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The Vascular Flora of Greater San Quintín, Baja California, Mexico

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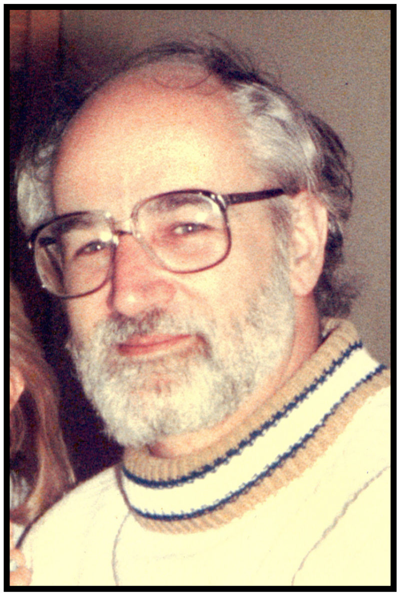
Dedication:
For my late uncle (Fredric) Charles Vanderplank, who bequeathed educational and travel funds that enabled my career, and who continues to inspire me.



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The Vascular Flora of Greater San Quintín, Baja California, Mexico.

Location

This study is focused on the area between parallels 30 and 31 on the Pacific Coast of Baja California, Mexico, here referred to as 'Greater San Quintín' (Fig. 1). Greater San Quintín lies near the southern end of the California Floristic Province (CFP), an extremely rich floristic region, yet one of the most critically endangered ecosystems on Earth. The CFP has been recognized as a global biodiversity hotspot (Myers et al. 2000). Such hotspots are defined by the presence of more than 1,500 endemic plant species in an area that has lost at least 70% of original habitat (Myers et al. 2000). The CFP is mostly in the U.S. and extends from southern Oregon through California including all of the Pacific drainages, south to near El Rosario, Baja California (Howell 1957, Thorne 1993, Peinado et al. 1994, Raven & Axelrod 1995). The distribution of the CFP essentially coincides with the presence of winter-spring rainfall and the absence of summer precipitation (Caso et al. 2007, Minnich & Franco-Vizcaíno 1998). CFP vegetation once occupied 324,000 hectares of land; however, today only 80,000 hectares (less than 25%) remain naturally vegetated (Myers et al. 2000). The CFP is home to approximately 4,426 native plant species, of which ca 2,125 are endemic within it (Brooks et al. 2002, Myers et al. 2000). Almost 50% (1,031) of the endemics are threatened with extinction or have already gone extinct (Brooks et al. 2002).

The southern limit of the CFP has been the subject of debate for decades. Rather than being a sharp transition, there is a gradual transition that begins near the U.S./Mexico border. The southern limit of the CFP in Baja California corresponds to water availability (Shreve 1936). Winter rainfall decreases rapidly at around 32º latitude (Caso et al. 2007); however, in the summer rain shadow caused by the Sierra San Pedro Martir, CFP vegetation occurs where coastal fog augments water availability. This extends CFP vegetation into areas with relatively low winter rainfall where desert vegetation would otherwise occur. The southern boundary of the CFP is often placed near the 30th parallel where large columnar succulents such as *Pachycereus pringlei* and *Fouquieria columnaris* begin to appear; however, more northward the vegetation begins to transition from that typical of the CFP to include a greater representation of succulents. Therefore, the vegetation in northwestern Baja California is extremely heterogeneous and supports many putatively relictual species and plant associations (Shreve 1936, Peinado et al.1995a). The coastal strip from 32º latitude southward to 29.5º has been shown to be an area of high endemism (i.e., high richness of endemic species) within the Peninsula of Baja California, harboring at least 106 endemic plant taxa, as well as several near-endemic taxa (Riemann & Ezcurra 2007).

In light of this heterogeneity in the vegetation, there have been multiple attempts to name and characterize the coastal scrub habitat of northwestern Baja California: Thorne (1976) designated it as Maritime Desert Scrub, Heady et al. (1977) and Mooney (1977) called it Succulent Scrub, Kirkpatrick and Hutchinson (1977), Axelrod (1978) identified the region as Diegan Coastal Sage Vegetation, and Delgadillo (1998) referred to it as Coastal Succulent Scrub. Most recently this habitat has been referred to as Maritime Succulent Scrub (Barbour et al. 2007, Rundel 2007, Harper et al. in press).

Phytosociological studies have shown diverse shrub associations in northwestern Baja California (as in other Mediterranean climate regions). The climate gradient from north to south correlates with increased diversity (both for endemic species and for vegetation types) as the aridity increases (Peinado et al.1995a). The area between parallels 30 and 31 appears to be an ecoclimatic transitional zone between Mediterranean climate to the north and tropical desert to the south (Peinado et al. 1995a). This transitional zone has the greatest floristic diversity and transitional vegetation associations recorded here have the highest endemic community values (i.e., greatest densities of narrowly endemic taxa, Peinado et al. 1995a).

The flora of Greater San Quintín is thus of special interest because it occupies the transitional zone from Mediterranean climate to desert vegetation. The volcanic field and vast salt marshes have long attracted botanists to the region; however, the area is today better-known as an agricultural valley and the flora of the region is being heavily impacted.

Physical setting

The Sierra San Pedro Martir trends north-south, forming the backbone of the northern portion of the Baja California peninsula; with elevations exceeding 3000m, it is the highest mountain range in Baja California (Delgadillo-Rodríguez 2004). Greater San Quintín is located on the Pacific coastal plain to the west of the Sierra San Pedro Martir (Cartron et al. 2005). Three major drainages from the mountains reach the Pacific Ocean within the boundary of the study area. Greater San Quintín (Fig. 2) embraces ca. 360 sq km, including Isla San Martín, 5 km from the coast. It encompasses the San Quintín volcanic field with elevations to 260 m, a significant portion of the San Quintín agricultural Valley, the town of San Quintín itself, around 200 km of coastline, including several linear km of stable dune systems, and one of the most pristine wetland environments in the world (West 2000).

Geologically, Greater San Quintín is located in the central portion of the Pacific Coastal Lowlands geomorphic province 16 km southwest of the Santillán and Barrera Line, a major northwest trending tectonic boundary (Luhr et al. 1995). The volcanic field is one of only two sites presently known in the world where highly strained mantle xenoliths are found in alkali basalts (Cabanes & Mercier 1988 cited in Luhr et al. 1995). The bay probably developed as a result of wave and tidal processes over the last 6000 years. Eight volcanic complexes are clustered in two geographically separated sets; two cones are more isolated (San Martín Island, and the tip of the peninsula known as Punto Mazo) (Fig. 3). An eleventh element is the 30 m sea cliff to the west of the northern group of cinder cones. All but two volcanoes have formal names (CETENAL 1976); the remaining two were informally named by Luhr et al. (1995) in honor of two pioneering geologists: Woodford who first studied the geology of the region in 1928, and Basu, who conducted his research in the area during the 1970s. The three largest cones, Kenton, Ceniza, and Riveroll, are the oldest; the middle-age cones are Woodford, Basu, and Media Luna; and the youngest are Sudoeste, Vizcaino, and Mazo (Luhr et al. 1995). San Martín Island is thought to also be one of the younger cones (Luhr et al. 1995). Eruptive activity at the San Quintín volcanic field probably continued into the Holocene period and the youngest olivine-rich lavas erupted as recently as a few thousand years ago (Luhr et al. 1995). At present, the cones are surrounded by and often covered with recent aeolian sand deposits. Seven km east of the volcanic field is the prominent Santa María scarp along a NNW trend. This scarp is related to a marine terrace that is 40-80 m elevation above the gently sloping plain (Gorsline & Stewart 1962).

Mean annual temperatures for the San Quintín coastal area are 60-65°F (Junak & Philbrick 1994). There is a lengthy dry season between April and November, and the mean annual rainfall is ca. 105-137mm (Junak & Philbrick 1994) with the majority falling during December, January and February. Although rainfall is low for most of the year, Greater San Quintín experiences frequent heavy fogs caused by the California current off-shore (Herbert et al. 2001), and the associated humidity provides significant extra water resources and apparently ideal conditions for lichen growth (Rundel et al. 1972).

Evidence from packrat middens dated to ca 1770 years BP and located 185 km south in Cataviña indicates that the climate is now drier than in the late Holocene period and that a different plant community existed at that time (Sankey et al. 2001). Fossil pollen records from northwestern Mexico indicate that climate variability was high during the late Holocene and the rapid response of vegetation to paleoenvironmental changes is evident (Ortegas-Rosas et al. 2008). Although the area was once forested down to 1,200 m, the only native tree known from more than one individual in the flora of Greater San Quintín is *Aesculus parryi* (Hippocastanceae), which reaches just 1.5 m in height.

Socioeconomic and conservation context

In 1994 the North American Free Trade Agreement (NAFTA) reduced restrictions on trans-border commerce. This led to international interest in Baja California for large scale agricultural and industrial projects, notably including those that cannot be easily developed in the U.S. due to environmental restrictions (Dedina 2007). At the beginning of the 21st century there was a boom of land purchases in Baja California, with a 'frenzy' of coastal development (Dedina 2007). Baja California officials have been quoted as saying that because there are "many, many problems at the border, we want to reorient growth to the south and take advantage of the natural resources between Ensenada and San Quintín" (Lindquist 2006).

