GIS MAPPING OF BIOLOGICAL STUDIES IN THE PUENTE-CHINO HILLS WILDLIFE CORRIDOR INCLUDING SPECIES DIVERSITY AND RELATIVE ABUNDANCE

A Project

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SIGNATURE PAGE

PROJECT: **GIS MAPPING OF BIOLOGICAL STUDIES IN THE PUENTE-CHINO HILLS WILDLIFE CORRIDOR INCLUDING SPECIES DIVERSITY AND RELATIVE ABUNDANCE**

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ABSTRACT

Known as a global “hotspot” of biodiversity because of its unique and threatened flora and fauna, some areas of southern California area are becoming islands of habitat. The Puente-Chino Hills, on the eastern side of the Los Angeles Basin, provide an excellent example of an ecosystem at risk. Government agencies, concerned citizens, and researchers are drawn to the region for several reasons: its biodiversity, its beauty and to understand what is at risk of extinction. This hill complex has undergone four important biological studies in the past few years, including a vegetation, carnivore, herpetofauna, and avian study. Only the vegetation and avian projects include digital maps.

My project has put into digital form both the carnivore and herpetofauna studies, through the use of geographic information systems. For both studies, themes were created for study sites and included a presence/absence layer as well as a detail relative abundance layer. The importance of my contribution is three fold: I added two more layers to an existing GIS mapping project, I helped two completed studies become compatible with other projects, and finally my work will become a historical documentation of species once found in the Puente-Chino Hills.

Biological corridors connecting the fragmented habitats are one important remedy in the management of these hills and preservation of its natural processes. Without connections to viable habitats the wildlife in the Puente-Chino Hills will become island populations. The habitat will lose its diversity of species and eventually become a landscape devoid of many endemic inhabitants. If that is the case, this mapping project will document what was once here, or be used in finding solutions to the situation.

TABLE OF CONTENTS

LIST OF MAPS

LIST OF PHOTOS

LIST OF FIGURES

LIST OF TABLES

"When we try to pick out anything by itself,

we find it hitched to everything else in the universe."

-- John Muir

INTRODUCTION

The Puente-Chino Hills of southern California are located at the eastern end of the Los Angeles Basin. These hills lie at the juncture of four counties and fifteen cities. The faults that uplifted the hills, the waterways that carved them, and the region's temperate climate, combined to create a diverse array of plant and animal communities. Human populations are now threatening the survival of those native communities.

While human influences have always left their mark on the landscape, only recently has the prolific growth of the region begun to irreversibly modify it. With the loss of the natural resources that has so defined this region, concerned citizens and governmental agencies have begun to recognize the importance of this open space.

In the 1980s, Chino Hills State Park was formed on the eastern side of the hills nearly coinciding with preservation efforts on the western side of the hills in Whittier. In the mid 1990s, citizens at both ends of the hills came together to unite their preservation efforts. With their increased understanding of conservation biology, residents, elected officials and government agencies of the area are working together to preserve this important landscape.

The region is rich in flora and fauna, due in part, to the vegetation communities, which support such a diversity of life. Though some species thrive alongside humans, most do not. Species vulnerable to human intrusion and fragmentation are at risk of extinction in these hills. Roads are the biggest threat to the landscape, not only because of their direct impacts, but also because they open the hills to future development.

The mountain lion and Orange-Throated Whiptail Lizard, with widely varying habitat requirements, are examples of two species at risk that are found in these hills. In order to preserve these and other critical species, studies have been funded and conducted along the corridor to inventory the species diversity and species richness along the length of the hills. The science of conservation biology has important implications for this region in particular.

My project converted two of four biological studies into digital form, using ArcView 3.2. The new layers include presence/absence and relative abundance for both the carnivore and herpetofauna studies. There is another layer that depicts culverts found in the Puente-Chino Hills, which the mammal study researched. This conversion is a contribution to a larger GIS mapping project of the hills, already underway at Whittier College.

A CHANGING LANDSCAPE

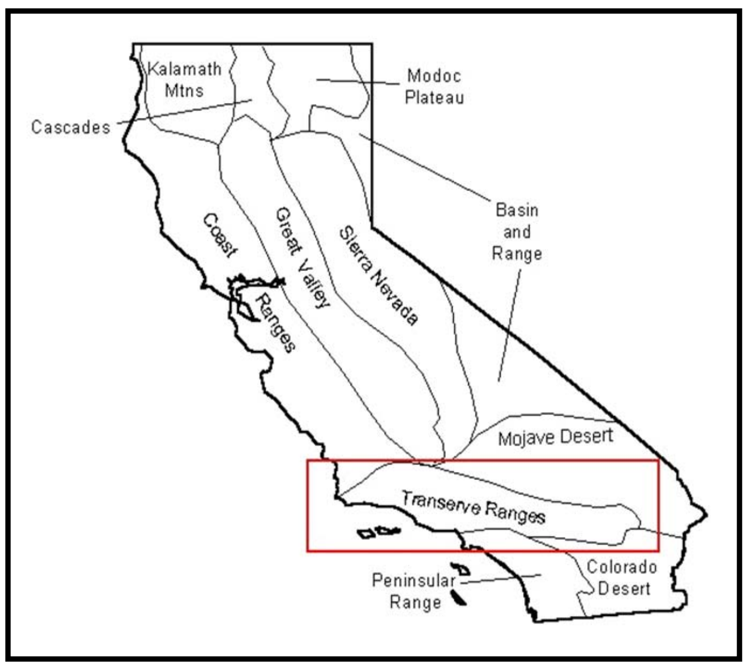
Geologic Impacts

"Southern California is different from much of the rest of the nation in that our folding and faulting have occurred so recently that much of the topographic relief is due directly to earthquake movement" (Sharp 1972, 5). Mountains rise abruptly thousands of feet surrounding the Los Angeles Basin, while it is also being penetrated by various hill systems (Sharp 1972). Scattered across the Basin are many uplifted hills, which routinely undergo slope creeps and landslides.

During the Pliocene, 5 million years ago, the Los Angeles Basin was undergoing significant deposition from erosion, while also enduring uplift from the San Andreas Fault. The local San Gabriel, San Bernardino, San Jacinto, and Santa Ana Mountain Ranges were formed during this era. Debris and alluvium from this uplift washed down the mountains and created the gentle slope of the Los Angeles Basin, which leads to the Pacific Ocean. Among the prominent hills of the Los Angeles Basin emerge the Puente-Chino Hills at the eastern side. Nearly 1.8 million years ago, during the Pleistocene, the Puente-Chino Hills were uplifted by local faults. The hills are, in fact, the extension of the Santa Ana Mountains.

The Elsinore Fault caused the geologic separation from the Santa Ana Mountains. This fault runs at an angle to the Whittier Fault, which cuts the base of the complex and appears to end near the 605 freeway at the Whittier Narrows. The Whittier Fault displays lateral movement as well as uplift. On the northeastern side of the complex lies the Chino Fault. This fault has a single distinct line that parallels State Route 71 (Durham and Yerkes 1964). The Elysian Park Fault separates the Puente Hills from the San Gabriel Mountains. The intersection of these faults contributed to the wide-ranging oil deposits found in the area.

Many geologists include the Puente-Chino Hills as a part of the Transverse Ranges (See Map 1) which are east-west trending units. Interestingly, across the entire continent there are very few Transverse Ranges, therefore Southern California's range is somewhat unique (Norris and Webb 1976). Overall, the Transverse Ranges "seem to incorporate a greater spectrum of rock types and structure than any other (geologic) province in the



Map 1. California's Geomorphic Provinces (Source: Harden, p 1)

state" (Norris and Webb 1976, 304). This unusual alignment contributed to the species diversity found in the area, because it created rare habitats from the combination of geology, climate, topography, and weather.

Three major rivers flow into the Basin: the San Gabriel, Los Angeles and Santa Ana Rivers. These rivers tend to erode the landscape easily because of the soft alluvial deposits left from the Pliocene era. The Santa Ana River specifically had a pre-established course long before the Puente-Chino Hills were formed. Geologically, the uplift is relatively young (Norris and Webb 1976), and the river didn't divert north of the hills, because it was established before the uplift began. More importantly the Santa Ana River, which borders the southern portion of the hill complex, bisects the Santa Ana Mountain chain from the Puente-Chino Hills. The San Gabriel River bounds the northwestern portion of the hills.

Human Impacts

Southern California's Puente-Chino Hills complex spans four counties (Los Angeles, San Bernardino, Riverside, and Orange) and is surrounded by fifteen local jurisdictions (See Map 2).

Map 2. Location of Study Area in Los Angeles Basin
(Source: Thomas Bros., p. *v*)

It is located between the 91, 71, 60, and 605 freeways. "The Puente-Chino Hills represent a continuous series of open space consisting of both private and public lands" (Haas and Crooks 1999, 3). Most of the open space is still ecologically intact, but a large portion of the complex is threatened by development at the urban edge.

The discovery of oil lead to the first major influx of human activity in the hills, which continues to this day. Nearly all of the strata where oil is drilled dates to the Pliocene age. This region is "one of the most prolific oil-producing regions in California" (Durham and Yerkes, 1964, B3). Oil operations attracted commercial businesses needed to sustain and support the work force. The hills also offered adventure and prosperity for early Spanish and European settlers.

In their quest for black gold settlers and their families created many small towns across the hills, including: Brea, Yorba Linda, La Habra and Whittier. Each of these cities, along with many others began to emerge and consequently develop the landscape. The local geology, which included landslides, steep slopes and tar seeps, made development difficult, but allowed the oil industry to boom. Seven oil companies were directly involved in the production and drilling of oil by 1957 (See Photo 1, next page). Today the main companies involved in oil production in the hills are: Union Oil, Shell Oil and Standard Oil (Kowalik and Kowalik 2000). "The Puente-Chino Hills corridor is a unique combination of very valuable cultural, historic and natural resources and serves as a reflection of the living history of Southern California" (WCCA n.d., 1).

Surrounded by four of the fastest growing counties in California the hills are experiencing the effects of explosive population growth (Kowalik and Kowalik 2000). One example was found after reviewing the population statistics for Orange County (See Photo 2, next page). Over the course of forty years the population grew 500%, from ½ million in 1950 to

2 ½ million in 1990. In fact, the population estimates for Orange County alone by 2020 are nearly 3 ¼ million (Center for Demographic Research 1999) (See Photo 3). Today, the hill complex is within an hour's drive of more than nearly 15 million people, half the state's population.

