effects of disturbance found that quality of habitat (as measured by the amount and intensity of disturbance), even in sites close to urban areas, can be a greater determining factor in species dynamics than fragmentation or edge effects.

Disturbance

Disturbance is defined as an event that causes a significant change from the normal pattern in an ecological system (Forman 1995). Natural disturbance occurs on many spatial scales and ranges in its effect on the biotic community. It can also range from lasting a day (as in windstorms, fires) or ranging over tens of thousands of years (the most widely acknowledged example being ice ages). It has been recognized in the research that many of types of natural disturbances can be important components of natural systems. Many plant communities and species are dependent on disturbance, especially for regeneration (Pickett and White 1985).

As mentioned, disturbance can be a natural occurrence in an environment, occurring in the form of windstorms, fire, landslides, or disease in regular intervals. In an area such as southern California, disturbance is certainly not a foreign event. In fact, fire, a common disturbance, is essential for the healthy function of this Mediterranean-type ecosystem. This type of repeated, natural disturbance event over time creates a succession of individuals that are able to adapt to short-term changes in the environment, with fire adapted species being one such example.

Ecological effects of disturbance

Many researchers have argued that the spatial structure of populations emerges from the collective behavior of individuals interacting with landscape features, and that knowledge of the mechanisms underlying individual movements will improve our understanding of patterns of spatial distributions (Stapp and Van Horne 1997).

Disturbance in chaparral creates a spatiotemporal mosaic of sites within the landscape. Landslides, fire, soil creep are among the processes that change resources. The resultant increase in space, water and light availability allows for greater spatial heterogeneity and differences in species diversity. Natural disturbance changes vegetational structure and in return this impacts other biota.

Spatial structure has an overlying influence on distribution of individuals and not just quantity of resources. For example, small rodents such as deer mice are more abundant in shrub-dominated areas, reflecting the importance of vegetative cover for many rodents to reduce exposure to predators (Stapp 1996, Kotler and Brown 1988). Stapp and Van Horne (1997) found that in shortgrass prairie, deer mice (*Peromyscus* spp.) densities were positively correlated with dense aggregations of shrubs. Mice appeared to respond both behaviorally and demographically to the spatial arrangement and frequency of shrubs.

The interactions between disturbance and population dynamics are linked through resource availability. Disturbance alters the resource base of a given system by destroying old resources, creating new resources and modifying existing resources (Fox and Fox 1986). Type, diversity and frequency of disturbance interact with site factors such as soil type, topography, climate, and surrounding vegetation to influence future vegetation. This affects each community in two general but profound ways. First, as discussed, different taxa have been shown to respond to different degrees in both magnitude and temporal effect of the response (Dunstan and Fox 1996). Second, invasion of natural communities by exotic species has been strongly correlated with disturbance.

Exotics

Invasibility of a community by exotic plant species can generally occur on two different levels. Intact ecosystems are more likely to succumb to colonization by alien species if they are originally of low diversity (Robinson et al 1995). This theory is based on two assumptions: 1) species pools of potential colonizers are limited by spatial and temporal constraints, 2) as species accumulate, fewer resources remain available for new colonizers. In communities of high species diversity, competition for resources is

Fig. 2.1 – *Brassica nigra* dominance in a coastal sage scrub/chaparral transition habitat.

intense, making colonization difficult. Examples of ecosystems most likely to be invaded are grasslands and riparian. Chaparral communities typically vary from dense cover to patchy establishment of chaparral shrubs depending on a variety of conditions (for example; slope, soil type and aspect). These communities have frequent breaks in their natural plant cover where invaders can establish a foothold. Sometimes this foothold is maintained and expanded by allelopathic influences from the invader. A prime example of this are believed to be the mustards (*Brassica* spp.) in spreading masses on the California slopes (Black et al 1969).

Disturbance provides changes in resources such as light or mineral availability as well as space for invasion. These changes can thereby decrease habitat suitability for natives and create niches for invading plants. It has been confirmed in the literature that plant communities are generally more invasible when they are subject to some form of disturbance. Burke and Grime (1996) indicate that invasibility was positively correlated the with creation of bare ground and increased with the intensity of disturbance. Areas with repeated or sustained disturbance, especially those generated by humans, have an unusually high proportion of exotic species (Forman 1995).

Natural disturbance in such communities acts as a double-edged sword by also promoting the invasion of non-native and weedy plants (Ewel 1986, Hobbs 1991). The control of exotic vegetation has become an expensive task and one of the premiere management issues for many designated natural areas. Invasive vegetation can reduce or displace native species, both plant and animal, and may even alter ecosystems functions (Scholfield 1989). This displacement has been observed by Mack (1986) to be occurring in many native bunchgrass communities worldwide. In the Santa Monica Mountains, of 148 flowering species classified as disturbance oriented, over half (80) are exotic (appendix B).

The presence of exotics in California has been significant ever since the first non-native Americans arrived in this state. Historical records and observations help trace the occurrence of many adventive plant species. Frenkel (1970) estimated during the Spanish colonization 16 species were introduced to California during the years 1769 - 1824. The Mexican occupation from 1825 - 1848 led to another 63 exotic species. A total of 134 established alien plants species had been introduced to California by 1860, 55 of them occurring during the American pioneer era. In 150 years of American settlement of the western United States, approximately twenty species of *Bromus* alone, have been introduced (Munz 1974). The increase in habitats invaded has been both due to a larger source of exotics as well as a greater extent of disturbed habitat.

Recreation Ecology

Research into the types of threats to natural areas has shown that the majority of detrimental impacts can be grouped into seven significant human activities (Cole and Landres 1991). These groups are: (1) recreational use and management; (2) livestock grazing and its management; (3) fire management; (4) introduction and invasion of alien species; (5) diversion and impoundment of water; (6) emission of atmospheric pollutants; and (7) management of adjacent lands. Within these areas there exists a substantial amount of small-scale disturbance. The most pervasive small-scale disturbance takes form geometrically as linear disturbance. These are trails, fire roads and fire breaks.

Recreation ecology is the study of the effects of hiking, camping, and other "recreation" activities that occur in natural areas and have an impact on the local ecology. Within many park systems, there is a dichotomy of objectives with primary emphasis on the preservation of rare and endangered species and at the same allowing for potentially conflicting recreational activities. An important agent that has become increasingly of concern in recent decades to conservation biologists is the recreationist. One of the most serious types of recreational impact is damage to vegetation caused by trampling at campsites and along trails (Trull and Cole 1992). The trampled area results in increased sun and wind penetration, altering the microclimate and subsequently modifying resources (Forman 1995). A study of wilderness campsites in Minnesota found only 12 nights of campsite use per year resulted in a substantial amount of biophysical changes (Marion 1993). Furthermore, studies have shown that resource impacts are related to visitor use levels in a curvilinear fashion and therefore further increases in use caused little addition change (Marion 1993).

Trails

Trails have a central strip of repeated disturbance for travel, in addition to a resultant adjacent edge. The extensive distribution of trails can have pervasive environmental effects through alteration of natural drainage patterns, erosion and deposition of soil, introduction of exotic vegetation and increasing human-wildlife conflicts (Leung and Marion 1996, Kuss et al 1990). Sensitivity to such impacts varies among species and soil types.

Trail Construction

The initial trail construction is a damaging event resulting in the removal of vegetation along a linear strip. This creates not only a loss of vegetation, but also changes in light and moisture availability.

Erosion

Trails are among the recreation facilities most affected by erosion, due to their repeated, heavy use (Hammitt and Cole 1987) and exposed soil area. Trails in temperate regions act as partial-area runoff sources, contributing far more runoff and detached sediment per unit area than other drainage basin surfaces (Wallin and Harden 1996). Their erosional importance, out of proportion to their surface area, is largely the result of the soil compaction that occurs even with light trail use (Wallin and Hardin 1996). Compaction decreases pore space within the soil, resulting in decreased infiltration capacity and an increase in surface runoff and soil erosion (Wallin and Hardin 1996).

The amount of trail degeneration is determined by three factors: characteristics of the trail (topography, water bars, use of switchbacks), its environment (i.e. climatic conditions, soil types) and the type of activities occurring along the trail (hiking, biking, horseback riding, off-road vehicles) (Deluca et al 1998). It has been shown in numerous studies that following natural contours of the landscape can minimize trail erosion (Leung and Marion 1996).

The intensity of impact increases with recreation use and type (fig 2.2). Of the least significant are hikers. Whittaker (1978) found that horseback riding causes a more pronounced increase in trail width, depth, and loss of litter than hikers on trails in the Great Smoky Mountains National Park. Deluca et al. (1998) also found that horse use produced a higher sediment yield than hikers in their experiments. While sediment yield

Fig 2.2 Depth measurements taken on Bulldog Motorway.

was twice as great for hiker plots as compared to control plots (no traffic at all), horse plots yielded the greatest sediment loss with over four times that of the controls.

Not only does trail traffic result in soil erosion, but the remaining soil on the trail is compacted leading to an increase in bulk density. Compressed soil leads to decreased infiltration, further adding to runoff and increased sediment yield (Deluca et al 1998).

Wetter conditions also tend to amplify damage to trails and subsequent soil erosion. Runoff is increased and with that occurs an increase in soil erosion (Deluca et al 1998). The effects of soil erosion are evident in these pictures taken showing the below trail vegetation (affected by soil runoff) and the above trail vegetation which is not affected by erosion. The vegetation structure and species diversity is noticeably different (App. D).

Soils

Soil organisms play key roles in determining the structure and function of plant communities. They are responsible for nitrogen fixation, nutrient cycling, immobilization of essential nutrients, and production of phytohormones. In addition, the composition of soil microbial communities can affect plant growth and the competitive outcome between plants, altering species composition, as well as directly affecting a species ability to colonize an area (Zabinski and Gannon 1997).

The impact of hiking and other trail use tends to abrade the vegetation and organic layers and cause compaction of the soil (Cole and Landres 1996). Disturbance that includes loss of vegetation can have a significant impact on soil systems, leaving soils open to wind and water erosion. Loss of surface organic matter and plant root exudates decreases carbon substrate availability for microbial communities. If compaction of the soils is combined with devegetation, the loss of aggregate stability and reduction of pore space can affect soil microbial communities through their effect on water-holding capacity and aeration of the soil (Zabinski and Gannon 1997). While these process are poorly understood (Cole and Landres 1996) it has been demonstrated that biotic-abiotic, plant-soil interactions are characterized by strong positive feedback linkages (Perry et al 1989). Interference in these linkages inevitably causes changes in ecosystem structure vis a vis vegetation richness and community.

Plants

Changes in vegetation related to trail impact are caused by two factors: direct impact by mechanical damage and indirectly by changes in soil characteristics.   The major mechanical impacts are trampling, increases in nitrogen dumping from urine sources, and grazing. Indirectly, changes in soil are caused by runoff, which affects nutrient levels or by microclimatic changes in light and moisture availability. The most dramatic changes in soil are caused by soil compaction as a result of the pressure exerted by the recreationist (whether walking or biking) and accompanying animals. The resultant changes are an increase in soil density, reduction in soil space (porosity) and changes in moisture levels.

Trampling by recreationists, horses and dogs, is one of the most obvious signs of disturbance to vegetation as a result of trail usage. This direct impact manifests itself through modified species composition, and reduced height and cover (Adkison and Jackson 1996). This event can be a significant disturbance agent, particularly in park and wilderness areas, where nature preservation is a primary objective. Different types of plants will have a different response to disturbance. Vegetation types vary both in the ease which they are damaged and in their abilities to recover from that damage.

In terms of disturbance from such trailside activity, plants that are most resilient are: short stature, large size (i.e. too large to be stepped on), tufted or bunched habits of growth, stems that are woody or wiry and flexible, and leaves that are tough and/or growing in basal rosettes (Cole and Trull 1992). There is also a protection by proximity factor in which plants that are growing closest to vegetation which is taller tend to be shielded from mechanical crushing, or are growing on substrate which tends to cushion invasive events (Cole and Trull 1992). Other vegetation types can be resistant to low levels of disturbance such as trampling but fall out in the event of heavy levels. Low, woody species fall into this category (Cole and Trull 1992). Shrubby understories are often resistant to damage, but once damage occurs, recovery can be slow. The most fragile species tend to be broad-leaved herbaceous plants with erect, caulescent stems (Cole and Trull 1992). However, these species also tend to have a rapid recovery.

The end scenario in vegetation response to recreational disturbance incurred by trampling would be mostly durable graminoid species and/or taller, woody species. Research has shown that resistant vegetation types tend to be dominated either by tall, woody shrubs or graminoids that grow in bunches or as a turf.

The most significant impact of recreational disturbance comes from areas of rare or endangered species. Two such examples are the trampling of Robbin's cinquefoil (*Potentilla robbinsiana*) populations along hiking routes in the White Mountains of New Hampshire and recreational trampling of Missouri bladderpod (*Lesquerella filiformis*) in Missouri (Thomas and Willson 1992).

The intense root system of chaparral species extends well beyond the immediate surrounding of the plant. The compaction of soil on the trail due to usage can affect the survivability of plants adjacent to the trail even if they don't sustain direct trampling.

Again, the damage and subsequent changes in trailside vegetation is affected by trail usage type. In addition, grazing pressure and nitrogen availability (in the form of manure and urine) are greatest near trails used by animals (Dale and Weaver 1974).

Animals

The presence of trails can affect animal community and structure. In the Perinet Nature Reserve in Madagascar, trail creation and subsequent vegetation trampling has created microhabitats that are not only unsuitable for native endemic mammal species but also tend to favor an introduced competitor, the black rat (*Rattus rattus*), thereby upsetting the local community structure (Stephenson 1993). In Tilden Regional Park, there exist three separate mountain biking trails through the middle of protected Alameda whipsnake habitat area (Knight and Gutzwiller 1995).

Other disturbance

Disturbance as a result of trail usage can manifest itself in ways that aren't physically obvious. Heavy use of trails by human and dogs can interfere with conduits of natural animals by scents left behind (Forman 1995).   Human presence can also affect the reproductive success of organisms. Research has indicated that intrusion into natural areas by humans can potentially tamper with the seasonal timing of mating song and subsequent breeding season (Gutzwiller et al 1997).

Chapter 3

Study Area

Location

The Santa Monica Mountains National Recreation Area (SMMNRA) is located 20 miles to the west of the city of Los Angeles in southern California (fig. 3.1). SMMNRA comprises a little over 150,000 acres in a mosaic of private and public lands, extending along the range of its namesake. The SMMNRA is unique in that it serves as an umbrella organization for federal, state and local conservation agencies. Within the boundary of the park also exist urban communities and private land uses. This has created a situation where open areas are adjacent to private lands and a plethora of land uses occur side by side. True to its name, the natural areas make up a network of state, local and federal lands that are open to hiking, horseback riding, biking as well as camping. Bunched among those areas are urban, residential, industrial and on the outskirts, agricultural, land uses.

As mentioned before, fragmented landscapes such as this one have received a lot of attention in the literature in terms of metapopulation dynamics and its implications for conservation. However, preliminary research has shown that for small mammals in particular, fragmentation in the SMMNRA is not the primary influence on species diversity or community structure (Ray Sauvajot, Pers. comm.). Many of the predictive effects extolled by landscape ecologists have not been concretely verified by empirical work. Instead, research in this area as well as other studies have supported the contention

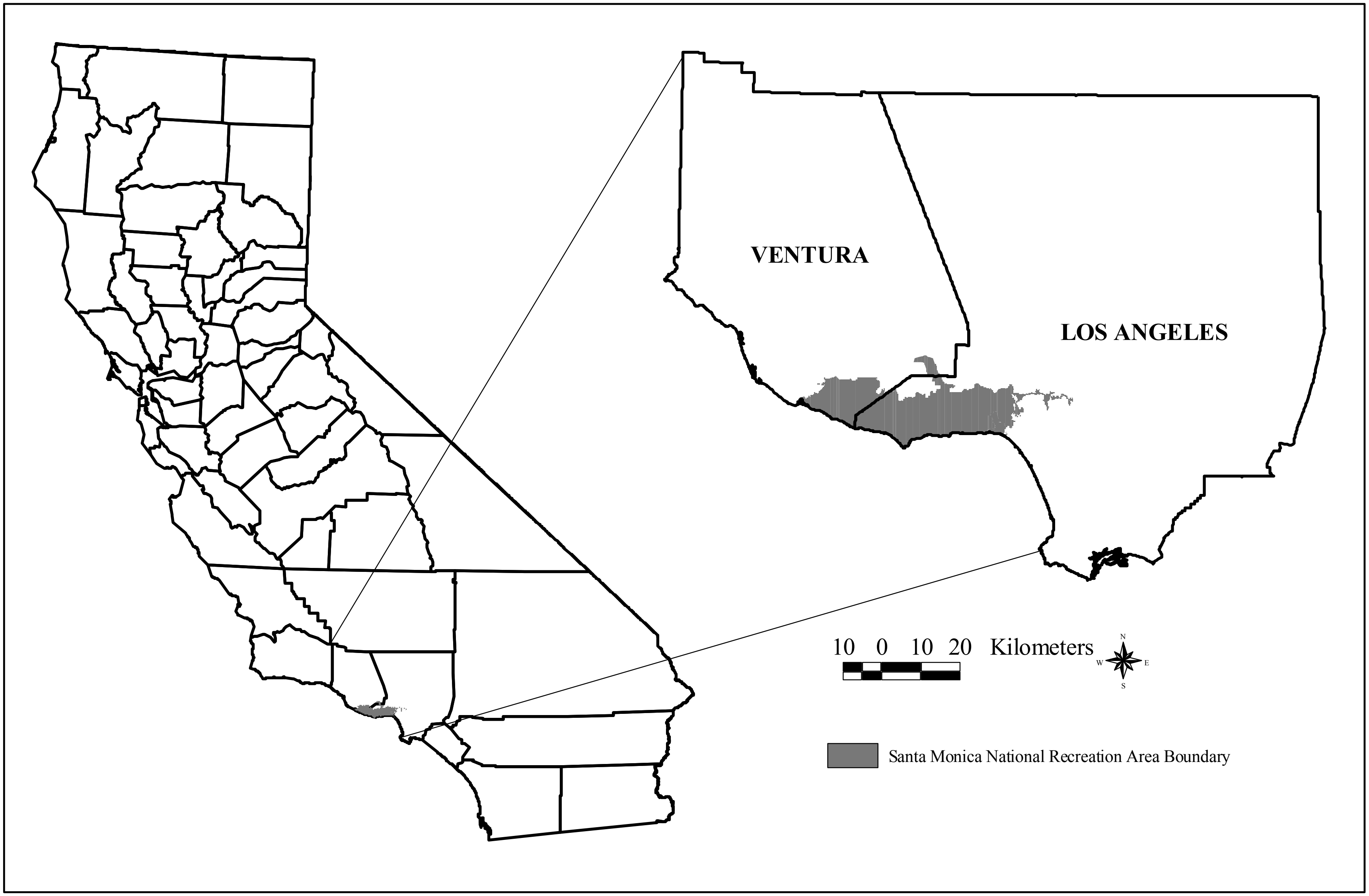


Fig 3.1 – Location of Santa Monica Mountains Recreation Area within California.

that habitat quality plays an influential role in species dynamics (Sauvajot and Buechner 1996, Dunstan and Fox 1996). Conclusions found that quality of habitat, even in sites close to urban areas, can be a greater determining factor in species dynamics than fragmentation or edge effects.

The SMMNRA is not foreign to disturbance. The natural disturbance regime of the area includes fire, landslides, intense rainfall and earthquakes. All of these events interrupt the natural sequence but especially in the event of fire, are considered routine and essential. Most pervasive on the landscape in both a spatial and temporal sense, have been anthropogenic disturbances. The most permanent and damaging have been the continual development of the land for urban, residential and agricultural purposes. Given the large amount of development over the years, the SMMNRA can still boast a substantial amount of open space (fig 3.2). Proportionately, developed areas account for 12.8% of the total SMMNRA area with agriculture contributing only another 0.15% of total acreage. Most of the area of the SMMNRA is not developed, with the majority of anthropogenic land uses occurring in lower elevations (along the coastal areas and in the metropolitan area of Los Angeles lying to the east of the recreation area). These areas are densely population. While the low-lying areas only encompass one-sixth of the state's total land area, they contain over fifty percent of the state's population (Schoenherr 1992).

Not all the open space that exists within the SMMNRA are pristine natural areas. Within these areas there exists a substantial amount of small-scale disturbance. Activities occurring in this area are grading, landscaping, use of areas for off-road vehicles (ORV).

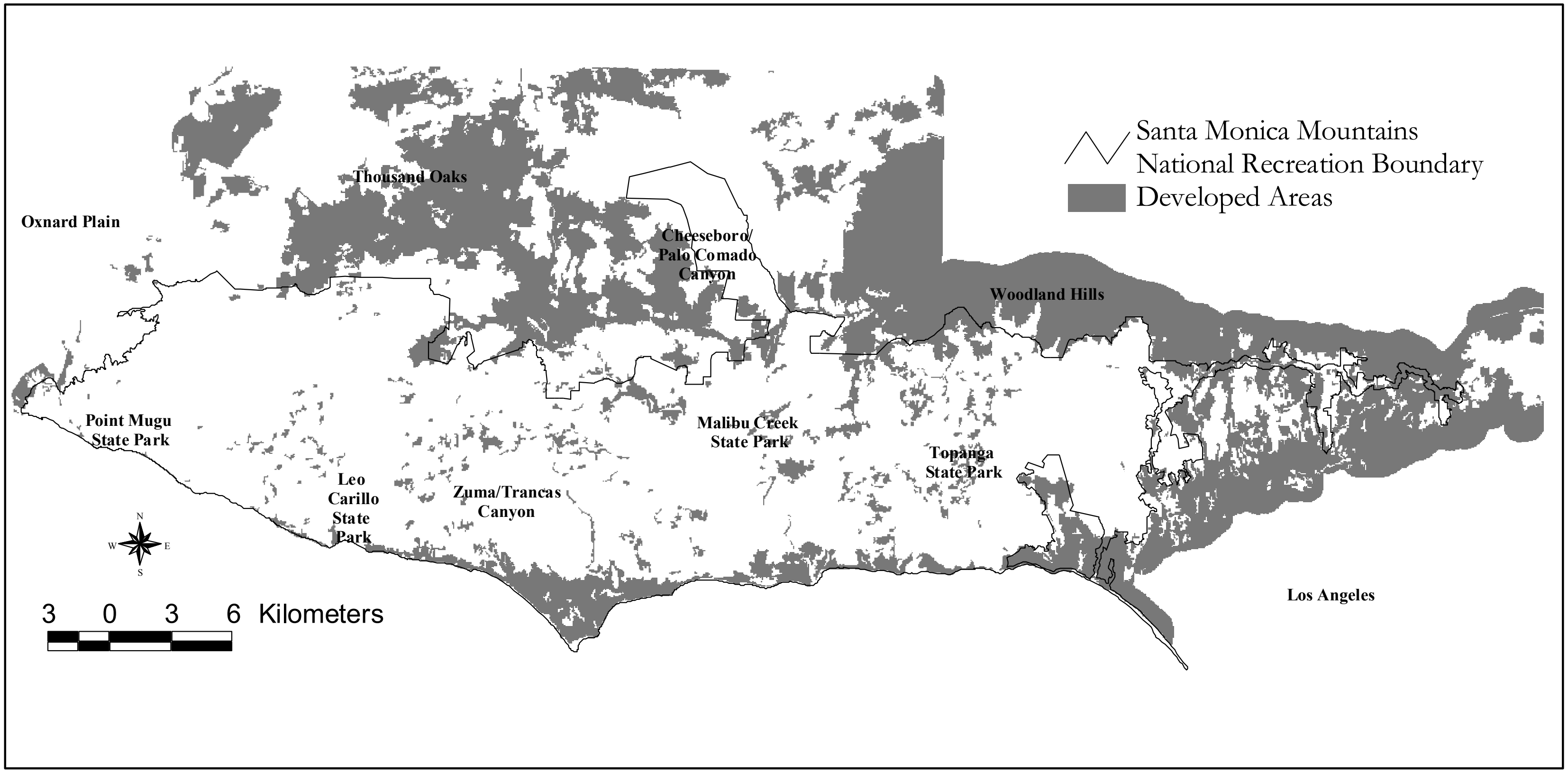


Fig 3.2 - Unshaded areas signify open areas within the Santa Monica Mountains National Recreation Area (Source: SMMNRA digital files).

The most pervasive small-scale disturbance takes form geometrically as linear disturbance. These are trails, fire roads and fire breaks. Trails (fig 3.2) are the major transportation system and the facility more commonly found in protected areas. The purpose of this study is to examine more closely what potential effects trails have on the immediate chaparral vegetation communities.

The obvious effects of trails are noticeable to the eye. The first and foremost is bare ground. With the exception of a few stragglers, vegetation is completely removed from the trail, leaving the soil exposed. The SMMNRA contains many soils, which range in the moderate to very-high erosion categories (USDA 1967). Soil denudation combined with a short, but often intense rainy season, commonly results in landslides.

Soil erosion is compounded by soil exposure and rough usage of the terrain. A visual survey of trails, especially those that allow multiple usage (hikers, bikes, and horses) show moderate to deep crevices etched into the trail path by water erosion.

Physiography

The Santa Monica Mountains are the southern-most range of the transverse ranges. The Santa Monicas stretch from Griffith Park on the east, to Pt. Mugu at the western tip. The total distance from east to west is about 74 kilometers, with the average width being 12 kilometers. The highest point in the range is Sandstone peak at 948 meters. The average elevation is 304.8 meters.

The Santa Monica Mountains lie in an almost straight east-west direction. This anomaly is a result of the northward motion of the Pacific plate along the San Andreas Fault (Schoenherr 1992). Only two other ranges in the California, the San Bernardino Mountains and the San Gabriel Mountains which are also located in Southern California, have this orientation. Along the southerly base of the range lies the Pacific Ocean. The highest peaks of roughly 914 meters lie within 4-6 kilometers of the ocean (Bauer 1936).

Geology

The mountains are generally an uplifted faulted and folded east-west trending block. The major up-fold or "anticline" has a greater uplift along the axis at the eastern end of the range. Santa Monica slates characteristically dominate the eastern end of the park, considered the Coldwater and Franklin areas. Granites have intruded these slates. The slates were originally deposited as marine muds during the Jurassic period about 140 mya. The shale formation was then intruded about 120 mya by molten rock to form granites.

Slates and granites are also found in Topanga State Park but are buried under a younger layer of sandstones. About 14 mya the covering of the area by the sea left behind a deposit of thick-bedded sandstone that predominates in this park. In the western part of the range igneous rocks, both intrusive and extrusive (volcanic) are seen in many places.

Soil

All of the soils that the trails passed over had high erodibility and moderately slow to slow permeability (Edwards et al 1970, USDA 1967). The majority of soils in the Santa Monica Mountains are unstable and with removal of vegetation easily erode during the heavy storms that occur during the winters.

Soil	Permeability	Degree of soil limitation for path/trail
Gsf – Gilroy rocky clay loam	Moderately slow	severe
Hrf – Hambright Rocky Clay Loam	Moderately slow	severe
MnF – Millsholm Loam	Moderately slow	severe
SR – Sedimentary rockland	Moderate	severe

Table 3.1 – Summary of erosion characteristics for site location soils.

Climate

The climate of the area is typically mediterranean with dry, hot summers (mean 21.8^{o}C) and cool, wet winters (mean 12.8^{o}C). Topographic features such as the proximity of the ocean cause local variations in the physical conditions, slope exposure, slope gradient and elevation. In Los Angeles the average precipitation is 38 cm/year but wetter in the mountainous areas receiving as much as 76.2 cm/year. The bulk of the precipitation comes during the period from November to April (90%). Precipitation in areas near ocean at the south base of the mountain: 33-48 centimeters (Bauer 1936). Precipitation in areas within the mountainous area: 53-76 centimeters. Precipitation at north base of mountain: 46-50 centimeters. Altitude is of less importance than distance from the ocean in influencing rainfall (Bauer 1936).

Aspect affects the amount of rainfall received. Northerly and easterly slopes tend to receive about 20% more rainfall overall than westerly or southerly (66 cm as compared to 56 cm per year). Bauer (1936) asserts that the different amounts of rainfall contribute considerably to the differences in vegetation.

Vegetation

The Santa Monica Mountains boasts a rich diversity of plant species. The total number of species in the Santa Monica Mountains is 805 with 25.6% of those exotic (Raven and Thompson 1986). These species are grouped into several different types of vegetation communities in the Santa Monica Mountains (table 3.1).

Vegetation Community	Area (m)	Percentage
coastal dune/bluff scrub	8668800	1.05%
coastal sage scrub	273619800	33.15%
coastal sage scrub-chaparral transition	4288500	0.52%
northern mixed chaparral	414370812	50.20%
red shank chaparral	3332700	0.40%
chamise chaparral	16560000	2.01%
coastal cactus scrub	6104700	0.74%
non-native grassland/herbaceous	48546000	5.88%
salt marsh	1931400	0.23%
valley oak	5905800	0.72%
coast live oak	24050700	2.91%
walnut	1286100	0.16%
riparian (Sycamore-Oak)	11696400	1.42%
non-native conifer/hardwood	253800	0.03%
coastal strand	4860000	0.59%
Total	825475512	100.00%

Table 3.2 – List of vegetation communities and area (m) occupied in the Santa Monica Mountains area (data from NPS digital vegetation coverage).

Chaparral constitutes one of California's most common vegetation communities, making up 4.9 million hectares. Four different types of vegetation associations are recognized as chaparral communities (table 3.2). All are characterized by dense scrub vegetation. These associations are coastal sage scrub, northern mixed chaparral, chamise chaparral and red shank chaparral.