The peninsula of Baja California is often considered to be well protected in light of the large conservation area 'Valle de Los Cirios' in the central desert. It is important to note that this protected area preserves only one of the many vegetation types on the peninsula (Riemann & Ezcurra 2007) and the percentage of land already protected is a poor indicator of conservation needs in the surrounding areas (Rodríguez et al. 2004). The coastal corridor of CFP in Baja California is facing the greatest development and urbanization pressures in the state (Riemann & Ezcurra 2007). Despite the high endemism and level of conservation priority, there is currently no legal protection for any of the coastal lands in the CFP of Baja California other than that provided by ZOFEMAT (Zona Federal Marítimo Terrestre) concessions, which control land use of the tidal zone around the entire coast of Mexico (Riemann & Ezcurra 2005).

History of the area

The indigenous people of this region were the Kiliwa. They inhabited a large area of the northern part of the peninsula, stretching across the Sierra San Pedro Martir and including territory on both the Pacific and

Gulf of California coasts. Their lifestyle relied heavily on coastal resources and plants of the maritime succulent scrub, including *Agave shawii* (Asparageae), which they used for food and fiber (Hodgson 2001). Much evidence remains of their impact on the landscape, including large shell middens that often support high cactus diversity.

Portuguese explorer Juan Rodríguez Cabrillo landed in San Quintín in 1542 and named it “Bahía de la Posesión” [Bay of Possession] (Lazcano-Sahagún 2004). When Spanish missionaries came to San Diego in 1769, they began to build a road between the missions of San Diego, San Telmo and San Fernando Velicata and so the transpeninsular highway began. In 1775 a mission was founded at Santo Domingo, which was accessed via the bay of San Quintín (Lazcano-Sahagún 2004). In the middle of the 19th century only one wooden house, where salt was sold and which served as an office for the seafood industry, was documented in the bay (Phelts-Ramos, 2004). However, at the end of the 19th century, the British company, Lower California Development Company, an affiliate of the Mexican Land and Colonization Company, colonized the lands of the bay and attempted to grow crops in the area. British, U.S. and Mexican citizens trickled into the area planting crops and constructing a small wharf. In 1891 operations began for a dam, irrigation works and a flour mill on the inland side of San Quintín Bay (Taylor 1996). The settlement was abandoned in 1917 because the English had failed to comply with the colonization law of 1883 (Phelts-Ramos 2004).

There were only four ranches in the San Quintín Valley before Mexican title 3050 was registered in 1947 (Ramírez-Velarde 2004); this decree granted certain agricultural lands in the valley to families from other regions of Mexico as compensation by the government (González-López 2004). Over the last few decades San Quintín has been characterized as a refuge for immigrants from different states and, as new agricultural technology permitted longer growing seasons, many migrants settled in the area permanently (González-López 2004). Today the area is home to a still-expanding agricultural zone producing strawberries, tomatoes, cut flowers, onions and other crops. The region is currently experiencing floristic changes owing partly to land use changes, and a number of agricultural weeds and plants escaping from cultivation are establishing themselves, with some spreading rapidly (Soto 1987).

San Quintín itself is one of a series of rapidly expanding agricultural towns along the transpeninsular Highway. The town is currently home to ca. 50,000 people, and the colonies to the north and south (Lazaro

Cárdenas and Vicente Guerrero, respectively; Fig. 3) are also growing rapidly with the regional agricultural expansion. Consequently, the biological diversity (flora, fauna, vegetation) and landscape (the adjacent coastal ecosystems, volcanic cones, and riparian areas), are under extreme pressure from development and agricultural expansion (Fig. 4).

Current land use and conservation status

In addition to agriculture and urbanization, the area is home to the largest oyster farm in Baja California and to economic activities as diverse as salt ponds, fishing, tourism and dirt-bike riding. There are numerous examples of active natural resource harvesting in the area that may exceed ecologically sustainable levels, including harvesting of beach rocks, gravel extraction from rivers, mining of volcanic rock, and salt harvesting in saline flats. Current threats to the flora of Greater San Quintín include agriculture, mining, trash dumping, cattle grazing, recreational off-road vehicle use, invasive species, urban development, and vegetation clearing for future development. A significant new impact may be a lowered water table as a result of water extraction for agriculture. Despite these impacts, Greater San Quintín supports several fragile ecosystems that are globally scarce. Some of these ecosystems are still comparatively intact and pristine, especially as one moves further from populated areas.

At this time (2010), Greater San Quintín is under consideration for declaration as a natural protected area or “Area Natural Protegida (ANP).” The challenge of identifying core areas for conservation of the rich assemblage of rare and endemic plants is heightened by competition for land use and heterogeneity of the vegetation itself. Preliminary results of the Conservation Plan for San Quintín (unpubl., available from the Rancho Santa Ana Botanic Garden library) produced by The Nature Conservancy of Baja California have identified four distinct terrestrial habitats in need of conservation: salt marsh (Fig. 5), dunes and beaches (Fig. 6), rivers and riparian areas (Fig. 7), and the maritime succulent scrub (Fig. 8). (Note that the areas identified as rivers and riparian habitat are not perennially wet but are most often dry washes with sandy substrates.) There are many sub-habitats that can be identified on differing scales in association with dominant vegetation and/or soil type; however, these four broad habitats are easily distinguished visually and each includes many plant species. The vegetation has been similarly categorized by the Instituto Nacional de Estadística y Geografía, México (INEGI), although upper salt flats are distinguished from inundated marshes (Fig. 9).

Previous biological studies

The area has drawn considerable attention from biologists and there have been a number of studies of the biological diversity in the vicinity of Greater San Quintín including marine algae (Aguilar-Rosas & López-Carrillo 2005, Quiróz-Vásquez 2005), lichens (Rundel et al. 1972), birds (Ruiz-Campos et al. 2005, Palacios & Mellink 2000), and mammals (Best 1983 , Sprague et al. 1978, Schultz et al. 1970). The area was home to a narrowly endemic kangaroo rat, *Dipodomys gravipes,* which was apparently recently driven to extinction by agriculture (Best 1983). Greater San Quintín is home to a large colony of Black Brant geese, which are dependent on the eelgrass of the shallow bays as a food source (West 2000), and which are currently the subject of a local biodiversity pride campaign organized by Audubon RARE (www.rareconservation.org).

The current study benefits greatly from several prior works on the plants of this region. These include a prior checklist of vascular plants (Thorne 1989), studies of San Martín Island (Vanderplank & Mata in review*a*, & *b*, Junak & Philbrick 1994, Thorne & Junak 1989), notes on some of California's rare plants in the region (Vanderplank 2010), studies of the coastal dunes (Johnson 1977), and descriptions of the vernal pools in the region (Moran 1981). The pristine marsh habitats have been studied extensively by scientists on both sides of the border (Delgadillo et al. 1992, James & Zedler 2000, Keer & Zedler 2002, Morzaria-Luna et al. 2004, Neuenschwander et al. 1979, Ruiz-Campos et al. 2005, Zedler et al. 2001), and notably by U.S. scientists as model systems for restoration efforts in California (West 2004).

Prior to the present study, two species had been documented as endemic to Greater San Quintín. *Dudleya anthonyi* Rose (Crassulaceae) is endemic to the volcanic rocks of the San Quintín cinder cones (Thomson 1993) and *Chenopodium flabellifolium* Standley (Amaranthaceae) is known only from San Martín Island (Crawford & Evans 1978, Junak & Philbrick 1994).

As part of a study of vegetation associations in the broader region, Peinado et al. (1995a, & b) mention several plant associations of particularly high endemic community value (ECV). Notable among those in the maritime succulent scrub of Greater San Quintín are the *Rosa minutifolia-Aesculus parryi* association of wetter environments and the *Bergerocactus emoryi–Agave shawii* associations of drier zones (a tropical desert vegetation association that has penetrated the Mediterranean climate) (Peinado et al. 1995b). That these two associations occur in relative proximity is apparently due to patterns retained from the late Wisconsin glacial period when woodland occurred as much as 1200 m lower than it does today and desert vegetation was forced onto the driest rocky areas and steep southern slopes where this association is most often found today (Peinado et al. 1995a). Other associations of high ECV are the *Ephedra californica-Lycium brevipes* association of coastal dunes with salt spray influence and the *Atriplix julacea–Frankenia palmeri* association in places where sodium carbonate has formed through the alkalinization of saline soils (Peinando et al. 1995a).

Conservation significance

As we enter a period of global climate change, it is predicted that we will see extinctions on an unprecedented scale. The CFP is no exception and current estimates are that 66% of endemic species will experience up to 80% range reductions in the next century under even modest climate change scenarios (Loarie et al. 2008). The transitional vegetation of the southern CFP is likely to be particularly susceptible to changing climate; notably, as reported here, a considerable percentage of species are locally endemic and thus likely reliant on the present-day climate regime.

Floristic information, in the form of specimen documentation of the naturally occurring plants and abundance data, is critical to our understanding of plant biogeography. It also provides information relevant to taxonomic, ecological, and vegetation research, and for study of broader patterns of interactions. These data are crucial to making sound conservation and management decisions.

The goals in this study were to catalogue, voucher and produce an annotated checklist of the plants in the Greater San Quintín area, to assess the status of the vegetation and current threats to the flora, and to document the rare and endemic plants of the region. In studying the distribution of perennial species across Greater San Quintín, my goals were to examine the long-lived taxa that dominate the vegetation, to assess floristic richness and diversity in the four major habitat types, and to highlight areas of conservation priority using data on the rare and endemic species.

METHODS

Documenting the Flora

A goal of this study was to document the present-day flora of San Quintín for comparison with historical records and to serve as a baseline to assess potential future changes in the flora. To accomplish this, extensive collections were made during every calendar month. Thirty-five visits (varying from just a few hours to a full week) were made to the region between 2005 and 2010, for a total of ca. 75 days spent in the field.