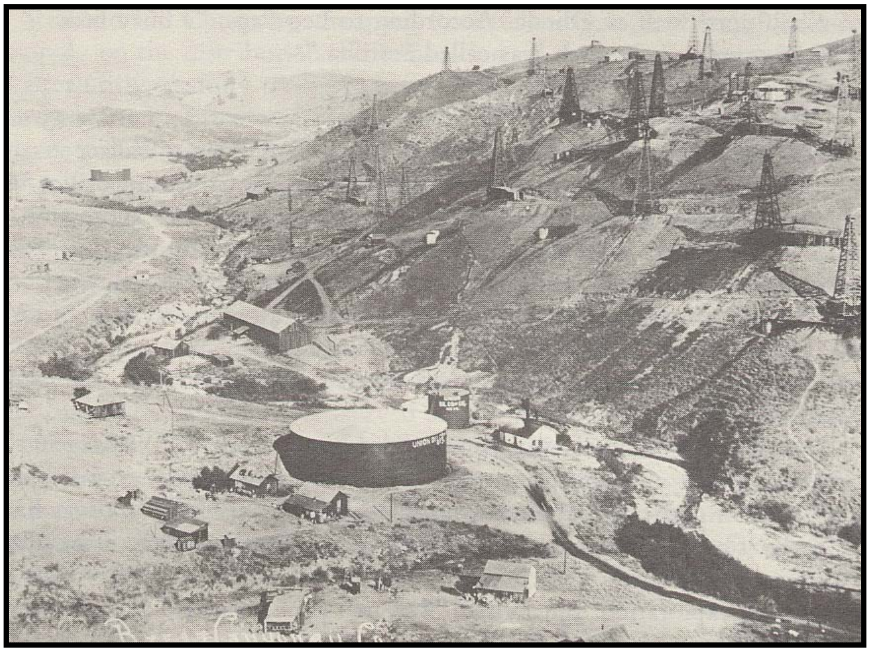


Photo 1. Oil Fields in Brea (circa 1908)
(Source: Hampson, p. 18)

Photo 2. Puente-Chino Hills (circa 1960)
(Source: Durham & Yerkes, p B32)

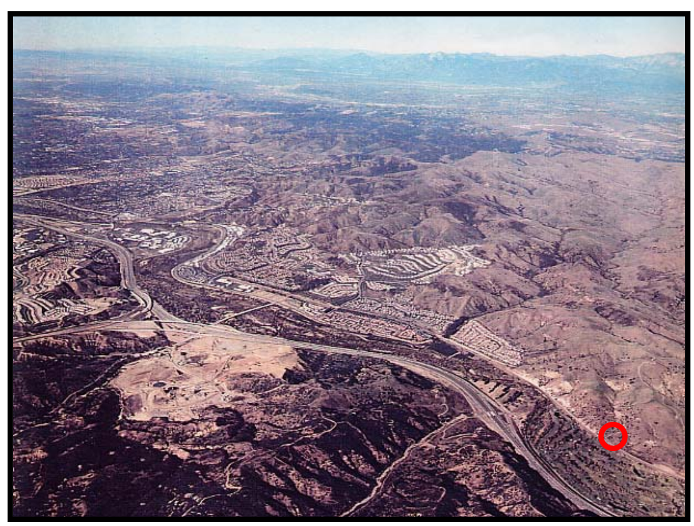
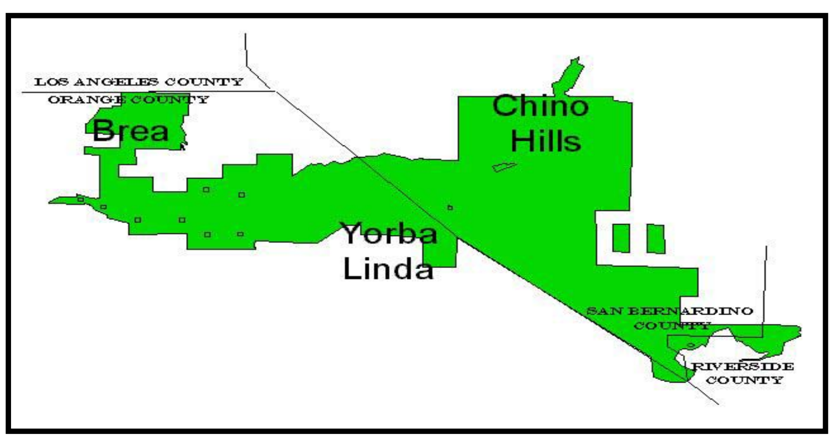


Photo 3. Puente-Chino Hills (circa 1995)
(Source: C. Schlotterbeck)

As residents see their hills becoming increasingly developed they have come together to protect what is left. On the western side of the hills, the City of Whittier has been acquiring hillside property for many years with the use of Los Angeles County Park funds. In addition, when the Puente Hills Landfill was last expanded, an agreement was reached to set aside a surcharge of one dollar per ton to acquire natural habitat to mitigate the destruction of the canyons adjoining the landfill. The Puente Hills Landfill Native Habitat Preservation Authority administers these funds. To date these two entities, the City of Whittier and the Habitat Authority, have purchased or received in donation over 4,000 acres (Hills for Everyone 2001).

In the late 1970s, concerned community members organized to create Chino Hills State Park (CHSP) by working with their local and state legislators and the State Parks Department. Establishment of this State Park has become the most complicated and expensive series of acquisitions in State Park history (See Photo 4). To date the State has spent nearly $90 million with over 30 separate acquisitions to piece together this 13,500-acre State Park (C. Schlotterbeck 2001) (See Map 3).

Photo 4. Telegraph Canyon in CHSP
(Source: C. Schlotterbeck)



Map 3. Chino Hills State Park
(Source: M. Schlotterbeck)

HABITAT FRAGMENTATION

Species Survivability

A habitat is "a place where an organism or population lives within a natural landscape" (Kaufman et al. 1996, 45). Habitat fragmentation is the tearing of the fabric of natural landscapes into smaller and smaller pieces. In fact, the alteration of habitats by human activities has been called the greatest threat to biodiversity on earth (Meffe et al. 1997).

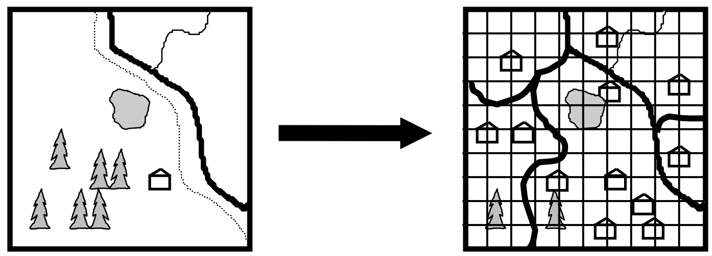


Figure 1: **The Fragmenation of Landscapes (Source: M. Schlotterbeck)**

The effects of subdivided land cause many ecological repercussions (See Figure 1). In fact, as land is subdivided, there is an increase in fragmentation, population density of humans, and an expansion of roads and fences. As humans invade the land they bring subsidized predators (cats and dogs), introduce exotic species (birds and plants) and nourish nuisance animals (trash and pet food). Wildlife generalists also increase, whereas wildlife specialists decrease as fragmentation occurs (Meffe et al. 1997).

In general, fragmentation begins with a gap, the initial loss of native habitat, which overtime gets bigger and bigger (See Figure 2, next page). Humans invade the land after a gap has occurred and make the gap bigger. Colonization and resource extraction proceed to enlarge the gap (Meffe et al. 1997). Subsequently, the partial or total isolation of biotic elements occurs as fragmentation increases. For the Puente-Chino Hills specifically, oil extraction and grazing fueled the initial fragmentation.

Roads, trails, developments, and power lines are all ways a landscape is fragmented. Originally there were just a few small roads in the hills that meandered from town to town (See Photo 5). When the 57 freeway was built through Brea Canyon it essentially divided the Puente-Chino Hills, into two sections: eastern (Chino Hills) and western (Puente Hills).

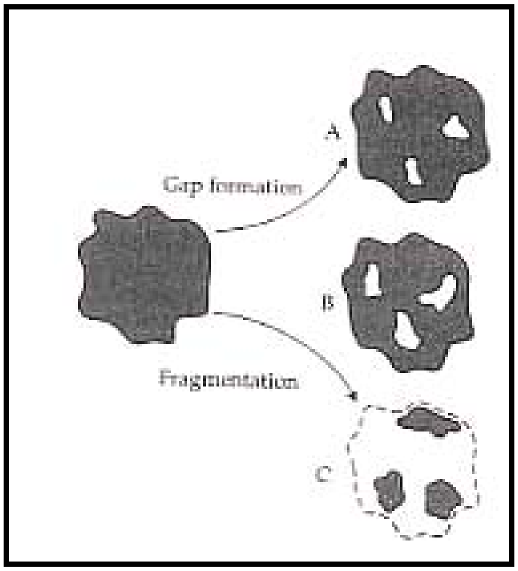


Figure 2. The Formation of Gaps
(Source: Meffe et al., p. 278)

Photo 5. View of 57 Freeway Route Looking North (circa 1960)
(Source: Hampson, p. 70)

Although a loss of habitat is a significant threat to all biological resources, some species thrive in such a landscape. There are three types of species that live in a fragmented landscape. First, species that thrive in a matrix of human land uses include animals that can utilize human debris, trash and pet food for their own benefit. Raccoons, gophers, skunks, and opossums belong in this category. A second type is species that are able to maintain a viable population within an individual habitat fragment. The amount of land needed to maintain a viable population for these herbivores is minimal and they tend to have very high fecundity. Mice, squirrels, and rats fall into this category. Third, species that are highly mobile such as coyotes can survive in a fragmented area (Meffe et al. 1997). Mobile species are able to solve immediate problems, such as a lack of food, shelter or water, by quickly moving to a new more suitable habitat. These animals thrive because of the human influence on the food chain –residents bring domesticated animals that are potential prey for these urban fringe omnivores.

Conversely, there are species highly vulnerable to fragmented landscapes. The Principles of Conservation Biology lists nine species types that are considered vulnerable to fragmentation. The first three types of species include those that are naturally rare, wide ranging or those considered poor dispersers. In the Puente-Chino Hills these species include mountain lions (wide ranging) and the California gnatcatcher (poor disperser). Three more species types include those with low fecundity, short life cycles, and ground nesters. The burrowing owl is an example of a ground nester that is already locally extinct. Two more types include species that are dependent on patchy or unpredictable resources, or those that must live in the interior parts of the habitat. The cactus wren is an example of an animal that survives in patches of prickly pear cactus. The final type is species vulnerable to human exploitation, such as capture or poaching, include turtles and snakes (Meffe et al. 1997).

Major Cause of Habitat Fragmentation

Direct and indirect impacts of roads are a major cause of fragmentation. Dr. Reed Noss delineates eleven major impacts that roads have on the environment. The primary impact is that of roadkill. In the United States an estimated one million animals per day are killed on our roads. This estimate, however, only accounts for the animals found on the roads, not those that crawl off the side of the road to die elsewhere. Roads are also known to create barriers to migration for certain sensitive species (Noss 1999). Guardrails, fencing, thick vegetation, center dividers and fast moving cars create obstacles for movement between habitats.

Highways bring chemical, air and noise pollution to surrounding environments. With each mile of highway introduced into an undeveloped environment, three miles of habitat are opened up for development. Pressures for development increase with each new road introduced (Noss 1999). The major roads of the Puente-Chino Hills, especially the 57 freeway, have promoted development in the surrounding areas from of increased access.

Roads also dramatically change the hydrology of watersheds, increasing the speed and amount of peak run-off. An example of a watershed impacted by road development is Brea Creek that runs parallel to the 57 freeway in Diamond Bar. Because of its altered hydrologic pattern this creek has eroded much of the landscape. Roads provide access for humans into habitats, leading to poaching, off-roading, and soil compaction on trails. CHSP has had to deal with these issues ever since it opened in 1984.

While each of the impacts of roads is significant, the combined synergistic impacts are still unknown (Noss 1999). There is, however, a distinct correlation between animal deaths, the placement of roads, increased animal deaths and decreased availability of quality habitat.

Though once a completely contiguous and flourishing hill complex with few roads the Puente-Chino Hills is now divided by numerous roads and highways. Many of them run parallel to the base of the hills, including Lambert, Whittier Boulevard and Imperial Highway. However, development of roads that wind their way through the hills also occurs, including Hacienda Boulevard, Carbon Canyon Road, and Brea Canyon Road. Again, the 605, 60, 91 and 71 freeways surround this habitat complex, while the 57 freeway bisects it down the middle from Brea to Diamond Bar.

Islands of Habitat

Fragmented habitats often become islands of habitat disconnected from each other. Though they were once a "mainland" or continuous piece of habitat, the fragments are all now small individual pieces of habitat, looking like an island archipelago of habitat pieces. With enough time the species on these new "islands" will likely become extinct due to lack of genetic mixing.

There are four types of genetic problems associated with lack of genetic mixing (i.e. inbreeding). First, the founder effect is defined as a group of founders in a landscape having only a small percentage of the genetic diversity than that found in the larger population. This type of problem can be seen in large mammal populations that may be cut off from the Santa Ana Mountains from CHSP. Second, demographic bottlenecks occur when there is temporary reduction in the genetically effective population, due to some catastrophic event, like floods or fires. This problem can be seen when flooding causes the extinction of species dependent on stream bank habitats. Third, genetic drift is the random change in gene frequency due to chance alone. Fourth, inbreeding depressions occur when there is a reduction in the reproductive capabilities as a result of breeding with relatives (Meffe et al. 1997). California gnatcatchers are found in the Puente-Chino Hills and are very susceptible to inbreeding depressions.