All sites were located in mature northern mixed chaparral communities. Northern mixed chaparral is the most pervasive native vegetation community in the SMMNRA (fig 3.3). Northern mixed represents 51% of the total park area and comprises 62.2% of all vegetation (calculated from digital vegetation data). This association is defined as vegetation communities where *Adenostoma fasciculatum* (chamise) is codominant with typically forty percent cover with one of the following: *Ceanothus* (California lilacs) spp., *Quercus dumosa* (Coast live oak)*, Arctostaphylos spp*. (manzanita) (Holland 1986). The classification groups considered under the umbrella of northern mixed chaparral are listed in table 3.3 (Holland 1986). *A. fasciculatum* is the most common of the chaparral shrubs, occurring in 70% of all chaparral stands in southern California (Hanes 1971).

Chaparral habitat

Chaparral is composed of dense, intertwining, evergreen shrubs ranging on average from 1-3 meters in height. Mature chaparral is composed of one layer with no understory. Chaparral vegetation communities tend to grow on steep slopes with coarse textured, shallow soils. The presence of chaparral species tends to indicate a relatively thin, gravelly and well-drained soil. The range of this vegetation is from northern Baja to Oregon (Hanes 1971).

Fig. 3.3 – Mature northern mixed chaparral vegetation dominated by *A. fasciculatum*.

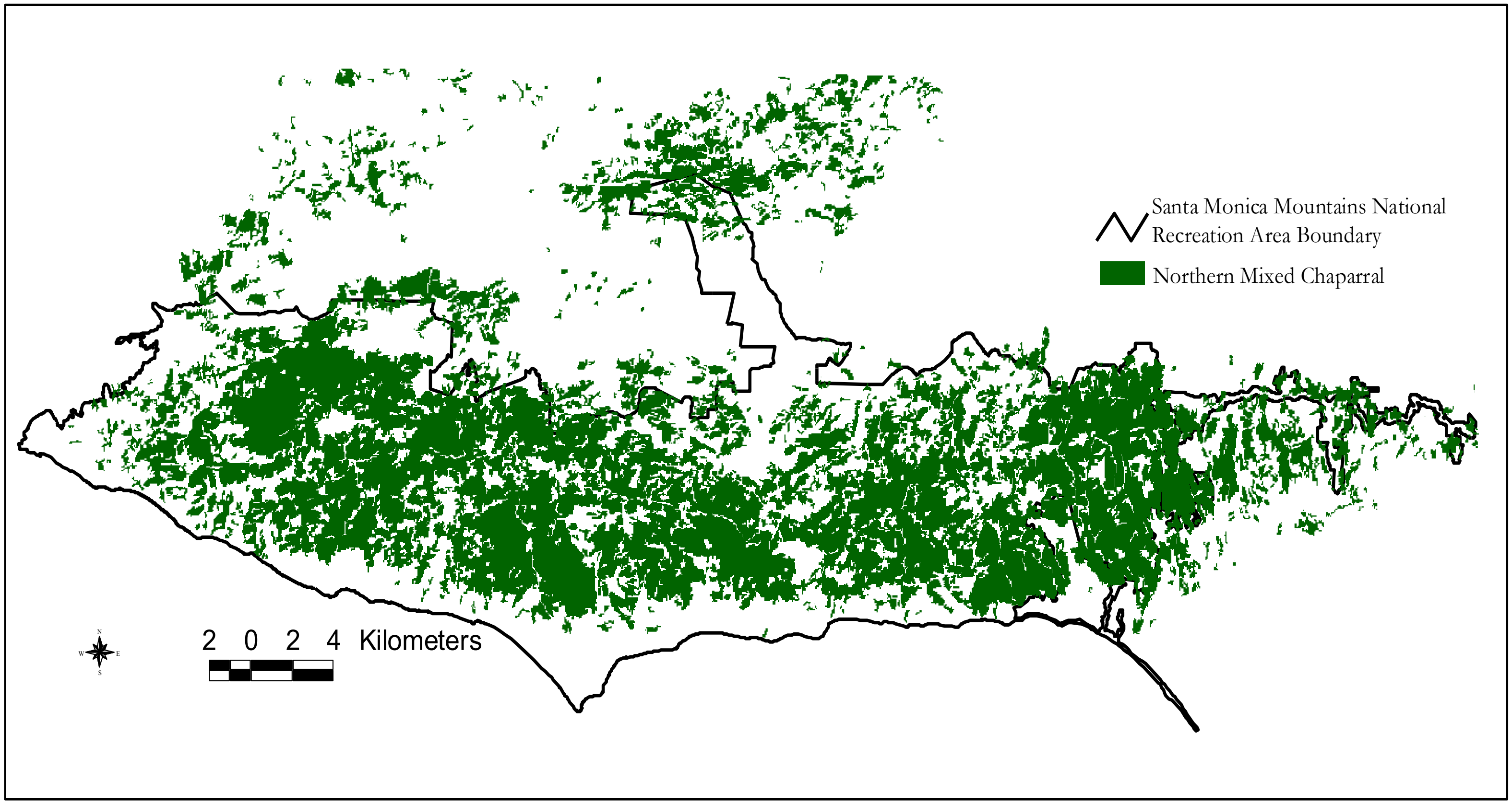


Fig. 3.4 – Distribution of northern mixed chaparral in the Santa Monica Mountains (Source: NPS digital files).

Northern Mixed Chaparral	Buck Brush Chaparral	C. crassifolius Chaparral	C. megacarpus Chaparral
37110	37810	37830	37840
Adenostoma fasciculatum	Adenostoma fasciculatum	Adenostoma fasciculatum	Adenostima fasciculatum
Aesculus californica	Ceonothus cuneatus	Ceonothus crassifolius	Arctostaphylos gladulosa
Arctostaphylos glandulosa	Garrya fremontii	Heteromeles arbutifolia	A. glauca
A. glauca	Heteromeles arbutifolia	Quercus dumosa	Ceanothus megacarpus
A. viscida	Quercus dumosa	Rhus ovata	C. sponosus
Ceanothus cuneatus	Rhus diversiloba	Ribes malvaceum	Cercocarpus betuloides
C. greggii			Eriogonum fasciculatum
C. leucodermis			E. parvifolium
C. velutinus			Hazardia squarrosa
Cercis occidentalis			Helianthenum scoparium
Cerocarpus betuloides			Prunus ilicifolia
Eriodictyon californicum			Malosma laurina
Fraxinus dipetala			Salvia mellifera
Fremontia californica			Yucca whipplei
Pickeringia montana			
Prunus ilicifolia			
Quercus chrysolepis			
Q. dumosa			
Q. wislizenii			
Rhus ovata			
R. tribolata malacophylla			
Toxicodendron diversilobum			

Table 3.3 - Vegetation associations of Northern mixed chaparral (from Holland 1986).
Table 3.3 – Species list for each vegetation association for Northern Mixed Chaparral.

Disturbance

Fire

The most devastating of natural disturbance in the Santa Monica Mountains, fire destroys all above ground vegetation. Set by lightning under dry and hot conditions, fire disturbance is a natural cycle in chaparral regeneration. Senescence in chamise chaparral can aid fire spread with interior shrub temperatures reaching over 31.5^{0} C and the release of combustible gases (Schoenherr 1992). Natural chaparral fires occur on average every 20-30 years.

Soil slip and landslides

Soils slip is thought to cause the greatest quantity of earth displacement in the Los Angeles area (Campbell 1975). Soil slips is most common in mountainous areas that experience heavy periods of rain (Campbell 1975). Soil slip is defined as the movement of earth along a planar or curved saturated base that leaves a well-defined head scarp. A wedge shaped or elliptical scar on the involved hillside is produced as a result. Soil slips are smaller, shallower, and more common than landslides. Landslides tend to occur following storms as pore pressures accumulate to greater depths (Campbell 1975).

Post-disturbance vegetation

Pre-fire mature chaparral is dominated shrubs *A. fasciculatum* and *Ceanothus* ssp. Stassforth's report (1995) found *A. fasciculatum* had the highest average density with 0.54 individuals per square meter. The event of fire destroys most above ground growth.

The initial successional phase of chaparral recovery starts with a flush of herbaceous annuals and short-lived perennials (Horton and Kraebel 1955). Some of these germinate from seeds stimulated by heat, and others from chemical compounds released by charred wood (Keeley 1984).

After a few years, the shrub species that occupied the area pre-burn event reestablish their dominance and the herbs disappear, unable to compete with these vigorously growing shrubs for nutrients, moisture and light (Stassforth 1991). The majority of chaparral shrubs regenerate after fire by root-crown burls (lignotubers). In cases where the shrub is killed, germination by seed is a second strategy.

Chaparral succession is considered an autosucessional process; all species are present at the beginning of the cycle immediately following the fire event. Herbaceous species germinate from bulbs and seeds previously dormant in the soil bank. Over time, less competitive species drop out as the post-fire crownsprouting of the chaparral shrubs crowds them out. Canopy closure of more dominant shrubs occurs after five to ten years (Horton and Kraebel 1955).

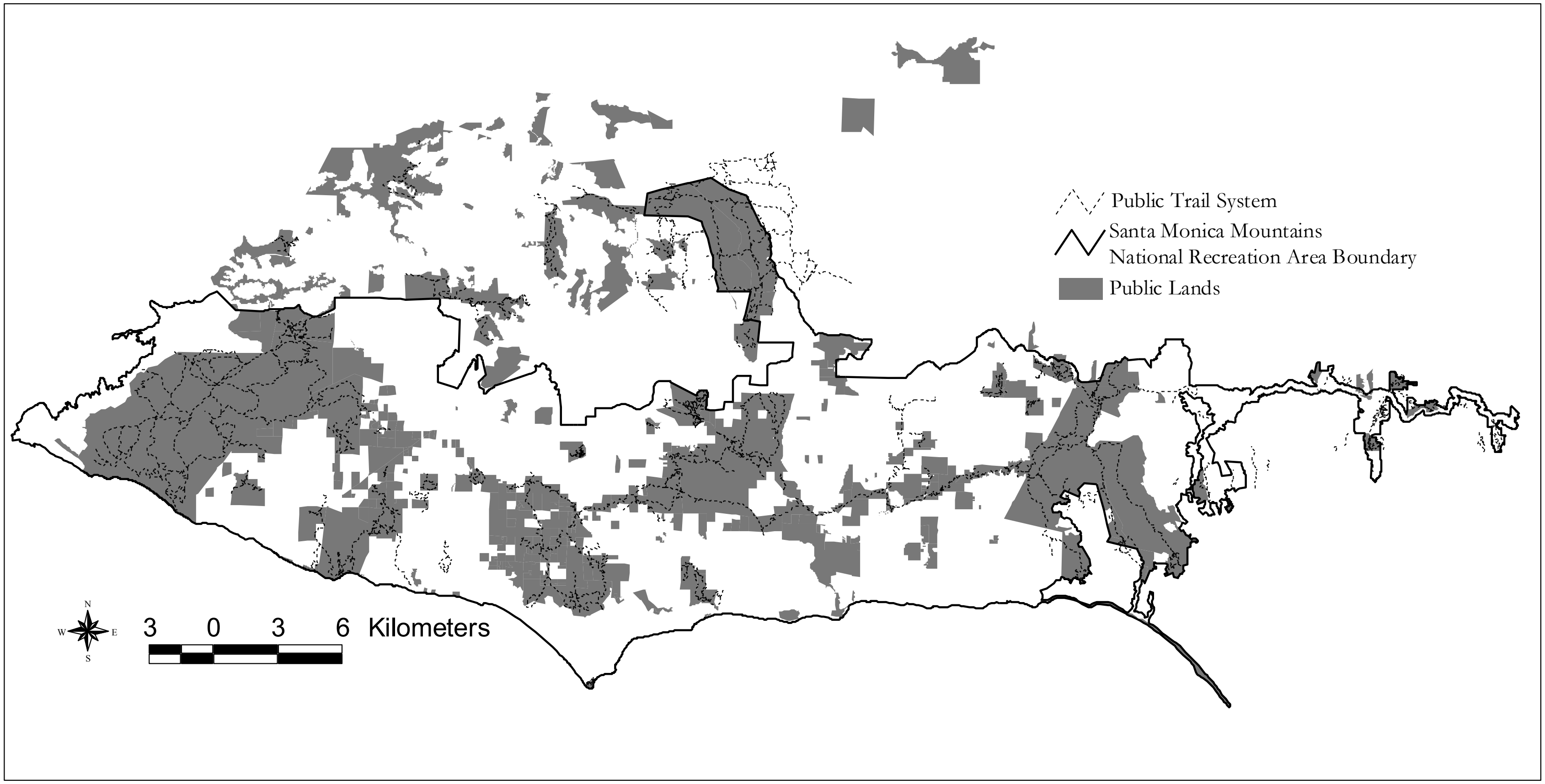


Fig. 3.5 – Public trail system in the Santa Monica Mountains National Park Service. Trail data from NPS digital files.

Chapter 4

Methodology

Study Sites

As stated in the introduction, the objective of this thesis is to determine the effects of trails on the surrounding vegetation community. In order to reduce influencing factors and to minimize natural heterogeneity, similarity between sites in terms of topography was attempted.

Site Selection

Northern mixed chaparral can be found in many successional phases as a result of disturbance, the most common disturbance being fire. Therefore, sites were located in areas where trail presence was the only known disturbance. In order to avoid differences due to fire recovery, only areas that had not burned within the last ten years were selected. In addition, all sites were located in areas that were not previously grazed as to eliminate potential influences of cattle on vegetation composition that are independent of trail presence. Sites were also located in areas that are undisturbed by other impacts (e.g. housing, campsites). The end objective was to locate sites in mature aged stands of northern mixed chaparral.

All sites were selected based on similar aspect. Only sites that had a northerly direction were chosen. A northerly direction was defined as having an aspect ranging from 0 – 45 degrees or from 315 – 365 degrees. Ridges were avoided due to topographical differences in vegetation structure. Also, sites where the presence of overhanging chaparral branches constituting one hundred percent vegetation coverage over the trail were avoided due to differences in trailside light availability compared to other sites. Sites in prohibitively steep topography were not chosen for practical purposes.

The second factor in site selection was to pick three areas that met each type of trail usage and location. The first category was on trails that are restricted in use, i.e. allowing only hikers. To ascertain the hiker only status of trails, sites were first located digitally by isolating trails designated as hiking only. Once those transect sites had been located, confirmation of this status was ascertained by looking for the absence of tell tale

Fig. 4.1 – Location of areas where fire has burned within the last 10 years (1988 – 1998) (Source: NPS digital files).

signs of biking and horseback riding activities. For biking this meant tread marks, and for horseback riding this entailed hoof marks and presence of fecal matter. The second class were trails that are available for all types of recreational trail use, i.e. horseback riding, biking and hiking. For multiple use trails, only trails that allowed all three main activities, hiking, biking and horseback riding were considered. None of the transects were controlled for the presence of dogs. Based on previous observations, few people heeded dog regulations at any of the various agencies that maintained the parks. In areas where dogs were permitted, few individuals observed the leash laws, allowing their dogs to freely wander off the established trails. Even in areas such as the state parks where dogs are expressly prohibited are these regulations rarely observed. While performing transects at the Malibou Lake and Bulldog Motorway sites (both located within Malibu State Park), I observed several dogs that passed by.

In addition to selecting trails based on usage, I also select trails that were located near urban areas in order to compare them with trails located a significant distance within a park to compare the edge effect of anthropogenic influences. Sites were considered remote that existed more than 500m from the trailhead. Near urban areas were located within 300m of a development.

Using GRID (a vector based analysis platform within the Arc/Info GIS program) all possible northern mixed chaparral sites that met the above criterion were selected and confirmed with a visual check of the area. The fire database only stored coverage for fires greater than 100 acres so sites were visually verified for any signs of a recent (within the past 10 years) burn. Other signs of disturbance such as slope failure or soil creep were also checked for.

Site Locations

The following are brief descriptions and maps of each site. Where noted, information was taken from McAuley (1991). Additional information about aspect, elevation, soil, time of last burn was taken from digital files.

LOCATION	SLOPE (°)	ELEV (m)	Soil
AH_HOR	22	314	Hrf
BD_MUR	10	212	SR
CF_HON	24	476	SR
CR_MUN	4	221	Hrf
DH_MUN	16	280	Gsf
GT_HOR	6	467	SR
LC_MUR	24	395	Mnf
LR_MUN	4	265	Gvf
MR_MUR	8	520	SR
RT_HOR	32	535	N/A
ST_HON	9	289	HrF
TC_HON	6	116	N/A

Table 4.1 – Summary information for site locations,

Multiple Use Trails, located near urban areas:

Site 1:Dead Horse Trail - DH_MUN

This trail allows for all types of activities. The chaparral in this area is more open than in other sites. This trail is located off Entrada road with the transect located 177m from trailhead. This area last experienced recorded burns in 1925 and 1948 (McAuley 1991). The initial stretch of this trail where the transect site was located consists of solid basalt, a volcanic rock (McAuley 1991). Leading to the trail start is a disturbed grassy area consisting mostly of wild oats and barleys. The trail width was on average 70-80cm across and sparsely populated by pineapple weeds. Along the trail grew stunted forms of barley.

Site 2: Crag Motorway - CR_MUN

This trail was located near the entrance of Malibu State Park off Crag Road. The trail itself is a fire road extension and called Crag Motorway. The transect is located 228m from the gate separating the paved Crag Road from dirt Crag Motorway. This was a graded trail that allowed for horse usage. The areas leading into the trail were covered with grasses and black mustard. The transect slope lay northwest and was covered with thick vegetation dominated by scrub oak, chamise and ceanothus. The trail itself was devoid of vegetation, partially the result of periodic grading. Being a graded fire road, the average width was over 3 meters.

Site 3: Los Robles - LR_MUN

This trail is on a site designated by COSCA. Leading to the site is a disturbed area with large areas of grading. The transect is located 267m from the trailhead. The trail itself is mostly devoid of vegetation. Along the trail edge pineapple weed predominately grows. The average trail width is 2.5 meters.

Multiple Use Trails, located more than 500m from start of trailhead:

Site 4: Bulldog Motorway - BD_MUR

This transect is located 1102m from the trailhead on Crag motorway. Further along this trail, evidence of intense trail erosion was evident. Half of the trail had been completely eroded down to the parent rock and exposed networks of roots from adjacent shrubs. The trail was sparsely populated with pineapple weed and stunted growths of barley. The average trail width was 1.5 meters.

Site 5: Liberty Canyon - LC_MUR

This transect was near a horse riding ranch for disabled persons. The transect is located 1823m from the trailhead off Liberty Canyon Road. The trail itself was sparsely populated with wild oats, barley and scarlet pimpernel. The average trail width was around 1 meter. The lower hills leading up to the site were covered with black mustard. Beneath that lay a streambed with running water. The fields consisted mostly of grass species and some typical riparian species (such as *Baccharis glutinosa* (mule fat)) near the streams. The transect site itself lay almost due north and consisted of very dense, difficult to penetrate chaparral brush. The trail edge did not extend very far off the trail and was sparsely vegetated.

Site 6: Munsch Ranch Trail - MR_MUR

This transect was located 1.6km past the Munsch Ranch. Before the start of the chaparral vegetation, much of the vegetation communities were predominately grassland sparsely populated with chaparral species shrubs such as *A. fasciculatum* and *Ceanothus* spp. The trail itself was devoid of vegetation. The average trail width was 60-70 cm.

Hiker only trails, located near urban areas

Site 7: China Flat Trail - CF_HON

This trailhead was located behind the Oak Park development. The trail itself was devoid of vegetation and eroded severely in parts to exposed bedrock. This narrow trail had overhanging shrubs and averaged 30-40cm in width.

Site 8: Temescal Canyon - TC_HON

This trail seemed to be one of the most managed trails. This site was located in Palisades, adjacent to the surrounding residential area off Sunset Blvd. The trail was devoid of vegetation. The average trail width was 50-60cm.

Site 9: Social Trail – ST_HON

This social trail (i.e. a trail not officially created by park authorities but one created by residents of the adjacent community and usually designated for private use) was located coming out of a community near the intersection of Agoura Hills Road and Liberty Canyon Road. Directly preceding the trail leading out of the development was an exotic grassland area created by repeated mowing of the firebreak.

Hiker only trails, located more than 500m from start of trailhead.

Site 10: Roger's Trail -RT_HOR

This transect is located in Topanga State Park and was accessed through Temescal Canyon Gateway. The transect is located 1312m from the nearest trailhead. The trail is devoid of vegetation and had waterbars located along it to channel water and control erosion. The average trail width is 70-80cm.

Site 11: Garapito Trail - GT_HOR

This hikers only trail is located near the northern end of Topanga State Park. The last time this area experienced a major burned was in 1988. The burned area occurred slightly northeast of the transect. The surrounding areas last experienced a burned in 1961. The average trail width was 60-70 cm.

Site 12: Social trail off Agoura Road - AH_HOR

This social trail ascended out of a development community off behind Agoura Hills Road. The transect was located 591m from the trailhead. Located nearby was a fire road leading to a firebreak. The trail width average less than 0.5 meters. Various grasses such as wild oats, wild rye grew along the trail.

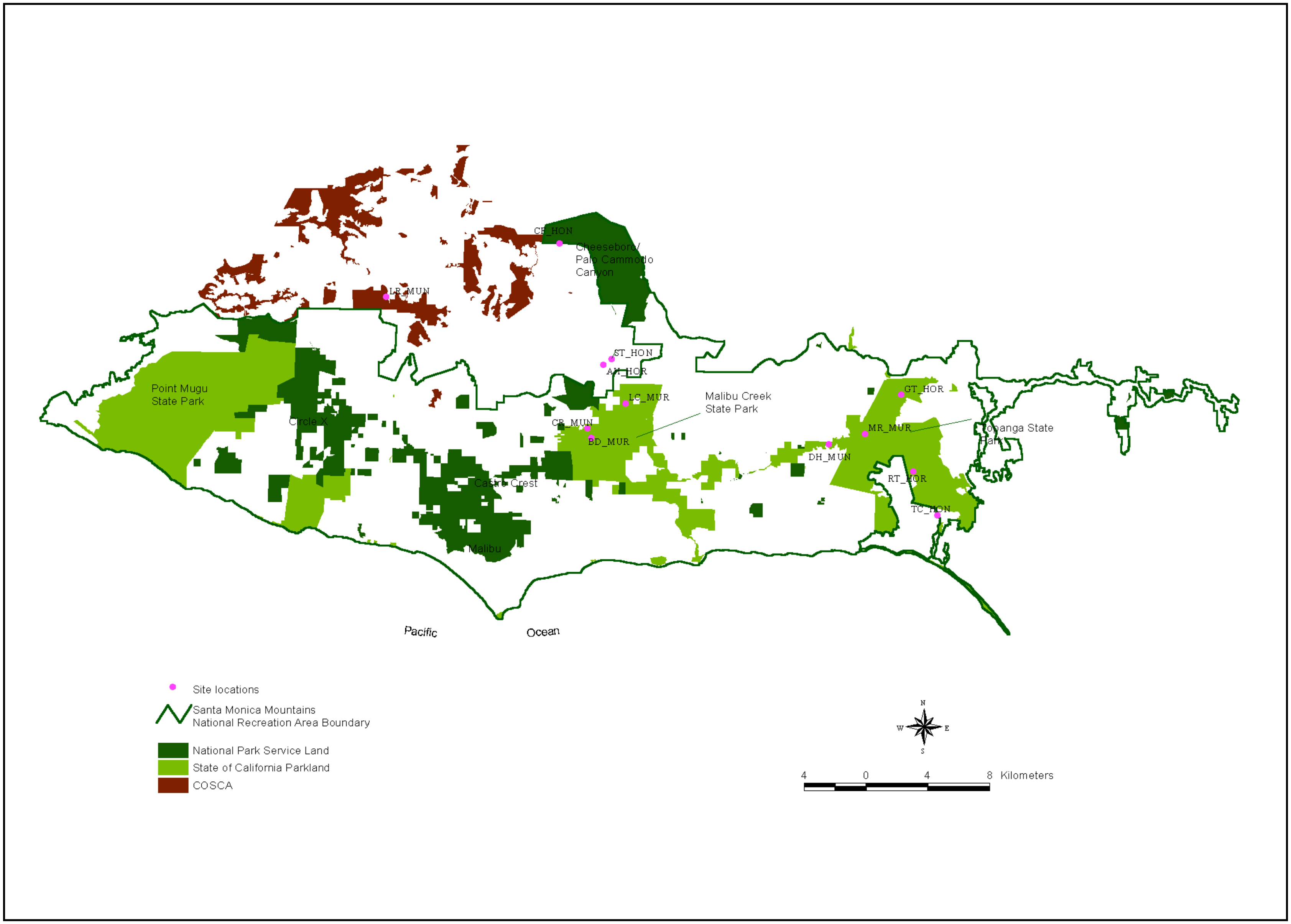


Fig 4.2 - Location of Sites.

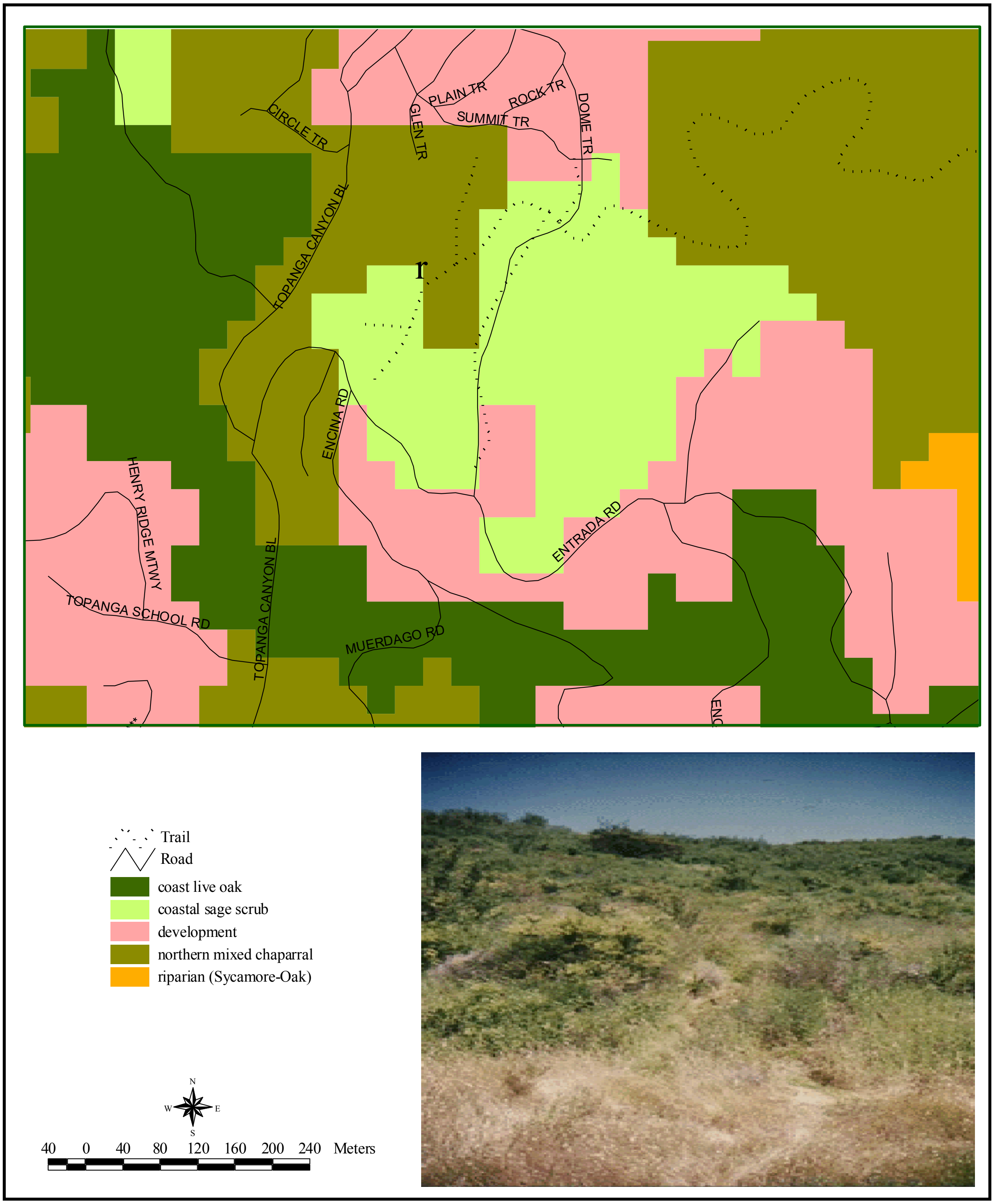


Fig. 4.3- Trail location and picture for Dead Horse Trail.