Every vascular plant taxon encountered in the study area was vouchered by herbarium specimens. The first set of specimens was deposited at Rancho Santa Ana Botanic Garden (RSA), with duplicates to Universidad Autónoma de Baja California (BCMEX) and San Diego Natural History Museum (SD) whenever possible. Likewise, as possible, Santa Barbara Botanic Garden (SBBG) received duplicates of specimens of plants from San Martín Island and Centro de Investigaciones Biológicas del Noroeste (HCIB) received duplicates of plants from the mainland. More than 1,600 collections were made and identified using extensive literature sources as well as the herbaria of RSA and SD. The resources of the www.BajaFlora.org website of San Diego Natural History Museum were invaluable, particularly for the identification of rare and endemic taxa. Taxonomy generally follows the *Checklist of Vascular Plants of Baja California* (Rebman in prep) and relies on recent taxonomic treatments when available. The *Flora of North America* (FNA 1993+) and *The Jepson Manual* (Hickman 1993) were often the most up to date resources for taxa extending into the U.S. For endemic taxa, the *Flora of Baja California* (Wiggins 1980) and taxonomic monographs were also utilized.

For each taxon, habitat was recorded as one or more of the four major habitats in the Greater San Quintín area identified by The Nature Conservancy of Baja California (i.e., saltmarsh, dunes, maritime scrub and riparian). These data enabled the creation of four nested checklists, one for each broad habitat type.

The present study began with the intent to compare the current flora with older checklists for the region (Junak & Philbrick 1994, Thorne 1989) and also with the unpublished checklist for San Quintín (Baja California Coastal Wetlands Inventory, BCCWI 2001) that was assembled from the previously cited publications and collectors' notes. These resources provide useful insight into the history of the flora; however, since the areas covered were almost certainly different from that used in the present study, care must be taken in making direct comparisons. The lack of voucher specimens for a number of taxa reported by earlier authors also makes it impossible to confirm identifications. The online resources of www.BajaFlora.org, CONABIO, GBIF, and other digital herbarium repositories provided a wealth of data that was not readily accessible in the past. These were searched to compile historic information on the flora. Because herbarium labels often provided detailed location data or were georeferenced, it was possible to establish which of these collections fell inside the study area in most cases. Taxa documented by herbarium specimens as historically present in the study area but not relocated in the course of this study, excluding misidentifications and nomenclatural changes, were examined in detail to assess possible causes for their apparent loss.

As conditions allowed, conservation seed collections for long-term storage were made following guidelines based on both ethics and population biology as developed by Guerrant et al. (1995). These call for collections from more than 40 maternal lines (when possible) but without impacting more than 15% of the total seed for the population in a given fruiting season. These collections were deposited for long-term storage in the Rancho Santa Ana Botanic Garden conservation seed bank. Plants of conservation importance in the area were prioritized, favoring species that are locally or regionally threatened.

Assessment of the perennial vegetation by km square

Sampling Methods**:** A goal of this study was to investigate the distribution of long-lived taxa that dominate the vegetation and can be identified year-round (see below). A 1 km grid was created in ESRI ArcMap and georeferenced to overlay the study area (the top-left (NW) corner of the grid lies at: N 30. 738 and W 116. 039). TerraSync software was used to import the grid into a Trimble Juno GPS unit. This made it possible in the field to determine which km square one was standing in while collecting data. The "estimation method" (described below) was used to gather quantitative data on occurrence and abundance of perennial species and selected invasive annual species within each grid square. San Martín Island was treated separately and details on the distribution of the perennial vegetation of the coastal scrub can be found in Vanderplank and Mata (in review*b*). Grids that contain only agricultural fields or urbanized areas were excluded from the vegetation analysis but included in the floristic survey.

All perennial plants that could be identified year-round were included in the analyses: geophytes and herbaceous perennials that could not be consistently identified throughout the year were excluded. Select non-native annual taxa were included in the analysis; these have high potential for invasiveness and that can be identified year-round. The goal was to provide spatially informed information on habitat integrity and to document the current extent of the most abundant non-native species.

Each square km in the study area was visited and a strong effort was made to record species diversity within each square having native vegetation and to transect through different vegetation types therein to record plant diversity. A visual assessment of the km square was made to estimate the percentage of natural vegetation and the degree of heterogeneity of the vegetation. More time was spent in heterogeneous areas in an effort to encounter all the taxa occurring there. Site visits per square varied from 20 minutes to several hours, depending on the extent and diversity of natural vegetation. Sampling continued until new species were no longer discovered. Trials in the area showed that this method encountered a significantly higher number of species than alternative methods (e.g., quadrat and transect techniques) that sample smaller areas. This method is designed to give an indication of diversity and abundance, but the findings do not constitute exhaustive inventories. As noted above, geophytes and plants that do not have above-ground presence year-round were excluded, including *Marrah, Dichelostemma, Cuscuta, Spergularia, Castilleja,* and *Amuaria*. Several taxa cannot readily be differentiated from one another at all times of the year and, for this reason, have been pooled at a taxonomic level higher than species (or subspecies when relevant). Examples include the three species of the genus *Lycium* reported from the San Quintín area (these drought-deciduous shrubs cannot easily be distinguished without leaves), *Mammillaria dioica* and *M. louisae,* perennial *Astragalus* species with green leaves (e.g., *A. fastidius, A. gruinus,* and *A. trichopodus*), and the genera *Stephanomeria*, *Opuntia* and *Suaeda*.

The estimation method used the following categories of abundance per km square:

- Rare – fewer than 3 individuals
- Scarce – 3-10 individuals
- Uncommon – >10 but < 100 individuals (1/10,000 m^2)
- Frequent – 100-1,000 individuals (1/1,000 m^2)
- Common – 1,000-10,000 individuals (1/100 m^2)
- Abundant – 10,000-100,000 individuals (1/10 m^2)
- Dominant - or >100,000 individuals (1/1 m^2)

Estimates are based on number of plants seen and their distribution patterns. For example, if 25 individuals of a species were seen evenly distributed throughout an area of homogenous marsh, and the marsh was estimated to be four times the size of the area intensively surveyed, it was estimated that there were ca. 100 individuals in the entire marsh. When estimating numbers of plants that sprout from roots or rhizomes (e.g., salt grasses such as *Distichlis* spp.) the numbers of individual sprouts were considered, such that these should not be taken to estimate numbers of individuals.

Squares with less than 10% coverage of natural vegetation and that did not have unusual habitats or plant taxa of conservation or other special interest were excluded from the perennial vegetation study. These were often small areas surrounded by urbanization or agriculture that likely suffered from edge effects. Percentage of land that is vegetated was recorded for all km squares where data was taken (e.g., if 5% is sea, 10% is a barren salt lake, 5% is roadway, and 10% buildings, the total area of natural vegetation = 70%). This is because the relationship between species and area is well documented to be not linear (Vandermeer & Goldbery 2004). Number of species in a given square will also depend upon a number of other factors (e.g., number of habitats, homogeneity) in addition to area in natural vegetated.

***Analysis*:** The resulting data matrix of perennial and selected non-native annual taxa and numbered km squares was scored for presence/absence of each species, and perennial species richness was calculated for each square. Pearson's residuals were calculated (using the square root of mean species richness across the study area and a confidence interval of 0.99) as an indication of which squares were most species rich or poor.

To analyze the distribution of endemic and rare taxa, each taxon was scored for endemism and rarity in the matrix. Endemic taxa are those that are restricted or nearly so to the CFP of Baja California, as well as those that are endemic to the Baja California peninsula (the vast majority of these are endemic to small areas of the peninsula). Taxa were evaluated for rarity using the findings of O'Brien et al. (in prep) who assessed the rarity of all taxa in the CFP of Baja California. Taxa on three lists of concern (i.e., rare globally, rare in CFP Baja California but more common elsewhere, and watch-list taxa) were together categorized as "rare" by these authors. In the present analysis, in the few incidences where multiple taxa were lumped, the category of the most abundant taxon was used (e.g., if two taxa are combined and the more numerous one is rare, the taxon was considered rare in the analysis). The analysis was also run excluding the lumped taxa with no notable difference in results.

ESRI ArcMap was used to map species distributions across the study area. Data from the matrix were attached to the grid layer using spatial coordinates for each km square (see supplemental data for selected species maps). Relevant data layers were obtained from the Instituto Nacional de Estadística y Geografía, México (INEGI), including shore outline, elevation, relief, and habitat types as registered by the Mexican government. The range and abundance of several individual species were also mapped over a base map with a coastline layer. Following analysis of the data matrix, squares with extreme species richness or paucity (Pearsons residuals, $P<0.01$) were mapped. The same was done for species richness with the data set reduced to three subsets: native species, endemic species, and rare species.

Multivariate analysis: To examine the distribution of species across habitat types as distinguished by The Nature Conservancy of Baja California, a non-centered, non-standardized principal components analysis (PCA) of the presence-absence matrix for 206 native perennial taxa was conducted. Nonmetric multidimensional scaling analysis (NMSA; results not shown) was investigated as an alternative method of analysis.

Results of the PCA by species were scored for the strongest signals contributing to the first and second axes, and separated into three corresponding habitat types. These scores were then mapped to extract the dominant habitat type for each km square in the analysis. This map was compared to the habitat maps from INEGI (Fig. 9) and habitat maps generated using indicator species. Indicator species were selected based on their observed consistent presence in, and restriction to, specific habitats.