Island Populations

As noted earlier, habitat fragmentation is a global threat. It is so significant that scientists specifically research the dynamics of fragments or islands. This new and evolving scientific field is known as island biogeography. Essentially, "island biogeography has been the scientific record of the gains and losses of species" (Quammen 1996, 54). Though first studied on true oceanic islands, by scientists such as Charles Darwin and Alfred Wallace, the research has now begun on the mainland, where islands are formed because of human development, not oceans. Even applicable to mainland islands, author and biogeographer David Quammen stated, "islands are where species go to die" (257).

It is already known, from Darwin and Wallace, that the size of an island dictates the number and kinds of species. Therefore, smaller islands support fewer species, while larger islands support more species. Since all species have their own niche or role in an ecosystem, when one species disappears there is a cascading effect. Islands small in area gain and lose more species than larger islands. There are two thoughts behind this phenomenon. First, when an island is created, it is isolated and many species fail to arrive there. Failure may result from isolation, distance, water, dispersal or colonization barriers. Second, if the species actually arrives on an island, it may colonize the area, but fail to survive. Failure, this time, involves local extinction (Quammen 1996), since the species exists in another area and immigrated to the island.

Local extinction is the "eradication of any geographically discrete population of individuals, while others of the same species may survive elsewhere" (Quammen 1996, 292).

When a small number of individuals are present in a population they have a higher risk of going extinct for two reasons. First, they naturally fluctuate in size from time to time. Second, since they are already a small population, during the low point of this fluctuation they are at an increased jeopardy of reaching zero. Knowledge of the presence and absence, as well as population size, of local fauna is critical to predicting whether a species will become locally extinct.

Two factors, deterministic and stochastic, cause the fluctuations. Deterministic factors involve the cause and effect relationships that can be somewhat predicted and controlled. These include: hunting, trapping, poaching and habitat destruction. The Puente-Chino Hills is vulnerable to fluctuation caused by deterministic factors, because of its proximity to urban areas. Stochastic factors are those that operate beyond human prediction, including truly random geophysical events (earthquakes or floods) or biological causes (plague). The hills are vulnerable to these natural fluctuations, since they are part of the naturally occurring ecosystem. There is little known about the processes involved in natural extinction except for those that occur on true oceanic islands. Natural extinction on mainlands has been pre-empted by man-made extinction. More is known about the effects of human caused extinction due to habitat isolation (Quammen 1996).

Larger areas support more species than smaller areas. This is known because of the species-area relationship and can be expressed by the equation:

$$\mathbf{S = cA^z}$$

where,

S = the number of species

A = the area

c & z = constants

For example, “division of an area by ten divides the number of amphibian and reptile fauna by two” (Quammen 1996, 388). Nature reserves have historically been established as “an island of protection and relative stability in an ocean of jeopardy and change” (Quammen 1996, 445). Thus they have been established as a “sample” of the landscape rather than being seen as a part of a tapestry of relationships. Therefore they are destined to become a mainland island unless connected to another island. The remaining natural lands in the Puente-Chino Hills are only a remnant of what the ecosystem once was, making it prone to species instability and local extinctions.

In fact, studies conducted by William Newmark in the Yellowstone ecosystem suggest that mammal species are disappearing from North America’s National Parks because the parks, even though they may include tens of thousands of acres, are too small to support them. If this is true, even the largest nature reserve will not hold its species diversity over time. With its relatively small size, the fate of the species diversity in the Puente-Chino Hills is at best uncertain.

Newmark also discovered evidence of what is known as ecosystem decay, which is defined as “the process of species loss from severely fragmented ecosystems” (Quammen 1996, 629). He essentially determined through his research that National Parks are equivalent to land bridge islands. They represent areas of natural landscape that are now bounded but were once connected to larger areas, and have now become isolated. Though larger parks consistently lose fewer species than the smaller parks, area alone was the best predictor of the species diversity. One way to combat island populations is to connect the habitat to other viable habitats, through biological or wildlife corridors. There are still opportunities for connections in the Puente-Chino Hills.

HABITAT CONSERVATION

Wildlife Corridor Conservation Authority

Recognizing the unique and disappearing landscape of the Puente-Chino Hills, citizens and government officials came together in the mid 1990s to unite their efforts within the hillside system. Together they formed a Joint Powers Authority, in 1995, whose purpose is to create a contiguous backbone of protected open space in these hills.

The Wildlife Corridor Conservation Authority (WCCA) "was created out of a community desire to preserve the historic and natural resources, cultural traditions and scenic landscapes of the Puente-Chino Hills" (MRCA n.d., 1). The purpose of WCCA is to protect, the Puente-Chino Hills wildlife corridor through regional planning, and/or acquisition. WCCA is composed of the Cities of Brea, Whittier, Diamond Bar, and La Habra Heights, three state agencies: California Departments of Parks and Recreation, Fish and Game and the Santa Monica Mountains Conservancy (SMMC). Other representatives include the Los Angeles Board of Supervisors and one public member each from the unincorporated areas of Los Angeles and Orange Counties (J. Schlotterbeck 2001). WCCA utilizes its nine-member governing board, a sixteen member advisory board and professional staff from SMMC to influence the planning process throughout the hills.

The Mountains Recreation and Conservation Authority (MRCA) is a Joint Powers Authority of the SMMC in both the Simi and Conejo Recreation and Parks Districts. MRCA receives funding through grants and the SMMC. MRCA helped fund various biological assessments in the corridor (J. Schlotterbeck 2001). Overall evaluation of the corridor, its connectivity, function and value can only occur when current biological assets are determined. Therefore, WCCA has used numerous studies and assessments of the hills in order to prioritize the purchases and establish future planning goals.

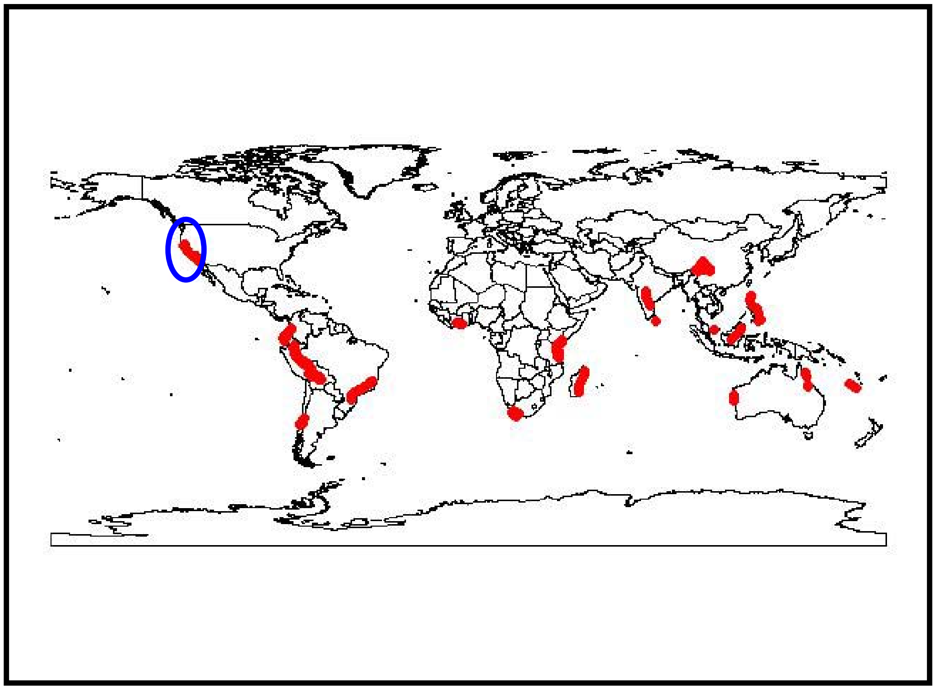
Biological Corridors

Biological corridors are defined in several ways. For this paper a biological corridor is "a linear landscape feature that facilitates the biologically effective transport of animals between patches of habitat, thereby preventing isolation of populations" (Rosenberg et al. 1997, 677). Through the years, biologists have combined their definitions of corridors to include both form and function.

There are many types of corridors used by wildlife and needed for wildlife migration. There are differences in shape, size, function, and effectiveness. One type of corridor used by large predators is an underpass, which allows animals to move under a freeway in an urban area. Culverts under roadways are a second type of corridor also used by large predators (Haas and Crooks 1999). Studies indicate that mammals are using culverts and underpasses to facilitate movement into different habitats. For the Puente-Chino Hills the link to the Cleveland National Forest is currently through an underpass connecting the two mountain ranges.

Species at Risk in the Puente-Chino Hills

Biodiversity is "our living natural resource base, our biological capital in the global bank" (Meffe et al. 1997, 141). Southern California is known as a "hotspot" of biodiversity: "a geographic location characterized by unusually high species richness, often endemic species" (Meffe et al 1997, 677). "The southwest ecoregion of southern California contains a greater diversity of vegetation types, vertebrate species, and endemic species than any other area of



Map 4. Global "Hotspots" of Biodiversity
(Source: Meffe et al., p. 140)

comparable size in the United States" (Noss et al, 1997, 2). They are "hot" because they are imminently threatened by a loss of species due to development (See Map 4).

The Puente-Chino Hills region is very significant, locally, regionally, and globally, because it contains two important and disappearing vegetation communities: coastal sage scrub and walnut woodland. These plant communities contribute to the large number of species characteristic of southern California (Kowalik and Kowalik 2000). Two species that have significant value to the Puente-Chino Hills include the mountain lion and the Orange-Throated Whiptail Lizard. Mountain lions are known as keystone species, or a species that makes a significant impact on the community, but have a relatively low abundance. The Orange-Throated Whiptail Lizard is a sensitive species for the reptile community due to its specialized diet. These two species will now be examined as to their characteristics, role in the ecosystem and what is known from previous studies about each.

Mountain Lion

Mountain lions, (*Felis concolor*), found in Southern California are golden brown in color and vary in size according to their sex (See Photo 6). The animals utilize only undeveloped areas, in order to remain a safe distance from civilization. A male cougar needs nearly 25,600 to 80,000 acres of territorial range to traverse for mating and hunting. They also tend to have larger home ranges than females and allow only two females to overlap portions of their own territory. After mating with a female, males do not take part in the rearing of the cubs. Cougars face two main threats: accessibility to home range and lack of breeding partners (Hund 1997a)

Photo 6. Mountain Lion
(Source : M. Schlotterbeck)

The accessibility to these open space tracts is becoming threatened due to land development. Mountain lions roam the Puente-Chino Hills and cross to the Cleveland National Forest using a culvert under the 91 freeway, in Yorba Linda (Beier 1998). Dr. Paul Beier's mountain lion study of the Santa Ana Mountains listed Coal Canyon as a significant point for mountain lion movement. One cougar M6 used the underpass 22 times in the course of a year (Beier 1998). This particular cougar had a split home range between CHSP and the northern end of the Cleveland National Forest. Without Coal Canyon, mountain lion populations would be lost from the Puente-Chino Hills and eventually from the Santa Ana Mountains themselves (Harris, Hund, Bartel n.d.).

Absence of the cougar from an ecosystem where it belongs encourages what is known as a meso-predator release. In essence, after the cougar, as top predator, disappears from an area it once inhabited, an explosion of midlevel predators (meso-predators) occurs. These animals include the skunk, opossum and raccoon (Hund 1997b). Since they are better raiders of bird's nests, the flying species become stressed. Once the bird population diminishes because of lack of offspring, then the plants change because the birds are no longer present to distribute the seeds (C. Schlotterbeck 1999). The food supply will not be able to support such a large population of meso-predators and eventually they will die out, followed by the animals lower in the food chain (Hund 1997a). This simplification of the ecosystem is called trophic cascade. Even more localized than Beier's 1993 study of the wildlife corridor, was one conducted by Chris Haas and Kevin Crooks, in the Puente-Chino Hills, which will be examined in detail later in this paper.