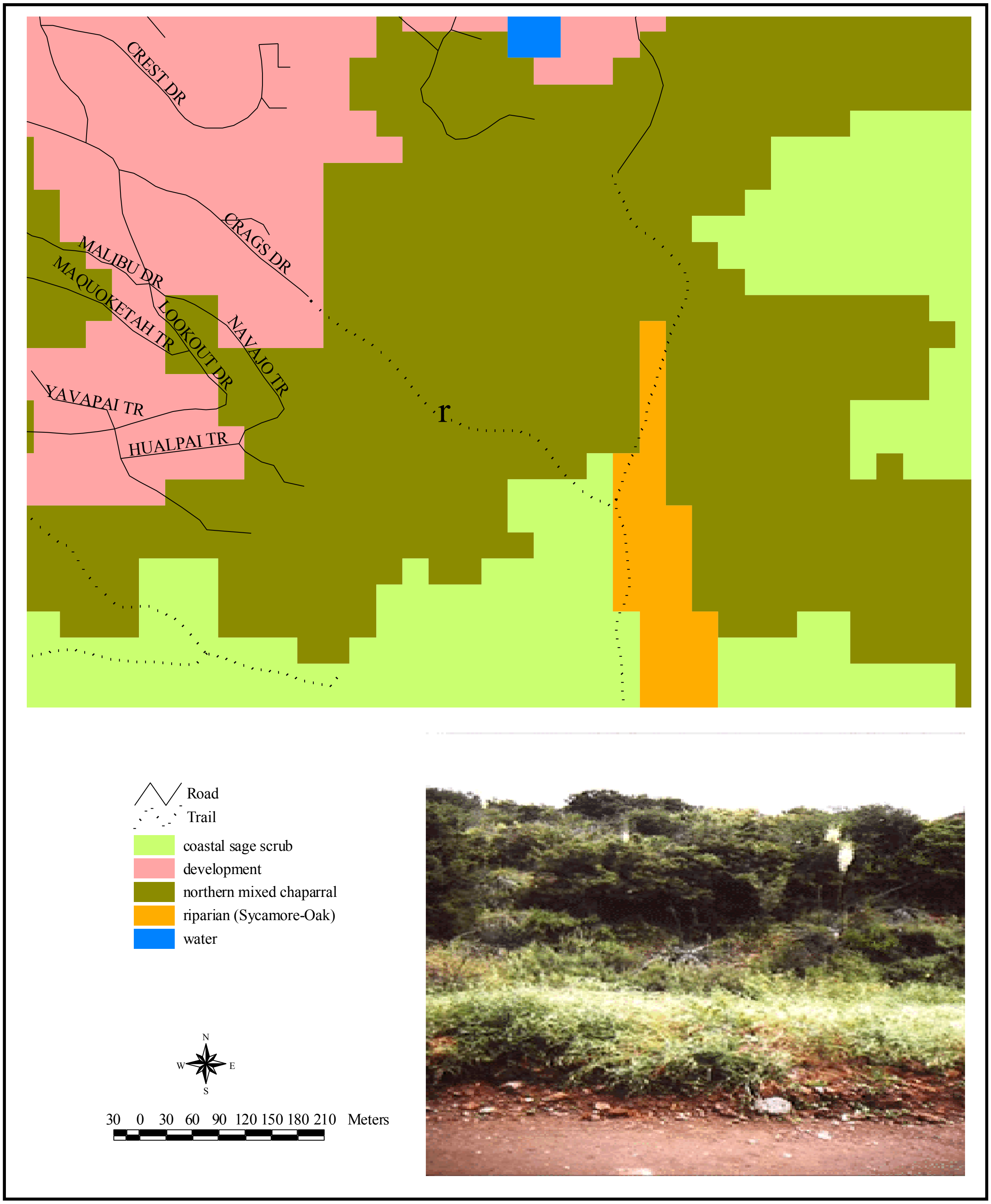


Fig. 4.4 – Trail location and picture for Crag Motorway transect.

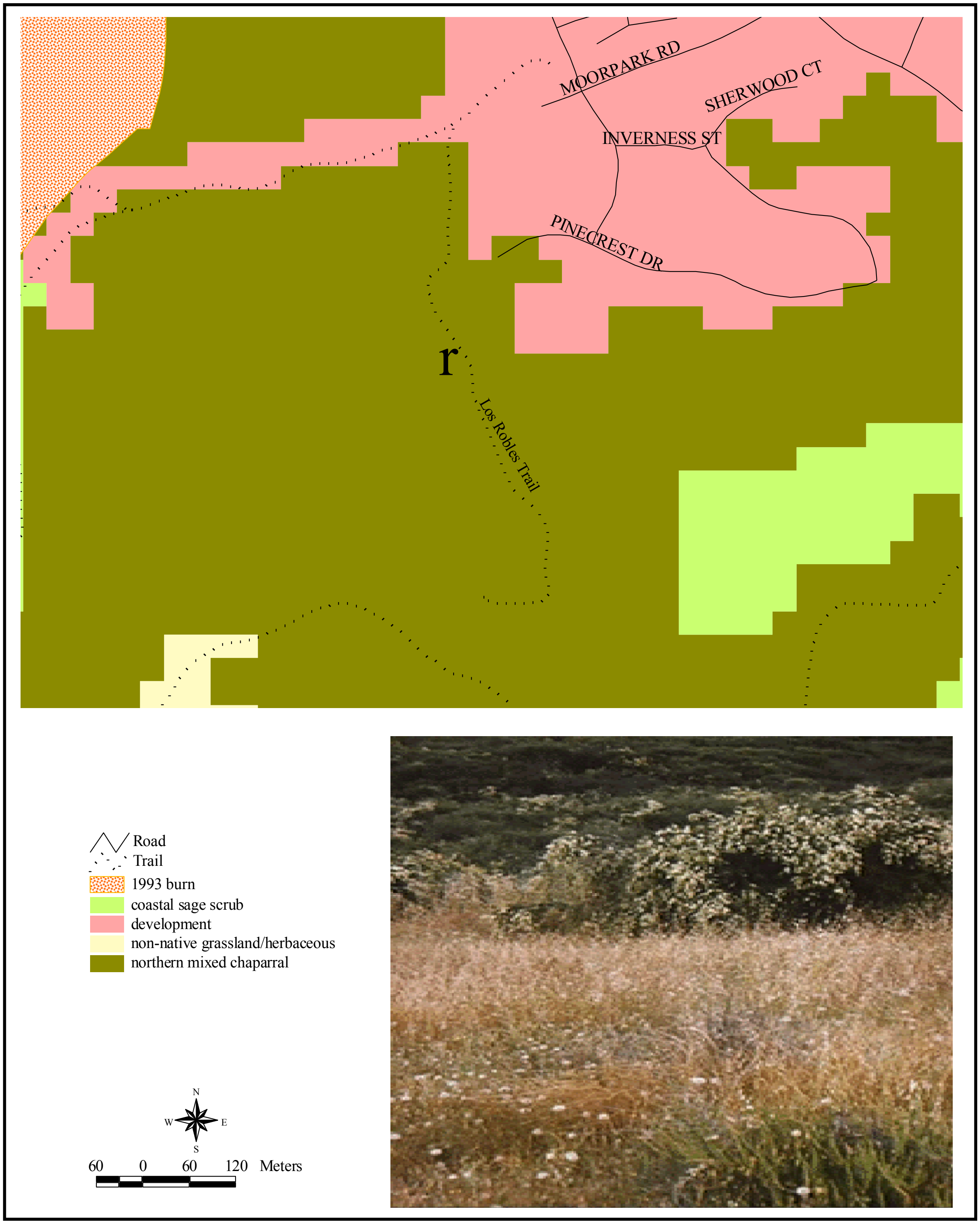


Fig 4.5 – Trail location and picture for Los Robles transect.

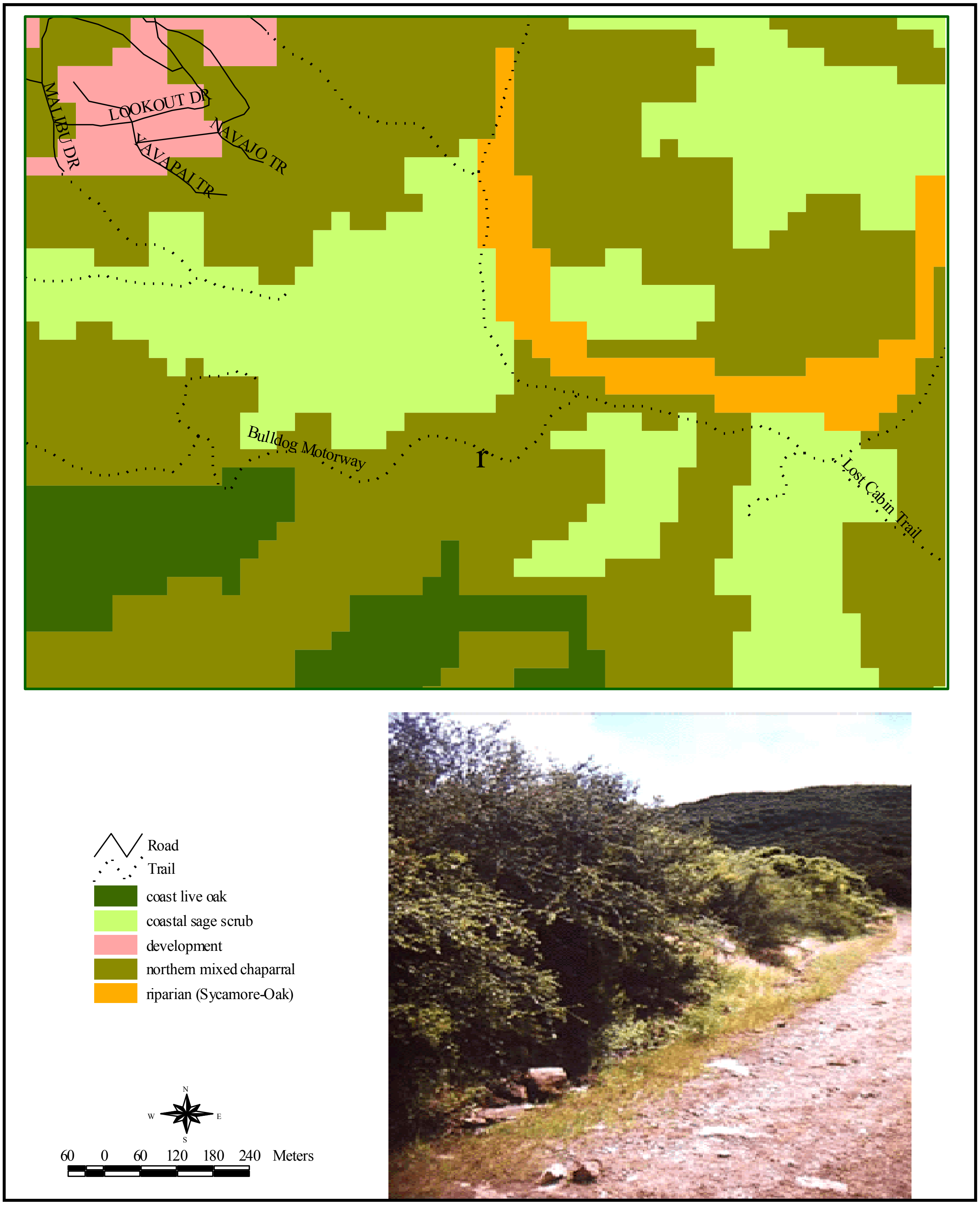


Fig. 4.6 – Location and picture for Bulldog Motorway transect.

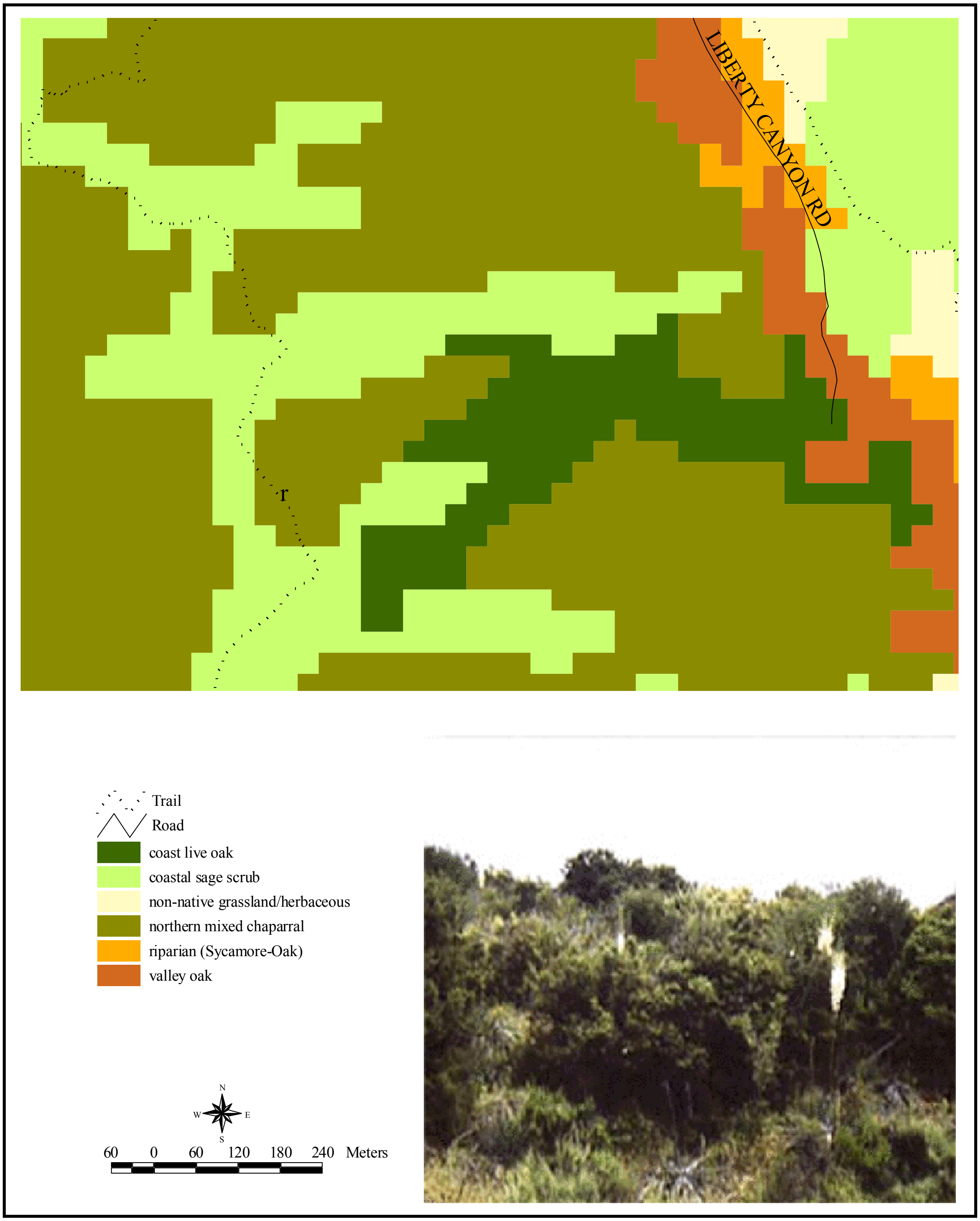


Fig. 4.7 – Trail location and picture for Liberty Canyon transect.

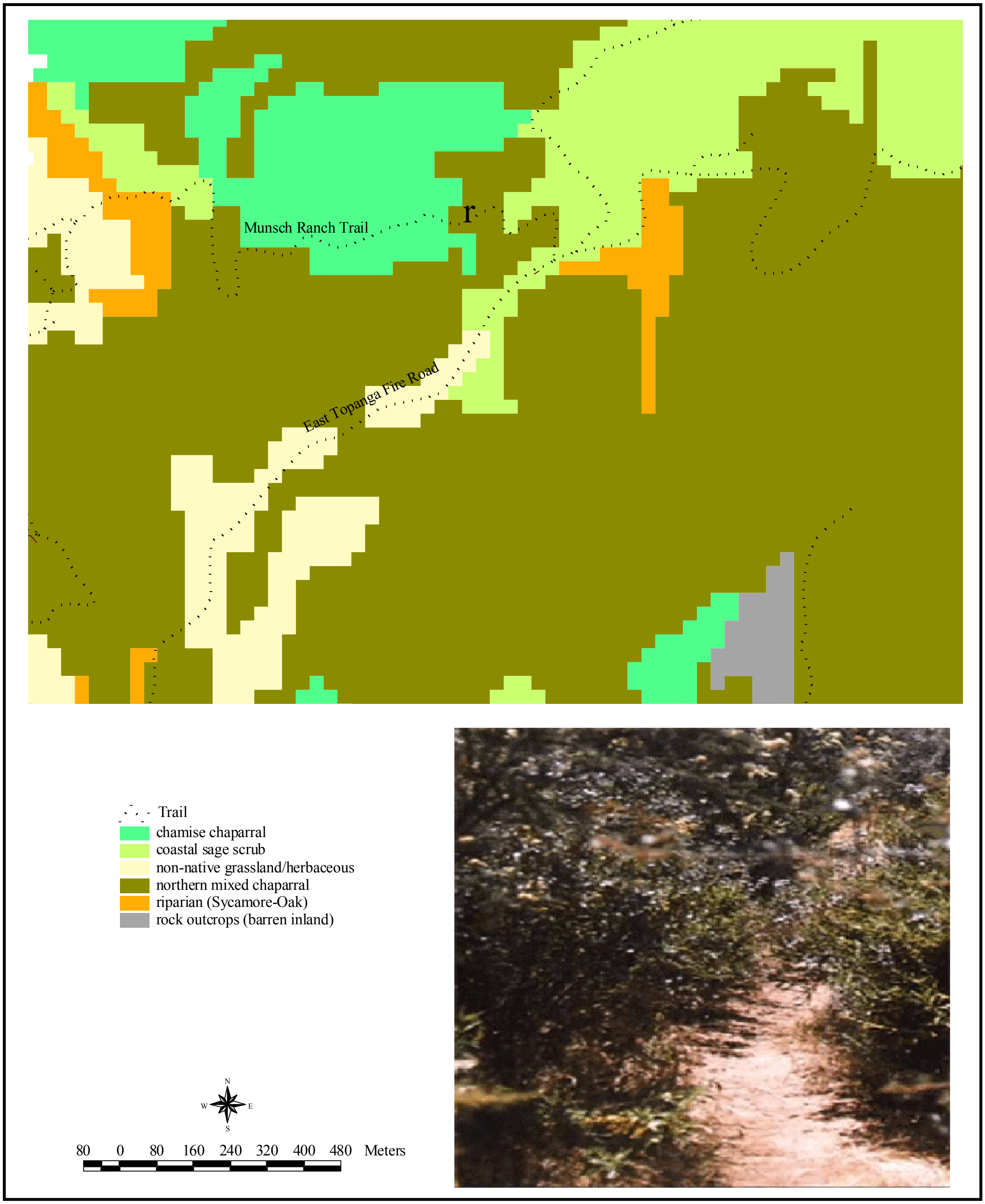


Fig 4.8 – Trail location and picture for Munsch Ranch trail transect.

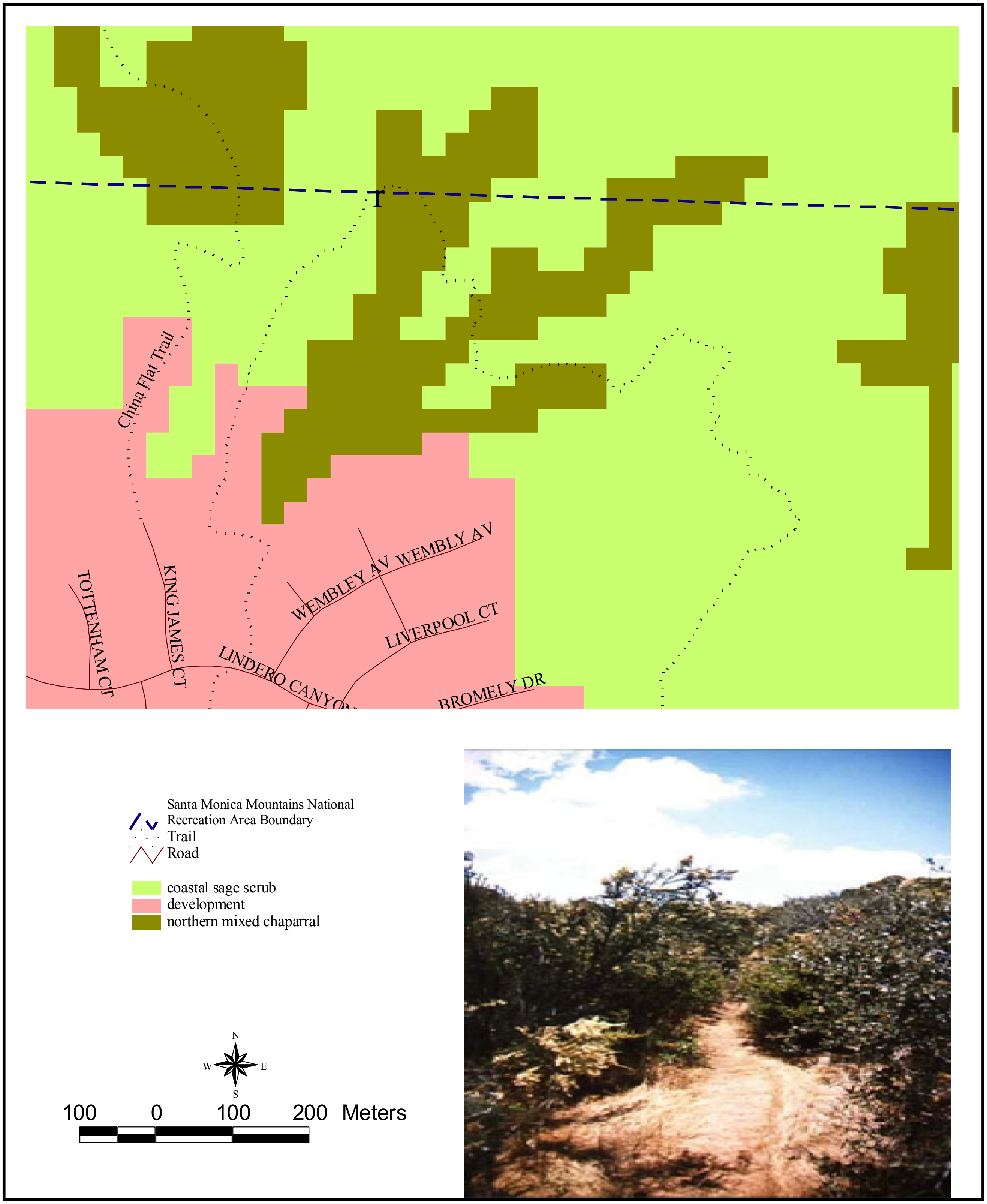


Fig 4.9 – China Flat transect location and picture.

Fig. 4.10 – Trail location and picture for Temescal Canyon trail transect.

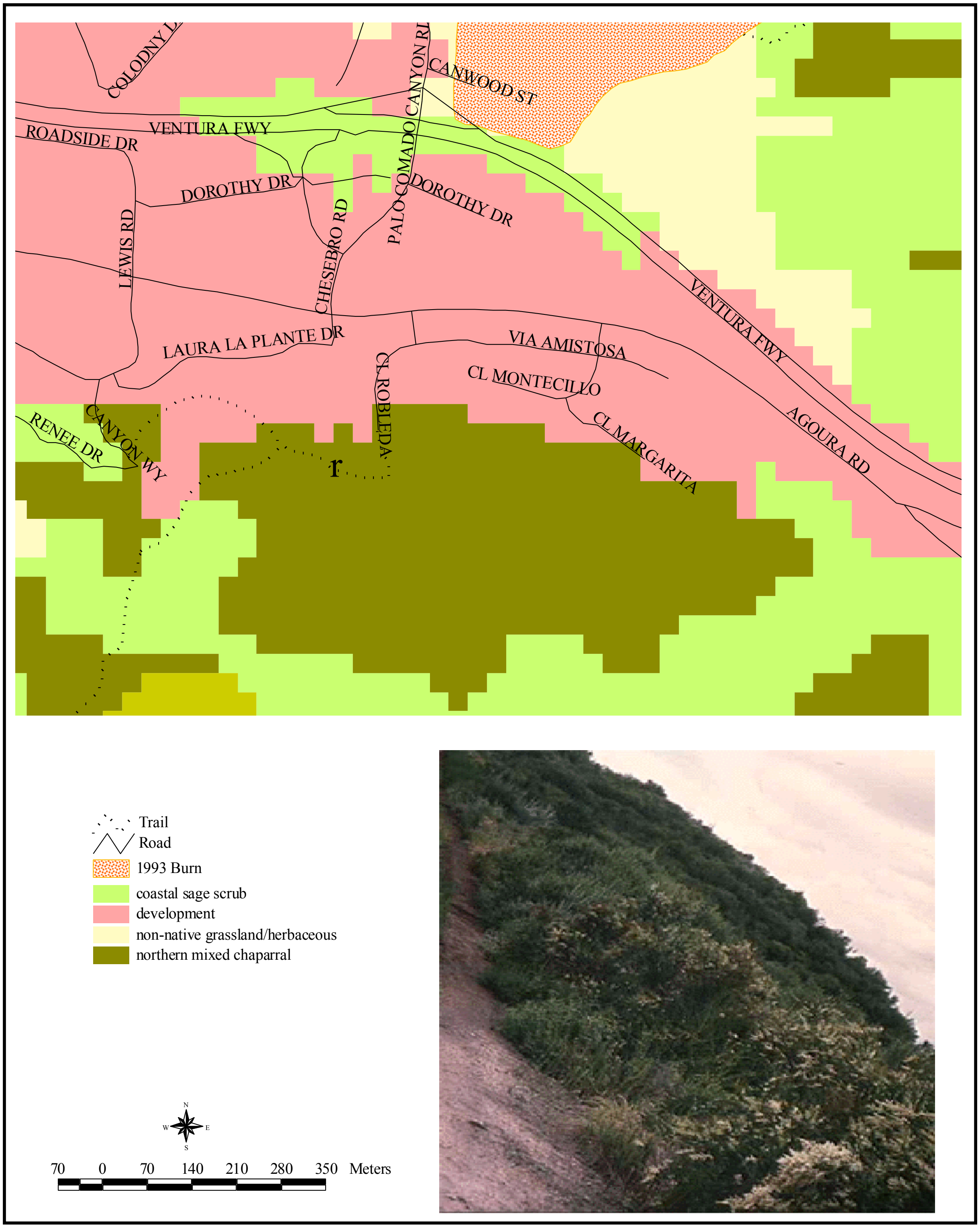


Fig 4.11 – Trail location and picture for social trail transect.

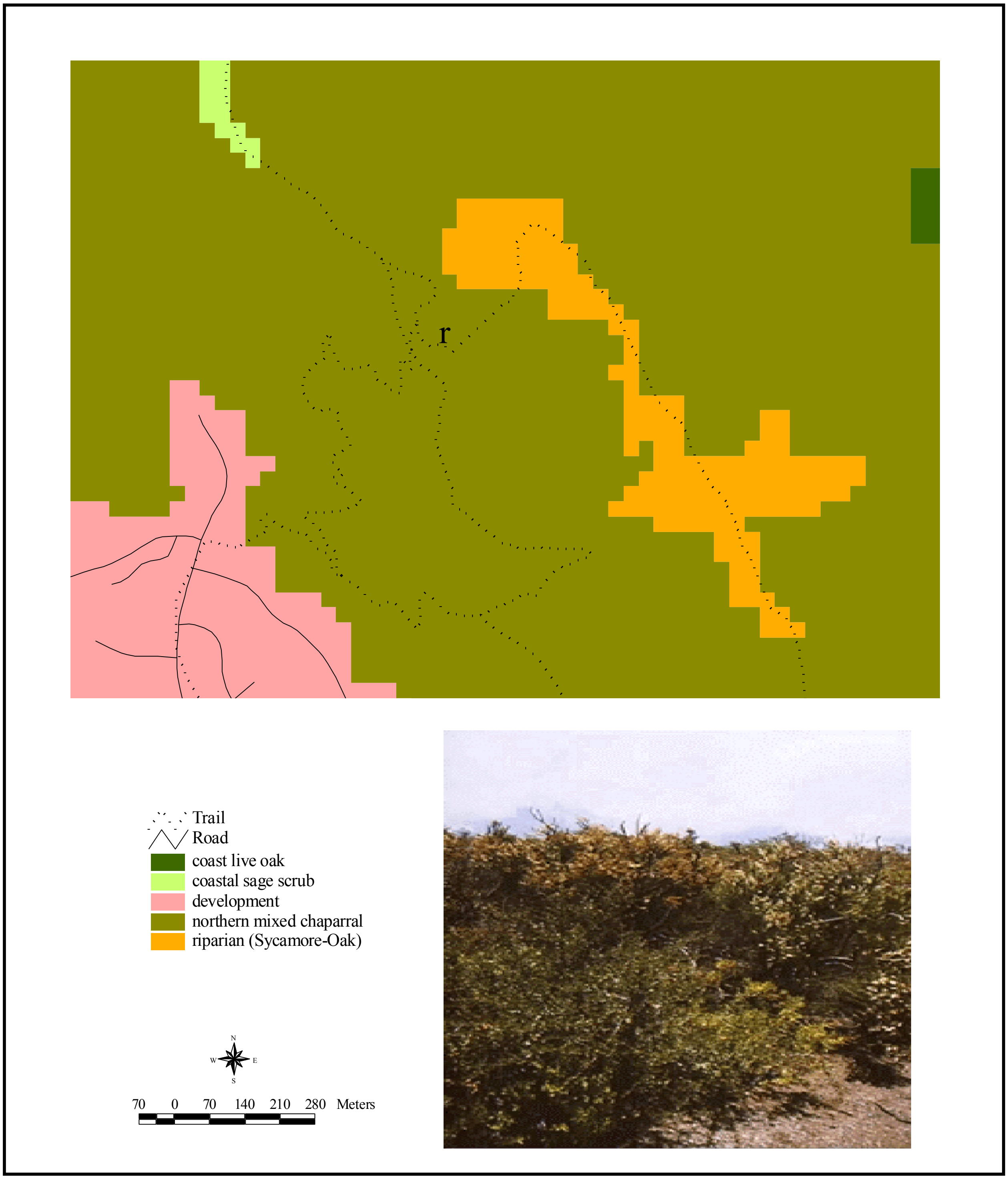


Fig. 4.12 – Trail location and picture for Roger's trail transect.