RESULTS

Part 1: The Flora of San Quintín

Additions to the flora: The flora of San Quintín, as documented in the present study, includes 429 taxa (Table 1, appendix 1) vouchered by more than 1600 collections. Thorne (1989) documented 216 taxa for the area. The intensive collection efforts of the last five years have approximately doubled the number of taxa known from the region. After accounting for changes in nomenclature, Thorne’s checklist included 35 taxa that were not encountered in the present study. Six were found to be misidentifications and were, in fact, taxa that are documented in this study. Therefore, 242 taxa were added to the known flora of the region in the current study.

Table 1. Numerical summary of the Flora of San Quintín by composition, nativity, conservation status, and life form**.** 'Sensitive' refers to taxa that are rare (as determined by O'Brien et al. in prep) or endemic (i.e., endemic to the peninsula of Baja California or nearly endemic to the California Floristic Province of Baja California [may range 10 km north of the U.S./Mexico border or into the most northern desert ranges south of El Rosario]). Note that rare and endemic are not mutually exclusive categories (i.e., some taxa are both). Percentages are relative to the total flora with values relative to the native flora only in parentheses for sensitive, rare and endemic taxa.

Taxa	**Number of Taxa**	**% Total Flora (% Native Flora)**
Families	73	
Genera	270	
Species	421	
Species and infraspecific taxa	429	
Native	351	82%
Non-native	78	18%
Sensitive	119	28% (34%)
Rare	104	24% (30%)
Endemic taxa	63	15% (18%)
Annual (inc. facultative annual)	205	48%
Aquatic perennial herb	4	1%
Geophyte	9	2%
Perennial herb (incl. suffruticose perennial)	116	27%
Shrub (inc. succulents)	90	21%
Tree	5	1%

Table 2: The ten largest native plant families in Greater San Quintín (family ranking including non-natives in parentheses). Data are number of native taxa (number including non-natives in parentheses), and percentage of the native flora (percentage including non-native taxa in parentheses).

Ten Largest Plant Families	**# Native taxa (# total taxa)**	**% Native Flora (% Total Flora)**
Asteraceae (1)	58 (67)	17% (16%)
Fabaceae (3)	29 (33)	8% (8%)
Boraginaceae (5)	27 (27)	8% (6%)
Amaranthaceae (4)	18 (29)	5% (7%)
Cactaceae (7)	18 (19)	5% (4%)
Poaceae (2)	18 (34)	5% (8%)
Polygonaceae (6)	17 (22)	5% (5%)
Solanaceae (9)	12 (13)	3% (3%)
Brassicaceae (8)	9 (18)	3% (4%)
Plantaginaceae (10)	9 (9)	3% (2%)

The largest family is Asteraceae, which accounts for 16% of the flora (Table 2). Following Asteraceae, there are several families that each account for 5-8% of the flora. Of note are the high numbers of native species in the Cactaceae, Boraginaceae and Polygonaceae. There are a large number of Amaranthaceae; however, almost 50% of these are non-native. Poaceae are one of the largest plant families in the world, yet poorly developed soil, arid climate and historical factors push Poaceae further down the list of native taxa.

Range extensions:

Considerable range extensions were documented for three species in the present study.

Ceanothus bolensis (Rhamnaceae) is a narrow endemic from Cerro Bola in the northern coastal ranges of the Sierra Juárez; a sterile specimen from the San Quintín area is here tentatively identified as of this species. If confirmed with fertile specimens, this would represent a range extension of 180 km to the south.

Cheilanthes brandegeei (Pteridaceae) is a desert fern endemic to the peninsula; its documentation for the San Quintín flora is a northward range extension of 85 km.

Salvia brandegeei (Lamiaceae) is a coastal chaparral species previously known from the Channel Islands and Colonet Mesa; its discovery in the San Quintín area represents a southward range extension of 100 km (Vanderplank et al. 2009).

Narrowly endemic species:

Amsinckia inepta (Boraginaceae) is reported from a few scattered localities outside of Greater San Quintín. Based on this species' habitat requirements, these specimens from outside Greater San Quintín may be misidentified. Study of specimens will be required to check identifications and determine whether the species is actually endemic to the volcanic field of Greater San Quintín.

Astragalus anemophilus (Fabaceae) is nearly endemic to the dunes of Greater San Quintín, with one known vouchered occurrence outside the area, 20 km to the south on the dunes of El Consuelo.

Chenopodium flabellifolium (Chenopodiaceae) is a little-known herb endemic to Isla San Martín. It occurs only on the southeastern portion of the island, representing a global range of approximately one km^2 (Vanderplank & Mata in review*a*).

Chorizanthe (Polygonaceae). With 5 species, Greater San Quintín appears to be a center of diversity for the genus. Notably, it lies in the center of the range of three species that are narrowly endemic to the Baja California peninsula (appendix 1). Two of these, *C. chaetophora* and *C. inequalis*, each have a range that spans less than 120 km of the peninsula.

Cryptantha pondii (Boraginaceae) is endemic to Baja California and known from very few collections. Future studies and examination of herbarium sheets may reveal this species to be a fairly restricted endemic.

Dudleya anthonyi (Crassulaceae) is endemic to the volcanic field of San Quintín where it grows in large numbers directly on lava rock and scree slopes. (A few non-reproductive individuals resembling this taxon were observed to be in poor condition on the El Socorro Dunes on the mainland during the vegetation study.) Isla San Martín is home to the largest population (Vanderplank & Mata in review*b*).

Leptosiphon laxus (Polemoniaceae) is not known outside the latitudinal boundaries of Greater San Quintín, but is typically found further inland; specimens were only collected twice during this study, both times from small populations on the larger cinder cones.

Oenothera wigginsii (Onagraceae) is near endemic to the dunes of Greater San Quintín, with only one known vouchered occurrence outside, some 90 km to the south on the dunes of Puerto Santa Catarina.

Solanum palmeri (Solanaceae) is known only from Isla Todos Santos and Greater San Quintín (including Isla San Martín). Isla Todos Santos is off the coast of northern Baja California, adjacent to Ensenada, some 160 km north of Greater San Quintín.

Plants on the official list of protected species in Mexico: Two cactus species in Greater San Quintín are listed as threatened by the Mexican government in the *NORMA OFICIAL MEXICANA NOM-059-SEMARNAT-2001.*

Cylindropuntia californica var. *rosarica* is a narrow endemic of the Baja California peninsula, occurring from the Colonet area to El Rosario (ca. 120 km). In Greater San Quintín it occurs only on shell middens, the one in Ejido Nueva Odisea harbors ca, 200 individuals.

Lophocereus schottii is native to the deserts of Baja California and Sonora. Greater San Quintín is at the edge of its range, where it is scattered along coastal dunes, middens, and sandy patches of succulent scrub.

Taxa that warrant further taxonomic study: Collections of taxa from a species complex formerly in the genus *Anitirrhinum* (Plantaginaceae) suggest that further taxonomic study of plants from Greater San Quintín is warranted. In particular, a pubescent form of *Neogaerrhinum strictum* with climbing pedicels on Isla San Martín raises questions about specific and generic boundaries. These individuals may have resulted from hybridization between *Neogaerrhinum strictum* and *Sairocarpus pusillus*, a taxon that has changed status from forma *pusillum* of *Antirrhinum nuttallianum* subsp. *subsessile* (Munz 1974) to the rank of species as currently treated (Sutton 1998).

A collection of *Cryptantha* (Boraginaceae) from 2005 following heavy rainfall could not be identified and may represent a new taxon (*Vanderplank, O'Brien & Arvizu 050202-42b*).

Mammillaria louisae (Cactaceae) is not included in Wiggins (1980), but is distinguished by its extremely large flowers and very small vegetative body. It has historically been confused with *M. hutchinsoniana*, which is a larger plant that occurs farther south.

Phacelia ixoides (Boraginaceae) collections from San Quintín and Isla San Martín frequently exhibit lobed sepals. This character is not ubiquitous, but is not seen in specimens from outside the study area and deserves further study.

Excluded collections: Three taxa collected during this study are not included in appendix 1 because they could not be identified to species. Two are vegetative collections of individual plants (*Atriplex* sp. and cf. *Cordylanthus* sp.). The third is a collection of *Cryptantha* that comes from a mixed collection made in the volcanic field in 2005. The nutlets appear to be winged and the plant does not match any existing descriptions. The specimen has been sent to experts in this group and warrants further study as noted above.

Comparison with Thorne's (1989) checklist

Of the 29 taxa reported by Thorne (1989) that were not rediscovered, four were not considered further because of the differing delineation of Greater San Quintín (i.e., they were not documented within the present study area) or because only imprecise localities were given in the earlier study. Of the remaining 25 taxa, only two, *Limonium sinuatum* and *Spermolepis echinatus*, were represented by voucher specimens at RSA (table 3 reports these plus additional historical collections that were not found in the present study). Five additional taxa from the earlier checklist were represented by specimens at the SD herbarium, and these are discussed below. Because vouchers are lacking, the remaining 19 taxa have been excluded from the flora at this time (appendix 2).