Orange-Throated Whiptail Lizard

The Orange-Throated Whiptail, (*Cnemidophorus hyperythrus*), found in this region of southern California, has distinct light colored stripes down a black, brown or gray dorsal side (See Photo 7). On the ventral side. coloring is limited to whitish-yellow, while the head is yellow-brown to olive. These reptiles utilize the coastal regions of southern California, including Orange, Riverside, San Diego and San Bernardino Counties. This lizard prefers low-elevation coastal scrub, chaparral and mixed chaparral. The home range of males is roughly 0.007 acres, while females require 0.15 acres.

Photo 7. Orange-Throated Whiptail (Source: M. Schlotterbeck)

Eggs are placed in loose, well-aerated soil or under foliage. Orange-Throated Whiptail faces one main threat, loss of habitat (Department of Fish and Game 2001).

Though the acreage required to maintain this lizard is fairly minimal, the rate of destruction of its habitat, of low-lying coastal sage scrub, is significant. The whiptails rely on suitable, contiguous habitat, but development in the foothills of southern California makes finding contiguous habitat nearly impossible (Webster 2000).

As habitat is destroyed for the lizard, their food resource is also destroyed. The Orange-Throated Whiptail Lizard tends to forage on the surface and under surface debris. On occasion the whiptail has been known to feed on small arthropods, but when available the lizard feeds upon one particular species of termite as its main diet. Consumption in large quantity is preferred, as opposed to small meals. It has been estimated that nearly 80% of the whiptails diet consists of this termite. Without the termite the whiptail faces a dim future (Department of Fish and Game 2001), and because of their specialized diet they are prone to local extinction.

The California Department of Fish and Game stated in the Federal Register that nearly 1,213 acres of prime and suitable habitat for this species has been lost in Southern California. Conversely, 689 acres have been conserved there. The habitat requirements of this species are very similar to that of the San Diego horned lizard. Therefore, if land is saved for the San Diego horned lizard, habitat is also saved for the Orange-Throated Whiptail. Though, this species has been designated as a "sensitive species" by the California Department of Fish and Game the Orange-Throated Whiptail is threatened as a target for commercial collection (Department of Fish and Game 2001). Consequently, threats seem to come from several angles for this lizard. Ted Case and Robert Fisher, who researched reptiles in the Puente-Chino Hills, have done even more research on a local level. Their study will be examined in this paper.

INVENTORY OF THE PUENTE-CHINO HILLS

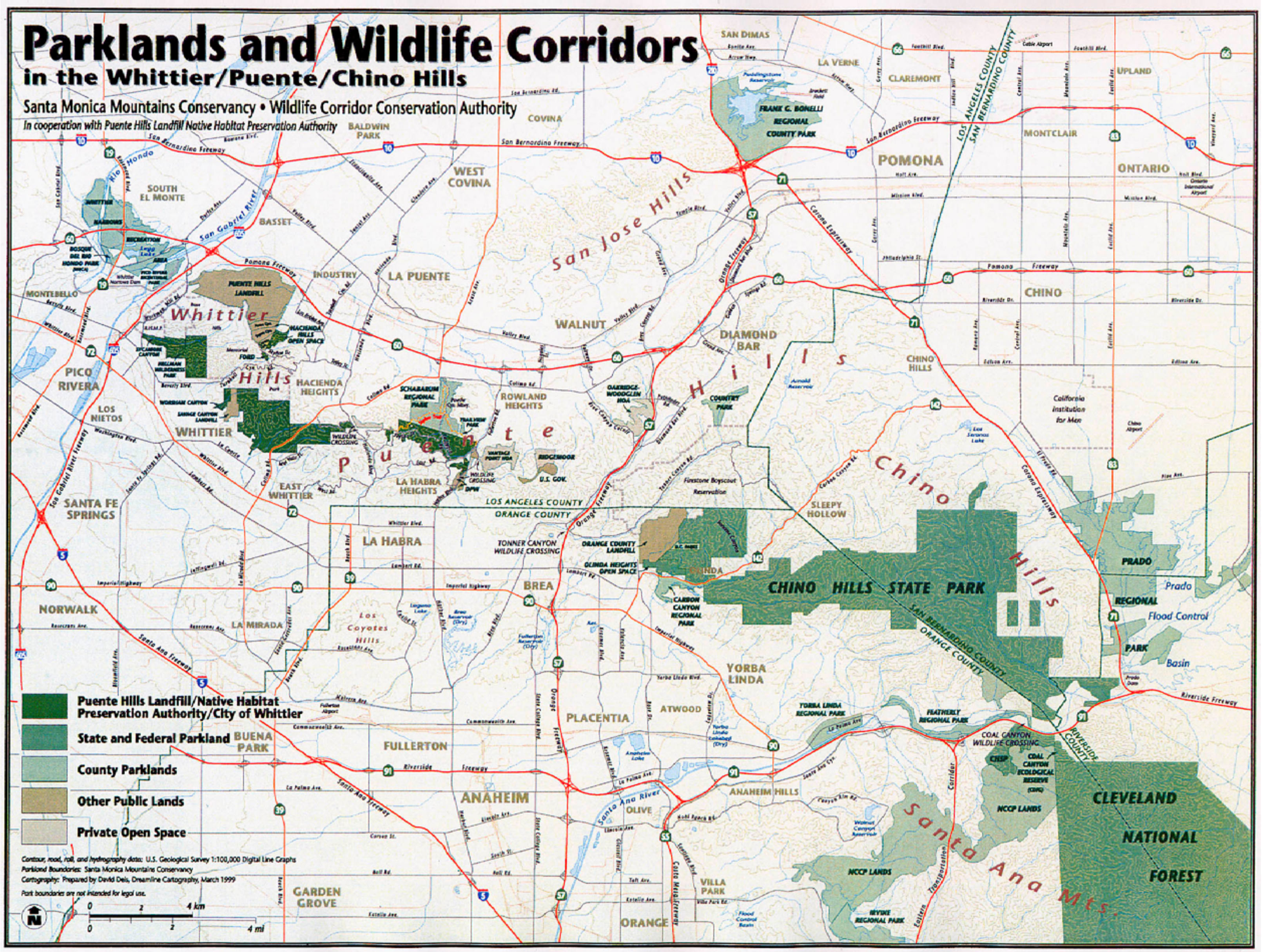
The Puente-Chino Hills wildlife corridor extends 31 miles and is almost entirely surrounded by urban landscapes. The wildlife corridor is several miles across at its widest point in CHSP, and narrowest, at less than one mile wide in La Habra Heights. There are eleven roadways that bisect the corridor, thus dissecting the land into many unequal sized fragments (See Map 5, next page). Though there are 40,000 acres of remaining continuous open space the most threatened areas of the wildlife corridor are: Turnbull Canyon, the oil fields above Brea, and Tonner Canyon.

Studies initiated along the corridor relay valuable and significant findings for WCCA as the results sometimes help influence critical decisions for the corridor. These studies have labeled the Puente-Chino Hills as a peninsular fragment at risk of isolation. Research on birds and plants is formatted already in GIS. Therefore, the carnivore (mammal) and herpetofauna (reptiles and amphibians) studies, which are not in GIS format, will be evaluated as they pertain to the Puente-Chino Hills.

Carnivore Study

Kevin Crooks, while a doctoral candidate at University of California Santa Cruz, supervised Chris Haas, a Master's candidate at California Polytechnic University Pomona, in a mammal study of the Puente-Chino Hills. They have been funded by two sources, the MRCA and the California Department of Parks and Recreation. Their research has found what animals are more likely to use certain corridors, how frequent the usage, and which corridors are important for migration (Haas and Crooks 1999 and Garvin 1998).

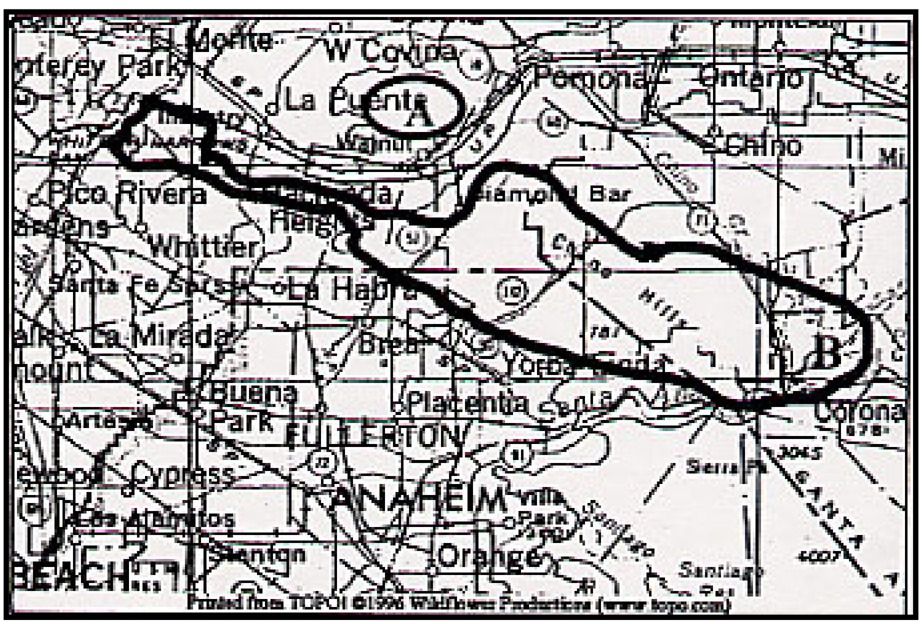
As a part of his requirements for a Master of Science in Biology, Chris Haas conducted this study to determine the distribution and relative abundance of carnivores in the Puente-Chino



Map 5. WCCA Map
(Source: SMMC)

Hills. Haas and a team of field staff created track surveys in various regions throughout the hills. He and his team utilized transects, which included track survey stations, scat surveys and infrared-triggered cameras to record mammal data. To determine if the mammals were utilizing underpasses and culverts, these transects were established in natural corridors, such as dirt roads, wildlife trails, and drainages (Haas 2000).

For the track survey stations "the entire study area was divided into seven sections. Each section was separated from adjacent sections by major roadways" (Haas 2000, 9) (See Map 6). Forty-two track transects were established throughout the hills. For the most part, each transect had 5 track stations unless constraints prevailed; however an additional 13 lone stations were allowed. They utilized scented lures to attract the animals at each track station. These lures were located in the middle of a 1-m^2 plot of finely sifted gypsum power (Haas 2000).



Map 6. Carnivore Study Area From Haas' Thesis
(Source: Haas, p. 94)

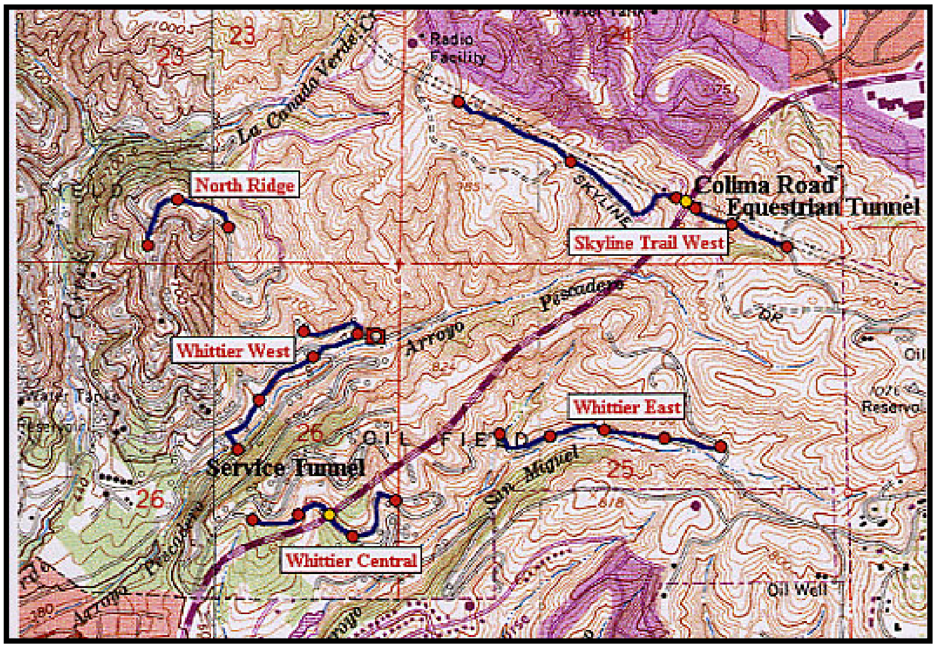
After an animal visited the scented lure, researchers identified species and the stations were reset. Monitoring of track stations occurred for 5 consecutive days to help identify species that occurred less often in a particular area. The relative abundance of each species visiting each station was divided by the total sampling effort (Haas 2000). Though valuable information, the data is not compatible with modern geographic analysis, GIS.

