Las Californias Binational Conservation Initiative

A Vision for Habitat Conservation in the Border Region of California and Baja California

Prepared by

Conservation Biology Institute

in partnership with

Pronatura Asociación Civil

and

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-Michael D. White and Jerre Ann Stallcup

1. INTRODUCTION

The Las Californias Binational Conservation Initiative began under the leadership of Pronatura, a nonprofit organization promoting conservation and sustainable development in México. Their objective was to foster the conservation of biodiversity, open space, and *areas rurales productivas* in the border region of Baja California. Pronatura initially conducted studies in the Tijuana River watershed, and ultimately focused on natural resources in the Tijuana-Tecate corridor of Baja California. The Nature Conservancy (TNC) and Conservation Biology Institute (CBI), nonprofit habitat conservation organizations in the United States, joined Pronatura in a binational partnership and expanded the study area to include the Sweetwater and Otay River watersheds in California, the binational Tijuana River watershed, and the Rio Guadalupe watershed in Baja California (Figures 1 and 2). Our collaboration, and our friendships, have sprung from the recognition that conservation of biological resources in this fragile and biologically rich region of over 5 million people must include landscape-scale conservation strategies, sustainable land use planning, and workable long-term management programs. This is an enormous and immediate challenge in the face of rapid regional growth and pressing socioeconomic realities.

This report discusses the biogeographic significance of the California–Baja California border region and proposes a binational conservation network (*enlace conservación*) that recognizes our shared natural resources and our socioeconomic and cultural differences. Our ultimate goal is for U.S. and Méxican governments, academic and research institutions, and nongovernmental conservation organizations to embrace and adopt a shared conservation vision for this border region and to collaborate in its implementation. We hope that this project will provide a framework for launching this process.

Need for the Project

The border region is a biologically diverse and unique landscape, at the center of an internationally recognized biodiversity hotspot (Mittermeier et al. 1999, IUCN 2000). More than 400 species in this region are endangered, threatened, or otherwise sensitive to human impacts. Historically, planning processes on both sides of the border have not recognized the shared natural resources and complementary conservation opportunities in this region. Natural resources and the environmental services they support, such as water quality and water supply protection, flood control, and scenic and recreational resources, function across large landscapes, which are increasingly threatened by expanding human land uses.

Figure 1. Location of study area (hatched) within the South Coast Ecoregion (shaded) of California and Baja California.