Potential losses from the flora

An additional 40 taxa reported from the study area based on specimens in regional herbaria were not relocated during this study. These are listed in table 3, along with possible reasons they were not relocated. Six were non-native taxa documented on private tomato farms and four were crop plants escaping cultivation (melon, cucumber, wheat, and tomato). One (*Cynara cardunculus*) is a ruderal weed that was described as scarce when collected and was not seen during this study. The remaining 29 species (23 native) fall into four groups based on the geographic region or habitat type from which they were collected. (1) The loss of *Calystegia macrostegia* and *Eschscholzia ramosa* from Isla San Martín is discussed in a paper updating the flora of the island (Vanderplank et al. in prep), and a third species, *Bromus carinatus* (specimen not seen) may also have been lost from this flora. (2) Eight taxa were collected at the vernal pools in Ejido El Papalote. (3) Nine taxa were from the Laguna

Mormona area adjacent to the northern salt flats. (4) Seven taxa were collected in riparian areas. Possible causes of the last three groups of localized extirpations are discussed below. Two additional taxa (*Hoffmanseggia glauca* from El Socorro Dunes and *Spermolepis echinata* from the Santa Maria Escarpment) were not relocated and may have been overlooked in this study or may be transient elements in the flora.

Table 3 – Species not relocated during the present study but documented to have occurred in Greater San Quintín by voucher specimens in regional herbaria. The family, taxon name, collection (collector/number/herbarium), abbreviated locality or habit, and native status are presented, along with possible reasons for not being relocated. Status is given for non-native species (*) and for rare taxa using rankings that follow O'Brien et al. (in prep): 1A - Plants presumed extinct and/or extirpated plants of CFP Baja; 1B - Rare and endangered in CFP Baja and elsewhere; 2 - Rare in CFP Baja but more common elsewhere; 3 - More information needed; 4 - Rare but not currently threatened with extinction in CFP Baja.

Family	**Taxon**	**Collection**	**Location/ Habitat**	**Status**	**reason not found**
Apiaceae	*Spermolepis echinata* (Nutt. Ex DC.) A. Heller	*Thorne 60290* (RSA)	Santa Maria escarpment		Transient in the flora?
Apiaceae	*Hydrocotyle ranunculoides* L.f.	*Moran 27975* (SD)	Riparian		Presumed extirpated
Apiaceae	*Hydrocotyle verticillata* Thunb. var. *verticillata*	*Moran 26337* (SD)	Riparian		Presumed extirpated
Apocynaceae	*Sarcostemma cynanchoides* ssp. *hartwegii*	*Moran 24762* (SD)	Riparian		Presumed extirpated
Asteraceae	*Centromadia parryi* ssp. *Australis* (D.D. Keck) B.G. Baldwin	*Moran 27955* (SD)	Vernal pool	1B	Presumed extirpated
Asteraceae	*Psilocarphus tenellus* Nutt. var. *tenellus*	*Moran 21820* (SD)	Vernal pool		Presumed extirpated
Asteraceae	*Lactuca serriola* L.	*Soto 26* (BCMEX)	Tomato farm	*	Agricultural weed
Asteraceae	*Pluchea odorata* L. (Cass.) var. *odorata*	*Harbison s.n.* (SD)	Riparian	*	Presumed extirpated
Asteraceae	*Stephanomeria pauciflora* (Torr.) A. Nelson	*Moran 19311* (SD)	Riparian		Presumed extirpated
Asteraceae	*Cynara cardunculus* L. ssp*. cardunculus*	*Moran 21809, Thorne 61028* (SD)	Non-native ruderal	*	Transient in the flora?
Asteraceae	*Conyza bonariensis* (L.) Cronquist	*Moran 28988* (SD)	Mormona	*	Presumed extirpated
Asteraceae	*Bidens laevis* (L.) Britton, Sterns & Poggenb.	*Hall s.n.* (SD)	Mormona		Presumed extirpated
Chenopodiaceae	*Chenopodium* cf. *hians* Standl.	*Soto 24* (BCMEX)	Tomato farm	*	Agricultural weed
Chenopodiaceae	*Salicornia depressa* Standl.	*Moran 29018, 28989, 29431* (SD)	Mormona	2	Presumed extirpated
Convolvulaceae	*Calystegia macrostegia* (Greene) Brummitt ssp.*macrostegia*	*Anthony 206* (SD)	San Martín Island	2	Presumed extirpated

Family	**Taxon**	**Collection**	**Location/ Habitat**	**Status**	**reason not found**
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	*Moran 25080* (SD)	Escaping cultivation	*	Did not persist
Cucurbitaceae	*Cucurbita pepo* L.	*Moran 25244* (SD)	Escape from cultivation	*	Did not persist
Cyperaceae	*Schoenoplectus californicus* (C.A. Mey.) Soják	*Harbison s.n.* (SD)	Riparian		Presumed extirpated
Cyperaceae	*Eleocharis montevidensis* Kunth	*Moran 28998* (SD)	Mormona		Presumed extirpated
Fabaceae	*Astragalus didymocarpus* Barneby var. *didymocarpus*	*Moran 29005* (SD)	Mormona	2	Presumed extirpated
Fabaceae	*Astragalus nuttallianus* var. *cedrosensis* M.E. Jones	*Moran 28981* (SD)	Mormona	2	Presumed extirpated
Fabaceae	*Lotus salsuginosus* var. *brevivexillus* Ottley	*Moran 28997* (SD)	Mormona	4	Presumed extirpated
Fabaceae	*Hoffmannseggia glauca* (Ortega) Eifert	*Moran 21780* (SD)	El Socorro Dunes		Transient in the flora?
Malvaceae	*Eremalche exilis* (A. Gray) Greene	*Moran 25950* (SD)	Vernal pool	2	Presumed extirpated
Papaveraceae	*Eschscholzia ramosa* (Greene) Greene	*Moran 17472* (SD)	Island taxon	4	Presumed extirpated
Plantaginaceae	*Plantago bigelovii* A. Gray	*Moran 25944 (*SD)	Vernal pool	2	Presumed extirpated
Plumbaginaceae	*Limonium sinuatum* (L.) Mill.	*Thorne 58110* (RSA)	Escape from cultivation	*	Did not persist
Poaceae	*Deschampsia danthonioides* (Trin.) Munro	*Moran 25949* (SD)	Vernal	2	Presumed extirpated
Poaceae	*Leptochloa fusca ssp. uninervia* (J. Presl) N.W. Snow	*Moran 25358* (SD)	Vernal		Presumed extirpated
Poaceae	*Setaria adhaerens* (Forssk.) Chiov.	*Moran 27956* (SD)	Vernal		Presumed extirpated
Poaceae	*Bromus ciliatus* L.	*Soto 5* (BCMEX)	Tomato farm	*	Agricultural weed

Family	**Taxon**	**Collection**	**Location/ Habitat**	**Status**	**reason not found**
Poaceae	*Echinochloa crus-galli* (L.) P. Beauv.	*Soto 25* (BCMEX)	Tomato farm	*	Agricultural weed
Poaceae	*Bromus carinatus* Hook. & Arn.	Oberbauer 135 (SD)	San Martín Island		Presumed extirpated
Poaceae	*Triticum aestivum* L.	Moran 10501 (SD)	Escape from cultivation?	*	Did not persist
Polemoniaceae	*Navarretia fossalis* Moran	Moran 25945 (SD)	Vernal pool	1B	Presumed extirpated
Portulacaceae	*Portulaca oleracea* L.	Soto 33 (BCMEX)	Tomato farm		Agricultural weed of private land
Solanaceae	*Solanum douglasii* Dunal	Soto 30 (BCMEX)	Tomato farm	*	Agricultural weed of private land
Solanaceae	*Nicandra physalodes* (L.) Gaertn.	Moran 26330 (SD)	Riparian	*	Presumed extirpated
Solanaceae	*Lycopersicon esculentum* Mill.	Moran 29010 (SD)	Mormona		Presumed extirpated
Verbenaceae	*Verbena scabra* Vahl	Wiggins 4766 (RSA)	Mormona	2	Presumed extirpated

Vernal pools: Vernal pools are seasonal wetlands that become inundated after winter rains due to an impervious soil layer and dry up gradually. These experience a brief waterlogged stage followed by extreme desiccation, often for longer than a single year (Keeley & Zedler 1998). Certain species are restricted to vernal pool habitats. Narrowly endemic plant species are often further limited to one kind of vernal pool (e.g., with a particular soil type or climate) that may occur in a highly restricted area. Loss of pool sub-types can therefore be expected to result in the loss of unique species (Bauder & McMillan 1998). Vernal pools are rapidly disappearing to urban sprawl and agriculture, and California has already lost between 93 and 97% of its vernal pools (Baskin 1994, Kangas 2005).

The clay mesas that promote the formation of vernal pools are an important habitat that has been almost entirely lost from Greater San Quintín and the surrounding region. Vernal pools were well-documented in the study area by Moran (1981) as occurring in Ejido El Papalote, but all have been plowed for agriculture. Moran documented the extirpation of *Orcuttia californica* Vasey (Poaceae) and *Pogogyne serpylloides* (Torr.) A. Gray (Lamiaceae) from the region as a direct result of agriculture in his 1981 report. Wiggins (1980) cited a specimen of *P. serpylloides* from the Santo Domingo region collected by Orcutt in the 1800s. This specimen was not studied as part of this study, but it the only known collection of this species from Baja California.

Interestingly, in spring 2010, Ejido El Papalote was inundated as a result of heavy winter rains; some areas, including those historically occupied by vernal pools, were underwater for several weeks. As a result, several species strongly associated with vernal pool habitats and that had not been seen in the four previous years appeared in roadside ditches (i.e., *Eryngium aristulatum* var. *parishii, Centromadia perennis, Plagiobothrys leptocladus*). Eight vernal pool taxa previously collected from this locality but that did not reappear in 2010 apparently have been extirpated by habitat destruction for agriculture; five of these taxa are considered globally rare.