They also conducted scat surveys in 32 transects for three species: coyote, bobcat and fox. Each time transects were cleared of scat and a level of confidence was placed for each identifiable scat sample. Again, the relative abundance was calculated but doesn't provide a number of individuals. Instead, the survey was used to determine presence/absence of the three aforementioned species at each transect (Haas 2000). This information in its current form is also incompatible with GIS.

The third and final method of survey was the use of remotely triggered cameras, which recorded the activity of wildlife species. Cameras were strategically placed out of view along the track and scat transects. For every trigger by the infrared sensor a picture was taken, including the date and time of the occurrence. The number of visits by each species photographed divided by the total sampling effort provided the relative abundance. Due to theft of some of the camera equipment, these survey results, like the scat survey, were only used to confirm/deny the presence of species (Haas 2000).

Haas provided locations for tracking stations, culverts and scat transects using the program TOPO! (See Map 7, next page). The maps I reviewed from the mammal study were in both black and white and color. They were also in varying scales, making it difficult to decipher the exact location of track stations because contour lines were difficult to follow in steep areas. Several times there were mistakes on the maps where excess markings occurred.

Though the information gathered by Haas is valuable, the data isn't compatible with digital maps. As a part of my Project, I incorporated his study area into a comprehensive GIS map. Using the topographic maps provided in his thesis, I digitized each scat transect, track station and underpass in the corridor, by following the topographic relief of his maps. The process of formatting the carnivore study into GIS will be detailed later.



Map 7. Example of Haas' Transect Map
(Source: Haas, Figure 22)

Herpetofauna Study

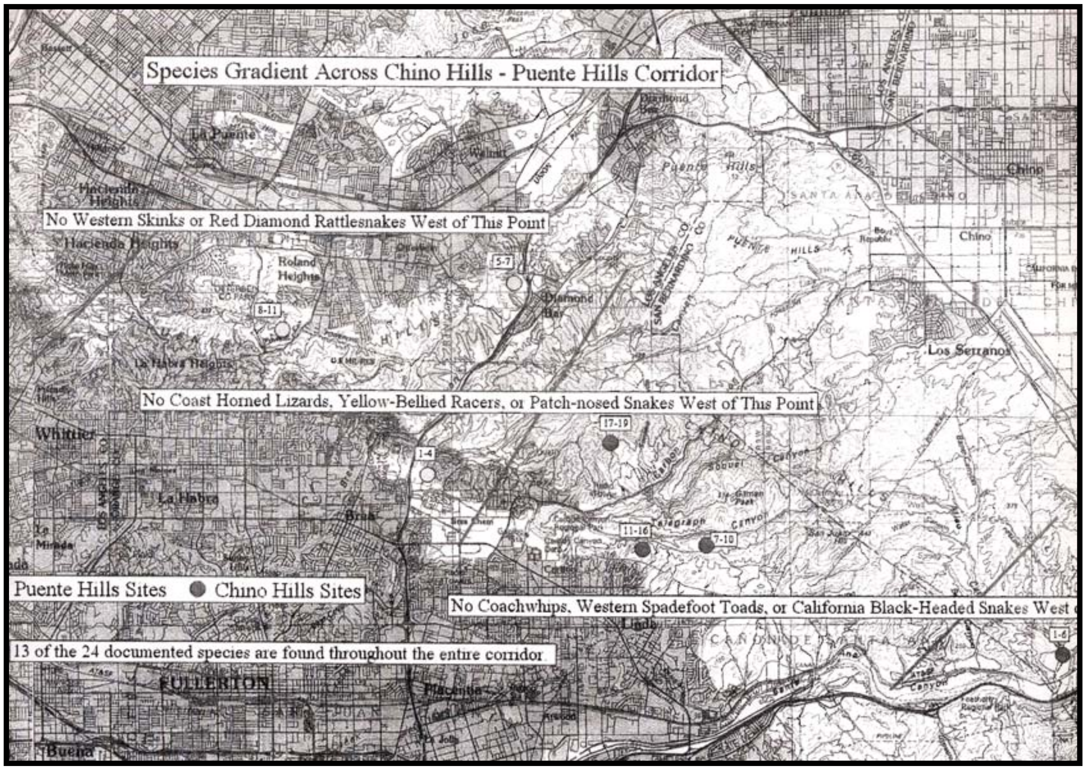
Drs. Ted Case and Robert Fisher were granted a two-year herpetofauna study paid in part by the MRCA with funds matched by the United States Geological Service. Their research has determined the presence and absence of particular species in this area, currently listed as California Species of Special Concern by the California Department of Fish and Game (Case and Fisher 1998).

This project was included as a part of a current larger study area of the California Floristic Province (Case and Fisher 1998). Importance of the Floristic Province is evidenced by the region's endemic species, as well as by the endemic invertebrates. An endemic species "is one that has arisen evolutionarily in the same place where it is presently found" (Quammen 1996, 195).

The high biodiversity makes this region a significant location to study; yet current biological resource data is lacking for this zone. Since 1994, pit-fall trap arrays and drift fence techniques have been utilized in over 25 sites. Information obtained from this study will provide baseline biological information, as well as diversity over various elevations (Case and Fisher 1998).

The Puente-Chino Hills arrays were distributed through various habitat types in the study area (See Map 8, next page). Each array consists of seven 5-gallon buckets (pit-fall traps) and was connected by shade cloth drift-fences in a Y-configuration. Sampling was conducted for ten consecutive days for each array equally distributed over a year's time. Overall, Case and Fisher feel the pit-fall technique is successful "in detecting species that are cryptic, secretive and nocturnal, or very active" (Case and Fisher 1998, 7).

Animals captured in the pit-fall traps are individually marked, by toe-clipping or scale clipping and then released. Other information such as weight and body length was recorded for immediate use, while the clippings were kept for molecular work in the future. Though most of the animals remain alive during the trapping, marking and release, others did not. Those animals that died in the study are preserved and donated to the California Academy of Sciences herpetological collection (Case and Fisher 1998).

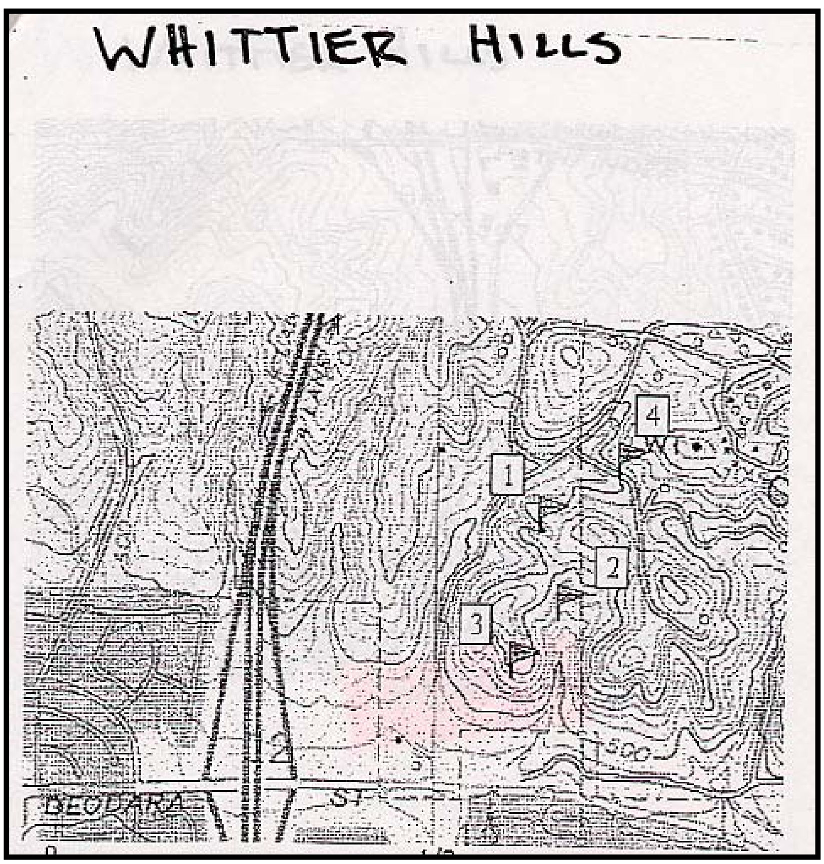


Map 8. Herpetofauna Study Area From Fisher's Study
(Source: Swift)

Within the Puente-Chino Hills, 25-35 arrays in various habitat types were to be established and later integrated into the overall Floristic Province information. Also included in the study are transects of the local canyons and surface litter searches. Animals killed by vehicles on nearby roads were cataloged and recorded in many locations as well. The researchers feel that the vegetation studies, both present and historical, may be able to help prioritize which fragments are most important to acquire and may help set management goals. Though the information gathered by Case and Fisher will be very valuable on a regional and statewide scale, however the data is not currently compatible with GIS.

Maps provided in the herpetofauna study were in black and white, making it difficult to decipher the exact location of pit-traps because contour lines were hard to follow (See Map 9, next page). The black and white maps were often fuzzy and didn't provide an adequate location description. Several times, there were no street names or incorrect street names. For example, several hours were spent trying to find Deodara Street near an unnamed four-lane freeway. It turns out that Deodara Street, in TOPO! is Lambert Road now. These inaccuracies made locating the arrays difficult. Phone calls to the SMMC Resource Division were utilized as a last resort to determine the locations of pit-traps difficult to locate.

I obtained maps of the pit arrays on TOPO! from SMMC. As a part of my Project, I incorporated their study area into a comprehensive GIS map. Using the maps provided in quarterly updates to MRCA, I digitized each array by following the topographic relief of the map and using current street names when provided. The process of formatting the herpetofauna study into GIS will be detailed later.



Map 9. Example of Fisher's Pit-Fall Trap Array Map
(Source: SMMC, Attachment)

PUENTE-CHINO HILLS WILDLIFE CORRIDOR MAPPING

Technique

Geographic Information Systems or GIS, is a computer program that "captures, stores, analyzes and displays geographic information" (ESRI 1996, G-5). Essentially, a GIS program creates maps in a digital form. Map alteration, reproduction, and comparison are easier in GIS than paper maps. Users can easily select specific data to be highlighted, create new data sets and run calculations from the data. Various layers of information (such as highways, rivers or oil wells) can be temporarily eliminated and/or new layers or data added through importing tables. All of these features and many more, make GIS maps better than maps in paper form.

A GIS map is created when themes are added to a view. Themes are geographic features that include points, lines or polygons. Along with themes a table is also added automatically. In the table, information about the points, lines, and polygons is recorded. Information such as location of a point, length of line, and area of a polygon are stored and called attributes. Tables can be edited and modified and used to calculate information. The projection of a map is a mathematical formula that transforms a spherical surface (three dimensional) into a planar surface (two dimensional).