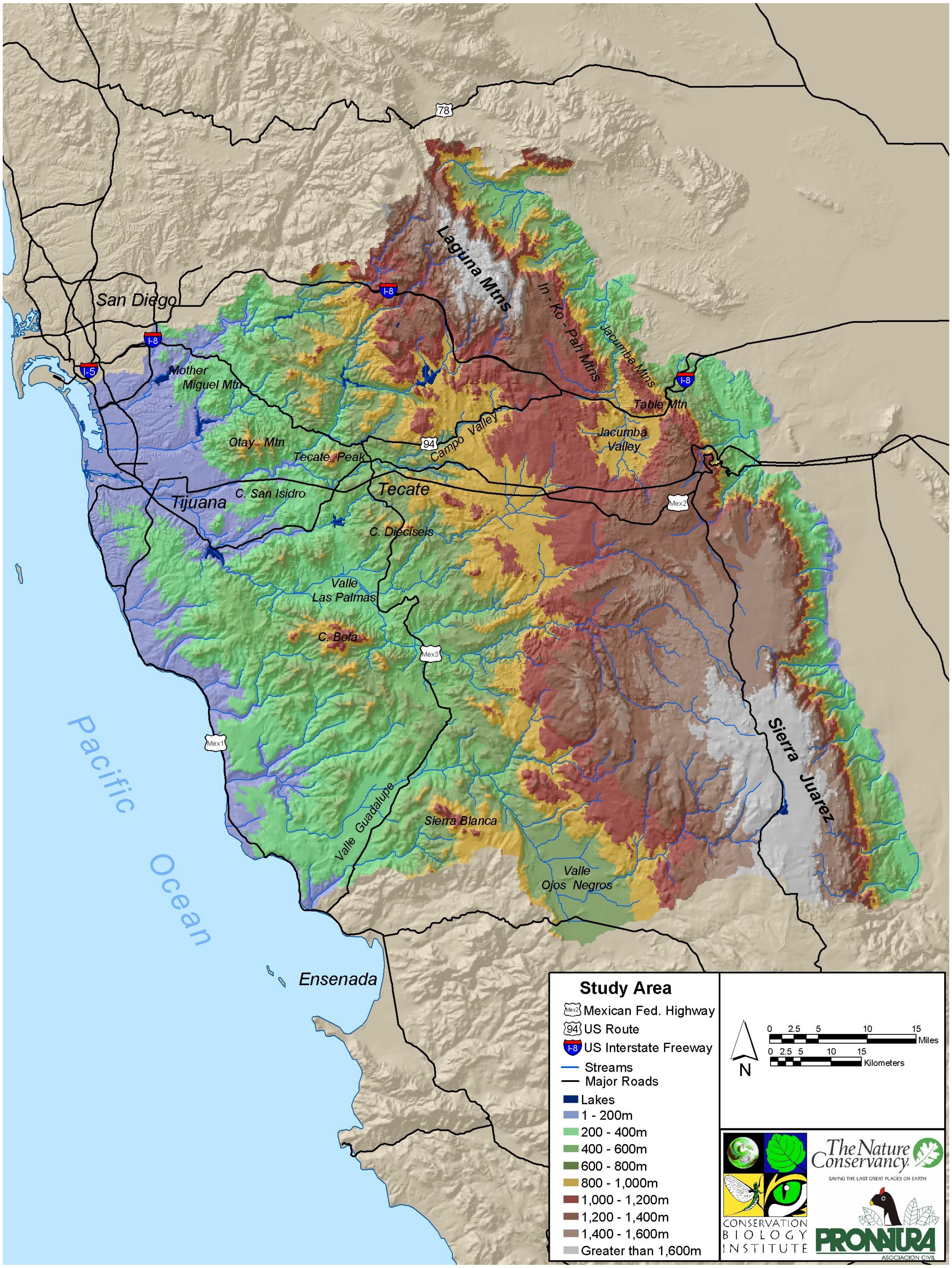

Figure 2. Las Californias Binational Conservation Initiative study area.

Land ownership patterns and available conservation mechanisms differ markedly between California and Baja California, complicating cooperative conservation planning. Within the Las Californias Binational Conservation Initiative study area, the U.S. federal government and State of California have already designated more than 375,000 acres (150,000 ha) as protected, public open space, which is complemented by more than 13,750 acres (5,500 ha) of County and City lands. In contrast, only 14,373 acres [12,350 acres (5,000 ha) at Parque Constitución de 1857 and 2,023 acres (819 ha) at Rancho Cuchumá)] are currently protected within the Baja portion of the study area.

Connectivity between wildland areas is critical to maintaining the values of these existing conservation investments. Historically, species dispersed freely across the international border, but road and highway corridors and associated developments are now major impediments to wildlife movement. Interstate-8 and State Road-94 in California and Highway-2 in Baja California largely sever connectivity between habitats north and south of these roads (Figure 2). Increasing development along these transportation corridors is closing off opportunities for maintaining trans-border habitat linkages. Sand mining in stream channels and riparian habitats, low density rural development of San Diego's backcountry, and agricultural activities on both sides of the border are affecting habitats and water supplies, which could severely impact human, plant, and animal communities. In addition, Native American Indian tribes have proposed new casinos and related projects in southern and eastern San Diego County. Their lands are governed by tribal regulations, which may not consider regional biodiversity protection and habitat connectivity needs outside the reservations.

The urgency of the Las Californias Binational Conservation Initiative is emphasized by the rapid urbanization of the San Diego, Tijuana, and Tecate region and their adjacent suburbs. Population growth and development patterns on both sides of the international border are fragmenting our landscape and quickly compromising our ability to conserve a functional and representative portion of the South Coast Ecoregion in Southern California and Baja California. Largely intact areas with reasonable land values in the eastern portion of the border region present a short-term opportunity to shape binational land protection patterns.

Increased urbanization is coupled with a human need for increased open space, particularly in Baja California where there is very little public land or designated open space. The patterns of ownership, land uses, topography, and biological resources suggest the need for binational conservation areas that represent these patterns. Conservation of habitats along the border, as opposed to allowing these areas to continue to be consumed by urban sprawl, would not only protect ecological integrity but would also symbolize a unified conservation ethic for the two countries and lay the framework for binational cooperation.

Objectives

The Las Californias Binational Conservation Initiative proposes a binational conservation vision for the border region that will:

1. *Encompass biogeographically important and unique natural resources, distributed from the coast, across the mountains, to the desert.*

2. *Identify threats to maintaining an interconnected conservation network and sustaining ecosystem processes.*

3. *Identify large, intact wildlands that represent the region's biodiversity.*

4. *Link protected areas to facilitate wildlife movement and protect existing conservation investments.*

5. *Promote collaboration in implementing land protection strategies that result in secure and sustainable conservation.*

6. *Lay the foundation for a binational park system that connects the Parque Constitución de 1857 in México to wilderness areas, forests, and park land in the United States.*

7. *Heighten the visibility of this little-studied, multi-cultural area and the global importance of implementing a strategy that conserves the integrity and functionality of its ecosystems, while enriching the health, economy, and standard of living of its residents.*

The following sections summarize how the biogeography of the Las Californias border region results in a remarkably diverse and unique flora and fauna, and how this diversity is threatened by human population growth and human land uses. In subsequent sections, we describe how these patterns of biodiversity and human land uses influence our approach for developing a conservation network, and how these patterns, along with various considerations for implementation, ultimately drive decisions on sustainable habitat conservation and sustainable patterns of human growth and land uses.

2. CONSIDERATIONS FOR HABITAT CONSERVATION PLANNING

Biogeography of the Study Area

Geomorphologic diversity

The shape and geologic composition of the landscape of Southern California - Baja California is a product of its long and complicated geologic history. Over the last 150 million years, plate tectonics has produced ancient volcanic islands, intruded vast quantities of magma, uplifted mountains, and dotted the landscape with volcanic flows and cinder cones. Some of these formations have been eroded and buried beneath younger sediments, folded and metamorphosed by the vast pressures of overlying rock, only to be uplifted and exposed again millions of years later. Within the last 5 million years, activity along the San Andreas Fault has pulled the Baja California peninsula away from mainland México, creating the Gulf of California and uplifting the Peninsular Ranges to near their current elevations (Grismer 1994).