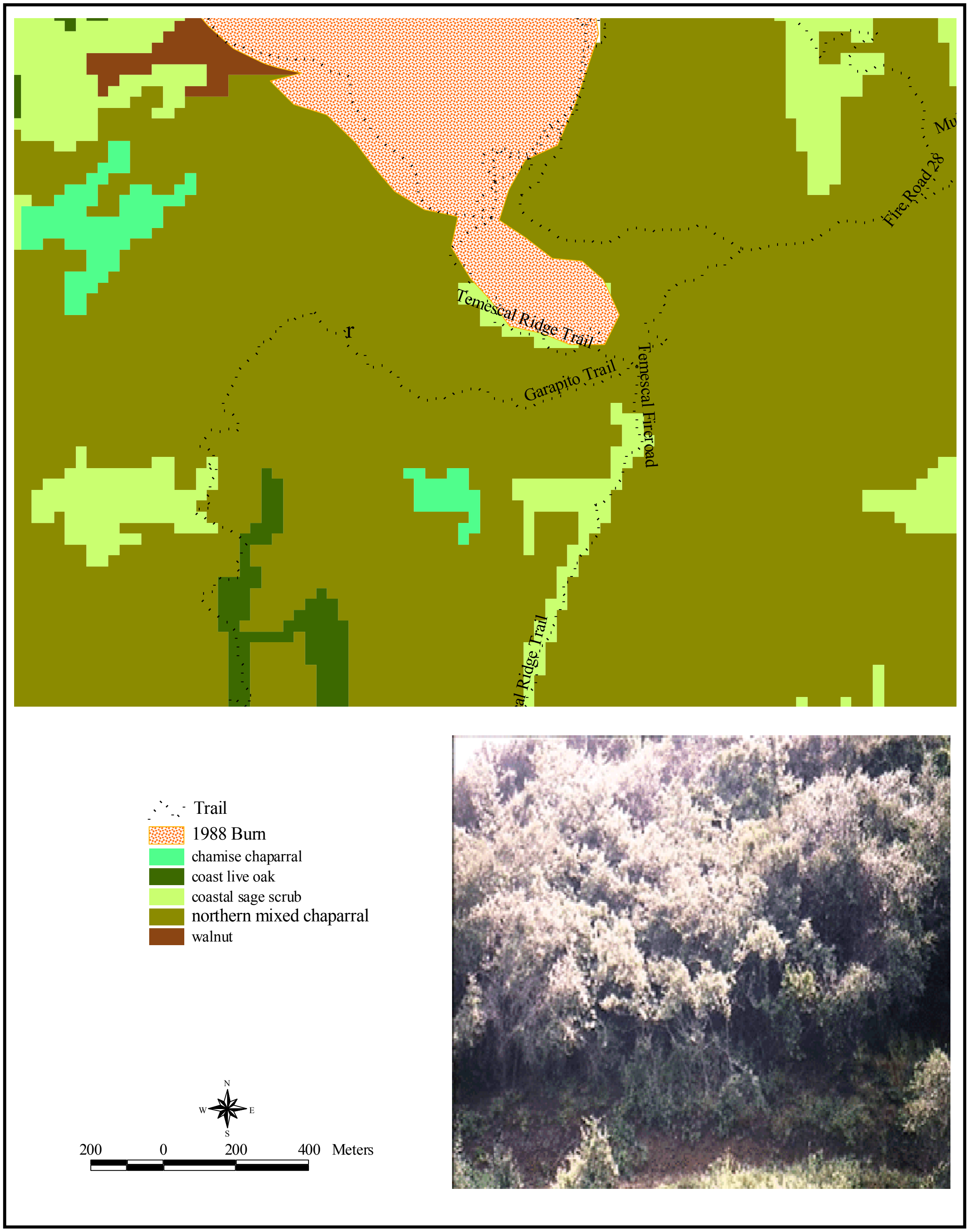


Fig. 4.13 – Trail location and picture for Garapito trail transect.

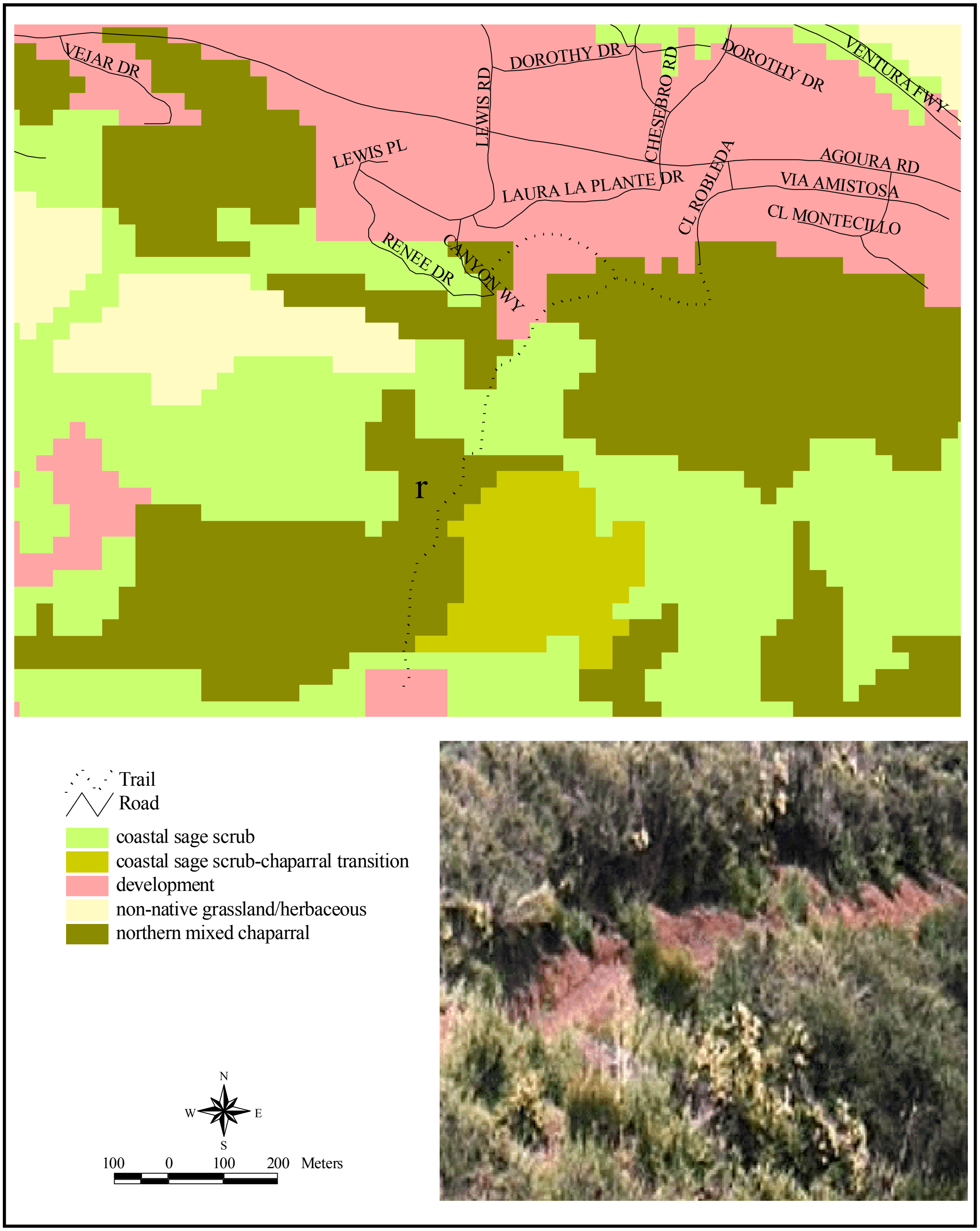


Fig. 4.14 – Agoura Hills trail location and picture.

Field methodology

The first aspect of the project was to document vegetation along a gradient. Along a 50m transect, the vegetation was sampled every 10m using 2m x 1m quadrats (see figure 4.2). Each quadrat had its long axis parallel to the trail (after Cole 1978). The transects were placed 0.5m, 5m, and 25m from the trail edge. The first transect (0.5m) measured trailside vegetation, the second transect (5m) measured transition vegetation and the last transect (25m) measured vegetation in undisturbed northern mixed chaparral.

Species identification and nomenclature for flowering herbs, shrubs and vines was taken from McAuley (1996) and Dale (1992). Graminoid identification and nomenclature was taken primarily from Crampton (1974) where possible and secondarily from Hitchcock's two volume Manual of the Grasses of the United States (1971).

Within each quadrat the frequency of each species was counted. For herbs, vines and grasses, individuals were counted that originated within the quadrat. Due to the size of shrubs, the presence of branches in the quadrat from neighboring shrubs counted as an individual.

Total cover for each shrub was also measured to allow for a uniform comparison of shrub presence. For herbs and grasses, the uniform area in which individuals were counted allowed for a standard measurement of presence by using abundance. Since shrub abundance was counted for each individual extending into a quadrat, abundance was not an adequate measure of dominance

Area occupied by individual shrubs within the quadrat was calculated using a 4-point measurement algorithm. The four points were attributed x, y coordinates based on their relative positions within the quadrat (see figure 4.13 below).

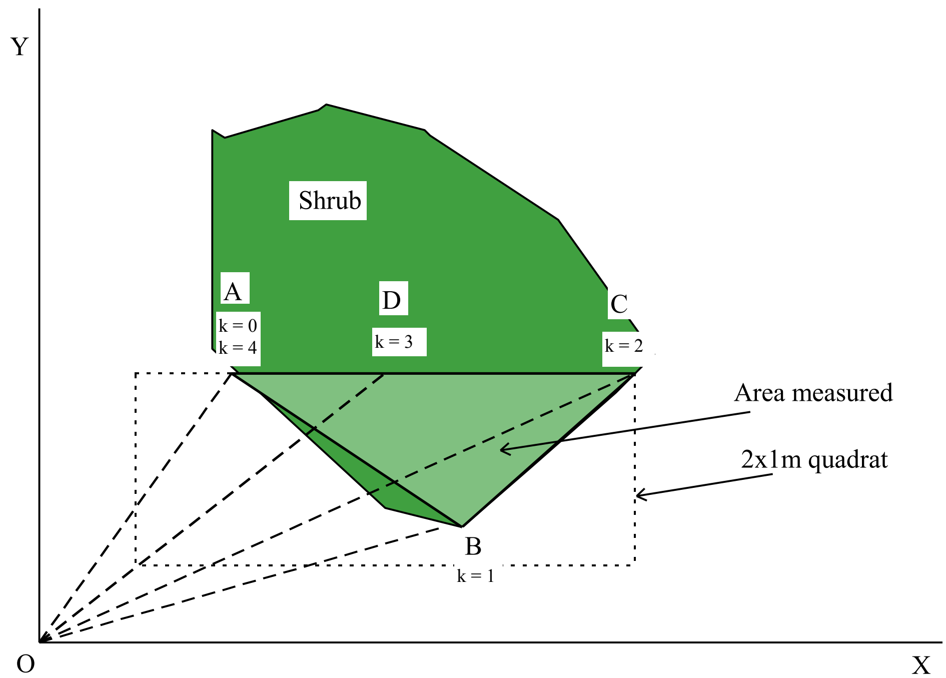


Fig. 4.1 - Diagram showing area measured in quadrat occupied by individual shrub.

In order to estimate the amount of area covered in the quadrat by the shrub an algorithm to calculate irregular shapes was used by summing the area of the triangles covering the shape minus the area of the triangle occupying the area from the ordinate to the shape. In clarification, the area of the shape in figure 4.1 was calculated by the following equation (derived from Etter 1996):

area (ABC) = area (OAD) + area (ODC) + area (OCB) - area (OAB)

Using the summation of the cumulative areas, the calculation was derived as:

$$\text{Area (ABC)} = \tfrac{1}{2} \sum_{k=0}^{n-1} (X_k Y_{k+1} - X_{k+1} Y_k)$$

Transect diagram

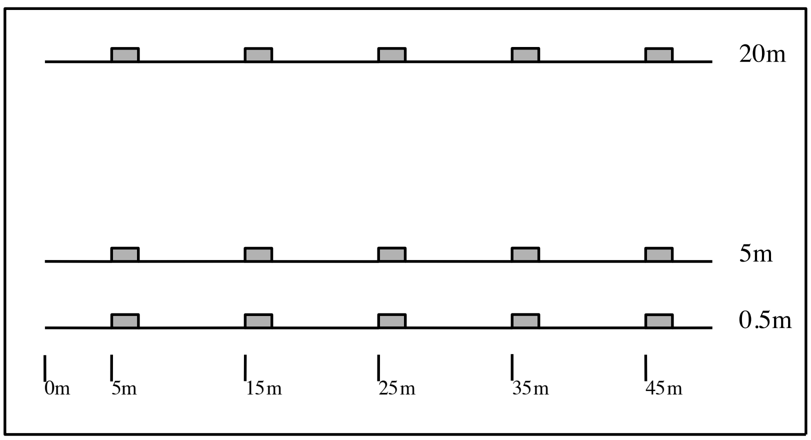


Fig. 4.16 – Transect diagram showing occurrence of sampling plots (shaded boxes) along transect.

Descriptive Analysis

Data manipulation

The data was transformed in several processes in order to standardize and thereby facilitate comparisons between trail location, usage and transect gradients. The different transformations are described below.

Species exclusivity

Species exclusivity was standardized as a proportion for both trailside (A) and undisturbed (C) transect gradients in order to understand the changes in vegetation composition. Species exclusivity was derived by dividing the number of taxa found exclusively in the particular transect by the total species in that transect. The calculation was then performed for the related transect for each usage and location site. Species exclusivity is both a function of species richness and uniqueness.

Simpson's index of similarity

Simpson's index (SI) was calculated to give a weighted measure of species richness. This index was calculated by the following equation (Gleason 1920):

$$\frac{2(\text{\# of species common to both transects})}{\text{\# of species in transect A + transect B}}$$

High SI values (over .5) indicated a dissimilar vegetation community and conversely low SI values indicated similar species in each transect.

Species incidence

The percentage of individual plots that a species occurred in was calculated for each trail usage and location type in order to assess the areal extent of dominant species. Species were analyzed for incidence that occurred in at least three plots per transect type.

Statistical analysis

Since the main objective of the statistical analysis was to determine the significance of differences in populations and species richness, ANOVA was used to determine the significance of most of the data. ANOVA was performed on frequency summations of growth form, life form and exotic species. Chi-square contingency was performed on cover data to determine if changes in shrub contribution was significant based on transect gradient. All analyses were performed with an alpha level of 0.05. Statistical tests were performed using JMP software (Sall and Lehman 1996).

Certain limitations were imposed on the analyses in order to remove outliers that might potentially skew data analysis. *Senecio flaccidus* var. *douglasii* (bush senecio) was not considered in the shrub ANOVA analysis due to its herbaceous seedling form at the time of sampling. This species matures and flowers (blooms starting in July – (McAuley 1996)) later than most of the other species sampled. Many of the individuals sampled had not yet branched and were present in high numbers in many of the transects. Including this species in the shrub frequency analysis would therefore have skewed the data and was subsequently removed during ANOVA calculations.

Sites that were determined to be outliers were also removed during calculations and have been noted appropriately. DH_MUN was the most open chaparral of all the sites and is considered an anomaly. This site was removed for all ANOVA and Tukey-Kramer HSD comparisons to reduce the effect of site heterogeneity on results. LR_MUN was removed to compare its effect on frequency results for herbaceous transect gradients.

Tukey-Kramer HSD comparisons were performed on all ANOVA results to test significance and thereby reduce false rejections influenced by noise in the data.

Chapter 5

Results

Individual species

There were four types of individual species response to trail presence in the study sites. With reference to species abundance in the trailside transect these are: species that decrease or disappear (decreasers), species that increase or were only sampled in this transect (increasers or invaders), species that are most common in the transition transect but are rare or decreased in both trailside and undisturbed chaparral transects (transition) and species that appear with relatively equal abundance in all transect types (neutral).

As expected, *Adenostoma fasciculatum* increased in abundance and cover in undisturbed chaparral transects as compared to trailside transects for all types and locations. The occurrence of *A. fasciculatum* was over fifty percent in all undisturbed chaparral plots. Occurrence of *A. fasciculatum* was rarest in multiple use trailsides transects located near urban edges (13.3%). The highest incidence of *A. fasciculatum* was in HOR at 66.7%. This shrub occurred in consistent percentages for all transition transects irrespective of type or location.

Ceonothus species tended to have similar incidences as compared to *A. fasciculatum.* Incidence was rare (under 10%) at almost all trailside transects. Again, incidence for trailside plots was highest for HOR types (13.3% for *C. crassifolius* and 26.7 for *C. cuneatus*). *C. megacarpus* incidence was also high for HON (33.3). Incidences increased for lilacs in all undisturbed chaparral plots.

	MUN			MUR			HON			HOR		
	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	13.3	40	93.3	26.7	60	60	33.3	53.3	80	66.7	80	93.3
ALHA	-	-	-	13.3	-	-	-	-	-	-	-	-
ANAR	20	20	40	46.7	6.67	6.67	-	-	-	6.67	-	-
ANKE	-	-	-	-	-	-	-	-	-	13.3	6.67	-
ARCA	-	-	-	6.67	13.3	-	-	-	-	13.3	-	20
ARGL	6.67	-	-	-	-	-	-	-	-	-	-	-
AVBA	80	86.7	33.3	33.3	6.67	-	33.3	-	-	20	6.67	-
BAPA	-	-	-	6.67	-	-	-	-	-	-	-	-
BRNI	20	33.3	6.67	13.3	-	-	13.3	-	-	20	13.3	-
BRRU	73.3	53.3	20	73.3	13.3	-	73.3	46.7	-	-	-	-
CAAL	-	-	-	6.67	6.67	-	-	-	-	20	20	-
CABR	-	-	-	-	-	-	-	-	-	6.67	-	-
CACA	-	13.3	6.67	-	-	-	-	-	-	-	-	-
CECR	-	-	-	-	-	-	-	-	13.3	13.3	6.67	-
CECU	-	-	-	6.67	20	33.3	-	-	-	26.7	46.7	73.3
CEME	6.67	13.3	46.7	6.67	13.3	20	33.3	73.3	66.7	-	-	6.67
CESP	-	-	-	6.67	6.67	13.3	-	13.3	33.3	-	-	-
CIVU	-	-	-	6.67	6.67	-	-	-	-	-	-	-
CLPE	-	-	-	-	-	-	-	-	-	6.67	-	-
CMCA	-	-	-	-	-	-	-	-	-	6.67	6.67	-
COBO	-	-	-	-	-	-	6.67	-	-	-	-	-
CRIN	20	20	33.3	-	-	-	-	-	-	46.7	33.3	-
CRMI	-	13.3	20	-	-	-	-	-	-	6.67	-	-
DEPI	20	-	-	-	-	-	-	-	-	-	-	-
DICA	-	20	6.67	6.67	33.3	-	6.67	-	-	-	20	-
ELGL	6.67	20	26.7	26.7	6.67	-	46.7	26.7	-	-	-	-
EMPE	-	-	-	-	-	-	-	-	-	-	-	6.67
ENCA	20	6.67	-	-	-	-	-	-	-	-	-	-
ERCI	13.3	-	-	-	-	-	-	-	-	-	-	-
ERFA	-	-	13.3	6.67	13.3	-	-	-	-	20	13.3	6.67
ESCA	-	6.67	-	-	-	-	-	-	-	-	-	-
FEME	33.3	26.7	6.67	6.67	13.3	-	6.67	6.67	-	-	-	-
GAAN	-	6.67	-	-	13.3	-	6.67	-	-	-	-	-
GNCA	-	-	-	-	-	-	-	-	-	13.3	-	-
HEAN	-	-	-	6.67	-	-	-	-	-	-	-	-
HESC	-	-	-	-	-	-	6.67	-	13.3	-	-	-
HOLE	20	6.67	6.67	-	-	-	-	-	-	-	-	-
HOVU	40	33.3	-	26.7	-	-	-	-	-	13.3	-	-
KOCR	-	6.67	6.67	13.3	-	-	-	-	-	-	-	-
LOSC	20	20	-	6.67	-	-	20	-	-	53.3	33.3	20
LOUT	-	-	-	26.7	13.3	13.3	-	-	-	-	-	-
LUSP	53.3	26.7	-	20	-	-	-	-	-	-	-	-
LUTR	6.67	-	-	-	-	-	-	-	-	-	-	-
MALA	-	-	-	-	-	13.3	-	-	13.3	6.67	6.67	-
MAMA	6.67	-	-	6.67	-	-	-	-	-	-	-	-
MEPO	-	-	-	66.7	-	-	6.67	6.67	-	-	-	-
MESA	-	-	-	6.67	-	-	-	-	-	-	-	-
MIAU	-	-	-	-	6.67	6.67	-	-	-	-	-	-
MIBR	-	6.67	20	-	-	-	-	-	-	-	-	-
PHGR	6.67	-	-	-	-	-	26.7	20	6.67	-	-	-

PHPA	-	-		-	-	6.67	-	-	-	-	-	-
PHVI	13.3	-	-	-	-	-	-	-	-	-	-	-
PLER	6.67	-	-	-	-	-	-	-	-	-	-	-
POAN	-	-	-	-	-	6.67	-	-	-	-	-	-
QUDU	-	-	-	33.3	26.7	46.7	-	-	-	6.67	-	6.67
RHOV	-	-	20	-	-	-	-	-	6.67	-	-	6.67
RIMA	-	6.67	-	-	-	-	-	-	-	-	-	-
SAME	-	13.3	40	26.7	53.3	33.3	33.3	40	13.3	53.3	53.3	40
SEFL	46.7	40	26.7	40	20	6.67	-	-	-	-	6.67	-
SEVU	6.67	6.67	-	-	6.67	-	-	-	-	6.67	-	-
SIBE	-	-	-	13.3	20	6.67	-	-	-	-	-	-
SIGA	6.67	13.3	-	-	-	-	-	-	-	-	-	-
SOXA	-	20	6.67	-	-	-	-	-	-	-	-	-
SPJU	13.3	26.7	6.67	-	6.67	-	-	-	-	-	-	-
STPU	20	6.67	-	33.3	-	-	13.3	-	-	26.7	13.3	-
TAOF	46.7	46.7	13.3	6.67	-	-	6.67	-	-	6.67	-	-
TODI	-	-	-	-	-	-	-	-	-	-	6.67	6.67
YUWH	-	20	40	13.3	6.67	6.67	-	-	-	6.67	6.67	6.67

Table 5.1 – Species incidence for all transects.

Site	A to C	A to B	B to C
CF	0.4	0.4	0.833
ST	0.25	0.8	0.625
TC	0.375	0.55	0.5
GT	0.333	0.636	0.333
AH	0.538	0.621	0.261
RT	0.462	0.571	0.667
DH	0.5	0.556	1.063
CR	0.333	0.485	0.581
LR	0.25	0.788	0.4
MR	0.476	0.455	0.728
LC	0.091	0.462	0.444
BD	0.414	0.625	0.519

Table 5.2 – Similarity index for all transects

	MUN			MUR			HON			HOR		
	DH	CM	LR	BD	LC	MR	CF	TC	ST	RT	GT	AH
ADFA	D	D	D	D	D	D	D	D	D	D	D	D
ALHA				I								
ANAR	I	I	I									
ARCA			I		M							
ARGL		I										
AVBA	I	I	I	I	I			I	I			I
BAPA						I						
BRNI			I									
BRRU	I	I	I	I	I	I	I	I	I			I
CAAL				I						I		
CACA	D											
CECR		D										
CECU				D	D	D						
CEME	D	D	D	D	D	U	D	D	D	D	D	D
CESP					D	U	D		D			
COBO		I										
CRIN		D	U					I	I	I	M	I
CRMI	D											
DEPI	I											
DICA	D	M		M	M							
ELGL	I	M	M	I	I	I		I	I			
EMPE		D										
ENCA							I					
ERCI			I									
ERFA	D			D	M	I				I		M
ESCA		M										
FEME			I			I			I			
GAAN					M							
HESC		D										
HOLE							I					
HOVU	I	I	I									
KOCR	D											
LOSC	M	M	M							I	I	I
LOUT				I								
LUSP	I	I	I	I	I							
LUTR		I										
PHGR							I	I	I			
QUDU				D		D						
SAME			D	M	M	M	M	I	M	I	M	D
SEFL	M	D	I	I	I							
SEVU	M											
SIBE				I								
SIGA			I									
SOXA	D											
STPU	M	I	I		I	I	I					I
TAOF			I									
TODI				M								
YUWH	D	D	D							U	U	U

Table 5.3 – Species abundance pattern with reference to trailside.

Lotus scoparius (deerweed) displayed a response probably associated with intensity of trampling stress. In transects where trampling stress was lowest (hiker only and remote transects) this shrub was sampled in trailside transects. In multiple use transects near urban edges, *L. scoparius* was either less common or not present alongside the trail but was found significantly in transition plots. That this shrub was not censused in the undisturbed transects was not surprisingly as this shrub falls out with age of northern mixed chaparral sites due to crowding out by *A. fasciculatum* and *Ceanothus* spp.

TYPE	A	B	C
MUN	17150	68385	0
MUR	6341	0	0
HON	35098	0	0
HOR	87659	14479	0

Table 5.4 – *Lotus scoparius* coverage (cm^2) per transect type (A = trailside, B = transition, C = undisturbed chaparral)

Salvia mellifera (purple sage) had a similar response as *L. scoparius* with the exception of a consistent but reduced presence in undisturbed chaparral plots. Growing outside of the confines of mature northern mixed chaparral, *S. mellifera* individuals are much larger and taller in size. Therefore, while *S. mellifera* is able to exist in mature chaparral sites, it is under smaller morphological conditions. Again, *S. mellifera* was absent from trailside plots in multiple use plots located near urban edges.

Dichelostemma capitatum ssp. *pauciflorum* (blue dicks) appears to favor transition, with abundance found highest in this transect for all usage and location types. *Festuca megalura* (foxtail fescue) had a similar response.

Lupines, while present in significant numbers along multiple use trails near urban areas, tended to drop out in multiple use remote areas. No lupines were found in transects under either hiker only conditions.

Overall species richness

	ST	TC	CF	RT	AH	GT	LR	CR	DH	BD	LC	MR
Total Richness	13	14	12	10	22	17	23	29	28	26	23	17
A richness	10	13	10	9	16	13	16	16	13	17	15	16
C richness	6	3	5	4	10	5	8	14	19	12	7	5
% A exclusivity	0.5	0.85	0.70	0.67	0.56	0.77	0.81	0.63	0.39	0.65	0.87	0.69
% C exclusivity	0.5	0.33	0.40	0.25	0.30	0.40	0.63	0.64	0.58	0.50	0.86	0.00

Table 5.5 Tabulation of species richness with comparisons between trailside (A) and undisturbed chaparral sites for both richness and exclusivity

Most site locations had a higher proportion of species exclusivity in trailside transects (A) than in undisturbed chaparral transects (C). Only DH_MUN had a distinctively higher species exclusivity in the undisturbed chaparral transect compared to the trailside transect. Both ST_HON and CR_MUN had species exclusivity proportions that were nearly equal for both transect gradients.

Exotics

Exotic species richness along trails was found to be significant for trail usage but not for location. Multiple use trails were significantly different in species richness than hiker only trails irrespective of location. The average exotic species richness was only 3.7 species at hiker only locations compared to 7.8 species for multiple use sites.

	LR_MUN			CR_MUN			DH_MUN		
Transect	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Overall species richness	16	17	8	16	17	14	13	23	19
Exotics	9	8	1	7	5	3	8	7	7
Perennials	6	8	6	6	9	8	4	14	11
Annuals	10	9	2	10	8	6	9	9	8

	MR_MUR			LC_MUR			BD_MUR		
Transect	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Overall species richness	16	6	5	15	11	7	17	15	12
Exotics	3	1	0	4	3	0	6	4	1
Perennials	12	5	5	8	8	7	11	11	10
Annuals	4	1	0	7	3	0	6	4	2

	ST_HON			TC_HON			CR_HON		
Transect	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Overall species richness	10	10	6	13	5	3	10	7	5
Exotics	3	3	0	3	1	0	2	2	1
Perennials	5	5	5	9	4	3	4	5	4
Annuals	5	5	1	4	1	0	6	2	1

	RT_HOR			AH_HOR			GT_HOR		
Transect	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Overall species richness	9	5	4	16	13	10	13	9	5
Exotics	1	0	0	4	1	0	2	0	0
Perennials	7	5	4	11	9	10	5	6	5
Annuals	2	0	0	5	4	0	8	3	0

Table 5.6 – Summary species richness for all transect locations.

There was a noticeable difference in exotic species richness between near and remote locations along trails but this discrepancy was not determined to be significant from ANOVA analysis. In multiple use sites exotic species richness consistently declined in remote sites compared to near sites. The average decline was 31.67%. In contrast, exotic species richness along hiker only trails was similar for both location types. Remote locations averaged 2.7 species while near locations average 2.3 species per transect. Average species richness was noticeably dissimilar in multiple use trails when broken down by location type. Near locations average 4.3 exotic species per transect as compared to 8 species for remote sites.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Hikers only	6	22	3.67	1.87
Multiple Use	6	47	7.83	5.77

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	52.08	1	52.0	13.65	0.004	4.96
Within Groups	38.17	10	3.82			
Total	90.25	11				

Comparisons for all pairs using Tukey-Kramer HSD

	MU	HO
MU	-2.51	1.65
HO	1.65	-2.51

Positive values show pairs of means that are significantly different.

Fig 5.6 – ANOVA and Tukey-Kramer HSD results for trail usage.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Near	6	32	5.33	9.07
Remote	6	20	3.33	3.07

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12	1	12	1.97	0.19	4.96
Within Groups	60.67	10	6.07			
Total	72.67	11				

Fig 5.7 – ANOVA summary results for trail location. Tukey-Kramer HSD was not performed since the ANOVA results were not significant.

All of the exotic species were categorized as increasers, indicating that their strongest presence occurred along trails.

Surprisingly, *Brassica nigra* (black mustard) was not a significant trailside invader. This species is a common exotic along roadsides and tends to form dominant clusters on adjacent hillsides. *B. nigra* was sampled at only four of the sites, three of those being multiple use trails. The average abundance of *B. nigra* along trails was 5.5 individuals per transect.

Life forms

Overall species richness was significantly higher along trailside transects for annuals than in undisturbed chaparral transects. Annual species representation in undisturbed chaparral was minimal with many transects sampling no annuals at all. Only two multiple use sites, DH and CR, had annual species declines that were less than 60%.

ST	TC	CR	RT	AH	GT	LR	CR	DH	MR	LC	BD
80%	100%	83%	100%	100%	100%	80%	40%	11%	100%	100%	60%

Table 5.9 - Annual species richness decline from trailside to undisturbed chaparral transects.