For this project, topographic maps, which show relief of an area, such as mountains, valleys and streams, were used to locate various points on the researcher's map. New themes can be created and a complimenting attribute table is automatically added as well. One form of creating a new theme is by heads-up digitizing, where a point, line or polygon is drawn on the screen from observing a map.

Whittier Project

Dr. Cheryl Swift, professor of biology at Whittier College, and a team of roughly eight others have been working seven years on GIS mapping of the Puente-Chino Hills wildlife corridor. The purpose of the project was to create a single source of information that is connected and stored together for WCCA. This will help provide an effective planning tool for the wildlife corridor. There are roughly seven goals for the project (Swift 2001).

The conversion of the existing land ownership to a coverage, as well as the addition of a transportation coverage that includes all major and minor arterials are the first two goals. Three more goals include the completion of a vegetation layer, compatibility of ownership and vegetation layer, as well as a creation of a layer that depicts topography. Another goal is to provide a means to answer questions about particular parcels in the corridor, with a "point and click" format. The final goal is the creation of a basis for future layers of data collected in the avian, herpetological, and mammalian habitat use studies. In order to help complete the project, I was assigned to map the two unmapped biological studies of the hill system into GIS (Swift 2001).

Biological Studies

I obtained my data from Dr. Swift and Jeff Henderson of the Whittier Project. Dr. Swift provided background knowledge of the project and delineated the goals for the corridor. Henderson, a GIS instructor at Whittier College, provided me with major roads of Los Angeles and Orange Counties, two themes, as well as twelve TIFF (image) files of the United States Geological Survey quadrangles for the entire corridor. They were all in decimal degrees (latitude/longitude) projection. To keep things consistent, I continued to utilize that projection. I was to complete the carnivore and herpetofauna study goals, since the avian and vegetation study were already transferred into GIS format.

Carnivore Study

In order to familiarize myself with the carnivore study I contacted the author, Haas, and discussed the project with him. He sent me his thesis, a final report for WCCA, as well as culvert and transect indices. I inquired about the specific type of coding system he had used during his research to label each scat transect or track station. Haas defined each station from east to west and I did the same. If the transect moved in a north to south direction, each point was labeled from north to south (See Figure 3).

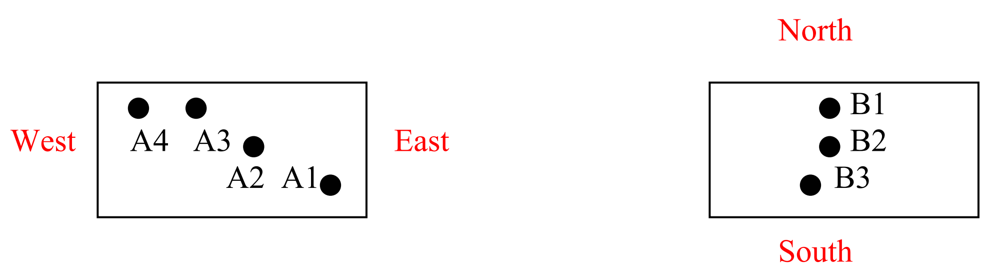


Figure 3. Labeling Technique
(Source: M. Schlotterbeck)

For each scat transect digitized, I labeled the line in the attribute table using the entire name. The theme was named "scat." This included 38 scat transects in total (See Table 1, next page).

Using the scat indices I added more fields in the attribute table listing each species researched and determined their presence or absence. Included in the indices were ten different animals. For example, if an animal was present in a scat transect the cell in the attribute table was listed as the letter P; if the animal was absent the letter A was used. The addition of these attributes will show the user at a quick glance what species were present or absent at a specific transect along the entire research area (See Table 2, next page) (See Map 10, next page).

Location
Aliso Canyon
Bike Path
Canyon 4
Canyon 6
Dam
East Ridge
Ford
Hacienda Blvd.
Hanger Ridge
Harbor Central – East
Harbor Central – West
Harbor North
Harbor South

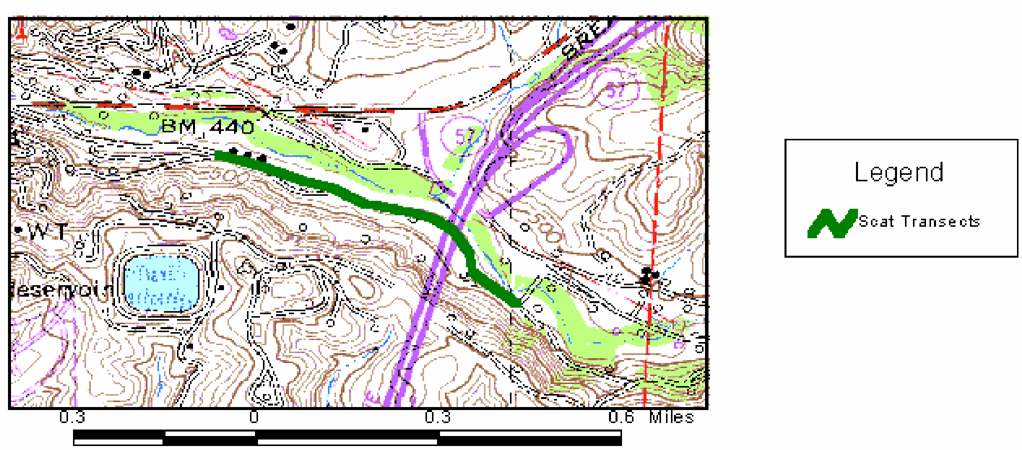
Location
Landfill East
Landfill West
North Ridge
Powder Canyon North
Powder Canyon South
Powder Canyon West
Prado
Railroad East
Railroad West
Santa Ana River
SART
Shell Canyon
Skyline Trail East

Location
Skyline Trail West
Sonome Canyon
Sonome Canyon East
Sonome Canyon West
Spillway
Telegraph Canyon East
Telegraph Canyon West
Tonner Canyon East
Tonner Canyon West
Whittier Central
Whittier East
Whittier West

Table 1. All Scat Transects
(Source: M. Schlotterbeck)

Location	*Bobcat*	*Coyote*	*Gray Fox*	*Mule Deer*	*Opossum*	*Striped Skunk*	*Raccoon*	*Lt Weasel*	*Domestic Dog*	*Domestic Cat*
Tonner Canyon West	A	P	P	A	P	P	A	A	A	A

Table 2. Presence/Absence for Tonner Canyon West Transect
(Source: M. Schlotterbeck)



Map 10. Location of Tonner Canyon West Transect
(Source: M. Schlotterbeck)

I duplicated the scat transect theme and converted it into a new shapefile with the same attribute table. This new theme was called "detailscat". Working with the indices again, I created a more detailed version of the presence/absence table to demonstrate the relative abundance of each monitored species as determined by Haas. Each species' relative abundance was added to the attribute table (See Table 3).

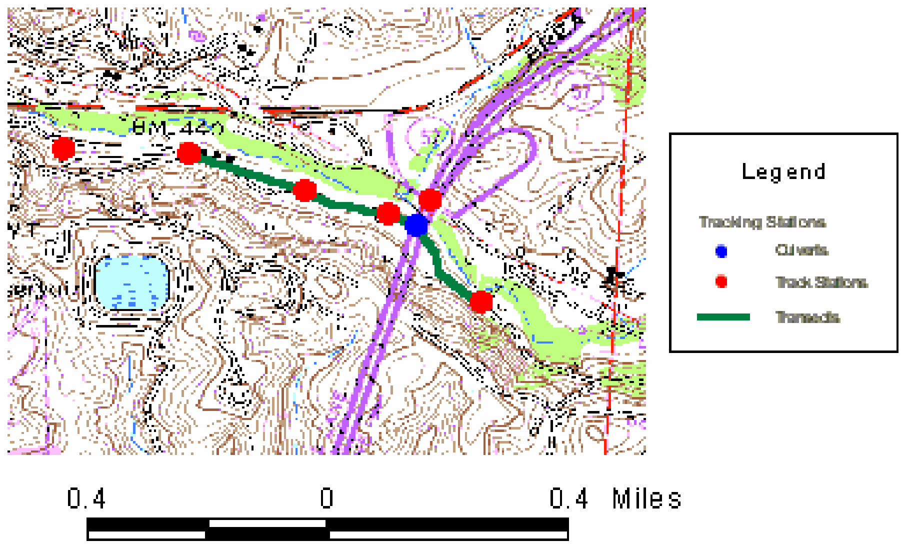
Location	***Bobcat***	***Coyote***	***Gray Fox***	***Mule Deer***	***Opossum***	***Striped Skunk***	***Raccoon***	***Lt Weasel***	***Domestic Dog***	***Domestic Cat***
Tonner Canyon West	0.000	0.241	0.192	0.000	0.167	0.030	0.000	0.000	0.000	0.000

Table 3. Relative Abundance for Tonner Canyon West
(Source: M. Schlotterbeck)

For each track station digitized, I created a new theme called "mammals". I created a system of labeling the points in the attribute table to accommodate the GIS format. A column was added to identify if the point was a track station, labeled "TS" or a culvert, labeled "CU." This included 194 track station and 42 culverts. I selected the first letter of each word of each track station or culvert within the transect or canyon to easily identify to point in my attribute table. For example, Tonner Canyon West (ToCW) there were six track stations and one culvert, labeled from east to west (See Table 4) (See Map 11, next page).

Shape	***Type***	***Location***
Point	TS	ToCW1
Point	TS	ToCW2
Point	CU	ToCW3
Point	TS	ToCW4
Point	TS	ToCW5
Point	TS	ToCW6
Point	TS	ToCW7

Table 4. Track Stations in Tonner Canyon West
(Source: M. Schlotterbeck)



Map 11. Location of Tonner Canyon West Track Stations
(Source: M. Schlotterbeck)

The following table decodes all of the abbreviations I used for the mammal theme. It also includes the number of track stations and culverts researched for Haas' project (See Table 5, next page).

Again, Haas' indices were utilized to determine the presence/absence of each species for the all track stations and culverts. As with the scat transects the presence/absence coding system of P/A was used. A second more detailed shapefile was created called "detailmam" to give the relative abundance of the species.

In order to provide the basis for future analysis, I created a single theme consisting of only culverts. Then I created six themes distinguishing the various types of culverts researched. This will allow a comparison of species use and overall activity in each type of culvert. The various types of culverts researched include (See Table 6, next page).

Transect Name	*Location Abbreviation*	*TS*	*CU*
71 Freeway (1-28)	71-		28
91 Freeway Central	91C		1
91 Freeway East	91E		1
91 Freeway West	91W		1
Aliso Canyon	AC	5	
Bike Path	BP	5	
Canyon 4	C4	4	
Canyon 6	C6	4	
Carbon Canyon	CC	7	1
Citrus Grove East	CGE	4	1
Citrus Grove West	CGW		1
Coal Canyon	CoC		1
Dam	DAM	2	
East Ridge	ER	5	
Ford	F	4	
Harbor Central-West	HW	3	
Hacienda Blvd.	HB	8	1
Hanger Ridge	HR	5	
Harbor Blvd. Equestrian Trail	HBET		1
Harbor Central-East	HE	3	
Harbor North	HN	3	
Harbor South	HS	6	
Landfill East	LE	5	
Landfill West	LW	5	
Monterey East	ME		1
Monterey West	MW		1
North Ridge	NR	3	
Pasture Road	Past	1	
Powder Canyon North	PCN	5	
Powder Canyon South	PCS	5	
Powder Canyon South-East	PCSE	1	
Powder Canyon West	PCW	5	
Prado	Pr	5	
Railroad East	RE	3	
Railroad West	RW	4	
Santa Ana River	SAR	4	
SART	SART	3	
Shea	Shea	1	
Skyline Trail East	STE	4	
Skyline Trail West	STW	6	1
Sonome Canyon	S	5	
Sonome Canyon East	SCE	5	
Sonome Canyon West	SCW	5	
Spillway	S	4	
Telegraph Canyon East	TeCE	5	
Telegraph Canyon West	TeCW	6	
Tonner Canyon East	ToCE	4	
Tonner Canyon West	ToCW	6	1
Turnbull Canyon	TSC	7	
Whittier Central	WC	4	1
Whittier East	WE	5	

Table 5. Abbreviations for Track Stations
(Source: M. Schlotterbeck)

Culvert Type	*Number*
Underpass	29
Service Tunnel	1
Round Culverts	3
Equestrian Tunnel	3
Box Culvert	4
Arch Culvert	2

Table 6. Culvert Types
(Source: M. Schlotterbeck)

From my work on the carnivore study mapping, Haas' research is now in digital form. Two themes were created for the scat transects and two for track stations. For the scat transects and track stations, one theme listed a generic presence/absence data, while a second theme for each listed a detailed relative abundance data. An overall culvert theme was created for all types of culverts found throughout the hills. I then separated each culvert type, six types in total, into its own theme, thus seven themes were created for culverts. All in all eleven themes were created for the carnivore study.