A small clay mesa north of the Santa Domingo escarpment (near the hospital in Vicente Guerrero) occasionally has some vernal pool taxa in low areas on its disturbed margins. Although previously undocumented, remnants of vernal pools can be seen in this area and may have been more extensive prior to urban expansion.

Laguna Mormona: Nine taxa that were not recollected come from areas adjacent to Laguna Mormona, a historic place name from an AAA atlas that refers to the large saline lagoons that form in the northern portion of the study area adjacent to a small Mormon colony known as Zarahembla. Although agriculture was clearly encroaching this area historically (e.g., Moran 1980 noted that his collection of *Astragalus didymocarpus* was growing at the edge of a barley field), there has been considerable agricultural expansion in the last decade which appears to be the cause of the local extirpation of these taxa (five of which are considered globally rare). One of these species, *Salicornia depressa*, is not known from any other locations in Baja California, although it is more common elsewhere. The heavy rainfall in spring 2010 inundated this region and as of July 2010 many hectares of land that are usually in cultivation are still under standing water (Fig. 10). In light of these dramatic weather events it would seem an ideal year to determine whether any of these species re-appear as the water subsides. It is also interesting to note that several of the species missing from the Laguna Mormona region were found in the Santo Domingo Wash during the current study.

Riparian Habitats: Seven taxa that were not relocated occurred in riparian habitats in Greater San Quintín. Río Santo Domingo was a historical locality for a small number of taxa that require very wet conditions (e.g., *Hydrocotyle* spp.). Agricultural water use in the San Quintín region is exceeding sustainable levels (Aguirre et al. 2001) and it is possible that the lowered water table in the San Quintín valley is the cause of the local extirpation of these populations. It may also be a causal factor in the disappearance of many taxa from the Laguna Mormona region. Fifty species documented in riparian areas in the current study were here assessed as rare, meaning that three or fewer individuals were seen over the duration of this study (29 additional species are reported as scarce; i.e., slightly more abundant than rare). Further lowering of the water table in this region may lead to the extirpation of a large number of species, particularly in vulnerable riparian habitats.

Non-native taxa: Non-native taxa not found in recent years were mostly documented by Soto (1987) who had access to many private agricultural areas and searched specifically for non-native species in tomato fields. Other non-native taxa that were not relocated were escapees from cultivation that may not have persisted in the flora (e.g., *Limonium*, cucumber, watermelon).

Comparative floristics

The closest available modern flora for comparison is the recent checklist for Punta Colonet (Harper et al. in press). This flora is similar in size, including 435 taxa, 383 of which are native to the region. Of these, 52 are endemic, or near endemic, to the peninsula (13.5% of the native taxa, a value very similar to that for Greater San Quintín). The region covered by the checklist for Punta Colonet is slightly larger than Greater San Quintín; however, the collecting effort has been more extensive for the San Quintín region. Thus, the two areas have floras of a similar relative size and both are high in endemism.

Plants used by local inhabitants

Local ethnobotanical data are scarce due in part to large numbers of immigrants without local knowledge and the absence of native Kiliwa residents in the study area. Certainly, the Kiliwa made use of a substantial number of local plants, such as the roasting of agave "hearts" (e.g., Gentry 1978, Hodgson 2001). Historical reports of plants uses in the area include *Salvia columbariae* seeds and *Dichelostemma capitatum* bulbs for food, crushed stems of *Stenocereus gummosus* as a fish poison, and *Euphorbia misera* sap as an arrow poison and crushed stems for treating snake bites (Figueroa 2009, Del Barco 1980). The seeds of *Ferocactus* spp. were eaten, and Simmondsia chinensis (jojoba) was used extensively as a medicine for various ailments (Figueroa 2009, Del Barco 1980). Local residents currently make use of some plants, most of which is consistent with widespread practices in Mexico, especially northwestern Mexico (e.g., Felger 2007). For example, *Mammillaria* fruits are eaten fresh, *Dudleya* flowering stalks are chewed and the sweet nectar sucked (*D. anthonyi* is favored over other species), and preparations of *Lophocereus schottii* stems are esteemed as a remedy for diabetes and as diabetes preventative. Cladodes (pads) and fruits of the native *Opuntia* are sometimes harvested for food, as are the tasty fruits of *Stenocereus gummosus*. Dried *Stenocereus* flowers can be smoked and dried flowers of *Rosa minutifolia* are sometimes taken as a tea, as a remedy for indigestion (pers. obs. 2009). The flower stalks of some plants are harvested for cattle fodder, e.g, *Agave shawii* (Gentry 1978). Where *Typha dominguensis* occurs in the region it is often cut for fodder (pers. obs. 2009)

In the Sonoran Desert region people generally made use of at least 18% of the local flora for medicinal purposes and 15% for food, and about 10% of those generally served as major food resources or staples (Felger 1979, 2007). Thus we can expect that among the native flora around 50 species might have been utilized for food and a slightly larger number were probably used for medicinal purposes. Information for the majority of the edible and medicinal plants (those occurring in the United States) in flora can be found in Moreman (1998) and BDMTM (2009).

Conservation collections

Forty-eight seed collections were deposited in the conservation seed bank at RSABG. Twenty-eight of these accessions are sensitive species, with 17 endemic to Baja California and 27 rare, threatened or endangered in CFP Baja (table 4). These collections will be available for use in future restoration projects in this area, if necessary. Seeds of some species can be grown out after viability trials for other research and educational purposes. Rapid habitat loss on a global scale is diminishing populations and genetic diversity of many species. Collections of genetically diverse and viable seeds provides some security to the survival of the species in the event of large-scale extirpations.

Table 4 – Accessions deposited in the conservation seed bank of Rancho Santa Ana Botanic Garden during this study. Family, taxon name, and whether they are considered rare or endemic in Baja California are provided, with rankings that follow O'Brien et al. (in prep): see legend of table 3 for key to codes for rarity and endemism.

Accession number	***Taxon***	**Collection # Vanderplank**	**Sensitive**	**Endemic**	**Rare**
22109	*Abronia maritima*	061022-1	†		2
22110	*Aesculus parryi*	061021-2	†	7	4
22654	*Allium peninsulare*	080328-6	†		2
22683	*Ambrosia chenopodiifolia*	080426-1			
21595	*Artemisia californica*	050202-24			
22650	*Asclepias subulata*	s.n.			
21749	*Astragalus anemophilus*	050730-6	†	5	1b
21750	*Astragalus fastidius*	050731-1	†		2
22707	*Atriplex julacea*	080529-4			
22715	*Bahiopsis laciniata*	080529-7	†	6,7	
23019	*Bebbia juncea*	090928-1			
22159	*Camissoniopsis cheiranthifolia*	070226-1			
21648	*Chaenactis glabriuscula* var. *glabriuscula*	050318-4			
22729 & 23061	*Chenopodium flabellifolium*	080628-1	†	5	1b
22658	*Cistanthe maritima*	080325-11	†		4
22777	*Cordylanthus maritimus*	080816-5	†		1b
21599 & 21600	*Coreopsis maritima*	050202-44	†	6	1b
22621	*Dudleya anthonyi*	070811-8	†	5	1b
22710	*Dudleya attenuata*	080530-1			
21751	*Dudleya cultrata*	050731-3	†	5	1b
21594	*Echinocereus maritimus*	050202-65	†	9	4
22162 & 21597	*Encelia californica*	070225-14			
22776	*Eucnide cordata*	080529-15			
22161	*Euphorbia misera*	070224-4			

Accession number	*Taxon*	Collection # Vanderplank	Sensitive	Endemic	Rare
22809	*Ferocactus fordii*	080927-3	†	9	2
22712	*Gambellia juncea*	080529-24			
22709	*Harfordia macroptera*	080530-13	†	9	4
22142	*Hazardia berberidis*	061225-2	†	5	1b
22708 & 22107	*Helianthus niveus*	080529-2 & 060916-13	†		1b
22494	*Jaumea carnosa*	070127-1	†		2
22492	*Juncus acutus*	061125-7			
22164	*Lycium brevipes*	070225-31			
22810	*Mammillaria louisae*	080927-4	†	5	1b
22165	*Mirabilis laevis*	070225-17			
21752	*Nemacaulis denudata*	050731-6	†		1b
22713	*Oenothera wigginisii*	080529-3	†	5	1b
22714	*Penstemon spectabilis*	080327-41	†	9	4
21748	*Phacelia ixoides*	050730-4	†	5	1b
21598	*Phacelia parryi*	050202-42			
22143 & 21593	*Ribes tortuosum*	061226-1 & 050202-20	†	9	2
22620	*Salicornia bigelovii*	070811-4			
22651	*Salvia brandegeei*	00328-14	†		1b
22656	*Senecio californicus*	080329-5			
22163 & 21596	*Senecio lyonii*	070225-24 & 050202-43	†		2
22160	*Solanum palmeri*	070226-7	†	5	1b
22653	*Stylomecon heterophylla*	080328-4			
22169	*Trixis californica*	070227-2			
22655	*Viola pedunculata*	080328-7	†		4

Habitat overview

Checklists for each of the four major habitat types as delineated by The Nature Conservancy are presented in appendices 3-6 and summarized numerically in table 5. Because of their distinctiveness as habitats and in terms of species composition, middens and vernally wet areas are listed separately in appendices 7 and 8. Twenty-eight non-native taxa were considered ruderal weeds that did not occur within intact habitats and are excluded from the habitat checklists (see appendix 9, list of ruderal weeds).