This dynamic history has produced a diverse topography with a complex geology (Gastil et al. 1981). In coastal areas, uplifted marine sedimentary rock has formed mesas, whereas more recent volcanic flows have created tablelands in southern and eastern portions of the region. Remnants of Jurassic-age volcanic islands form part of a discontinuous, low mountain range in the coastal zone (Figure 2). These metavolcanic and gabbro peaks, including Otay Mountain, Tecate Peak, Cerro Dieciseis, and Cerro Bola, are rich in mafic minerals such as iron and magnesium. Several large inland valleys, including Valle de Ojos Negros, Valle de las Palmas, Campo Valley, and Jacumba/Jacumé valley, generally separate the coastal mountains from the inland Peninsular Ranges.

The northwest trending mountain ranges—Laguna, In-Ko-Pah, Jacumba Mountains, and Sierra Juárez—are part of the Peninsular Ranges. The Sierra Juárez in Baja California and the Laguna Mountains in California, both reaching elevations of >5,800 ft (1,800 m), are separated by a broad saddle approximately 3,000 ft (1,000 m) in elevation; thus, from a biological viewpoint, these mountains represent high elevation islands of habitat. The Peninsular Ranges are a mixture of igneous and metamorphic rocks that can be distinguished by age and composition into an older (>100 million years) western zone and a younger (<100 million years) eastern zone. The western zone is notable for the occurrence of gabbro peaks, such as Tecate Peak and Cerro Bola. The boundary between these zones, generally trending northwest to southeast, lies to the east of the Laguna Mountains, curves to the west south of the Lagunas, and swings south through the Campo Valley into Baja California (Walawender 2000). This region, from Campo and El Hongo to Jacumba and Jacumé, is extremely diverse in its geological composition and ranges in age from over 300 million years old to less than 20 million years old.

Geologic forces have tilted the foundation rock of the Peninsular Ranges (the Peninsular Ranges Batholith) to the west, producing a relatively gently sloping western slope and a very steep eastern escarpment. Erosion and faulting has produced rolling foothills carved by gentle, westward-draining streams on the western flank of the mountains, whereas the eastern flank is dramatically shear, with steeply incised canyons that drain to the desert floor.

Climate patterns

Climate patterns also shape patterns of floral and faunal diversity. Climate patterns across the border region begin to transition from a Mediterranean climate pattern in the north to a more Sonoran Desert climate pattern in the south, both with a high inter-annual variability (Axelrod 1978, Delgadillo 1998, Western Regional Climate Center 2004). These patterns have shaped the life histories of the species that have evolved here and distinguish this region from adjacent geographic locations.

Annual precipitation increases with increasing elevation, with significant contributions from snowfall at the highest elevations. Summer monsoonal precipitation becomes increasingly more important in the southern portion of the border region, particularly at higher elevations in the Sierra Juárez and coastal range (Delgadillo 1998, Minnich et al. 2000). The Peninsular Ranges produce a rain shadow such that the eastern escarpment of the Laguna Mountains and Sierra Juárez is much drier than the same elevations on their western slopes.

Temperatures rarely ever reach freezing in coastal areas, and daily temperature fluctuations are moderate. Inland from the coast, daily temperatures fluctuate widely, and freezing is common during the winter, particularly at higher elevations. Delgadillo et al. (1995) distinguish four bioclimate zones in the Baja California portion of the study area—*termomediterráneao* (coastal zone), *mesomediterráneao* (foothills), *supramediterráneao* (mountains), and *mesotropical* (Sonoran Desert on eastern side of the Sierra Juárez)—which also correspond to changes in vegetation community composition.

Hydrography

The border region is defined by major hydrographic units or watersheds that drain both the western and eastern slopes of the Peninsular Ranges (Figure 3). The largest watersheds drain the western slope and include (from north to south) the Sweetwater River, Otay River, Tijuana River, and Rio Guadalupe. Several small, unnamed hydrographic units drain directly to the Pacific Ocean. On the eastern slope, numerous drainages flow to two major hydrographic units—the northern Anza-Borrego, which flows to the Salton Sea, and the southern Laguna Salada.

Historically, there was likely a mix of ephemeral, intermittent, and perennial streams in the region. Ephemeral and intermittent flow is characteristic of low-order tributaries and many of the eastern-flowing streams. Perennial flow typically occurs in drainages with significant contributions from springs or in reaches where underlying geology forces water to the surface. However, current hydrologic regimes have been altered in most of the major drainages as a result of surface impoundments, groundwater pumping, irrigation, and urbanization.