	A	C	Total
ST_HON	5	1	6
TC_HON	4	0	4
CR_HON	6	1	7
RT_HOR	2	0	2
AH_HOR	5	0	5
GT_HOR	8	0	8
LR_MUN	10	2	12
CR_MUN	10	6	16
DH_MUN	9	8	17
MR_MUR	3	0	3
LC_MUR	7	0	7
BD_MUR	5	2	7
Total	74	20	94

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A	12	74	6.17	7.06
C	12	20	1.67	6.70

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	121.50	1	121.50	17.32	0.0004	4.30
Within Groups	154.33	22	7.015			
Total	275.83	23				

Comparisons for all pairs using Tukey-Kramer HSD

	A	C
A	-2.24	2.26
C	2.26	-2.24

Positive values show pairs of means that are significantly different.

Fig 5.10 – ANOVA and Tukey-Kramer results for annual species richness.

Growth forms

	ST	TC	CF	RT	AH	GT	LR	CR	DH	BD	LC	MR
Herb												
A	0.3	0.385	0.4	0.222	0.313	0.538	0.438	0.563	0.462	0.529	0.467	0.111
B	0.2	---	---	---	0.154	0.333	0.353	0.417	0.391	0.4	0.273	---
C	0.167	---	0.2	---	0.222	---	0.125	0.429	0.368	0.417	---	---
Grass												
A	0.4	0.308	0.2	---	0.25	0.077	0.313	0.313	0.385	0.235	0.267	0.313
B	0.4	0.4	0.286	---	0.231	---	0.412	0.176	0.261	0.333	0.091	0.167
C	0.4	---	---	---	---	---	0.25	0.214	0.316	---	---	---
Shrub												
A	0.3	0.385	0.3	0.778	0.438	0.308	0.25	0.125	0.154	0.235	0.2	0.563
B	0.4	0.6	0.714	1	0.538	0.667	0.294	0.353	0.348	0.267	0.636	0.833
C	0.833	1	0.8	1	0.778	1	0.625	0.357	0.316	0.583	1	1
Vine												
A	---	---	0.1	---	---	0.077	---	---	---	---	---	---
B	---	---	---	---	0.077	---	---	---	---	---	---	---
C	---	---	---	---	---	---	---	---	---	---	---	---

Table 5.11 - Proportion of total composition in each transect gradient comprising each growth form

Graminoids

Graminoids formed a significant presence in plots that occurred on multiple use trails nearest the trailheads. The highest individual numbers occurred in the trailside transects and decreased by about a third subsequently in the transition and undisturbed chaparral transects. In remote multiple use transects grasses were still significantly present but in less numbers and did not appear in the undisturbed chaparral transects. Grasses appeared in transects along hikers only trails but in reduced numbers.

The analysis of frequency for different life forms produced different levels of significance for each transect type. Graminoid frequency was the most consistently significant across the transect types. Tukey-Kramer HSD comparisons confirmed that graminoid frequencies were significantly different for all transect gradients. Graminoids were most represented in both abundance and composition along trails. For both remote

	A	B	C	Total
BD_MUR	524	50	0	574
RT_HOR	68	13	1	82
CF_HON	504	13	0	517
TC_HON	444	30	0	474
ST_HON	237	77	0	314
LC_MUR	258	16	0	274
MR_MUR	103	11	0	114
GT_HOR	14	0	0	14
LR_MUN	813	781	14	1608
CR_MUN	660	355	66	1081
AH_HOR	202	45	0	247
DH_MUN	1679	489	276	2444
Total	5506	1880	357	7743

Means for One-way ANOVA

Level	Number	Mean	Std Error
A	11	347.91	61.45
B	11	126.46	61.45
C	11	7.36	61.45

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A	11	3827	347.91	66981.49
B	11	1391	126.45	57215.67
C	11	81	7.36	395.65

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	657051.9	2	328525.90	7.91	0.002	3.32
Within Groups	1245928	30	41530.94			
Total	1902980	32				

Comparisons for all pairs using Tukey-Kramer HSD

	A	B	C
A	-214.23	7.22	126.32
B	7.22	-214.23	-95.14
C	126.32	-95.14	-214.23

Positive values show pairs of means that are significantly different.

Fig 5.12 – ANOVA and Tukey-Kramer results for graminoid frequency by transect.

locations graminoids were not present in undisturbed chaparral transects. Only multiple use sites at remote locations had a consistent representation of graminoids in undisturbed chaparral transects.

The contribution of herbs and graminoids to species richness is highest in the trailside transects irrespective of type or site. With the exception of the most disturbed type, MUN, graminoid species richness tended to be non-existent or very low in the undisturbed chaparral plots. Graminoid species diversity was higher in multiple use plots than hiker only plots.

Herbs

Herb species tended to have a mostly even representation (ranging between 30% - 55%) in all transect gradients with the highest richness occurring in trailside plots. Significant ANOVA analysis was rejected through Tukey-Kramer HSD comparisons showing that only difference between trailside and undisturbed chaparral frequencies were significant.

Shrubs

Shrub richness consistently increased with transect gradient. With the exception of MUN sites, shrub richness increased with distance from the trail. Shrubs consistently had their highest diversity in undisturbed chaparral transects. In all cases, species richness increased from trailside to transition to undisturbed chaparral.

Undisturbed chaparral transects were primarily dominated by shrubs. Most of the transects were located in closed, mature northern mixed chaparral which consisted primarily of *A. fasciculatum* and *Ceanothus* species. Also commonly sampled were shrubs such as *Rhus ovata* (sugar bush) and *Malosma laurina* (laurel sumac).

Shrub species frequency was not found to be dependent upon transect gradient with ANOVA analysis. Chi-squared contingency tests showed that change in cover was significant for shrubs with cover increasing uniformly towards the undisturbed chaparral transect for all types.

Trailside shrub cover was significantly different for trail usage type but not for location. Shrub cover for hiker only transects averaged 82.58% while cover for multiple use transects averaged only 25.6% along trails. For all transects cover for transition plots was consistently high, ranging from 52% to almost 100%. For the undisturbed chaparral plots cover almost 100% for transects with the exception of CR_MUN (70.8%) and DH_MUN (86.6%).

	A	B	C	Total
BD_MUR	3	10	33	46
RT_HOR	20	12	11	43
CF_HON	7	9	11	27
TC_HON	12	9	10	31
ST_HON	6	11	11	28
LC_MUR	2	22	20	44
MR_MUR	13	17	10	40
GT_HOR	18	16	13	47
LR_MUN	4	7	24	35
CR_MUN	1	11	15	27
AH_HOR	11	12	14	37
DH_MUN	2	17	29	48
Total	99	153	201	453

Means for One-way ANOVA

Level	Number	Mean	Std Error
A	11	8.82	1.85
B	11	12.36	1.85
C	11	15.64	1.85

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A	11	97	8.82	41.76
B	11	136	12.36	18.85
C	11	172	15.63	52.85

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	255.82	2	127.91	3.38	0.005	3.32
Within Groups	1134.73	30	37.82			
Total	1390.55	32				

N.B. – this analysis was performed removing DH data due to anomaly of this site.

Comparisons for all pairs using Tukey-Kramer HSD

	C	B	A
C	-6.47	-3.19	0.35
B	-3.19	-6.47	-2.92
A	0.35	-2.92	-6.46

Fig 5.13 - ANOVA and Tukey-Kramer results for shrub frequency by transect.

The highest contribution to species richness for shrubs occurred in HOR plots. The proportion of shrub species was between 30% and 78% of total species richness. Lowest shrub species richness was in the MUN plots.

Vines

Vines were rare in any plot. Vines that did occur were mostly sampled in trailside plots along hiker only trails. No vines were sampled in undisturbed chaparral plots. The overall contribution to species richness was low in all cases (1% or under). No ANOVA analyses were performed due to low or no frequencies and richness in all plots.

Additional note

While not quantified, I did notice the phenomenon of below trail vegetational response as compared to above trail vegetation in locations with steeper slopes. The below trail vegetation tended to be more disturbed (with exposed soils) and have patches of herbaceous plants extending beyond the transition zone (appendix D). This phenomenon appeared evident irrespective of trail usage. Picture A was taken at Franklin Canyon in Beverly Hills, which is a heavily used trails. Picture B was taken along the Garapito Trail which is designated for hikers only.

Chapter 6

Discussion

Summary of results

Results show that along trails, annual plants are more dominant than perennials irrespective of trail usage or location. In addition, the growth forms that were able to persist under trampling and other trailside stresses tended to be low growing herbs and graminoids. While very common in all types of locations in the multiple use transects, graminoids were not as abundant in hiker only transects near urban edges and were almost entirely absent from remote locations. There was a quantifiable gradient of the severity of vegetation composition change ranging from multiple use near urban locations which had almost completely different species along trailside transects compared to undisturbed transects, to remote hiker locations which tended to have a dominance of shrub species throughout all transects and a lower species index.

Vegetation profiles changed in trailside transect as compared with undisturbed chaparral transects. Undisturbed chaparral transects with the exception of Dead Horse trail were shrub-based and therefore only had only one level with no understory growth. The profile therefore tended to range in height from 1.5 – 4 meters. Trailside vegetation structure was multileveled with heights ranging from 5cm to over 3 meters. Multiple use trails tended to have mostly short vegetation as a result of a predominance of herbaceous and graminoid species. Hiker only trails tended to have more shrubs present but unlike the undisturbed chaparral had multiple levels with a herbaceous and graminoid level.

Overall vegetation community changes

Small-scale disturbances have been recognized as one of the processes influencing increased species diversity by creating favorable colonizable space (Lavorel et al 1994). In these variable environments, dispersal and dormancy strategies by plant species take advantage of the changed conditions for regeneration. Such strategies provide for fluctuating reproductive success through space and time. In summation, dormancy and dispersal are some of the regeneration traits likely to be especially important for coexistence in heterogeneous and frequently disturbed systems (Lavorel et al 1994). Environmental changes are responsible for creating changes in resources.

When a stress is constant (such as trailside trampling), factors that best appear to explain durability are morphological characteristics. Low growing plants that either have a tufted growth form or leaves in basal whorls that grow flat on the ground fare best. All graminoids fall into this category. Species that have subsurface adventitious buds also able to persist by regenerate above ground tissue rapidly.

Trailside life-form and growth-form occurrence

Annuals were the predominate form found in most disturbed microsites (Frenkel 1970). Annuals tended to dominate trailside transects. This correlates with several studies (Hall and Kuss 1989, Cole 1978, Dale and Weaver 1974) that found similar patterns. Ikeda and Okutomi (1992) found that perennials were less tolerant of trampling than annuals in their research.

The perennating tissue in graminoids is protected by its basal position and readily replaces aboveground tissue that may become damaged by trampling (Adkison and Jackson 1996). This characteristic helps explain the higher presence of graminoid species along the multiple use trails in both site locations. Trampling of species along these trails is higher than in hiking only trails due to user conflict. As different activities (biking, hiking or horseback riding) conflict, usually the party on the trail must step off the trail in order to accommodate the passage of the other party. Park officials in the Golden Gate National Recreation Area noted that bicyclists passing other users would either leave the trail or force the other users off the trail to the detriment of off-trail vegetation and wildlife (Bicycle vs. Babbitt 1994). This creates a higher occurrence of trampling off the trail and also partially explains why trail width tends to be larger on multiple use trails as compared to hiker only trails. The higher presence of graminoids on trailside transects relative to off-trail transects was also found in Adkison and Jackson's study (1996). *B. rubens* has been noted to be a common grass along roadsides and cleared areas (Frenkel 1970, Clorkey 1951).

Herbs were consistently represented across all types. Unlike shrubs and graminoids, this category includes a wide range of species that are both resilient (e.g. *Anagallis arvensis, Conyza bonariensis*) but also species that are susceptible to trailside stresses and therefore were either absent or found in low numbers alongside the trail (e.g. *Dichelostemma capitatum* ssp. *pauciflorum*, *Eschscholzia californica*). Trailside herbs that are most successful tend to have ground level leaves or perennating tissues (Bates 1935).

Only two vines species (*Antirrhinum kellogii, Marah megacarpus*) were even sampled and only appeared in a few plots as individuals. While all individuals sampled were found in either trailside or transition plots, vines tend to be highly susceptible to trailside stresses (Adkison and Jackson 1996). They argued that the separation of the root from the shoot due to trampling would prohibit the vine from existing alongside trails unless fragmented shoots were able to form ramets. In the case of *A. kellogii* and *M.*

megacarpus this was not an issue as both species were shielded from physical impact by intertwining among shrubs.

Exotics

In most cases, the undisturbed, closed chaparral habitat seemed robust to exotic invasions. The trailside and transition vegetation communities were more prone to invasion by exotics as compared to undisturbed chaparral. Where the chaparral canopy was closed, trails did not seem to provide invasion opportunities for species into off-trail vegetation. As was noted with the anomalous site, DH_MUN, open chaparral supported more overall species diversity as well as the highest exotic species richness.

The closed nature of chamise (*Adenostoma fasciculatum*) dominated chaparral tends to preclude species which need adequate light and moisture resources to germinate and grow. The ground level in closed chaparral is relatively devoid of vegetation. Only in gaps in shrub cover were other species observed. The reproductive tactics of chamise naturally provide better competitive adaptation against most other species, especially exotics. Following fire, when vegetation cover has been reduced to nothing, this shrub is able to quickly re-establish itself by crown sprouting, sending up new shoots from the burl. Chamise also produces mass amounts of seed in two types. One type requires scarification to germinate but the other one doesn't need fire in order to sprout. This duality ensures germination in both fire and non-fire years.

Species diversity increased in chaparral sites that were more open, concurring with the general theory on species invasiblity. The limiting factor, light, tends to restrict colonization by exotics and native annuals in the closed chaparral canopy. Frenkel (1970) found in his study of ruderal vegetation along roadsides in Central and Northern California that introduced species sharply decreased in proportion to distance from the roadside. Communities that lacked a closed tree/shrub canopy had a very high percentage of introduced species in the roadside habitats (Frenkel 1970). High light intensity and frequent breaks in plant cover characteristic of grassland may facilitate the invasion of alien species (Kaer 1986, Forcella and Harvey 1983).

Overall species richness

In undisturbed northern mixed chaparral, competitive succession results in codominance of *Adenostoma fasciculatum* with *Ceanothus* species. This association is essentially a diculture with occasional individuals of *Rhus ovata, Malosma laurina*, and other chaparral shrubs (table 3.1). With senescence, almost pure stands of *A. fasciculatum* exist.

The results in all transects except DH_MUN supported the intermediate disturbance hypothesis. This hypothesis states that disturbance is a stress which at high levels represses species but at low levels fails to prevent competitive exclusion many species by a reduced number of superior species (Connell 1975, 1978).

Levels of disturbance from the trail toward undisturbed chaparral become reduced as distance from the trail is increased. The trail path itself represents the most intense level of disturbance and often was either devoid of vegetation or contained only one or two species growing on it. The most common species observed were *Chamomilla suaveolons* (pineapple weed) and stunted forms of *Hordeum leporinum* (Hare Barley). The association of trail plants is known as a trampled community (Ikeda and Okutomi 1992). Their species composition is relatively simple due to the high stress level created by trampling. Species types observed along trails was corroborated with other case studies. Ikeda and Okutomi (1992) found that trampled communities usually consist of herbs and grasses with short life cycles.

The trailside and transition transects represented the intermediate levels of disturbance and had higher species diversity when compared to their corresponding undisturbed chaparral transects. DH_MUN possessed a higher undisturbed species diversity (19 species) than the trailside transect (13 species) but still had a higher transition species diversity (23 species). This anomaly is most likely explained by the open nature of the Dead Horse site. With proximity to extreme disturbance from not only the trail but the exotic dominated field leading to the trailhead, invasion of the open chaparral had occurred, resulting in a higher species richness than was typically recorded in other transect sites.

HON	**HOR**	**MUN**	**MUR**
61.90%	53.53%	8.89% (31.25%)	54.55%

Table 6.1 – Species richness decline from trailside transects to undisturbed chaparral. Parenthesis for MUN is species richness decline removing DH trail effect.

In all other transect the reduction of species diversity from trailside compared to undisturbed chaparral was significant, ranging from a decline of between 12% and 68%. The lowest reduction of species diversity was from the multiple use sites located near urban areas. The disturbance is highest at these locations not only from the types of activities but also from the levels. Multiple use trails tend to receive a higher amount of use than hiker only trails. In addition, use levels are highest near the trailheads and taper off as the distance into the trail is increased. While it was not possible to quantify this phenomenon, the results of the transect correspond. The transition vegetation tended to extend farther off the trail than comparable sites on hiker only trails. In addition, vegetation species sampled in the undisturbed chaparral transect were also indicative of higher levels of disturbance with the presence of lupines, grasses *Camissonia californica.* All of these have been classified as disturbance oriented species (see appendix).

Species exclusivity

Species exclusivity was calculated as a standardized method of quantifying significant changes in vegetation community structure between trailside (A) and undisturbed (C) chaparral transects. A high proportion (greater than 0.5) represented a significant change between species composition in either transect compared to the other. Smaller values were not considered significant due to the attribution of variation stemming from natural heterogeneity (Cole 1974).

The relationship of the exclusivity proportions determines the dynamics of those compositions. A low C value coupled with a high A value indicates significant trailside vegetation alteration. As analyzed previously, species diversity tends to be highest along trailsides as a result of disturbance. Undisturbed chaparral has the lowest overall species diversity, correlating with low disturbance. Thus this high A/low C combination indicates a trailside transect with higher disturbance and the associated unique species that are most successful under this type of condition.

High A and high C values indicate conditions similar to the high A/low C coupling but with significantly less undisturbed associated chaparral species located in the trailside transect, resulting in fewer common species between the two transects. Both transects, CR_MUN and LR_MUN that met this condition, were due to higher levels of disturbance close to the trailside transect from increased activities and trail usage type.

DH_MUN has been an anomaly for most analyses and proved to be no exception from that pattern in species exclusivity values. The higher species exclusivity proportion in the off trail transects is the reverse of almost all the other transects. The trailside vegetation community was dominated by two grasses, *Avena barbata* and *Bromus rubens*, and this accounted for the low species diversity and subsequent low exclusivity value. The contrasting open chaparral, which had a high species diversity, resulted in the flip-flop of species exclusivity values produced.

Low overall values for both A and C indicate that neither vegetation community is significantly different from the other. None of the site locations met this situation but ST_HON did have somewhat low proportions (0.5 for both). Cole (1978) recommended that vegetation communities be considered significant from each other when their values were higher than 0.5 due to the natural heterogeneity for most communities. Assumptions made for ST_HON is that while there is some change in vegetation composition, this trail appeared to be the least used of all the sites visited and therefore the lowered activity level has reduced the impact of trail presence.

Environmental Change

Trail presence results in microclimatic changes in light and moisture availability. In addition, the removal of shrubs during the trail construction process reduces root competition along the trail edge (Dale and Weaver 1974). These emergent favorable conditions for increased species diversity are countered by trampling stress, grazing pressure from horses and increased nitrogen availability from urine sources. The gradient created by changing resources and conditions outward from the trail creates different reproductive successes for different plants. This is illustrated by looking at the tendency of a plant species to increase or decrease in proximity to the trail edge. Clear decreasers are *Adenostoma fasciculatum,* the lilacs (*Ceanothus* sp.) and *Yucca whipplei*. All of these species are classified as shrubs. Clear increasers tend to be either graminoids or herbs such as *Avena barbata*, *Bromus rubens,* and lupines or weeds such as *Taraxacum* *officionale*. These species, many of which are classified as weeds and pasture plants, respond to three gradients, increased light, adaptations to trampling stress, and increased seed source (i.e. manure along the trail) (Dale and Weaver 1974). Along this gradient were plant species that seemed neither tolerant of trampling nor competitive in undisturbed chaparral. As a result, their frequencies tended to decrease toward both the trail and undisturbed chaparral. Their abundance therefore was measured highest in the transition. These species favor more light than is available in the closed chaparral and likewise avoid trampling in this gradient. Examples are *Dichelostemma capitatum* ssp. *pauciflorum*, *Salvia melliflora, and Galium angustifolium* ssp. *angustifolium*. Certain plants were not specifically affected by any one portion of the gradient and could be found in varying abundance throughout the transects. Most notable examples include *Eriogonum fasciculatum* and *Senecio flaccidus* var. *douglasii.*

Dispersal adaptations

The presence of more grass species and presence along trailheads and on multiple use trail can also be linked to dispersal adaptations. Many grass species and flowering plants found along trails have specific dispersal adaptations that allow themselves to be easily attached through burrs and other devices onto moving organisms. These adaptations allow seeds to be attached onto the clothing of humans and the fur of horse and dogs as they pass through the vegetation. The species is then able to colonize remote areas through germination upon dislodgment further along the trail or in another area. The newly created resources along the trail in the new area may allow the dislodged seed to be more competitive in establishment than seeds from the local area.

Imitation of Fire Effects

With cool, wet winters and hot, dry summers, the climate of this region, along with senescence of chamise, has created a regenerative cycle in which fire is a regular feature. Under natural conditions, the cyclical event of fire occurs on average every 20-30 years. This disturbance regime has resulted in chaparral species that are fire followers, i.e. plants that are present in the years immediately following a burn (see appendix for a list). The presence of trails has resulted in certain effects similar to a burn by creating and maintaining an open and light-exposed environment.

It was therefore no surprise that typical fire followers were present in the transects. Examples of sampled species were *Phacelias*, *Lupines* and two species of *Cryptantha*, as well as *Antirrhinum kelloggii, Calandrinia breweri, Calochortus albus, Camissionia californica,* and *Eschscholzia californica.* Observed but not sampled species include *Calystergia macrostegia* ssp. *cyclostegia* and *Daucus pusillus*. Herbs and suffrutescent (herbaceous) shrubs such as *Lotus scoparius* dominate the early post-fire recovery stage in chaparral communities.

Chapter 7

Conclusion

There is a growing recognition today that recreational activities have a distinctly negative impact on wildlife. The concept of benign non-consumptive (i.e. activities where wildlife and plants are not removed from their natural habitats) activities has been abandoned due to overwhelming evidence. As was noted by Knight and Gutzwiller "The notion that recreation has no environmental impacts is no longer tenable. Recreationists often degrade the land, water and wildlife resources that support their activities by simplifying plant communities, increasing animal mortality, displacing and disturbing wildlife, and distributing refuse" (1995: pp. 3).

The results from this study show a clear internal edge effect generated by trail presence. The existence of trails and the associated disturbance generated from usage create a strip of vegetation adjacent to the trail that is significantly different from the natural vegetation composition and structure of northern mixed chaparral vegetation. Moreover, multiple use trails, which form the majority of trails in the Santa Monica Mountains National Recreation Area, were shown to have a greater impact on the adjacent vegetation with a more significant difference in vegetation community, richness and structure. Vegetation along multiple use trails also tended to have a higher presence of exotics, most notably graminoids, presumably as a result of germination from horse feces.

Trails and biotic conservation

To preserve biotic diversity and functioning natural ecosystems, conservation efforts must include explicit consideration of disturbance processes, both natural and anthropogenic. More research is needed to determine the "recreation carrying capacity" of a given area. Wager (1964:3) defined recreation carrying capacity as the "level of recreational use an area can withstand while providing a sustained quality of recreation." Even in similar landscapes the recreation carrying capacity will differ. Within northern mixed chaparral communities, the carrying capacity would be dramatically lowered by the presence of sensitive species.

Given that the relationship of visitor use to ecological damage is curvilinear (Marion 1993), nearly all use must be eliminated to achieve significant reductions in most forms of recreational impact. It is therefore recommended that visitor use be barred in ecologically sensitive areas. Trails should be implemented to take advantage of resistant and resilient environments while avoiding sensitive locations. This policy should not only be implemented in areas that are sensitive to trampling but also in areas with animal populations sensitive to trail presence and/or activities. One example of this is noise pollution. Due to the infrequent but realistic chance of encountering mountain lions, many signs posted at trailheads recommend making as much noise as possible to avoid such encounters. Unfortunately, noise disturbance has been shown to interfere with breeding bird populations.

Temporal sensitivities should also be researched and understood in order to develop effective management. A good example of this is management practices in the

Monteverde Cloud Forest Preserve in Costa Rica. One of the key species attracting tourists to this area is the quetzal. During times of nest building, trails near the breeding sites are closed to avoid disturbance by visitors. Since research has shown that the incubating females are tolerant of tourists, the trails are re-opened during that period (HaySmith and Hunt 1995). Another bird species of high tourism interest, the Kirtland Warbler, is similarly protected during its breeding period in Michigan.

The end result is to implement management policies that permit the recreational use of designated natural areas without compromising their ecological and aesthetic integrity. The presence of a unique and temporal ecological requirement in a particular area has to be monitored in order to regulate or deny access as need arises. As trails provide a unique opportunity to guide recreationists to areas of interest, they also provide a forum in which to reroute visitors away from sensitive areas. Trails can also serve as entryways into remote areas that normally would not be accessible. This can sometimes be a negative factor, especially in the case of ORV use (Buechner and Sauvajot 1996).

Mitigating Factors

Trail construction

Since the runoff from trails affects trailside vegetation through changes in the microenvironment (Hall and Kuss 1989), mitigation of the factors which enhance deterioration of the trail is the first step towards minimizing trail edge effects. The most common types of trail deterioration that occur are erosion, muddiness and trail widening. Cole (1983) contends that much of this can be avoided by proper technique and engineering during trail construction. Minimizing trail erosion can be achieved by the creation of switchbacks that are cut along a gentler grade than the slope. This has the effect of slowing runoff, helping to increase water infiltration, thereby reducing erosion.

The addition of water bars helps to control erosion by channeling water off the trail onto adjacent vegetation where it can be more readily absorbed. Unguided water, flowing down a trail tends to etch deep erosion gullies. In fig. 7.1, two pictures were taken along Roger's Trail in Topanga State Park at sites located 10 meters from each other. Both sites are at the same slope and soil. The effect of water bars in preventing

Fig. 7.1 – Set of pictures showing the effect of using water bars on erosion.

erosion is well demonstrated in this case. The extensive erosion is evident on the mid to lower left side of the picture depicting the portion of the trail lacking water bars.

Another mitigating factor that is commonly recommended is trail construction along natural contours. While this is advisable to control soil erosion by following natural water diversions, in chaparral communities this is not always prudent. Firstly, riparian communities tend to exist along natural contours, particularly at canyon bottoms. Therefore, directing trails along such corridors would disproportionately concentrate recreational activities in this vegetation type. Secondly, increased contact with poison oak (*Toxicodendron diversilobum*) among recreationists would occur since densities of this highly toxic plant are highest in riparian areas.

Trails in chaparral, unlike recreation trails in many other ecosystems, tend to be permanent, having been cut through the thick brush. This is in conflict with the often practiced management procedures of altering trail routes to minimize trail damage and to allow previous routes to regenerate. The flip side is that shortcuts are rare due to the near impassability of closed chaparral, thereby eliminating a substantial amount of excess trail creation.

Trail visitation

The selection of recreational sites and trails can affect the intensity and amount of recreational impact. For example, in the Boundary Waters Canoe Area, vegetation groundcover average 52% of campsites with less than 25% tree cover and only 4% on campsites with 75-100% tree cover (Marion 1993). Those campsites with greater sunlight availability supported vegetation, which were more tolerant to trampling due to flexible growth forms and other unique characteristics.

The impact of recreational use is also dependent on the type of weather. Vegetation is more susceptible to damage during the growth season and during wetter times. As is already implemented, closure of trails and campsites during the rainy season helps to reduce recreational impacts.

Analysis of the effects of trampling along trails that have been established for a long period of time should lead to a better understanding of the relative tolerance of plant communities to human use and the displacement of native flora by exotic species better adapted to withstand human use pressures.

In addition, mitigating factors to prevent the introduction of exotics and displaced natives should be taken. The prolific distribution of feces from horses can serve as point sources of plant invasions due to their seed content. This was suggested in the study by the high presence of graminoid species only along trails that allowed horses. One common mitigating factor practiced in other preserves is to regulate horse feed to ensure that only native species are present. The extensive distribution of horse ranches and the numerous horse trails in the Santa Monica Mountains make this a formidable task but distributing information along trailheads and at ranches would help to educate horse owners about the problem and hopefully encourage adaptation of this practice.