Table 5: Summary of taxa by habitat, including middens and vernal wetland areas. Only plants of the CFP were assessed for rarity; desert species at their northern range limit were not included in O'Brien et al. (in prep.) and their status is not addressed here. Thus, because some plants have not been evaluated for rarity the percentage of plants that are rare is most likely higher than presented here. Categories are not mutually exclusive (e.g., a taxon may be rare and endemic); "sensitive" indicates the total number of rare and endemic taxa.

		Annuals		Sensitive		Endemic		Rare		Restricted to habitat		Native		Non-native	
Habitat	Total	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**
Saltmarsh	34	11	**32**	8	**24**	0	**0**	8	**24**	25	**74**	28	**82**	6	**18**
Dunes	100	42	**42**	39	**39**	24	**24**	35	**35**	28	**28**	89	**89**	11	**11**
Riparian	136	40	**29**	29	**21**	17	**12.5**	24	**18**	88	**64**	113	**83**	23	**17**
Scrub	209	116	**55**	64	**31**	36	**17**	53	**25**	144	**69**	188	**90**	21	**10**
Middens	17	5	**29**	14	**82**	8	**47**	10	**58**	2	**12**	16	**95**	1	**5**
Vernal	9	7	**77**	6	**67**	2	**22**	6	**67**	9	**100**	9	**100**	0	**0**

At least 20% of native species in all habitat types are sensitive (i.e., endemic and/or rare) (table 5). Twenty-four percent of the dune taxa are local endemics, and this habitat also has the highest percentage of sensitive taxa (39%). Maritime succulent scrub [scrub] has the most sensitive species, but is also home to the most species overall. All habitats except the dunes have a high percentage of taxa that do not occur in other habitats. This is at least partly due to the difficulty in delineating the vegetation of the El Socorro Dunes which gradually transitions from fore dunes with a very distinctive flora into a succulent scrub community on sandy soil that differs less from the surrounding scrub in species composition. The following sections describe notable patterns by habitat type.

Maritime succulent scrub**:** The volcanic field of San Quintín affects the composition of the maritime succulent scrub. These areas harbor the restricted endemics *Dudleya anthonyi* and *Chenopodium flabellifolium,* and several other species that are only found in the scrub on volcanic soils within the study area (e.g., *Ribes tortuosum,* *Coreopsis maritima, Senecio lyonii, Viola pedunculata*, *Allium peninsulare*). In contrast, the maritime succulent scrub to the north, east and south includes species such as *Myrtillocactus cochal, Agave shawii* and *Rosa minutifolia* which do not occur in the volcanic field. This is likely related to geology and soil deposition. The clay mesa north of the Santo Domingo Escarpment in Colonia Vicente Guerrero is also home to a distinctive composition of maritime succulent scrub; this is the only location for several species in Greater San Quintín (e.g., *Mammillaria brandegeei, Chorizanthe interposita,* and *Bloomeria crocea*). Throughout the scrub vegetation of the study area, *Ambrosia chenopodifolia, Mirabilis laevis, Eriogonum fasciculatum, Artemisia californica, Euphorbia misera,* and *Aesculus parryi* are abundant, regardless of the underlying geology.

***Dunes*:** The majority of the coastal dunes in Greater San Quintín are young and are still undergoing stabilization. These dunes are home to several threatened and endemic taxa, including *Abronia maritima, Astragalus anemophilous, Dithyrea maritima, Eulobus crassifolia* and *Lotus distichus;* however, few species can colonize these shifting sands. Young dunes are dominated by *Abronia maritima*, whereas the older stable dunes are dominated by *Croton californicus, Hazardia berberidis, Isocoma menzeisii* and *Lycium* spp. More than a km from the coast the dunes start to be colonized by maritime succulent scrub species but with a composition that is dominated by cacti and succulents, including *Agave shawii subsp. shawii, Bergerocactus emoryi, Cylindroptuntia spp., Dudleya cultrata, Lophocereus schottii, Mammillaria dioica, Myrtillocactus cochal* and *Stenocereus gummosus.* The large dune field at the southern end of Greater San Quintín (El Socorro Dunes) is an old stable dune system that exhibits the highest richness of perennial species among dunes in the study area. Many desert species occur at the northern edge of their range here and, within the study site, several species are found only on the El Socorro Dunes. Examples include *Adolphia californica, Funastrum arenarium, Heteromeles arbutifolia, Rhamnus insula,* and *Yucca schidigera.*

***Saltmarsh*:** Several pristine salt marshes occur in the shallow bays around the volcanic field. Among habitats, the saltmarsh has the fewest species, although it often has the densest vegetative cover. The inundated marshes are home to a surprisingly large number of taxa given the extreme saline conditions; they are dominated by *Arthrocnemum subterminale*, *Jaumea carnosa, Limonium californicum, Sarcocornia pacifica*, and sometimes *Spartina foliosa*. *Spartina* has been observed to be spreading in recent years in the marsh at the northern end of Bahia San Quintín (pers. obs.). Few annual taxa occur in the saltmarsh; tidal fluctuations and salinity may select for perennial habit. None of the saltmarsh taxa are locally endemic, but 29% of the species are sensitive. Most saltmarsh habitat occupies a narrow coastal band; as a result, coastal sampling squares include other vegetation types which dampened the saltmarsh signal in the vegetation analysis (see below). The saline flats are dominated by *Atriplex julacea* with *Frankenia palmeri* and often have a history of disturbance by grazing or agriculture.

Riparian Areas: The three major river drainages are similar in having high native and non-native floristic diversity; however, each of the drainages has a unique species assemblage. At the north end of the major river drainage of Río Santo Domingo encompasses a large area of native vegetation that is interspersed with areas altered by agriculture and gravel extraction. A large number of taxa known from a single plant were found in this wash (e.g., *Nemacladus sigmoideus, Amorpha apiculata, Pickeringia montana, Ceanothus spp.*, *Arctostaphylos glauca*). Most of these are more common in the chaparral habitats of higher elevations and may have washed down from the foothills of the Sierra San Pedro Martir.

Farther south, the San Simón River drains into the bay of San Quintín. Its course has been altered historically and there is much cattle grazing and agriculture in its bottomlands. *Prosopis glandulosa, Salix exigua* var. *hindsiana,* and *Salvia apiana* are most abundant here, and *Tiquilia plicata* is not found outside this drainage.

Arroyo El Socorro, at the south end of Greater San Quintín, is the least disturbed of the drainages, but proximity to agriculture and altered hydrology again result in a large number of non-native species. Taxa that only occur here include *Asclepias subulata, Bahiopsis triangularis, Encelia asperifolia,* and *Petalonyx linearis*.

Although the number of non-native taxa in these riparian habitats is not very different from the other habitats in Greater San Quintín, the vegetation study revealed that their abundance is much greater in riparian habitats (see below). The disturbance that waterways naturally experience may make them susceptible to invasion by non-native species, but all three drainages are also highly impacted by human-caused disturbances. In spite of this disturbance the riparian areas exhibit high diversity of perennial species, but the abundance of these species is often very low. Consistent dominant elements in riparian areas include *Ambrosia monogyra, Baccharis salicifolia,* and the non-native *Tamarix chinensis.* Note that Río Santo Domingo and

Arroyo El Socorro both have many 'waif' species and have more species in common with one-another than either does with Arroyo San Simón (appendix 1). Disturbances and hydrological changes have apparently resulted in lower florsitic diversity in Río San Simón.

Middens: Shell middens are a unique sub-habitat often nested within the other habitats. Shell middens occur within inundated marshes, inland surrounded by coastal scrub, and are an integral part of the formation of the El Socorro Dunes. Notable midden areas include El Socorro Dunes, Ejido Nueva Odisea (near the village), the marshes between the Old Mill and Bahía San Quintín, the marsh adjacent to El Pedregal, and the coastal region north of El Socorro on the saline flats near El Pabellón. These dunes are considered by some to be a giant midden resulting from extensive activity by prehistoric people and long-term shell-fish consumption and shell deposition. The midden flora of Greater San Quintín is often notably distinct from that of the surrounding areas and tends to have quite distinctive species assemblages rich in cacti. Eighty two percent of the taxa strongly associated with middens are sensitive species. This sub-habitat warrants recognition as part of the ANP and merits further study.

Vernal wetland: Vernal pool taxa appear after heavy inundation in low, clay-lined ditches in areas that were previously documented to house vernal pools. These vernal wetland taxa are totally restricted to this habitat (table 5) and 76% of the taxa are sensitive species. No intact habitat remains for these species.

Part 2: Vegetation Analysis

The analysis of vegetation by km squares tallied a total of 163 taxa, including 140 native perennials, across 206 km squares (appendix 10). This number is fewer than the total number of native perennials documented for Greater San Quintín as a whole for a number of reasons. Several perennials documented in the flora were not included in the vegetation analysis because (1) they occurred in areas that were excluded, (2) they were not located during the years of the vegetation survey, or (3) they are not recognizable year round (e.g., geophytes, herbaceous perennials). As detailed in the methods, a few taxa were lumped in the analysis at the next highest taxonomic level because they could not be identified to species year-round.

This analysis allowed individual taxa to be mapped across the study area and their abundance displayed for each km square. Figures 11 and 12 show the distributions of *Dudleya anthonyi* and *Lophocereus schottii,* which are of conservation concern.

Total species richness by km square across Greater San Quintín shows considerable variation (Fig. 13) and some statistically significant patterns (Fig. 14). The spatial patterns of richness are very similar for subsets of the flora (i.e., native, Fig. 15; endemic, Fig. 16; or rare Fig. 17) taxa. Areas of notable species paucity and richness of species are discussed below, along with discussion of possible causes for these patterns.