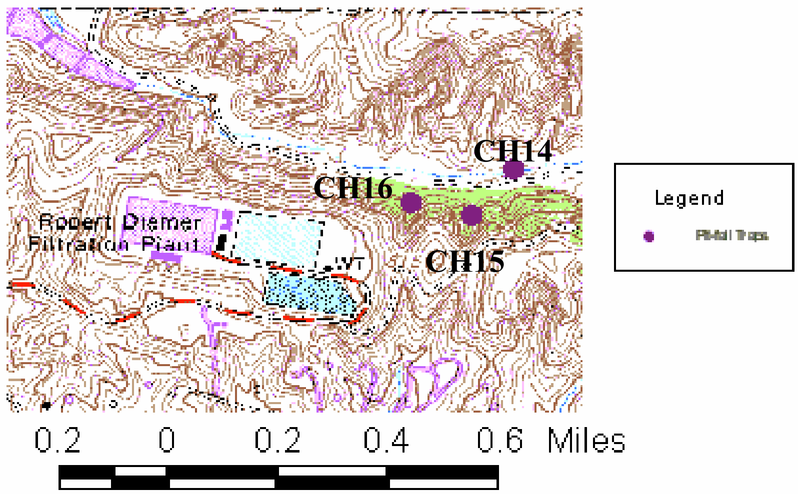
These themes overlay on the data I received from the Whittier Project. After the completion of this project, I will be providing Haas with a copy of all of the associated carnivore files. Haas also requested to have only the culverts along the 71 freeway in its own theme, consequently I created a theme for his use. The digital version of the carnivore information allows a viewer to see all of the biological studies included in the hill systems. This information in digital form will be especially helpful and useful when comparing future data on carnivores in the Puente-Chino Hills. Thus potential for the attribute tables includes a historical trend analysis when future studies are conducted.

Herpetofauna Study

For this study, I was unable to contact the researcher, Fisher, and discuss the project with him. Swift sent me his latest herpetofauna study data for the different pit trap arrays he established. SMMC sent me his project proposal for review. Fisher's data was separated into two sections of the corridor, including east and west of the 57 freeway. Fisher utilized two codes: one for the Chino Hills (CH) and one for the Whittier Hills (WH), also known as the Puente Hills. Each pit-fall trap array was already labeled with a number. I therefore, utilized Fisher's coding system in the attribute table.

Location	Blk_Bld_Sal	Pac_Slndr_Sal	Arb_Sal	Pac_Treefrog	West_Toad	West_Spd_Toad	West_Pond_Turtle
CH14	A	A	A	A	P	A	A
CH15	A	A	A	A	P	A	A
CH16	P	A	A	A	P	A	A

Table 7. Presence/Absence for CH14-16 Pit-Fall Traps Arrays (Source: M. Schlotterbeck)



Map 12. Locations of CH14-16 Pit-Fall Trap Arrays (Source: M. Schlotterbeck)

I created one new theme from the pit array data called "reptile." For each array location I heads-up digitized a point. This included 19 points in the Chino Hills and 19 points in the Whittier Hills. Similar to Haas' research, I included a generic presence/absence field for each of the 24 herpetofauna species researched, using Fishers most recent data (See Table 7) (See Map 12).

Instead of providing an analysis for the species diversity in the corridor, Fisher only provided the unanalyzed raw data. To determine the species diversity of the corridor, I calculated indices for each array by the Shannon-Weiner diversity index. I used this index to be consistent with the measurement techniques in the Haas study. The Shannon-Weiner index is commonly used as a measurement for diversity to compare ecological communities and assess impacts of disturbances (Meffe et al 1997). The equation used is:

$$H' = -\sum p_i \ln(p_i)$$

where:

H' = the species diversity

p_i = the proportional abundance of the i^{th} species

Species diversity includes proportional distribution of species. On the other hand, species richness is the number of organisms present in an area.

Each array, researched species and the species diversity were added to an attribute table from the indices. I converted the reptile theme into a new shapefile, called "detailrep." The diversity of the array is included in this table (See Table 8).

Location	*Species Diversity*
CH14	11.7131
CH15	15.7432
CH16	16.9232

Table 8. Species Diversity of CH14-16 Pit-Fall Trap Arrays (Source: M. Schlotterbeck)

From my work on the herpetofauna study mapping, two new digital themes have been created. The first includes a presence/absence survey for all the species, while the second detailed version includes the species diversity. Due to the history of Fisher's studies along the corridor and his findings published in quarterly reports to WCCA, a historical trend analysis can be found with further calculations and research.

Results

The Whittier Project will house the themes and be accessible to WCCA and researchers. These new digital maps will also be available to researchers to compare future studies as well as provide the foundation for historical analysis.

GIS mapping of these studies is needed because of the current lack of computerized maps for the corridor. With these new themes (See Maps 13-15, pages 42-44), different agencies interested in resource protection in this area, as well as other researchers can compare, utilize and reference the information from all fifteen of the themes I've created (See Map 16, page 45). It is known that without maintaining connectivity to other landscapes, many species within the Puente-Chino Hills will become an island population. These studies, by Haas and Fisher, may actually become a historical documentation of what once was present in the hills if connectivity is not maintained.

CONCLUSION

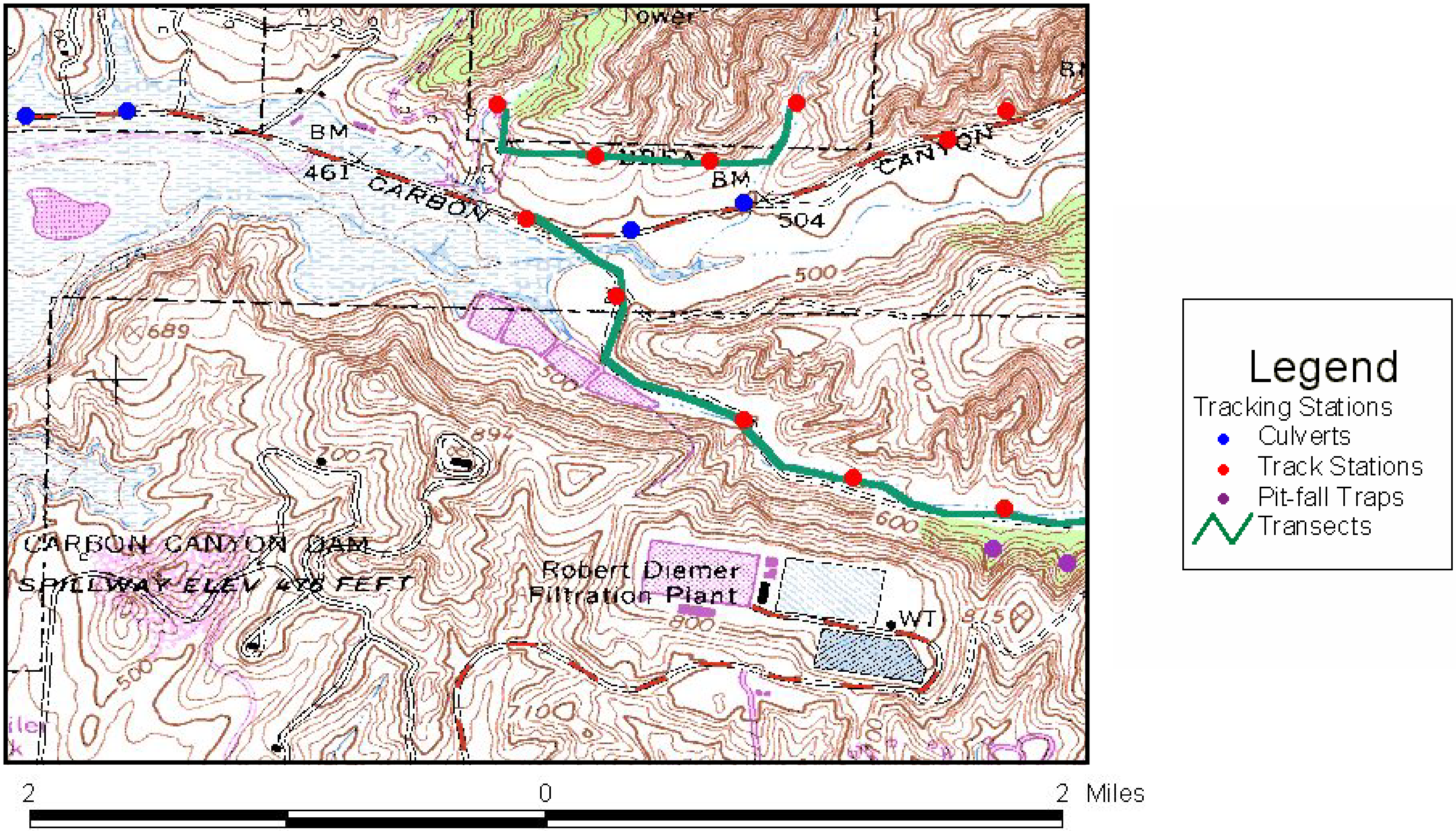
The Puente-Chino Hills are one local example of how a once thriving ecosystem, is now being fragmented and heading toward ecosystem collapse. Though studies have been conducted in the hills to determine the species present and absent from the region, there is no way of knowing how long the ecosystem will be able to maintain its current species diversity. Haas' and Fisher's studies of the carnivores and herpetofauna are extremely critical and valuable in this age of impending local extinctions. Looking toward the future, their data may provide a current inventory of species, but may later provide what species we have lost from the Puente-Chino Hills because of ecosystem decay.

While it is important to have an inventory of resources, it is also important to make the inventory a useful tool. My goal at the beginning of this project was to provide a more useable format for presenting Haas' and Fisher's data to agencies and researchers. By having their study locations, presence/absence data and species diversity on GIS, future studies will be more complete. Data additions and yearly comparisons will also be easier to make in a digital format.