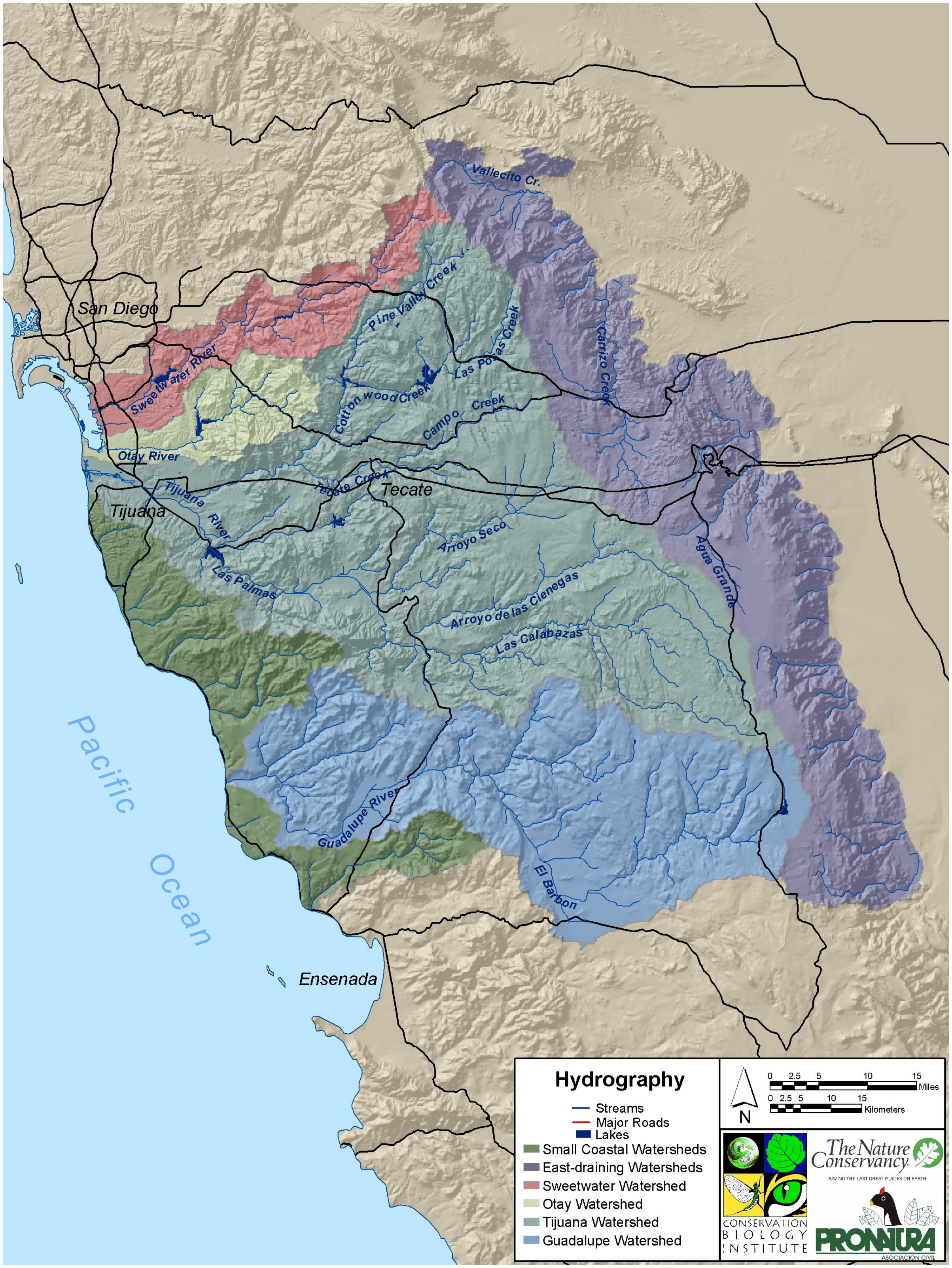

Figure 3. Hydrography.

Floristic regions and plant diversity

Since the concept of identifying biodiversity hotspots was introduced in 1988 (Myers 1988), it has become a common tool for establishing global conservation priorities (Myers 1990, Mittermeier et al. 1998, Mittermeier et al. 1999). Biodiversity hotspots are areas supporting high concentrations of species, particularly endemic species. Conservation International has designated the California Floristic Province, which stretches from Northern California to El Rosario in Baja California, as one of the world's 25 biodiversity hotspots. Although these hotspots comprise less than 1.5% of the Earth's vegetated land surface, they are estimated to contain over 70% of all vascular plant species. Moreover, as measured by species endemic to only a single hotspot, these 25 locations account for 44% of endemic plant species diversity, 35% of terrestrial vertebrate species, and 75% of all terrestrial animal species listed as threatened by the IUCN-World Conservation Union (Mittermeier et al. 1998, Mittermeier et al. 1999).

The border region lies at the center of the South Coast Floristic Region (Figure 1), which is renowned for supporting the highest number of endemic and relict plant species in the California Floristic Province (Stebbins and Major 1965, Raven 1988, Hickman 1996). Thus, the South Coast Region represents a unique portion of the overall biodiversity for which the California Floristic Province is recognized (Mittermeier et al. 1998, Myers et al. 2000, Stein et al. 2000). The border region also includes one of two distinct centers of relict plant species frequency in California (Stebbins and Major 1965, Raven and Axelrod 1978), including numerous endemic plant species, many of which are associated with unique or restricted soil or habitat types (Appendix A).

The border region historically has been divided into three phytogeographic regions based on climate, topography, and species composition—Californian, Coniferous Forest, and a small portion of Colorado (Microphyllous) Desert (Munz and Keck 1959, Wiggins 1980). Delgadillo et al. (1995) subdivide the Coniferous Forest into two bioclimate zones, restricting coniferous forests to the highest elevations (*supramediterráneao*). Within these phytogeographic regions, a rich mosaic of vegetation communities reflects the variability of physical and climatic factors at fine geographic scales (Figure 4). Vegetation community mapping within the California portion of the study area has identified 84 native community types (Appendix B), although undoubtedly there are many more unique species associations (i.e., vegetation series, associations, or unique stands, Sawyer and Keeler-Wolf 1995) that are yet to be described. Three general communities are representative of large portions of the border region—coastal sage scrub, chaparral, and coniferous forests—and provide good examples of its importance with respect to plant community biogeography.