Appendix A – Species sampled

CODE	Scientific Name	Common Name	Life cycle	Status	Life form
ADFA	*Adenostoma fasiculatum*	Chamise	p	N	S
ALHA	*Allium haematochiton*	Red-skinned onion	p	N	H
ANAR	*Anagallis arvensis*	Scarlet pimpernel	a	E	H
ANKE	*Antirrhinum kelloggii*	Twining snapdragon	a	N	V
ARCA	*Artemesia california*	California sagebrush	p	N	S
ARGL	*Arabis glabra*	Tower mustard	p	N	H
AVBA	*Avena barbata*	Wild Oats	a	E	G
BAPA	*Baccharis pilularis*	Coyote bush	p	N	S
BRNI	*Brassica nigra*	Black mustard	a	E	H
BRRU	*Bromus rubens*	Red brome	a	E	G
CAAL	*Calochortus albus*	Globe lily	p	N	H
CABR	*Calandrinia breweri*	Brewer's red maids	a	N	H
CACA	*Calochortus catalinae*	Catalina mariposa lily	p	N	H
CECR	*Ceanothus crassifolius*	Hoary-leaved ceanothus	p	N	S
CECU	*Ceanothus cuneatus*	Buck-brush	p	N	S
CEME	*Ceanothus megacarpus*	Big-pod ceanothus	p	N	S
CESP	*Ceanothus spinosus*	Greenbark ceanothus	p	N	S
CHSU	*Chamomilla suaveolons*	Pineapple weed	a	E	H
CIIN	*Cichorium intybus*	Chicory	p	E	H
CIVU	*Cirsium vulgare*	Bull thistle	b	N	H
CLPE	*Claytonia perfoliata*	Miner's lettuce	a	N	H
CMCA	*Camissonia californica*	Mustard evening primrose	a	N	H
COBO	*Conyza bonariensis*	Little horseweed	a	E	H
COCA	*Conyza canadensis*	Horseweed	a	N	H
CRIN	*Cryptantha intermedia*	Popcorn flower large flowered	a	N	H
CRMI	*Cryptantha micromeres*	Popcorn flower minute flowered	a	N	H
DEPI	*Descurania pinnata*	Tansy mustard	a	N	H
DICA	*Dichelostemma capitatum ssp. Pauciflorum*	Blue dicks	p	N	H
ELGL	*Elymus glaucus*	Blue wild rye	p	N	G
EMPE	*Emmananthe peduliflora*	Whispering bells	a	N	H

ENCA	*Encelia californica*	Bush sunflower	p	N	S
ERCI	*Erodium cicutarium*	Red-stem filaree	a/b	E	H
ERFA	*Eriogonum fasciculatum*	California buckwheat	p	N	S
ESCA	*Eschscholzia californica*	California poppy	a/p	N	H
FEME	*Festuca Megalura*	Foxtail fescue	a	E	G
GAAN	*Galium angustifolium ssp angustifolium*	Narrow-leaved bedstraw	p	N	S
GNCA	*Gnaphalium californicum*	California everlasting	b	N	H
HEAN	*Helianthus annuus*	Common sunflower	a	N	H
HESC	*Helianthemum scoparium var. vulgare*	Rock-rose	p	N	H
HOLE	*Hordeum leporinum*	Hare barley	a	E	G
HOVU	*Hordeum vulgare*	Barley	a	E	G
KOCR	*Koeleria cristala*	Old bunchgrass	p	N	G
LOSC	*Lotus scoparius*	Deerweed	p	N	S
LOUT	*Lomatium utriculatum*	Hog Fennel	p	N	H
LULA	*Lupine latifolius*	Broad-leaved lupine	p	N	H
LULO	*Lupine longifolus*	Bush lupine	p	N	W
LUSP	*Lupinus sparsiflorous*	Coulter's lupine	a	N	H
LUTR	*Lupinus truncatus*	Collar lupine	a	N	H
MALA	*Malosma laurina*	Laurel Sumac	p	N	S
MAMA	*Marah macrocarpus*	Wild cucumber	p	N	V
MAVU	*Marrubium vulgare*	Horehound	p	E	S
MEPO	*Medicago polymorpha ssp hispida*	Bur-clover	a	E	H
MESA	*Medicago sativa*	Alfalfa	p	E	H
MIAU	*Mimulus aurantiacus*	Bush monkey flower	p	N	S
MIBR	*Mimulus brevipes*	Yellow monkey flower	a	N	H
PHGR	*Phacelia grandiflora*	Large-flowered phacelia	a	N	H
PHPA	*Phacelia parryi*	Parry's phacelia	a	N	H
PHVI	*Phacelia visacida*	Sticky phacelia	a	N	H
PLER	*Plantago erecta*	California plantain	a	N	G
POAN	*Poa annua*	Annual bluegrass	a	E	G
QUDU	*Quercus dumosa*	Scrub oak	p	N	S
RHIN	*Rhus integrifolia*	Lemonade bush	p	N	S
RHOV	*Rhus ovata*	Sugarbush	p	N	S
RIMA	*Ribes malvaceum ssp. viridifolium*	Chaparral currant	p	N	S

SAME	*Salvia mellifera*	Black sage	p	N	S
SEFL	*Senecio flaccidus var. douglasii*	Bush senecio	p	N	S
SEVU	*Senecio vulgaris*	Common groundsel	a	E	H
SIBE	*Sisyrinchium bellum*	Blue-eyed grass	p	N	H
SIGA	*Silene gallica*	Windmill Pink	a	E	H
SOXA	*Solanum xanti*	Purple nightshade	p	N	S
SPJU	*Spartium junceum*	Spanish broom	p	E	S
STPU	*Stipa pulchra*	Purple stipa	p	N	G
TAOF	*Taraxacum officionale*	Dandelion	p	E	H
TODI	*Toxicodendron diversilobum*	Poison oak	p	N	H
YUWH	*Yucca whipplei ssp. Intermedia*	Chaparral yucca	p	N	S

Explanation of Codes:
p = perennial
a = annual
E = exotic
N = native
G = grass
S = shrub
V = vine-like
H = herbaceous

Appendix B – Disturbance oriented flowering plants in the Santa Monica Mountains

Scientific Name	Common name	Status	Disturbance type
Acourtia microcephala	Perezia	N	fire follower
Acroptilon repens	Russian knapweed	E	fields, pastures, along trails
Amaranthus albus	Tumbleweed	E	cultivated fields and disturbed places
Amaranthus deflexus	Low Amaranth	E	along streets, roads and other dist. places
Amaranthus retroflexus	Rough pigweed	E	disturbed soil and as a weed in gardens
Ambrosia psilostachya	Western ragweed	N	along roads and disturbed areas
Amsinckia menziesii var. intermedia	Common fiddleneck	N	fire follower, grassy hillsides
Anthemis cotula	Mayweed	E	along trails, roads and open fields
Antirrhinum kelloggii	Twining snapdragon	N	fire follower on dry soils
Antirrhinum multiflorum	Rose snapdragon	N	second year fire follower, disturbed dry slopes
Antirrhinum nuttallianum	Violet snapdragon	N	dry disturbed soils
Apiastrum angustifolium	Wild celery	N	fire follower
Artemisia biennes	Biennial sagewr	E	moist disturbed areas
Atriplex semibaccata	Australian Sl.	E	disturbed areas near roads, marshes
Bassia hyssopifolia	Five-hook bassia	E	disturbed soil near coast
Bidens frondosa	Sticktight	N	moist disturbed areas
Brassica nigra	Black mustard	E	meadows, disturbed areas, fires, trails
Brassica rapa	Field Mustard	E	meadows, disturbed areas, fires, trails
Buddleja saligna	Butterfly bush	E	disturbed areas
Calandrinia breweri	Brewer's red maids	N	fire follower, disturbed soils
Calochortus albus	Globe lily	N	fire follower
Calochortus catalinae	Catalina mariposa lily	N	fire follower
Calochortus clavatus ssp. pallidus	Yellow mariposa lily	N	fire follower
Calystergia macrostegia ssp. cyclostegia	Morning glory	N	fire follower
Camissonia boothii	Shredding primrose	N	disturbed areas, loose soils
Camissonia californica	Mustard evening primrose	N	fire follower, dry disturbed slopes
Camissonia micrantha	Small eveing primrose	N	fire follower, dry disturbed soils
Cardarua draba	Hoary cress	E	fields, disturbed places
Carduus pychocephalus	Italian thistle	E	roads, firebreaks, disturbed areas
Caulanthus heterophyllus	Jewel flower	N	fire follower, open places in chaparral

Centaurea melitensis	Yellow star th.	E	dry fields, roads, trails, disturbed areas
Centaurea solstitilis	Barnaby's st.t.	E	dry fields, roads, trails, disturbed areas
Chaenactic glabriuscula	Yellow pincushion	N	fire follower
Chaenactis artemisiifolia	White pincushion	N	disturbed areas, fire follower
Chamaesyce maculata	Spotted spurge	E	disturbed soil
Chamomilla suaveolens	Pineapple weed	E	gardens, plowed fields, trails, roads
Chanaesyce serpyllifolia	Thyme…..	N	disturbed soil near lakes and streams
Chenopodium album	Lamb's quarters	E	disturbed soil
Chenopodium ambrosiodes	Mexican tea	E	moist disturbed areas, along streams
Chenopodium berlandieri	Goosefoot	E	disturbed soil
Chenopodium multifidum	Cut-leaved goo.	E	disturbed areas mostly near the coast
Chenopodium murale	Sowbane	E	disturbed areas
Chenopodium strictum var. galucophyllum	White goosefoot	E	disturbed soil
Chrysanthemum coronarium .	Garland chicory	E	fields, along roads
Cichorium intybus	Chicory	E	disturbed areas
Cirsium vulgare	Bull thistle	E	disturbed soil
Clarkia bottae	Farewell-to-spring	N	disturbed soils, open areas
Cnicus benedictus	Blessed thistle	E	disturbed areas and valleys
Collinsia parry	Blue-eyed Mary	N	fire follower, disturbed soils
Convolvulus arvensis	Bindweed	E	cultivated fields, open places
Conyza bonariensis	Little horsewd	E	firebreaks, disturbed areas
Conyza canadensis	Horeseweed	N	firebreaks, disturbed areas
Coronopus didymus	Wart cress	E	disturbed areas
Cotula australis	Australian Br.	E	disturbed soil
Cryptantha intermedia	Large popcorn	N	fire follower
Cryptantha micromeres	Minute popcorn	N	fire follower
Cynara cardunculus	Cardoon	E	disturbed soil
Datura stramonium	Jimson-weed	E	disturbed soil
Daucus pusillus	Rattlesnake weed	N	fire follower and disturbed soil
Dimorphotheca sinuata	Cape marigold	E	roads, dsiturbed soil
Diplotaxis tenuifolia	Wall rocket	E	disturbed areas
Emmananthe penduliflora	Whispering Bells	N	fire follower
Eremocarpus setigerus	Turkey mullen	N	disturbed areas in sand and clay, pavement cracks
Erodium cicutarium	Red-stem filar.	E	cultivated fields

Escscholzia californica	California poppy	N	fire follower
Eucrypta chrysanthernifolia	Eucrypta	N	fire follower
Foeniculum vulgare	Sweet fennel	E	along roadsm trails and streambeds
Galinsoga parviflora var. parviflora	Small-flowered galinsoga	E	plowed ground
Gilia australis	Splendid gilia	N	fire follower
Glycyrrhiza lepidota	Wild licorice	N	moist disturbed areas
Hedypnois creytica	Hedypnois	E	disturbed areas
Helianthus annuus	Common sunflower	N	trails, disturbed places
Helianthus gracilentus	Slender sunflower	N	roadsides, dry fields, openings in chaparral
Hernaria hirsuta ssp. hirsuta	Hernaria	E	disturbed slopes in chaparral
Heterotheca grandiflora	Telegraph weed	N	firebreaks, disturbed areas
Hirchfeldia incana	Mediterranean mustard	E	disturbed areas, trails, roads
Hypochaeis glabra	Annual cat's ear	E	meadows, disturbed areas
Lamium amplexicaule	Henbit	E	disturbed areas, cultivated fields
Lepidium latifolium	Persian peppergrass	E	waste places
Lepidium perfoliatum	Shield cress	E	disturbed soil
Linaria canadensis var. texana	Blue toadflax	N	fire follower on dry slopes
Lotus pushinaus	Spanish clover	N	disturbed places, dry fields, Southern Oak Wood.
Lotus scoparius	Deerweed	N	dominant shrub after fire, firebreaks
Lupinus bicolor	Dove lupine	N	fire follower
Lupinus concinnus	Bajada lupine	N	dry, open disturbed places
Lupinus hirsutissimus	Stinging lupine	N	fire follower
Lupinus luteus	Yellow lupine	E	roads
Lupinus sparsiflorus	Coutler's lupine	N	fire follower, open chaparral, CSS
Lupinus succulentus	Arroyo lupine	N	fire follower
Malacothris celvelandii	Annual malacothrix	N	fire follower, disturbed areas
Malacothrix saxatilis	Cliff-aster	N	roadcuts, cliffs, open places
Malva nicaeensis	Bull mallow	E	waste places
Malva parviflora	Cheeseweed	E	waste places
Marribium vulgare	Horehound	E	disturbed soil
Medicago lupulina	Black medick	E	disturbed areas
Medicago polymorpha ssp. hispida	Bur-clover	E	grassy areas, trails
Medicago sativa	Alfalfa	E	roadsides, trails, cultivated fields
Melilotus alba	White sweetclover	E	moist, disturbed areas

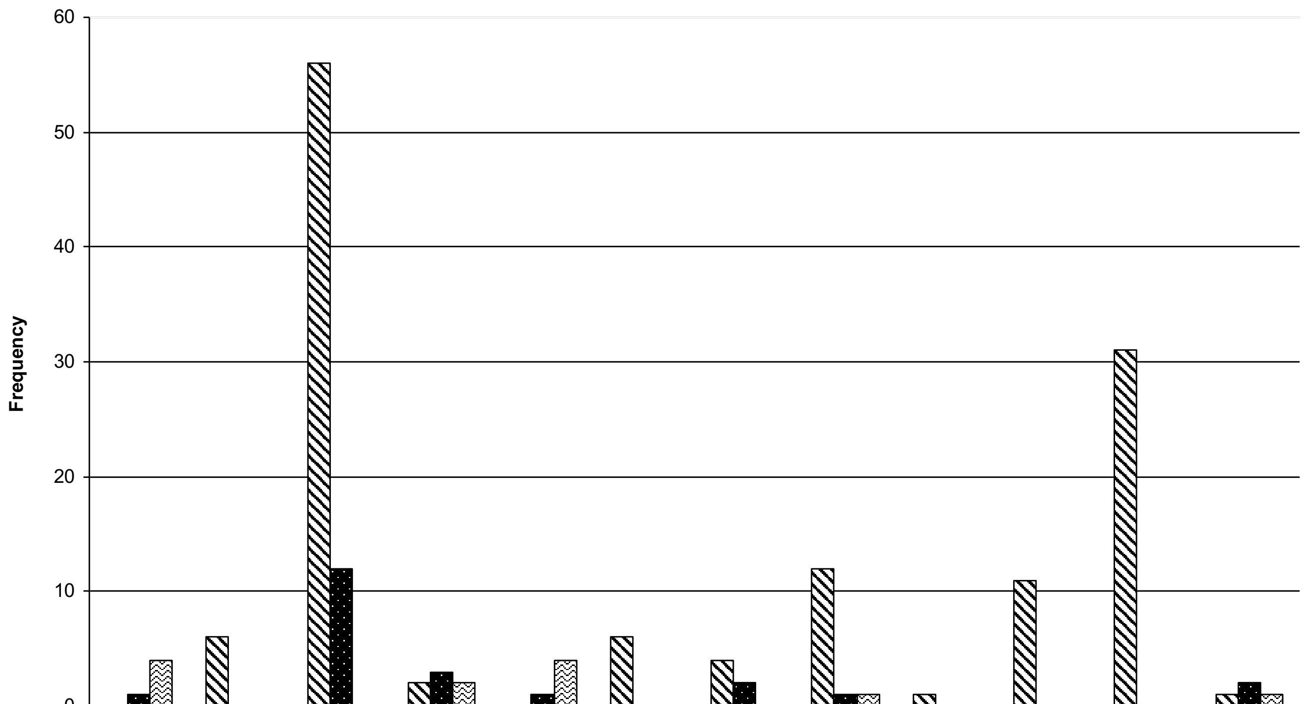
Melilotus indica	Sourclover	N	disturbed areas
Mentzelia micrantha	Blazing star	N	fire follower, disturbed soils
Modolia caroliniana	Bristly mallow	E	roadsides, fields
Nicotiana bigelovii	Indian tobacco	N	burned areas, disturbed areas
Olea europaea	Olive	E	disturbed areas, abandoned homesites
Pahcelia parryi	Parry's phacelia	N	fire follower, disturbed soils
Papaver californicum	Fire poppy	N	fire follower
Phacelia brachyloba	Yellow-throated phacelia	N	fire follower, disturbed soils
Phacelia distans	Fern-leaf phacelia	N	fire follower
Phacelia grandiflora	Large-flowered phacelia	N	fire follower
Phacelia minor	California bells	N	fire follower, disturbed soils
Phacelia viscida	Sticky phacelia	N	fire follower
Pholistoma auritum	Fiesta flower	N	fire follower
Picris echoides	Bristly ox-ton	E	grassy fields, disturbed soils, gardens
Plantago laceolata	English plantain	E	damp, disturbed soil
Plantago major	Common plantain	E	damp, disturbed soil
Polycarpon tetraphyllym	4-leaved polycarp	E	trails
Polygonum arenastrum	Common knotweed	E	disturbed soil
Rafinesquia californica	California chicory	N	fire follower, fire breaks
Ricinis communis	Castor-bean	E	disturbed areas
Salsola tragus	Tumbleweed	E	cultivated fields, fences
Salvia columbariae	Chia	N	fire follower
Scutellaria tuberosa	Skullcap	N	fire follower
Senecio flaccidus var. douglasii	Bush senecio	N	roads, trails, dry creek beds
Senecio vulgaris	Comm. groundsel	E	disturbed places
Silene gallica	Windmill Pink	E	trails, grasslands, fields
Silene multinervia	Many-nerved ca.	N	fire follower, disturbed soils
Silybum marianum	Milk thistle	E	pastures, disturbed soil
Sinapis arvensis	Field Charlock	E	fields, disturbed areas
Sisymbrium altissimum	Tumble Mustard	E	disturbed soil
Sisymbrium irio	London Rocket	E	gardens, disturbed areas
Sisymbrium officionale	Hedge mustard	E	disturbed areas
Sisymbrium orientale	Oriental must.	E	disturbed soil
Solanum elaeagnifolium	White horse-nettle	E	disturbed soils

Solanum rostratum	Buffalo berry	E	disturbed areas
Sonchus asper	Prickly sowthistle	E	disturbed soils
Sonchus oleraceus	Sow-thistle	E	disturbed soils
Spartium junceum	Spanish broom	E	disturbed areas, roads, trails
Stellaria media	Chickweed	E	cultivated areas, fire, Southern Oak woodlands
Stephanomeria virgata	Wand chicory	N	fire follower, disturbed area, openings in c, CSS
Stylomecon heterophylla	Wind poppy	N	fire follower
Taraxacum officionale	Dandelion	E	cultivated areas
Tribulu terrestris	Puncture vine	E	disturbed areas, roads
Trifolium incarnatum	Crimson clover	E	disturbed areas
Triodanus biflora	Little venus...	N	fire follower, open disturbed areas
Vicia sativa	Spring vetch	E	disturbed areas
Vicia villosa	Winter vetch	E	disturbed areas, grassy areas
Vicia villosa ssp. varia	Purple vicia	N	disturbed areas, grassy areas
Zygadenus fremontii	Star lily	N	fire follower

(Compiled from McAuley 1996. E = exotic, N = native species).

Appendix C – Species Frequencies for Transects

TC_HON

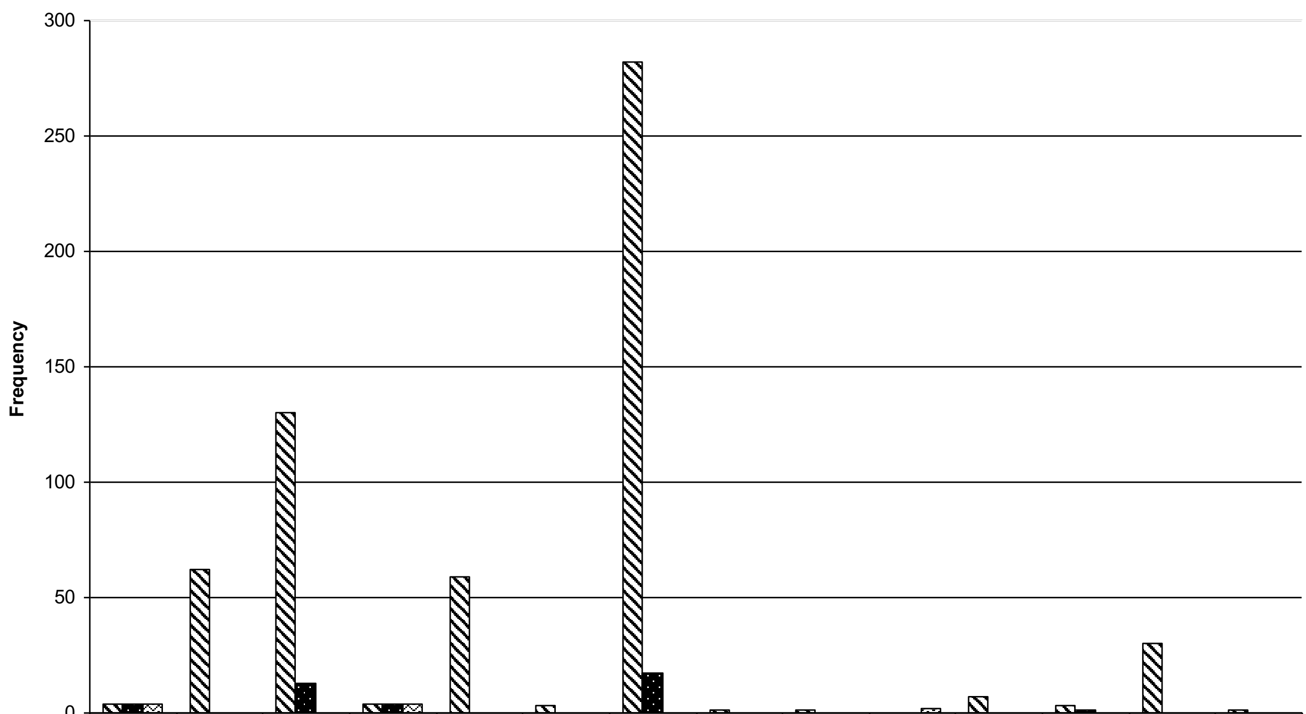


	ADFA	BRNI	BRRU	CEME	CESP	DEPI	ENCA	HOLE	MAMA	PHGR	PHVI	SAME
0.5m	0	6	56	2	0	6	4	12	1	11	31	1
5m	1	0	12	3	1	0	2	1	0	0	0	2
20m	4	0	0	2	4	0	0	1	0	0	0	1

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	2	1	1	1	1	1	1	---	---	---	1	1	---	1	1
AVBA	8	---	---	---	---	---	5	---	---	35	---	---	14	---	---
BRRU	47	---	---	43	---	---	9	3	---	---	---	---	31	3	---
CEME	---	1	---	2	1	1	---	1	1	1	1	1	1	---	1
CRIN	10	---	---	---	---	---	9	---	---	3	---	---	37	---	---
DICA	---	---	---	---	---	---	3	---	---	---	---	---	---	---	---
ELGL	97	---	---	112	---	---	---	---	---	---	---	---	73	17	---
GAAN	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
LOSC	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MALA	---	---	1	---	---	---	---	---	1	---	---	---	---	---	---
PHGR	---	---	---	---	---	---	---	---	---	7	---	---	---	---	---
SAME	1	1	---	1	---	---	1	---	---	---	---	---	---	---	---
STPU	---	---	---	---	---	---	---	---	---	13	---	---	17	---	---
TAOF	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---

App. C1 – Species frequencies per quadrat for TC_HON

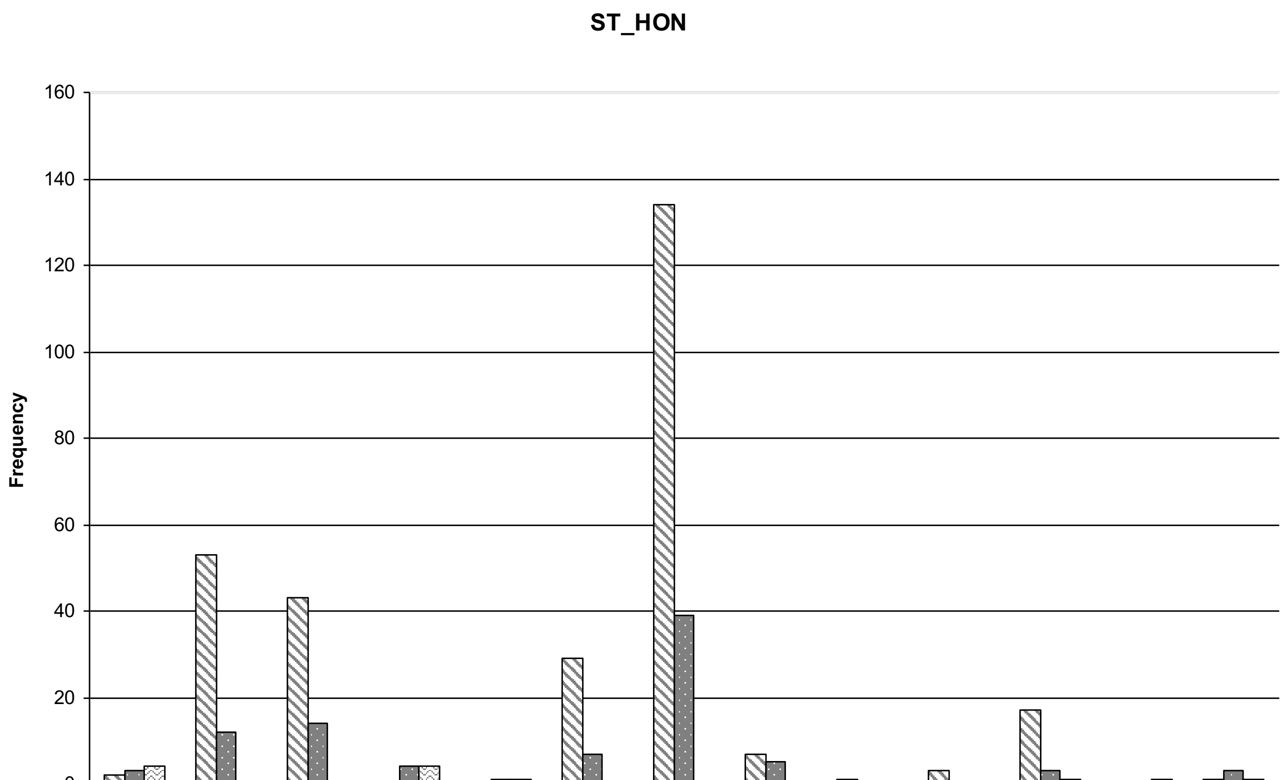
CF_HON



	ADFA	AVBA	BRRU	CEME	CRIN	DICA	ELGL	GAAN	LOSC	MALA	PHGR	SAME	STPU	TAOF
0.5m	4	62	130	4	59	3	282	1	1	0	7	3	30	1
5m	4	0	13	4	0	0	17	0	0	0	0	1	0	0
20m	4	0	0	4	0	0	0	0	0	2	0	0	0	0

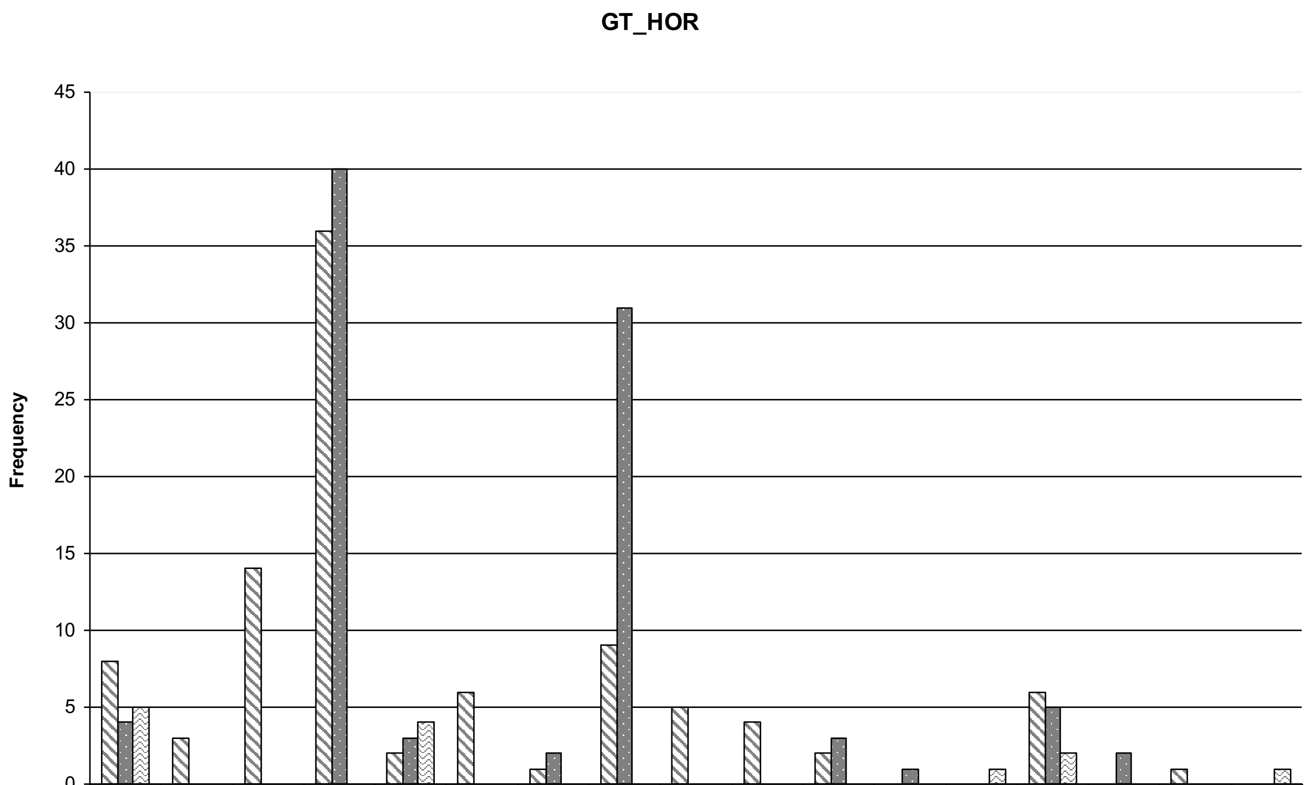
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	---	---	1	---	---	1	---	---	---	---	1	1	---	---	1
AVBA	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BRNI	4	---	---	---	---	---	---	---	---	---	---	---	2	---	---
BRRU	7	3	---	---	---	---	---	---	---	20	3	1	29	6	---
CEME	---	---	1	1	---	---	---	1	---	1	1	1	---	1	---
CESP	---	---	---	---	1	---	---	---	1	---	---	---	---	---	---
DEPI	2	---	---	---	---	---	---	---	---	4	---	---	---	---	---
ENCA	2	2	---	1	---	---	---	---	---	---	---	---	1	---	---
HOLE	---	---	---	---	---	---	---	---	---	---	---	---	12	---	---
MALA	---	---	---	1	---	1	---	1	---	---	---	---	---	1	---
MAMA	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
PHGR	---	---	---	---	---	---	---	---	---	11	---	---	---	---	---
PHVI	---	---	---	---	---	---	22	---	---	9	---	---	---	---	---
SAME	---	2	1	---	---	---	1	---	---	---	---	---	---	---	---