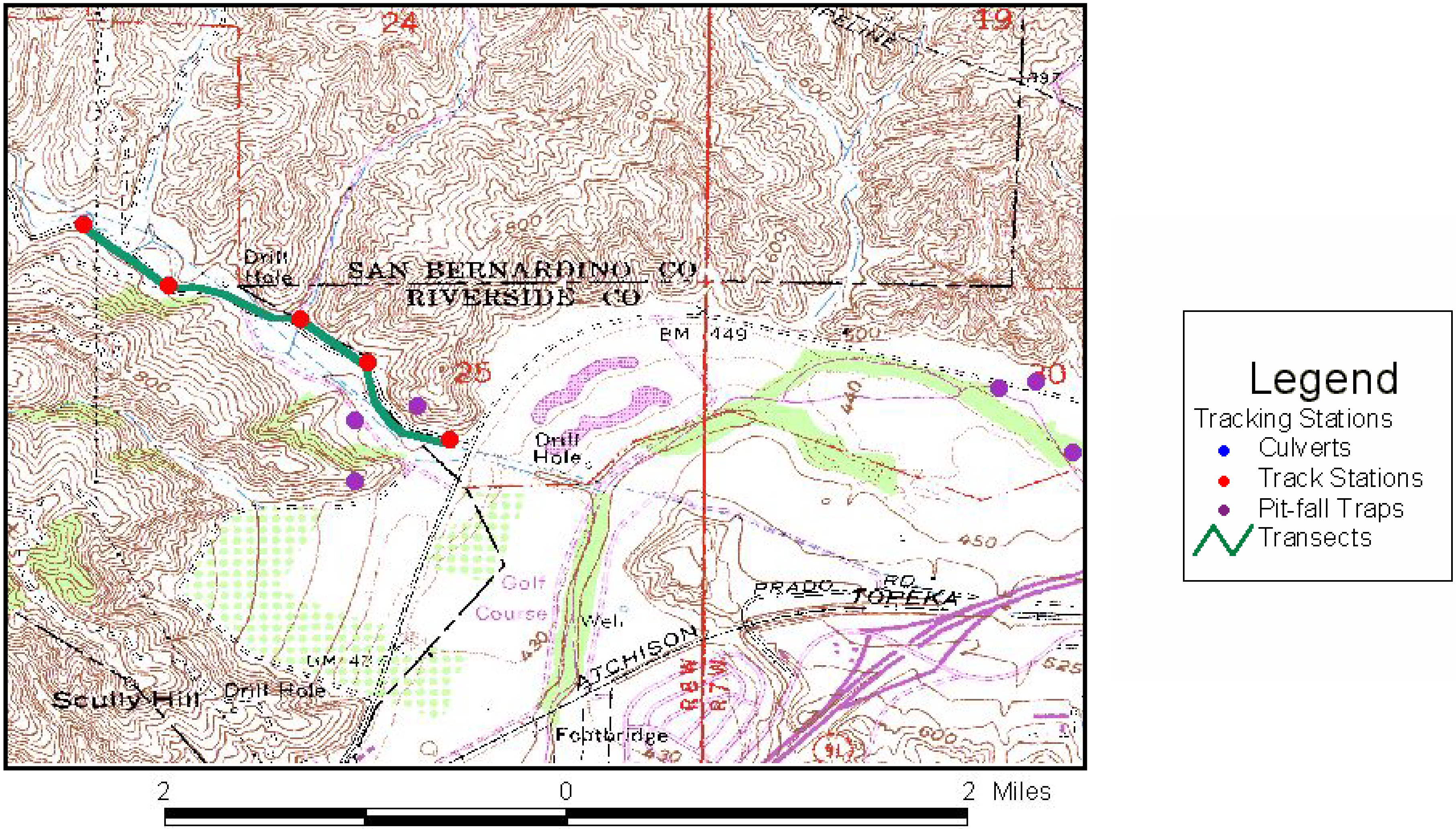
As other national studies have found, even our biggest National Parks are too small to maintain their species diversity over hundreds of years. Consequently, when comparing the acreage of Yellowstone and the species lost there, the Puente-Chino Hills may be heading toward ecological disaster. Since habitat fragmentation is an ever-increasing problem in previously rural areas, solutions need to be reached to help remedy the problem.

Specific solutions to the Puente-Chino Hills will include the permanent protection of numerous lands, which remain vulnerable to development. Restoration of the existing but impaired corridors also needs to occur. Proper management of the habitats currently being acquired and prioritization of the parcels needing to be purchased are both necessary to maintain the viability of this hill system. As the late environmental activist David Brower once said,

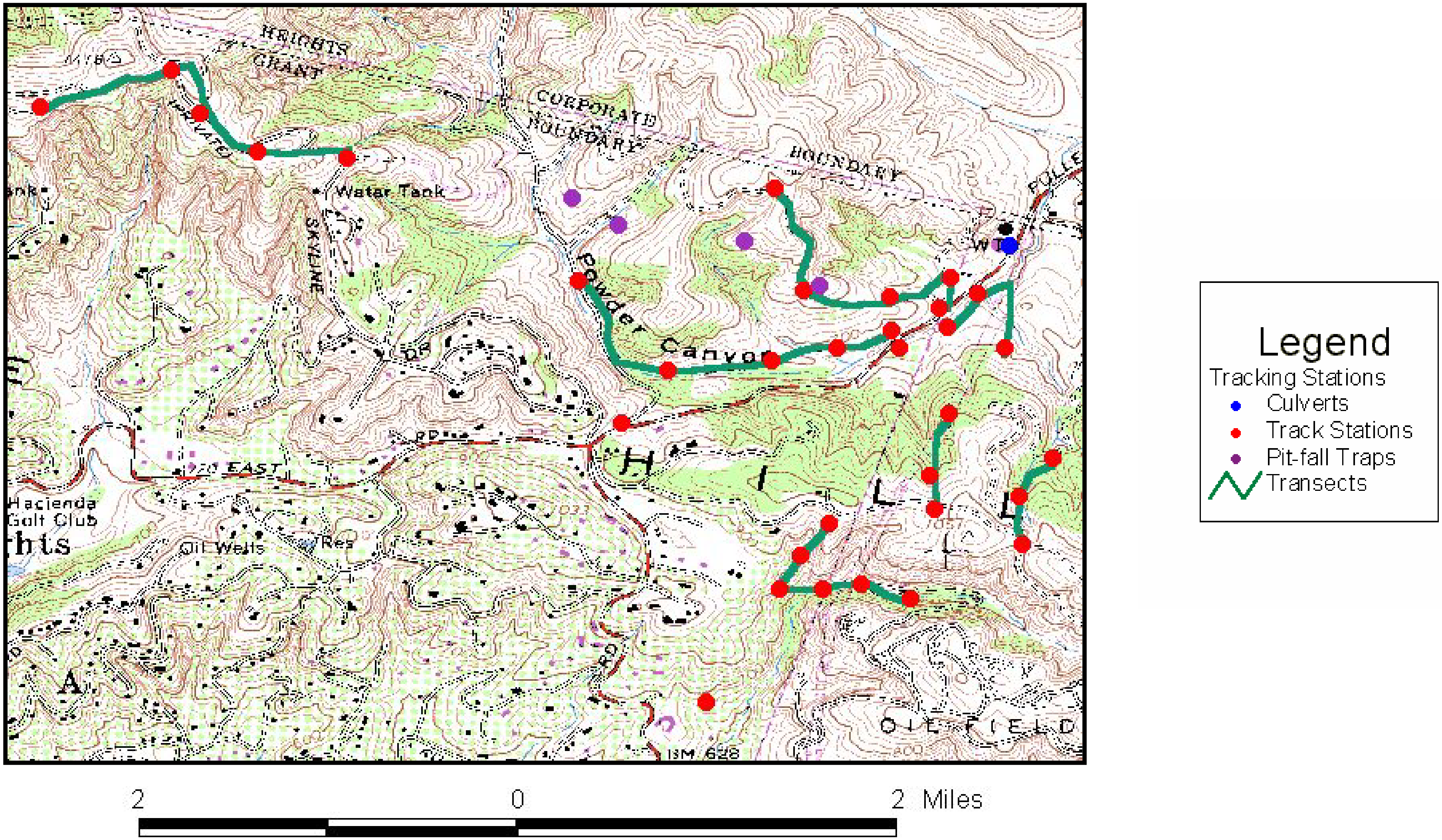
> "… we need boundaries around cities, not around wildness. Animals and seeds do not honor the straight lines on human maps. They follow riverbeds, they migrate through mountain passes, they forage from mountain to plain, they pass from public forest to private, they blow where the wind blows. At least they used to" (Brower 1995, 43).



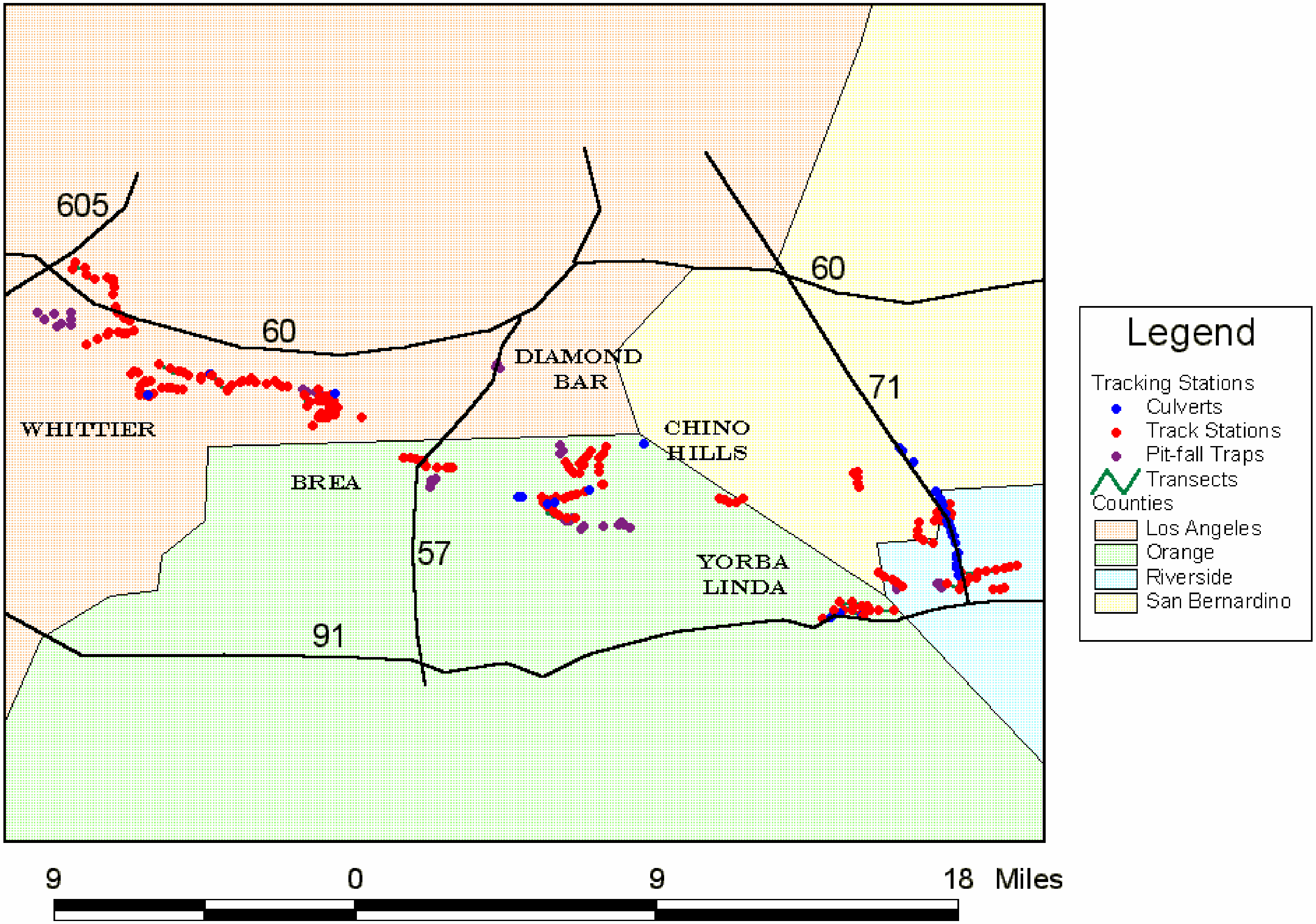
Map 13. Location of Carnivore and Herpetofauna Study Sites in Carbon Canyon (Source: M. Schlotterbeck)



Map 14. Location of Carnivore and Herpetofauna Study Sites along the Santa Ana River (Source: M. Schlotterbeck)



Map 15. Location of Carnivore and Herpetofauna Study Sites in Powder Canyon (Source: M. Schlotterbeck)



Map 16. Location of All Carnivore and Herpetofauna Study Sites in the Puente-Chino Hills (Source: M. Schlottereck)

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**NOTE: All personal and telephone interviews were conducted by Melanie Schlotterbeck.*