Coastal sage scrub is a low-growing, partially drought deciduous, vegetation community that occurs along the coastal zone from the northern California border to El Rosario, Baja California (Axelrod 1978). In Southern California and northern Baja California, it is greatly restricted relative to its original distribution and highly threatened by development. The coastal sage scrub community has been variously divided into major geographic divisions based on species composition (Axelrod 1978, Westman 1983, Zippen and Vanderwier 1994). Each division supports distinct elements of the overall biogeographic diversity of this community type. Three

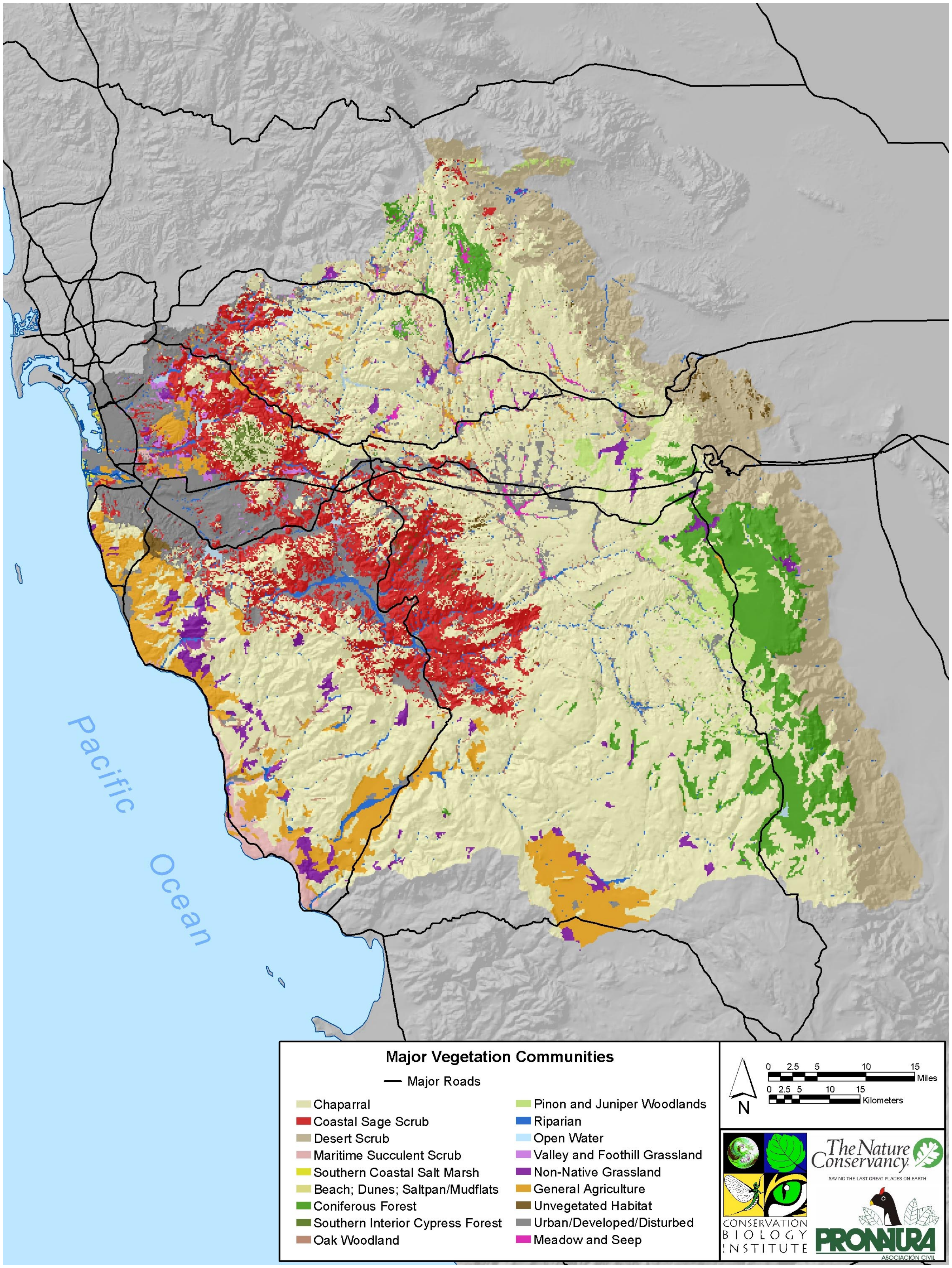

Figure 4. Major vegetation communities

coastal sage scrub divisions—Diegan sage scrub along the coast, Riversidian sage scrub to the east, and Martirian succulent scrub to the south (Westman 1983)—occur in the border region. Martirian succulent scrub differs from the other two communities by supporting an increased abundance of stem-succulent species [e.g, dudleyas (*Dudleya* spp.), Shaw's agave (*Agave shawii* ssp. *shawii*), velvet cactus (*Bergerocactus emoryi*), coast barrel cactus (*Ferocactus viridescens*), sour pitaya (*Stenocereus gummosus*), fishhook cactus (*Mammillaria dioica*), coastal prickly pear (*Opuntia littoralis*), chollas (*Cylindropuntia* spp.)], and other species indicative of the transition to Sonoran Desert communities further to the south (Westman 1983, Zippen and Vanderwier 1994, Delgadillo 1998).