App. C2 – Species frequencies per quadrat for CF_HON



	ADFA	AVBA	BRRU	CEME	CESP	CRIN	ELGL	FEME	GNCA	LOSC	PHGR	RHOV	SAME
0.5m	2	53	43	0	0	29	134	7	1	3	17	0	1
5m	3	12	14	4	1	7	39	5	0	0	3	0	3
20m	4	0	0	4	1	0	0	0	0	0	1	1	1

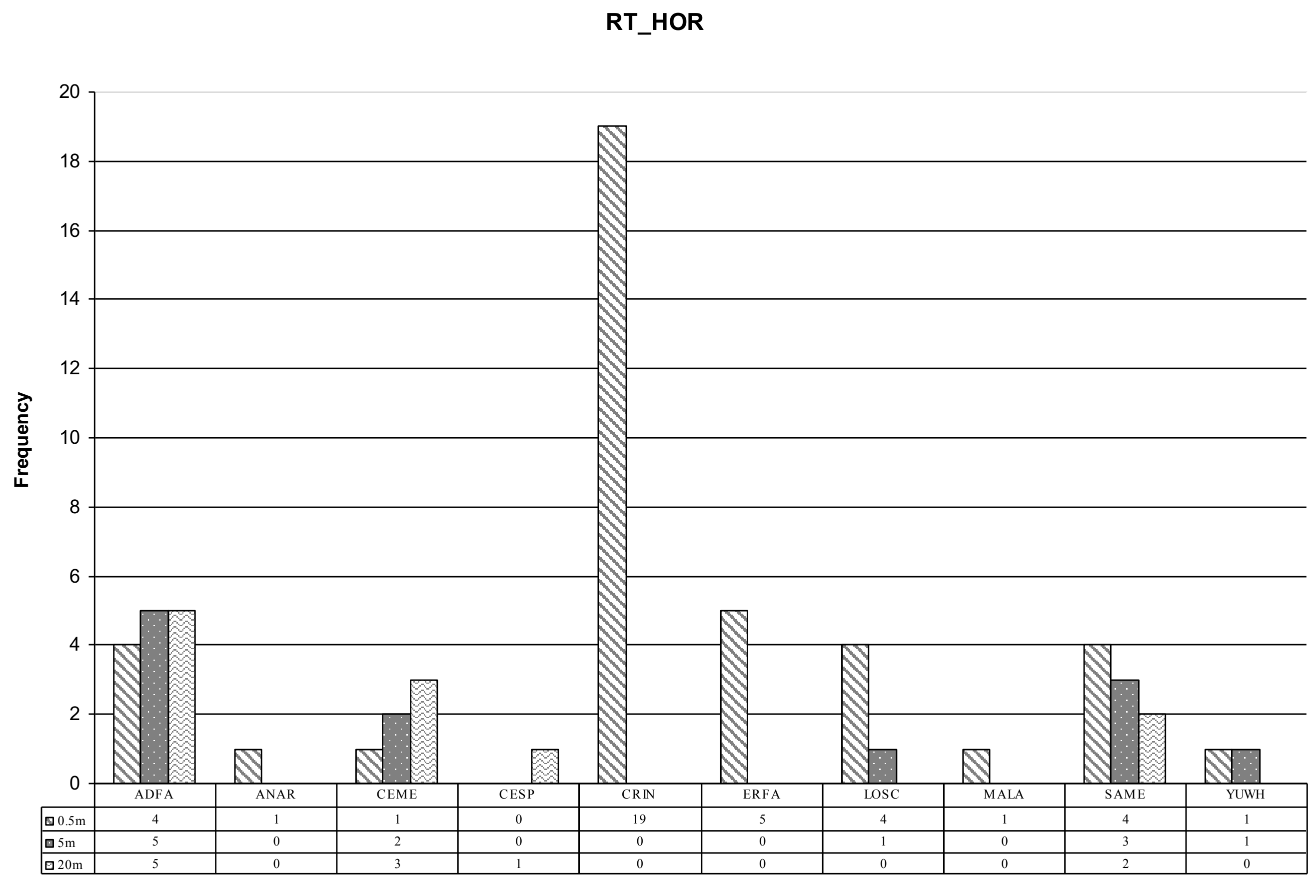
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	1	---	1	---	1	1	1	---	1	---	1	---	---	1	1
AVBA	---	---	---	---	---	---	---	---	---	---	---	---	53	12	---
BRRU	---	---	---	3	---	---	11	---	---	8	---	---	21	14	---
CEME	---	1	1	---	---	1	---	1	1	---	1	1	---	1	---
CESP	---	---	---	---	1	---	---	---	---	---	---	---	---	---	1
CRIN	7	---	---	17	---	---	5	7	---	---	---	---	---	---	---
ELGL	43	21	---	---	---	---	---	---	---	23	11	---	47	2	---
FEME	---	---	---	7	5	---	---	---	---	---	---	---	---	---	---
GNCA	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
LOSC	---	---	---	1	---	---	1	---	---	2	---	---	---	---	---
PHGR	---	---	---	7	2	---	7	2	---	6	1	---	4	1	---
RHOV	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
SAME	1	1	---	---	---	---	---	---	---	---	1	1	---	1	---



	ADFA	ANKE	BRRU	CABR	CEME	CLPE	CMCA	CRIN	CRMI	GNCA	LOSC	MALA	RHOV	SAME	SEFL	SEVU	YUWH
0.5m	8	3	14	36	2	6	1	9	5	4	2	0	0	6	0	1	0
5m	4	0	0	40	3	0	2	31	0	0	3	1	0	5	2	0	0
20m	5	0	0	0	4	0	0	0	0	0	0	0	1	2	0	0	1

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	2	1	1	1	1	1	2	---	1	1	1	1	2	1	1
ANKE	---	---	---	---	---	---	---	---	---	2	---	---	1	---	---
BRRU	---	---	---	---	---	---	---	---	---	---	---	---	14	---	---
CABR	---	8	9	12	20	---	---	11	---	16	---	---	---	---	---
CEME	---	2	1	---	---	1	---	---	1	---	1	1	3	---	---
CLPE	---	---	---	---	---	---	---	---	---	---	---	---	6	---	---
CMCA	---	---	---	---	2	---	---	---	---	1	---	---	---	---	---
CRIN	---	11	---	---	1	---	---	19	---	4	---	---	5	---	---
CRMI	---	---	---	---	---	---	---	---	---	---	---	---	5	---	---
GNCA	---	---	---	---	---	---	---	---	---	1	---	---	3	---	---
LOSC	---	---	---	2	---	---	---	3	---	---	---	---	---	---	---
MALA	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---
SAME	3	2	1	2	---	---	1	2	---	---	1	---	---	---	---
RHOV	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---
SEFL	---	---	---	---	---	---	---	2	---	---	---	---	---	---	---
SEVU	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---
YUWH	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1

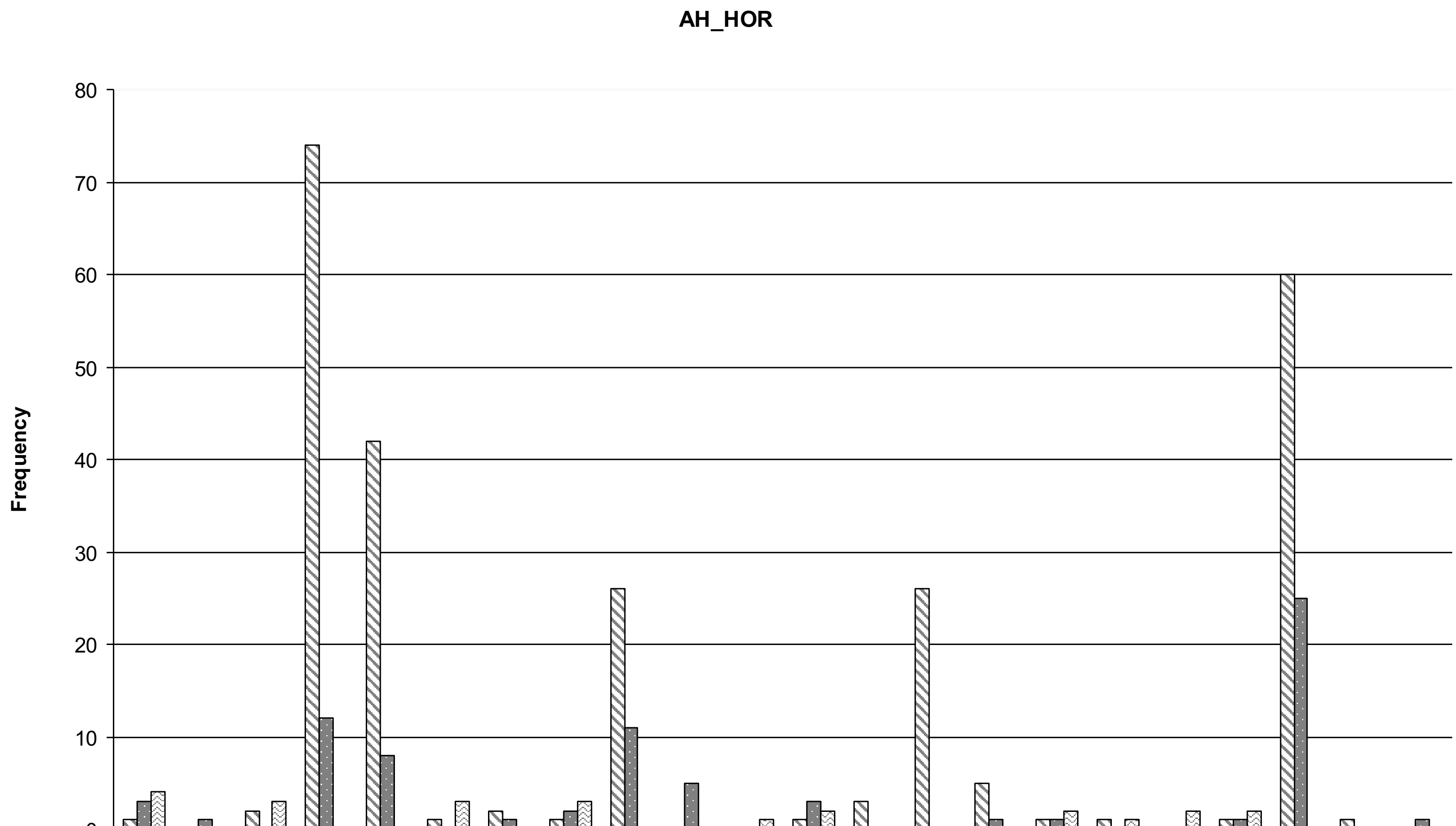
App. C4 – Species frequencies per quadrat for GT_HOR.



	ADFA	ANAR	CEME	CESP	CRIN	ERFA	LOSC	MALA	SAME	YUWH
0.5m	4	1	1	0	19	5	4	1	4	1
5m	5	0	2	0	0	0	1	0	3	1
20m	5	0	3	1	0	0	0	0	2	0

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	1	1	1	1	1	1	1	1	1	1	1	1	---	1	1
ANAR	---	---	---	---	---	---	---			1	---	---	---	---	---
CEME	---	---	1	---	1	---	---	1	1	---	---	---	1	---	1
CESP	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---
CRIN	---	---	---	---	---	---	---	---	---	7	---	---	12	---	---
ERFA	---	---	---	---	---	---	---	---	---	4	---	---	1	---	---
LOSC	1	---	---	1	---	---	1	---	---	1	---	---	---	1	---
MALA	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---
SAME	1	1	---	1	---	1	1	1	---	---	1	---	1	---	1
YUWH	---	---	---	1	---	---	---		---	---	---	---	---	1	---

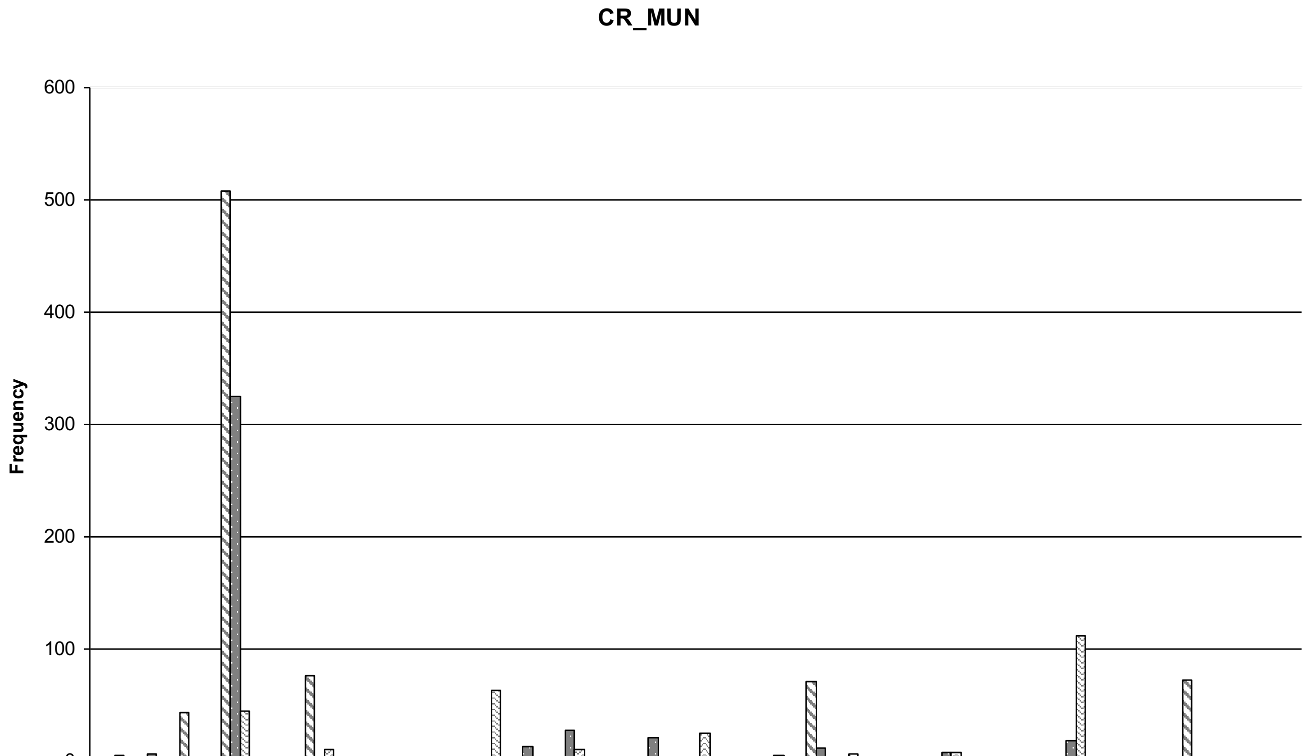
App. C5 – Species frequencies per quadrat for RT_HOR.



	ADFA	ANKE	ARCA	AVBA	BRRU	CACA	CECU	CEME	CRIN	DICA	ENCA	ERFA	ESCA	HOVU	LOSC	SAME	QUDU	RIMA	SAME	STPU	TAOF	YUWH
0.5Mm	1	0	2	74	42	1	2	1	26	0	0	1	3	26	5	1	1	0	1	60	1	0
5m	3	1	0	12	8	0	1	2	11	5	0	3	0	0	1	1	0	0	1	25	0	1
20m	4	0	3	0	0	3	0	3	0	0	1	2	0	0	0	2	1	2	2	0	0	0

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	1	---	3	---	---	1	---	1	1	1	1	1	---	---	1
ANKE	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---
ARCA	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---
AVBA	---	---	---	---	---	---	10	---	---	23	---	---	41	12	---
BRRU	---	---	---	---	---	---	29	---	---	---	5	---	13	3	---
CACA	---	---	3	---	---	---	1	---	---	---	---	---	---	---	---
CECU	1	---	---	---	---	---	1	1	---	---	---	---	---	---	---
CEME	---	---	---	---	---	---	---	2	1	1	---	1	---	---	1
CRIN	---	---	---	19	6	---	2	---	---	5	---	---	---	5	---
DICA	---	---	---	---	2	---	---	1	---	---	2	---	---	---	---
ENCA	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---
ERFA	1	1	2	---	2	---	---	---	---	---	---	---	---	---	---
ESCA	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---
HOVU	---	---	---	6	---	---	20	---	---	---	---	---	---	---	---
LOSC	1	---	---	2	---	---	---	---	---	1	---	---	1	1	---
QUDU	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---
RIMA	---	---	---	---	---	2	---	---	---	---	---	---	---	---	---
SAME	---	---	1	---	---	---	---	---	---	1	1	---	---	---	1
STPU	11	---	---	14	---	---	1	---	---	13	---	---	21	19	---
TAOF	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---
YUWH	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---

App. C6 – Species frequencies per quadrat for AH_HOR.



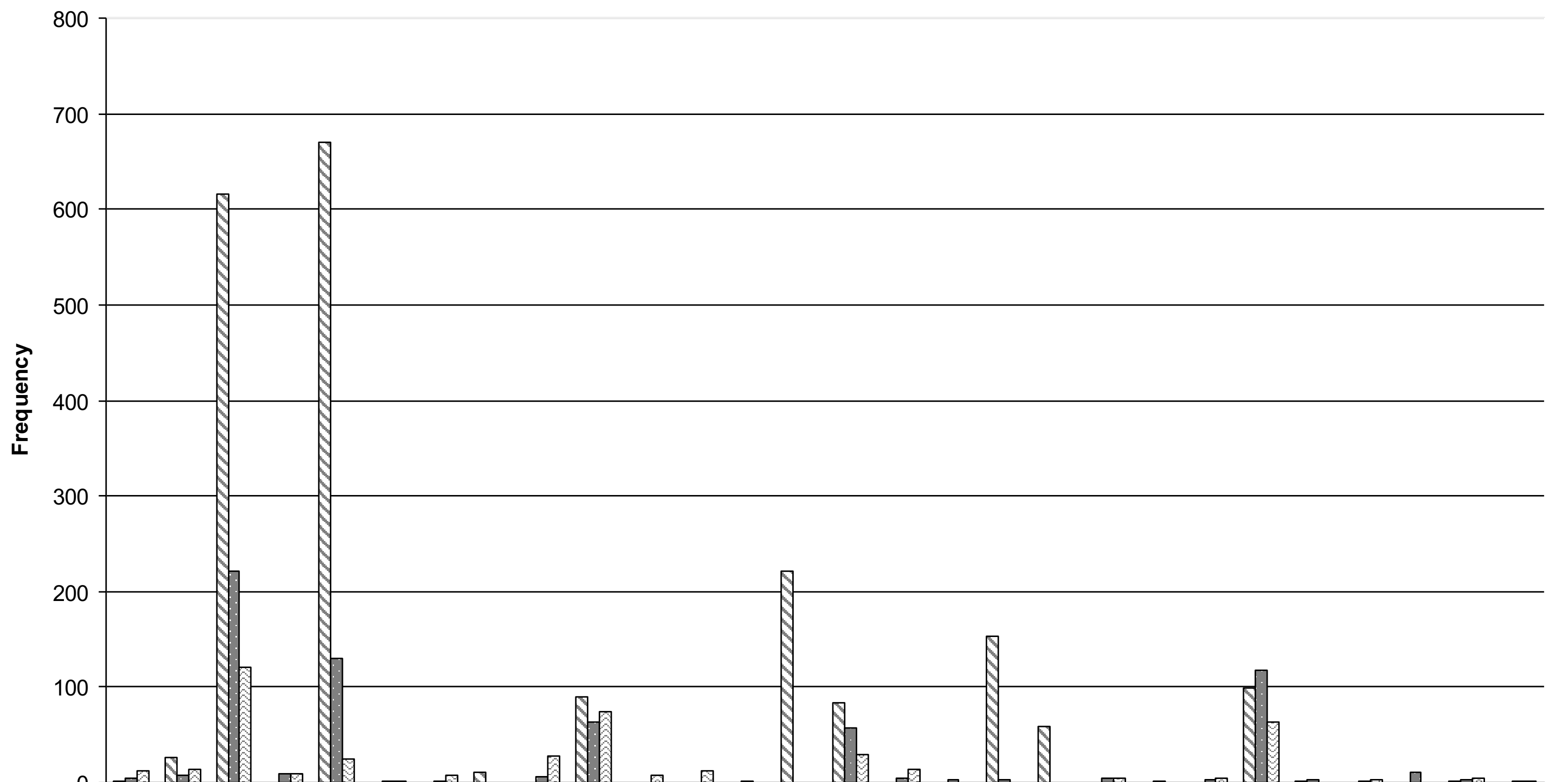
	ADFA	ANAR	ARGL	AVBA	BRNI	BRRU	CECR	CEME	COBA	CRIN	DICA	ELGL	EMPE	ESCA
0.5m	0	0	43	508	2	76	0	1	1	0	0	0	0	0
5m	0	6	0	325	1	2	0	1	0	0	13	28	0	21
20m	5	2	0	45	0	10	2	4	0	63	2	11	1	0

	HOVU	LOSC	LUSP	LUTR	MEPO	MIBR	PLER	RIMA	SEFL	SEVU	SOXA	STPU	TAOF	YUWH
0.5m	1	0	71	7	2	0	3	0	2	3	0	72	2	0
5m	0	5	12	0	3	8	0	1	18	0	1	0	4	3
20m	0	0	0	0	0	8	0	0	112	0	0	0	0	4

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	---	---	1	---	---	1	---	---	1	---	---	1	---	---	1
ANAR	---	---	2	---	6	---	---	---	---	---	---	---	---	---	---
ARGL	43	---	---	---	---	---	---	---	---	---	---	---	---	---	---
AVBA	139	27	---	46	201	---	113	47	---	86	11	9	124	39	36
BRNI	2	---	---	---	---	---	---	---	---	---	---	---	---	1	---
BRRU	7	2	---	21	---	3	12	---	7	27	---	---	9	---	---
CECR	---	---	---	---	---	---	---	---	1	---	---	1	---	---	---
CEME	---	1	1	---	---	1	---	---	---	---	---	1	1	---	1
COBA	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
CRIN	---	---	---	---	---	32	---	---	14	---	---	---	---	---	17
DICA	---	5	---	---	1	---	---	---	---	---	7	---	---	---	2
ELGL	---	---	11	---	---	---	---	---	---	---	28	---	---	---	---
EMPE	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---
ESCA	---	---	---	---	---	---	---	---	---	---	---	---	---	21	---
HESC	2	---	---	---	---	---	---	---	4	---	---	21	---	---	---
HOVU	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---
LOSC	---	---	---	---	---	---	---	2	---	---	2	---	---	1	---
LUSP	18	6	---	11	4	---	19	2	---	15	---	---	8	---	---
LUTR	---	3	---	---	---	---	---	---	---	---	---	---	7	---	---
MEPO	---	---	---	---	---	---	---	---	---	---	---	---	2	---	---
MIBR	---	---	1	---	---	6	---	---	---	---	8	---	---	---	1
PLER	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---
RIMA	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---
SEFL	---	---	56	---	---	---	---	---	23	---	---	---	2	18	33
SEVU	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---
SOXA	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---
STPU	56	---	---	11	---	---	5	---	---	---	---	---	---	---	---
TAOF	2	4	---	---	---	---	---	---	---	---	---	---	---	---	---
YUWH	---	---	---	---	---	1	---	2	1	---	---	2	---	1	---

App. C7 – Species frequencies per quadrat for CR_MUN.

DH_MUN

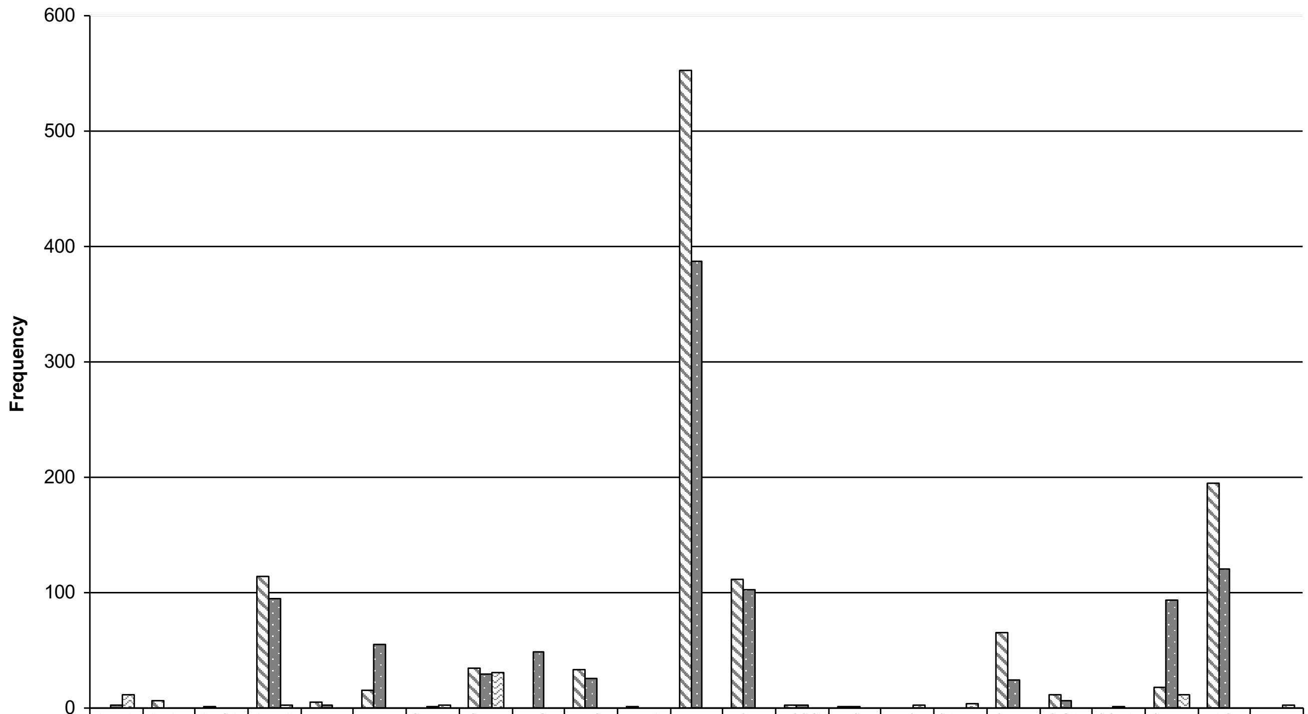


	ADFA	ANAR	AVBA	BRNI	BRRU	CACA	CRMI	DEPI	DICA	ELGL	ERFA	FEME	GAAN	HOLE	HOVU	KOCR	LOSC	LUSP	MEPO	MIBR	RHOV	SAME	SEFL	SEVU	SOXA	STPU	TAOF	YUWH
0.5m	2	27	616	0	670	0	0	11	0	89	0	0	0	221	83	0	0	153	59	0	0	0	99	1	0	0	2	0
5m	5	7	222	9	130	2	2	0	6	63	0	0	2	0	58	5	3	3	0	4	1	3	118	3	2	11	3	1
20m	13	14	120	9	25	2	7	0	28	75	7	13	0	0	29	14	0	0	0	4	0	5	63	0	3	0	5	1

CODE	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	---	---	1	---	1	3	1	3	5	---	1	2	1	---	2
ANAR	---	1	4	---	6	---	6	---	3	---	---	1	21	---	2
AVBA	232	173	72	---	43	---	256	6	---	128	---	---	---	---	---
BRNI	---	---	---	---	9	---	---	---	---	---	---	---	---	---	9
BRRU	114	41	---	395	10	15	2	17	10	108	6	---	---	56	---
CACA	---	1	2	---	1	---	---	---	---	---	---	---	---	---	---
CRMI	---	---	2	---	---	3	---	---	---	---	1	---	---	1	2
DEPI	11	---	---	---	---	---	---	---	---	---	---	---	---	---	---
DICA	---	---	5	---	5	17	---	1	6	---	---	---	---	---	---
ELGL	---	---	---	---	31	---	---	---	11	---	32	41	89	---	23
ERFA	---	---	---	---	---	---	---	---	---	---	---	7	---	---	---
GAAN	---	---	---	---	---	---	---	---	---	---	---	---	---	2	---
HOLE	---	---	---	---	---	---	78	---	---	143	---	---	---	---	---
HOVU		27	---	---	---	---	---	24	---	---	---	---	83	7	29
KOCR	---	---	---	---	---	---	---	---	---	---	5	14	---	---	---
LOSC		1	---	---	2	---	---	---	---	---	---	---	---	---	---
LUSP	37	3	---	6		---	2	---	---	---	---	---	---	---	---
MEPO	---	---	---	---	---	---	16	---	---	---	---	---	43	---	---
MIBR	---	---	---	---	---	---	---	---	---	---	---	---	---	4	4
RHOV	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
SAME	---	---	---	---	---	---	---	---	---	---	2	1	---	---	---
SEFL	21	---	---	---	---	---	32	78	63	---	11	---	46	29	---
SEVU	1	3	---	---	---	---	---	---	---	---	---	---	---	---	---
SOXA	---	---	---	---	---	---	---	---	3	---	---	3	---	2	---
STPU	---	---	---	---	---	---	---	---	---	---	---	---	---	11	---
TAOF	---	---	---	---	---	---	---	3	---	---	---	---	---	---	4
YUWH	---	---	---	---	1	---	---	---	---	---	---	---	---	---	1

App. C8 – Species frequencies for DH_MUN.