Chaparral is comprised of dense thickets of hard-leaved (sclerophyllous) shrubs 4-12 ft (1-4 m) tall (Hanes 1965, Keeley 2000). The chaparral community is often classified relative to the dominant species (e.g., chamise chaparral, red shank chaparral, etc.), which vary according to soil conditions, aspect, elevation, and climate. California has a high diversity of chaparral types or communities; for example, Hanes (1965) identified 10 chaparral types, whereas Holland (1986) identified 36 unique communities within California alone! The border region supports 19 chaparral communities (Holland 1986) as a result of variable physical and climatic conditions, extending from the coast to the desert transition zone. Southern mixed chaparral commonly occurs from the coastal zone to the western foothills of the Peninsular Ranges, where it transitions to northern mixed chaparral, semi-desert chaparral, and montane chaparrals. The higher plateaus of the Sierra Juárez, in particular (Delgadillo 1998, Minnich and Franco Vizcaìno 1998), support the red shank chaparral (*Adenostoma sparsifolium*) community, which is unique to Southern California and northern Baja California (Hanes 1965).

Coniferous forest communities or species associations are also classified on the basis of dominant species (Delgadillo 1998, Holland 1986, Sawyer and Keeler-Wolf 1995), many of which are at or near the edges of their ranges within the border region (Minnich 1986, Minnich 1987, Delgadillo 1998). Closed-coned pine forests are represented by stands of knobcone pine (*Pinus attenuata*) in the coastal Sierra Blanca of Baja California. This population is disjunct from the next closest population in the Santa Ana Mountains of Southern California (Vogl 1973, Vogl et al. 1988) and is presumably a relict from times when cooler and moister climate conditions prevailed. Cypress forests are represented by Tecate cypress (*Cupressus forbesii*), which occurs in small, isolated groves on the archipelago of metavolcanic and gabbro peaks in the coastal range. Tecate cypress groves on Otay Mountain, Tecate Peak, and Guatay Mountain in San Diego County represent the northern limit of an extensive distribution of this species that extends south 100 miles (160 km) into northern Baja California (Minnich 1987).

Pine forests in the region are dominated by Jeffrey pine (*Pinus jeffreyi*), with a few small stands of incense cedar (*Calocedrus decurrens*) occurring near streams (Minnich 1987) and small stands of Coulter pine (*Pinus coulteri*) (Beauchamp 1986, Minnich and Franco Vizcaìno 1998). The Laguna Mountains and Sierra Juárez support two of the southernmost high-elevation islands of Jeffrey pine forest (the southernmost is in the Sierra San Pedro Mártir) within a more extensive and continuous distribution to the north. Pinyon and juniper woodlands also occur above 3,000 ft (1,000 m) in the northern Sierra Juárez and Jacumba Mountains and are dominated by Parry pinyon (*Pinus quadrifolia*), singleleaf pinyon (*Pinus monophylla*) on the drier eastern escarpment of the Peninsular Ranges, California juniper (*Juniperus californica*), and various chaparral species (Minnich 1987, Minnich and Franco Vizcaìno 1998).

Patterns of faunal diversity

The distribution of fauna in the border region can be grouped into biotic provinces that generally correspond to phytogeographic regions—Californian (Northwestern Coastal Slope), Coniferous Forest (Vancouverian), and Lower Colorado Valley (Sonoran or Colorado Desert) (Truxal 1960, Erickson and Howell 2001, Grismer 2002). Like plant species, the distributional patterns of animal taxa are a product of millions of years of geologic, climate, and evolutionary change. Grismer (1994, 2002) described historical biogeographic patterns to explain distributions of related herpetofauna taxa on and adjacent to the Baja California peninsula. Grismer's research provides insight into the derivation of faunal diversity and its complex evolutionary dynamics in the border region. For example, this area supports species whose closest kin are in mainland México, who rafted into their present position and evolved into new species as Baja California pulled away from the mainland. Many species show a taxonomic affinity to more northerly distributed species, their ancestors presumably invading the border region from habitats to the north. Some species evolved from taxa that were formerly widely distributed in Southwestern North America but were split by the northernmost extension of the ancestral Gulf of California about 3 million years ago. This allowed genetic divergence of populations on either side of the Gulf and subsequent recontact of these differentiated populations once the Gulf retreated to its present position. Several species were formerly more widespread in their distributions when climates were wetter, but have become restricted to higher elevations and stream courses with the onset of drying in the Pleistocene.

Among many bird species, the border region is a vulnerable point along dispersal routes between the two countries, further emphasizing the need for landscape-scale protection strategies. At least 12 long-distance migrants circumvent crossing the Gulf of California by moving through the border region (Unitt personal communication). The ranges of coniferous woodland species, if not reaching their southern limits here, have a distributional gap straddling the border; for example, the mountain chickadee (*Parus gambeli*) and dark-eyed junco (*Junco hyemalis*) are both divided into different subspecies in the California and Baja portions of the study area. The distribution of oak woodlands in the border region is patchy, thus forming bottlenecks in the ranges of many species [e.g., western wood peewee (*Contopus sordidulus*), acorn woodpecker (*Melanerpes formicivorus*), lazuli bunting (*Passerina amoena*), Hutton's vireo (*Vireo huttoni*), white-breasted nuthatch (*Sitta caroleninsis*)] (San Diego Bird Atlas 2004). Several riparian or freshwater birds reach the southern end of their breeding distribution near the border. For two declining species, the gray vireo (*Vireo vicinior*) and sage sparrow (*Amphispiza belli*), the extensive chaparral along the border between Otay Mountain and Jacumba likely serves as an important dispersal corridor (Unitt personal communication). Habitat specialists, such as the grasshopper sparrow (*Ammodramus savannarum*), are especially sensitive to habitat fragmentation and urbanization and need landscape integrity for dispersal.

Dramatic geologic and climate dynamics over millions of years drove evolutionary change and diversification of species within the border region, and evolutionary dynamics continue today. The distributions of fine-scale climate patterns (e.g., coastal-mountain-desert rainfall and temperature gradients), parent rock types and soils (e.g., clay soils derived from metavolcanic and gabbro rocks), and unique and isolated habitats (e.g., vernal pools, closed-cone pine forests) provide unique biophysical conditions that continue to fuel evolutionary processes. The large number of taxa that are endemic to the border region or with ranges in contact within the border region (Appendix A) affirm its importance as a *staging ground for evolution* (Jockusch and Wake 2002). The only way to ensure that evolution can continue innovating, and keeping pace with climatic and other anthropogenic changes in the region, is to conserve large, intact, and connected landscapes where ecological and evolutionary processes can continue at a grand scale.

Threats and Vulnerability

Many of the unique natural resources of the border region have already been lost to development, and ecological processes that sustain these resources have been altered by human land uses. The greatest loss has been in the coastal zone, where urban development and roads are most dense. Further inland, human threats are defined more by rural residential settlements, industrial and agricultural uses, and associated infrastructure. However, there are still large patches of habitat that are not currently altered by human uses. This section describes the potential impacts of human land uses to natural resources and how these issues should be considered in habitat conservation planning in the region.

Habitat fragmentation by development and roads

The loss and fragmentation of habitats is considered the single greatest threat to biodiversity at global and regional scales (Myers 1997, Noss and Csuti 1997, Brooks et al. 2002). Over 80% of imperiled or federally listed species in the U.S. are at risk from habitat degradation and loss (Wilcove et al. 2000). It has been estimated that 32% of California's diverse flora and vertebrate fauna are at risk (Stein et al. 2000). Urban sprawl, defined as encroachment of low-density, automobile-dependent development into natural areas outside of cities and towns, imperils 65% of species listed as Threatened or Endangered in California (Czech et al. 2001). Within an area defined as the Southern California Mountains and Valleys region, the most commonly cited endangerment factors are residential and industrial development, introduction of exotic species, agricultural development, heavy equipment, and grazing (Flather et al. 1998).

The border region provides a textbook example of the effects of habitat fragmentation. Road construction and conversion of land to urban and intensive agricultural land uses have fragmented and isolated natural habitats, particularly in the coastal zone. The remaining habitat fragments, lying within a matrix of altered land cover, experience edge effects in the form of altered physical conditions (Saunders et al. 1991, Pickett et al. 2001) and fire regimes (Keeley and Fotheringham 2001), increased invasions by exotic plant and animal species (Suarez et al. 1998, Brothers and Spingarn 1992), changes in vegetation structure (Pickett et al. 2001), loss of top predators and changes in interspecific interactions (Bolger et al. 1991, Crooks 2002), and altered population dynamics (Soulé et al. 1992). Roads have even broader geographic impacts, serving as sources of pollution, altering hydrologic patterns, disrupting migration patterns, and causing direct mortality via road kill (Beier 1995, Trombulak and Frissell 2000).

Modifications to watershed processes

Poff et al. (1997) discuss the concept of the *natural flow regime* of riverine systems as the critical determinant of their biological composition. The natural flow regime can be described by five key characteristics—magnitude, frequency, duration, timing, and rate of change of discharge (Poff et al. 1997). Because land use changes, such as urbanization and agriculture, can modify the natural flow regime of stream systems, aquatic and riparian communities that depend on a natural flow regime are ultimately affected. Agriculture and some urban land uses can deplete groundwater supplies and surface flow in streams. Urbanization increases the area of impervious surfaces (Paul and Meyer 2001), which increases storm runoff, peak discharges, and flood magnitudes downstream (Dunne and Leopold 1978, Gordon et al. 1992, Leopold 1994). Importing water into an urban watershed for landscape irrigation may also increase dry-season base flows and can cause intermittent streams to become perennially flowing, thereby altering the composition of riparian vegetation communities (White and Greer in press). Urbanization and agricultural development produce other adverse changes to watersheds and stream systems, including increasing nutrient and contaminant loads, elevating water temperatures, facilitating invasion by nonnative aquatic species, and, ultimately, reducing the abundance of native aquatic and riparian species (Paul and Meyer 2001).