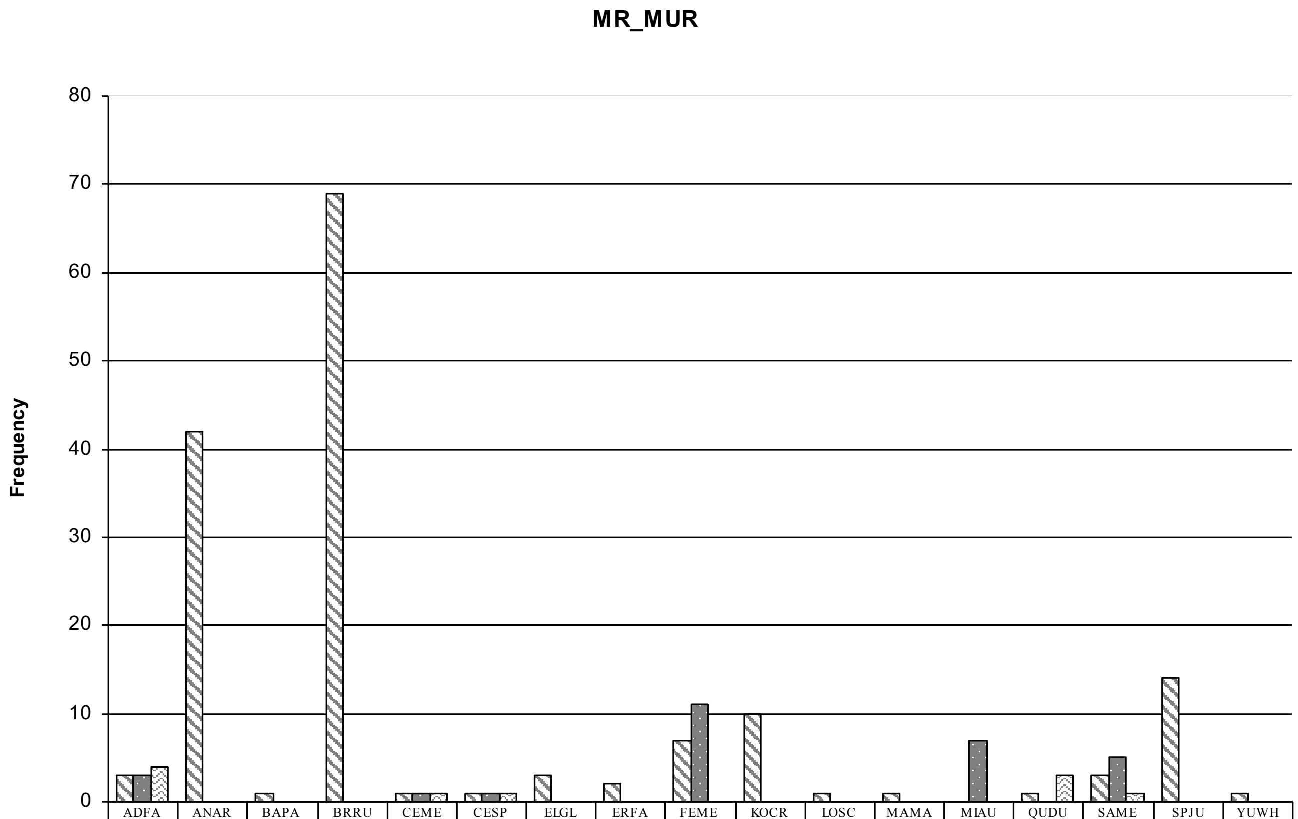
LR_MUN



	ADFA	ANAR	ARCA	AVBA	BRNI	BRRU	CEME	CRIN	ELGL	ERCI	ERFA	FEME	HOVU	LOSC	LUSP	RHOV	SAME	SEFL	SIGA	SOXA	STPU	TAOF	YUWH
0.5m	0	6	1	114	5	16	0	35	0	33	1	553	112	2	1	0	0	66	12	0	18	195	0
5m	3	0	0	95	3	55	1	30	49	26	0	387	102	2	1	0	0	25	7	1	93	121	0
20m	12	0	0	3	0	0	3	31	0	0	0	0	0	0	0	3	4	0	0	0	11	0	2

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	---	1	1	---	---	2	---	---	5	---	1	3	---	1	1
ANAR	---	---	---	---	---	---	12	25	---	---	---	---	6	---	---
ARCA	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
AVBA	26	20	---	35	17	3	---	---	---	41	18	---	---	15	---
BRNI	---	1	---	---	1	---	2	---	---	3	---	---	---	1	---
BRRU	14	6	---	---	---	---	---	33	---	---	16	---	2	---	---
CEME	---	---	1	---	---	---		---	---	---	---	1	---	1	1
CRIN	9	---	---	9	---	---	---	2	10	---	28	21	17	---	---
ELGL	113	122	---		---	---		---	---	---	---	---	---	49	---
ERCI	4	12	---	21	11	---	1	---	---	7	3	---	---	---	---
ERFA	---	---	---			---		---	---	---	---	---	1	---	---
FEME	---	---	---	103	79	---	139	79	---	142	107	---	56	---	---
HOVU	40	---	---	31	97	---	---		---	4	---	---	37	5	---
LOSC	---	---	---	---	---	---	---	2	---	1	---	---	1	---	---
LUSP	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---
RHOV	---	---	---	---	---	1	---	---	1	---	---	1	---	---	---
SAME	---	---	1	---	---	---	---	---	2	---	---	1	---	---	1
SEFL	28	8	---	17	---	---	21	---	---	---	---	---	---	17	---
SIGA	---	---	---	---	2	---	---	---	---	12	---	---	---	5	---
SOXA	---	---	---	---		---	---	---	---		---	---	---	1	---
STPU	2	26	---	---	5	---	---	---	11	16	41	---	---	21	---
TAOF	64	31	---	85	61	---	26	8	---	9	14	---	11	7	---
YUWH	---	---	---	---	---	---	---	---	1	---	---	1	---	---	---

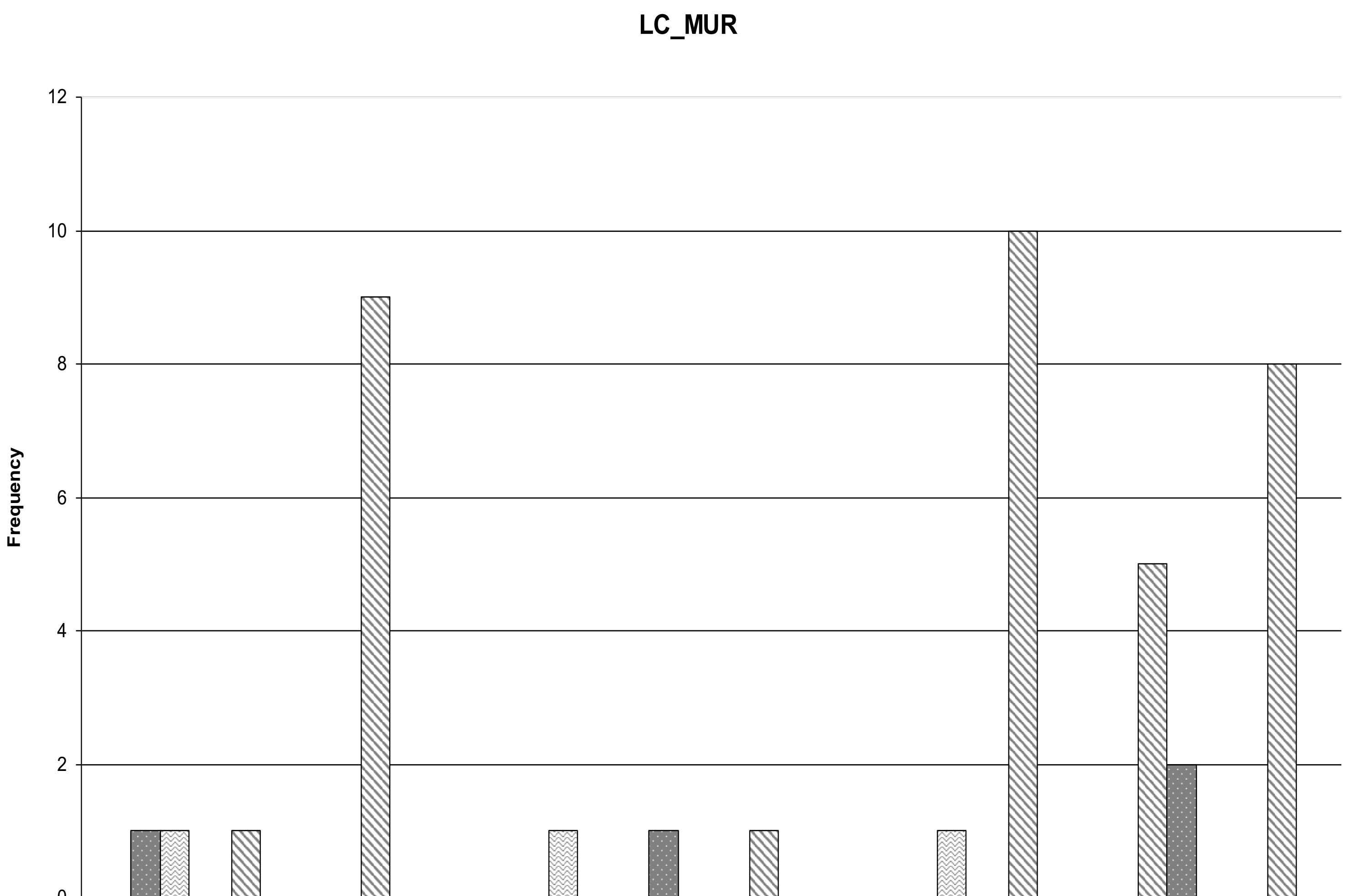
App. C9 – Species frequencies per quadrat for LR_MUN.



	ADFA	ANAR	BAPA	BRRU	CEME	CESP	ELGL	ERFA	FEME	KOCR	LOSC	MAMA	MIAU	QUDU	SAME	SPJU	YUWH
0.5m	3	42	1	69	1	1	3	2	7	10	1	1	0	1	3	14	1
Series2	3	0	0	0	1	1	0	0	11	0	0	0	7	0	5	0	0
20m	4	0	0	0	1	1	0	0	0	0	0	0	0	3	1	0	0

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	1	1	1	1	1	2	1	1	---	---	---	1	---	---	---
ANAR	11	---	---	23	---	---	1	---	---	7	---	---	---	---	---
BAPA	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---
BRRU	---	---	---	3	---	---	23	---	---	---	---	---	43	---	---
CEME	---	---	---	---	---	---	---	1	---	1	---	---	---	---	1
CESP	---	---	---	---	---	---	---	---	---	---	---	1	1	1	---
ELGL	---	---	---	---	---	---	---	---	---	---	---	---	3	---	---
ERFA	1	---	---	---	---	---	---	---	---	1	---	---	---	---	---
FEME	---	---	---	7	5	---	---	---	---	---	6	---	---	---	---
KOCR	6	---	---	4	---	---	---	---	---	---	---	---	---	---	---
LOSC	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MAMA	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---
MIAU	---	---	---	---	---	---	---	---	---	---	---	---	7	---	---
QUDU	---	---	1	1	---	---	---	---	1	---	---	---	---	---	1
SAME	---	1	---	1	1	---	---	1	1	---	1	1	1	1	---
SPJU	---	---	---	---	---	---	4	---	---	---	---	---	10	---	---
YUWH	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---

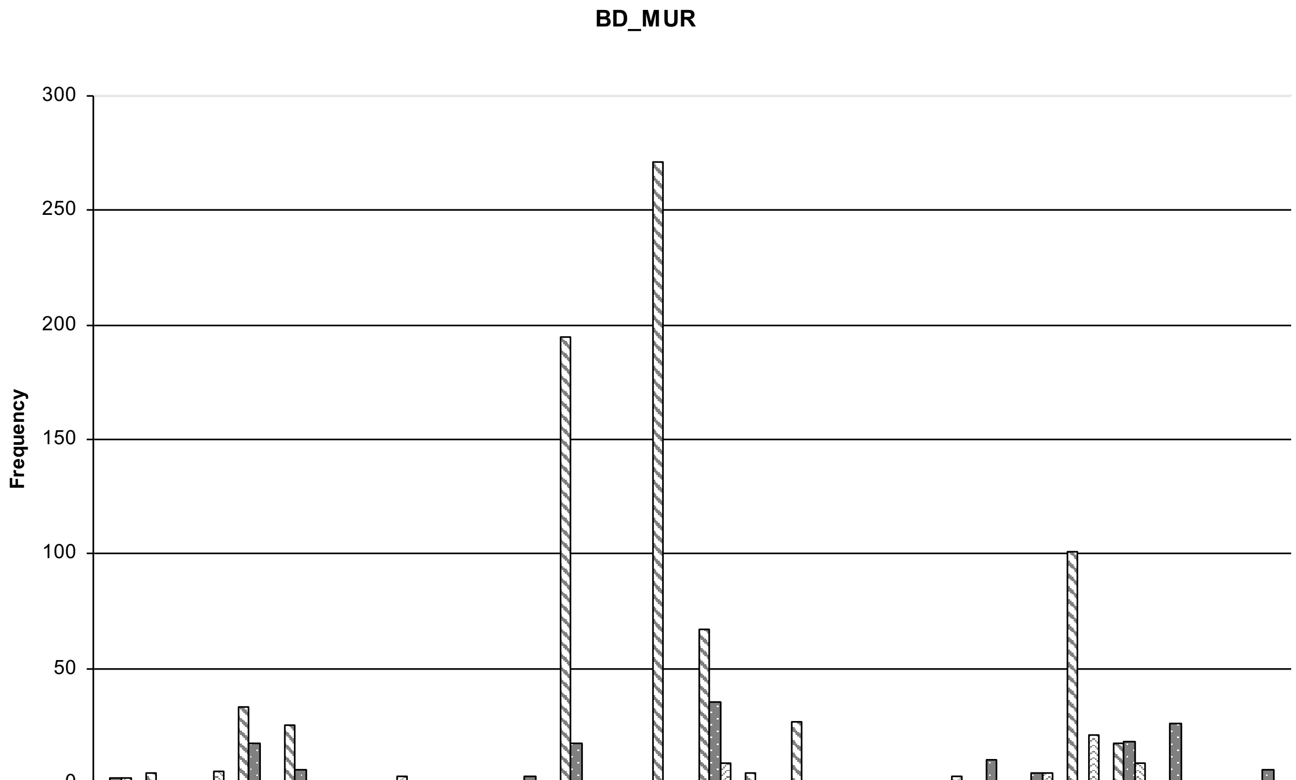
App. C10 – Species frequencies per quadrat for MR_MUR.



	ADFA	ARCA	BRRU	CESP	ERFA	HEAN	SAME	MEPO	SEFL	STPU
0.5m		1	9			1		10	5	8
5m	1				1				2	
20m	1			1			1			

	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	---	---	---	---	1	3	---	3	1	---	1	1	---	2	1
ANAR	---	---	---	6	1	---	8	---	---	---	---	---	21	---	---
ARCA	---	---	---	---	---	---	---	1	---	1	---	---	---	1	---
AVBA	25	---	---	---	---	---	---	---	---	---	---	---	23	---	---
BRNI	1	---	---	---	---	---	---	---	---	---	---	---	13	---	---
BRRU	43	---	---	39	---	---	36	---	---	9	---	---	20	16	---
CECU	---	1	1	---	1	---	---	---	---	---	---	---	---	---	1
CEME	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1
CESP	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---
DICA	---	5	---	2	---	---	---	---	---	---	---	---	---	---	---
ELGL	---	---	---	27	---	---	---	---	---	---	---	---	---	---	---
ERFA	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
GAAN	---	3	4	---	3	---	---	---	---	---	---	---	---	---	---
HEAN	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---
LUSP	---	---	---	---	---	---	---	---	---	---	---	---	11	---	---
MALA	---	---	---	---	---	1	---	---	1	---	---	---	---	---	---
MEPO	31	---	---	11	---	---	17	---	---	10	---	---	2	---	---
SAME	---	3	2	1	---	---	---	---	1	---	---	1	---	---	---
SEFL	23	25	---	53	21	---	---	---	---	5	2	---	43	---	---
SEVU	---	---	---	---	---	---	---	---	---	---	---	---		1	---
STPU	---	---	---	9	---	---	19	---	---	8	---	---	---	---	---
TAOF	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---

App. C11 – Species frequencies per quadrat for LC_MUR.

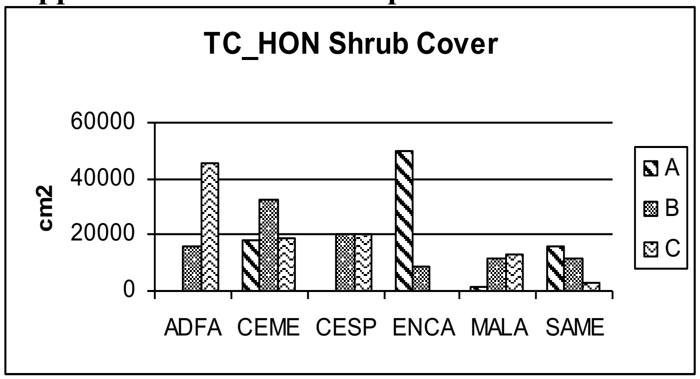


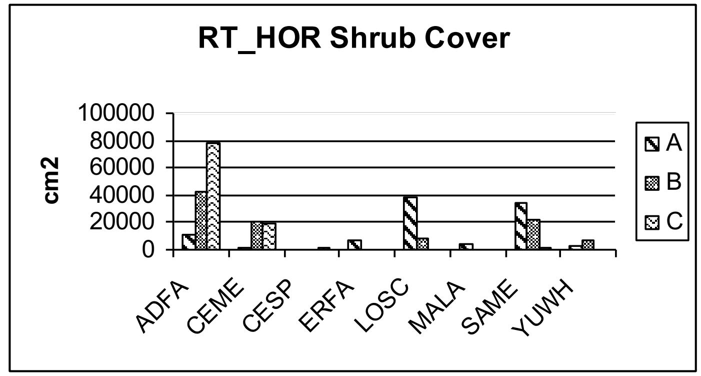
	ADFA	ALHA	ANAR	AVBA	BRRU	CAAL	CECU	CEME	CIVU	DICA	ELGL	ERFA	HOVU	LUSP	MEPO	MESA	MIAU	PHPA	POAN	QUDU	SEFL	SIBE	SPJU	TAOF	TODI
0.5m	1	4	0	33	25	1	1	0	1	0	195	0	271	4	27	1	0	0	0	1	101	17	0	1	0
5m	2	0	0	17	6	1	1	1	1	3	17	0	0	0	0	0	0	0	10	4	0	18	26	0	6
20m	2	0	5	0	0	0	3	1	0	0	0	1	0	0	0	0	1	3	0	4	21	9	0	0	1

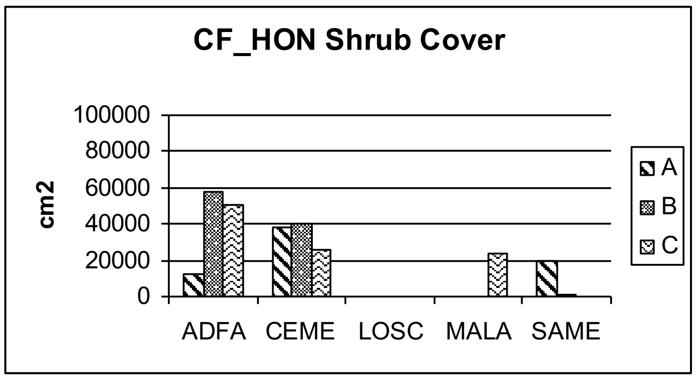
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ADFA	---	---	---	---	1	1	---	---	---	1	1	---	---	---	1
ALHA	---	---	---	---	---	---	---	---	---	1	---	---	3	---	---
ANAR	---	---	---	---	---	5	---	---	---	---	---	---	---	---	---
AVBA	---	---	---	9	17	---	4	---	---	---	---	---	20	---	---
BRRU	---	---	---	5	6	---	---	---	---	17	---	---	3	---	---
CAAL	1	---	---	---	---	---	---	---	---	---	---	---	---	1	---
CECU	1	---	1	---	1	1	---	---	---	---	---	1	---	---	---
CEME	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---
CIVU	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---
DICA	---	---	---	---	---	---	---	---	---	---	3	---	---	---	---
ELGL	---	---	---	56	17	---	51	---	---	88	---	---	---	---	---
ERFA	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---
HOVU	143	---	---	33	---	---	33	---	---	31	---	---	64	---	---
LOUT	7	---	---	6	12	2	37	---	---	17	---	---	---	23	---
LUSP	---	---	---	3	---	---	---	---	---	1	---	---	---	---	---
MEPO	3	---	---	7	---	---	7	---	---	5	---	---	5	---	---
MESA	---	---	---	---	---	---	1	---	---	---	---	---	---	---	1
MIAU	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PHPA	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3
POAN	---	---	---	---	---	---	---	---	---	---	---	---	---	10	---
QUDU	1	1	1	---	---	---	---	1	1	---	1	1	---	1	1
SEFL	---	---	---	---	---	---	78	---	---	---	---	---	23	---	21
SIBE	13	7	---	---	1	9	---	---	---	4	---	---	---	10	---
SPJU	---	---	---	---	---	---	---	26	---	---	---	---	---	---	---
TAOF	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
TODI	---	6	---	---	---	---	---	---	1	---	---	---	---	---	---

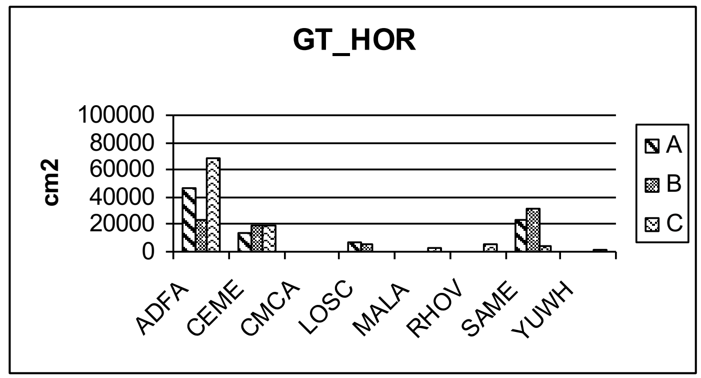
App. C12 – Species frequencies per quadrat for BD_MUR.

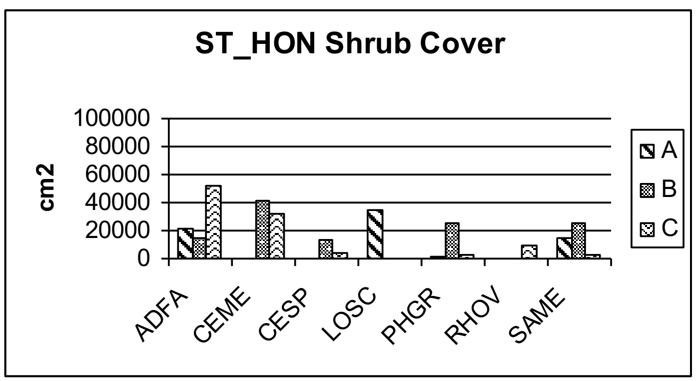
Appendix D – Shrub cover per transect

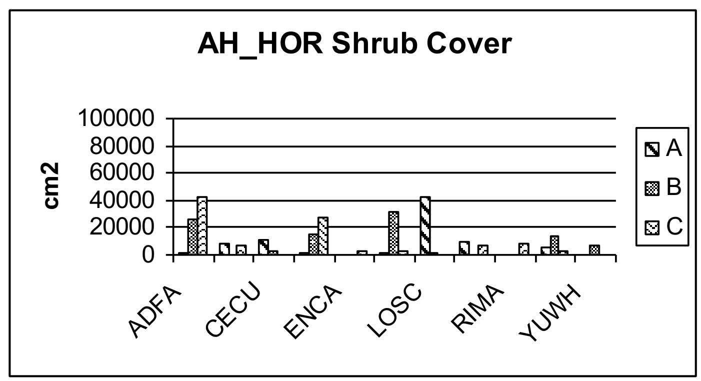


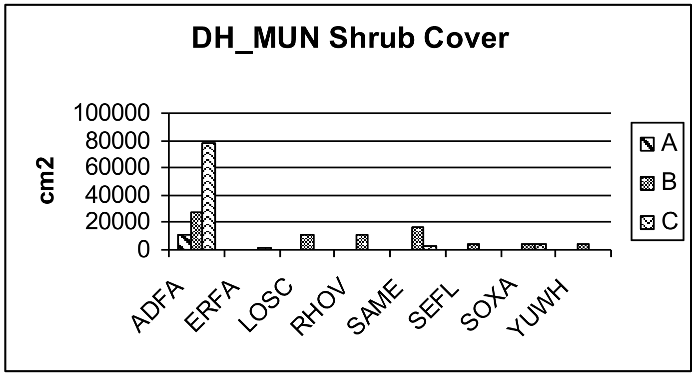


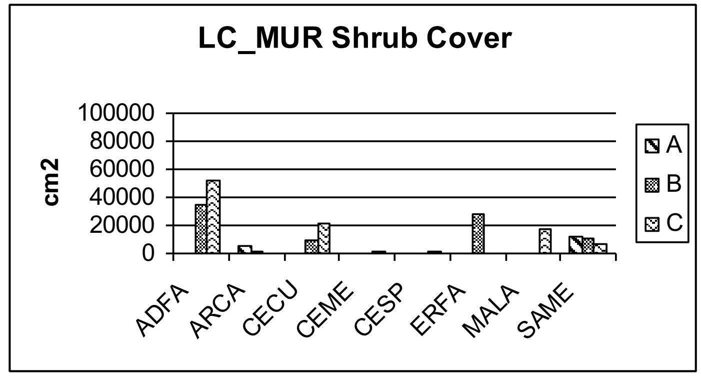


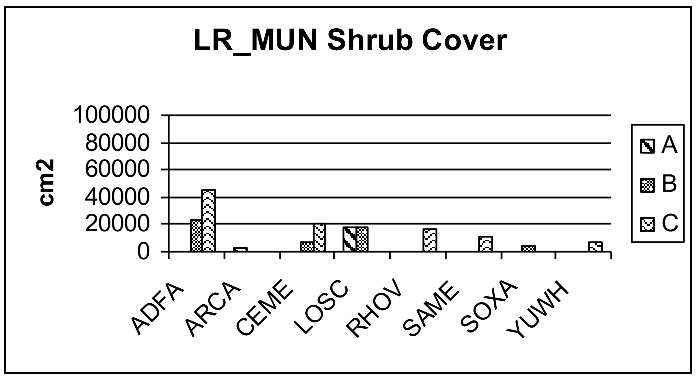


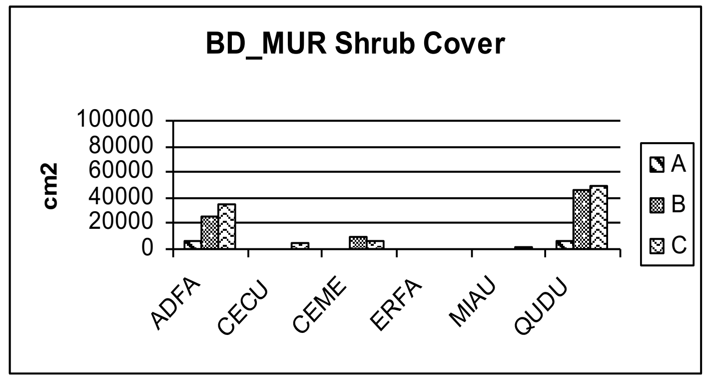


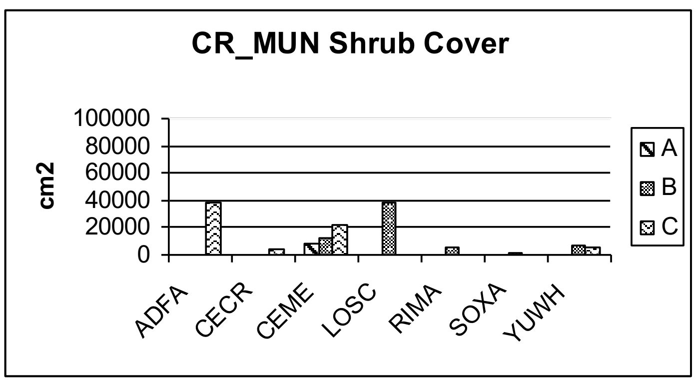


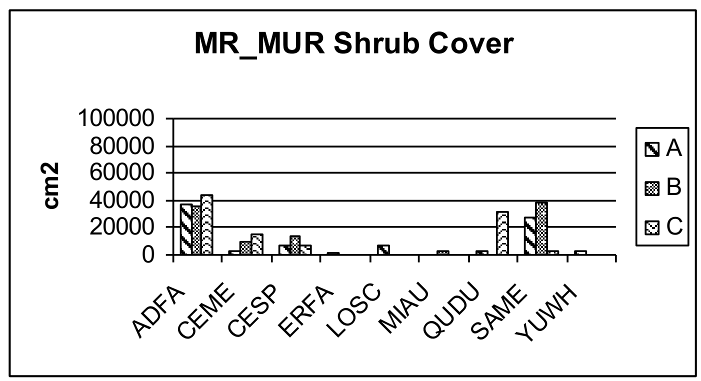

DH_MUN Shrub Cover
cm2
100000
80000
60000
40000
20000
0
ADFA
ERFA
LOSC
RHOV
SAME
SEFL
SOXA
YUWH
A
B
C


LC_MUR Shrub Cover
cm2
100000
80000
60000
40000
20000
0
ADFA
ARCA
CECU
CEME
CESP
ERFA
MALA
SAME
A
B
C


LR_MUN Shrub Cover
cm2
100000
80000
60000
40000
20000
0
ADFA
ARCA
CEME
LOSC
RHOV
SAME
SOXA
YUWH
A
B
C


BD_MUR Shrub Cover
cm2
100000
80000
60000
40000
20000
0
ADFA
CECU
CEME
ERFA
MIAU
QUDU
A
B
C


CR_MUN Shrub Cover
cm2
100000
80000
60000
40000
20000
0
ADFA
CECR
CEME
LOSC
RIMA
SOXA
YUWH
A
B
C


MR_MUR Shrub Cover
cm2
100000
80000
60000
40000
20000
0
ADFA
CEME
CESP
ERFA
LOSC
MIAU
QUDU
SAME
YUWH
A
B
C

Appendix E – Visual comparison of lower trailside vegetation compared to upper trailside vegetation

Bibliography

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