Climate change

Conservation scientists are concerned with the implications of global climate change for native biodiversity (Peters and Darling 1985, Kareiva et al. 1992, Malcolm et al. 2001). Climate models suggest that Southern California will experience increased winter precipitation, hotter and drier summers, and more severe El Niño events (Field et al. 1999). One consequence of these changes will likely be shifts in the distribution of vegetation communities and species ranges. It has been suggested that areas with high physical heterogeneity will allow species greater *choices* in the face of changing conditions (Meffe and Carroll 1997). Therefore, protecting contiguous habitat areas with broad elevational and other environmental gradients is critical to accommodating these shifts in species distributions.

3. APPROACH FOR DEVELOPING A CONSERVATION NETWORK

Different standards and criteria have been used to assess conservation values and develop conservation priorities (Pressey et al. 1993, Noss et al. 1997, Soulé and Terborgh 1999, Groves et al. 2000, 2002; Noss 2002, Groves 2003, Margules and Pressey 2000, Carroll et al. 2001). Conservation assessments generally focus on specific conservation objectives, depending on the information available and the ultimate implementation strategies. For example, assessments may prioritize protection of endemic or imperiled species or species requiring large areas for survival (focal species analysis), conservation of biogeographically unique or representative resources (representation analysis), conservation of areas exhibiting high landscape integrity or connectivity, protection of open space for human quality of life, or some combination of these. Because each set of conservation targets will likely have a unique distribution, different conservation approaches may prioritize different areas of the landscape.

Because there is not comprehensive data on species distributions for the study area, we used digital land cover information (vegetation communities, land uses, and roads) to identify areas with the following characteristics:

1. High ecosystem integrity, to maintain viability of resources and ecological processes, such as natural fire and stream flow regimes (e.g., Noss 1983, Poiani et al. 2000).
2. Representative of regional diversity patterns, i.e., including vegetation community types across the full range of biophysical conditions and climate gradients (Scott et al. 2001).
3. Support irreplaceable resources that are unique or highly restricted in their distribution (e.g., stands of knobcone pine, tecate cypress groves, Martirian succulent scrub) (Pressey et al. 1993).
4. Matrix lands between these areas that are compatible with human land uses and can be managed as working landscapes (Margules and Pressey 2000, Lindenmayer and Franklin 2002).

Vegetation Communities Map

Constructing a seamless, composite vegetation data set for the entire 2,846,052-acre (1,151,761-ha) study area required merging data from five different sources with variable resolutions and vegetation classification systems (refer to Appendix B for more detail). Relatively detailed data sets were available for San Diego County (San Diego Association of Governments and Anza-Borrego Desert State Park) and the binational Tijuana River watershed (CESAR 1995). The INEGI (1997) vegetation data for Baja outside of the Tijuana River watershed are of lower resolution and used a very different vegetation classification system. We used other non-digital data sources to assist in characterizing different portions of the region (e.g., Minnich and Franco Vizcaìno 1998). The data limitations encountered in this project emphasize the need for additional input and research by experts to document and fully understand the overall biodiversity, ecological functions, and ecosystem processes in the region.

Technical Approach—SPOT

The Spatial Portfolio Optimization Tool (TNC 2003) allows us to identify places within the border region that optimize achieving biodiversity conservation goals, in the most intact portions of the landscape, with the least amount of fragmentation. SPOT uses digital data layers as inputs to derive conservation portfolios that describe the biological integrity of the area (i.e., the *cost surface*, Figure 5), the distribution of biological resource targets (in this case, vegetation communities), and conservation goals for these targets. SPOT provides an objective way to identify priority conservation areas, which can be replicated by others to validate our results and modified as finer resolution data and additional information become available. Appendix B describes the inputs to SPOT (i.e., cost surface, biological targets, and goals), the approach used to derive the conservation network from the SPOT outputs, and constraints and other issues that influence our results.

Biological integrity of the landscape

Human modifications of the landscape are the largest threats to the integrity of biological resources and ecosystem functions. Therefore, we used the distribution of urbanization, agriculture, and roads as a measure of the human modification of the landscape in constructing the cost surface used by SPOT (Figure 5). The cost surface was also used to assess the integrity of watershed subbasins—i.e., the degree to which a watershed unit has not been altered by human activities and thus may retain intact watershed processes—and to assist in identifying priority conservation areas.

Biological resource targets and conservation goals

We relied on vegetation communities as biological resource targets for use in SPOT. This *coarse-filter* approach to identifying priority conservation areas (Groves 2003) potentially overlooks important conservation targets, such as individual species or unique physical habitats. We attempted to compensate for shortcomings in our data, as well as differences in data classification and resolution, by stratifying the study area based on known climate and biodiversity gradients (Figure 6). Thus, we forced SPOT to identify conservation portfolios in all portions of the study area, presumably increasing the potential for capturing diverse community types and the species they support.

We defined conservation goals as percentages of each vegetation community that should be included in portfolios within each stratum (Table B-3, Appendix B). These numerical targets are consistent with those used in other conservation planning exercises [e.g., Natural Community Conservation Planning (NCCP) programs in California, TNC ecoregional planning, Groves 2003]. To test the sensitivity of SPOT outputs, we evaluated a range of goal sets, representing a range of conservation objectives. For example, Goal set 1 prioritized irreplaceability (in this case, vegetation communities that are rare or restricted in distribution), while Goal set 5 used uniformly low goals among vegetation communities to emphasize habitat intactness.