Edge effects are seen in natural areas adjacent to agriculture and urbanized areas, and consequently richness is significantly reduced. Pale squares are most commonly adjacent to the colorless squares wholly lacking native vegetation (figs. 13-18); which extend into the study area from the transpeninsular highway that marks the eastern boundary. Species richness in the salt marshes and saline flats is much lower than in the other major habitats. This is particularly evident north of the volcanic field and south of the Santa María Escarpment (note bands of pale yellow squares along the coast (Fig. 13), a number have statistically fewer species than across the site as a whole as shown in Fig. 14).

Three primary regions of high species richness emerge—at the northern and southern extremes of the study area, and along the coast adjacent to the volcanic field. The northern region of high species richness has two distinct subareas: Santo Domino Wash (northern boundary of the study area) and a clay mesa (slightly southeast from the wash). The Santo Domingo Wash shows high species richness when all taxa are considered (Fig. 14); however, richness here decreases somewhat when non-native taxa are excluded, and the area lacks a significantly high number of rare (Fig. 17) or endemic (Fig. 16) species. In contrast, the clay mesa in Colonia Vicente Guerrero, north of the Santa Maria Escarpment retains a strong signal of high species richness for native, endemic and rare species (i.e., compare Figs. 14-17). This area is a disturbed patch of vegetation with diverse succulent scrub and some small remnant vernal pools. Both this area and the Santo Domingo Wash have significantly more non-native species than typical of the study area as a whole (see Fig. 18).

The coastal strip near the volcanic field that includes the tip of the peninsula at Monte Mazo, and Monte Sudoeste, is particularly diverse. This area includes a complex patchwork of habitats along the coast which likely contributes to high species richness. The precise km squares that show significant richness among the analyses vary slightly (i.e., compare Figs. 14-17), but the coastal strip is always rich in native, rare and endemic species. There are not significantly high numbers of non-natives in this area (Fig. 18), which is consistent with the relatively intact nature of the habitats. Monte Mazo, at the tip of the sand spit, does not harbor a significantly high number of endemic plants, but does have significantly high numbers of rare and native taxa (Figs. 16 and 17).

Near the southern end of the study area, the El Socorro Dunes stand out as the largest area of high species richness, and perhaps the most in need of conservation (see below). Because only one habitat type is represented across several km squares here, the observed high richness is not the result of habitat heterogeneity. Although there are some differences in the pattern of km squares that harbor significantly high numbers of native, endemic and rare taxa, the general area is rich in all of these. Notably, significant richness in non-native species is observed in one km square that falls inside the El Socorro wash at the southern boundary of the study area (Fig. 18).

Richness of non-native taxa correlates strongly with riparian areas, and their distributions follow all the major drainages (map 6). The non-native iceplant *Mesembryanthemum crystallinum* occurs almost ubiquitously across the study area (Fig. 19).

It is interesting to note that there was no correlation between percent natural vegetation in a square and species richness (Fig. 20). This is most likely due to heterogeneity of the landscape, with three habitat types in a sliver of land in some cases and in other cases a whole kilometer square of degraded salt marsh that might have only four perennial species. Some of these areas, particularly those that are now halophytic scrublands, appear to have been plowed historically and are undergoing a process of succession that provides some habitat for wildlife but is floristically depauperate.

Part 3: Multivariate Analyses

Principal Components Analysis: The PCA analysis explained only 25% of the variance on the first four axes with the first explaining 16% (Fig. 21). The first axis (x) correlates with distance from the coast, displaying a salinity/elevation gradient. Plants of coastal habitats are seen on the left (negative on axis 1) and the maritime succulent scrub species are seen on the right (positive on axis 1). If elevation is plotted against the sites as ordinated on the x-axis, a linear relationship is observed (see Fig. 22). The second (y) axis reflects soil type. Saltmarsh species fall in the upper left (positive on axis 2) and freshwater and sand dune species (sandy soils) appear on the bottom left (negative on axis two). For those species with a strong positive correlation on axis 1, there is little variation in axis 2. The species fall into three clear habitat types, with those that occur on sandy soils, regardless of whether on dunes or in riparian areas, placed together.

A seperate PCA analysis that removed species occurring in only one km square altered axis 2 to again show a soil gradient, but with better separation of upland species (sand versus silt) on the positive side of axis 1, and less resolution of coastal habitats on the negative side of axis 1 (results not shown).

Many species remain clustered in the center with variation in their distributions unexplained by these axes. Because the sampling regime (i.e., km squares) is not necessarily tightly correlated with habitats (i.e., there may be several habitats within any given square), many taxa are difficult to characterize in this analysis. That is, owing to fine-scale habitat heterogeneity, the PCA analysis by km square is limited in terms of discriminatory power.

Using species groupings from the eigenvector transformation of the PCA, locations can be separated by their dominant habitats (Fig. 23). The PCA data mapped back onto the study area to indicate the dominant habitats show results that are very consistent with the habitat map from INEGI and show surprisingly good resolution of the four primary habitats (Fig. 24). It was difficult to separate dunes from sandy washes as many dune species also occur in the riparian areas of Greater San Quintín which tend to have sandy substrates.

Indicator species: An indicator species from each of the primary habitats was selected based on restriction to that habitat type and abundance throughout it. Performance of these indicator species was compared to the results obtained from the PCA analysis (Figs. 25—28). *Ambrosia chenopodifolia* was used to indicate all areas with maritime scrub (Fig. 25); *Ambrosia monogyra* was used to indicate riparian areas (Fig. 26); *Batis maritima* was used as a saltmarsh indicator species (Fig. 27); and *Helianthus niveus* was used to indicate the sandy soils of young dunes (Fig. 28), although it occasionally occurs in riparian areas (particularly at the mouths of washes, compare figure 28 to figure 26). This comparison indicates that carefully selected indicator species can be used to assess broad habitat types in the region.

Non-metric multidimensional scaling: The non-metric multidimensional scaling analysis explained essentially all of the variance in just two axes, with up to 97% of the variance explained on the first axis. Consistent with the PCA analysis, axis 1 strongly correlates with the salinity/elevation gradient. The second axis appears to separate species based on their abundance. For example, the most ubiquitous species fall together negatively on the second axis, and the taxa found in just one or two samples often cluster along the opposite extreme of that axis. In an attempt to adjust for this bias, the analysis was re-run removing both the rarest and most abundant taxa (together and separately), but a third axis was never resolved and the second axis did not offer an easily interpreted pattern; the vast majority of the variation remained on the first axis.

Non-metric multidimensional scaling analysis (NMSA) is often considered the best tool for looking at patterns in presence-absence data across plant communities. In this case, however, the PCA analysis yielded more informative separations. This appears to be a product of species frequency distorting relationships in the data when using NMSA, as demonstrated by Ezcurra (1987). Rare species become so heavily weighted in the NMSA that species frequency becomes a stronger signal than the underlying environmental variables. It appears that the dominant relationships among the data were primarily linear and thus the NMSA had no advantage over the PCA. Other floristic analyses have found PCA to be the appropriate method to group species with respect to climatic variables (e.g., Perea et al 2005, León de la Luz et al. 2000, Altessor 1998, Montaña & Ezcurra 1991). Other factors that may have contributed a more satisfactory result from the PCA analysis in the present study include unexpected species turnover in the data resulting from many rare species as well as many almost ubiquitous species, and the complication of having multiple habitats within each sample (km square). The PCA eigenvector analysis compensates more readily for these data patterns than other analyses (Ezcurra 1987). With these data, the PCA analysis separated co-occurring taxa from major habitats more readily on the primary axes, but also yielded a large number of additional axes, the majority of which explained very little of the variation between sites.

Part 4: Conservation recommendations

The flora

Thirty-four percent of the species that comprise the flora of Greater San Quintín are rare and/or locally endemic. Greater San Quintín is also home to several taxa that do not occur far outside the study area. These taxa should be of the greatest concern for conservation. The San Quintín Volcanic Field, a unique geological formation in Mexico, is home to the majority of these taxa.

The unusual mix of plants with provenance from the desert area to the south, and the CFP to the north makes Greater San Quintín a floristically rich area. The high percentage of endemic taxa makes Greater San Quintín a priority for conservation. The habitat quality of the scrub, marshes and dunes should be preserved to the greatest extent possible and further anthropogenic disturbance of riparian areas should be avoided. This study provides baseline data from which future changes in the flora can be assessed and monitored. Ongoing assessment of habitat quality and the status of the globally rare and locally endemic taxa are strongly recommended.

Regions of particular concern

Coastal volcanic field: The coastal strip along the volcanic field of San Quintín includes many species that should be a high priority for conservation in Mexico due to their limited distribution. Since this area appears to be the most diverse within the San Quintín volcanic field and is home to a large population of the endemic *Dudleya anthyoni,* it should be a core zone in the proposed Area Natural Protegida (ANP). The cinder cones themselves should also be protected in light of the unique nature of their geology and vegetation. The cone that is home to the only population of *Salvia brandegeei* in the region, Riveroll, (the northernmost cone of the southern group) (Vanderplank et al. 2009) is of particular conservation priority given the pending threats from mining.

El Socorro Dunes: The El Socorro Dunes should also be prioritized as a core zone in the proposed ANP. Their unusual composition and high species diversity cannot be mitigated in other parts of Baja California. At the time of writing (July 2010) the entire dune system is slated for development and is being divided into narrow strips that connect the main road to the beach. There is a wealth of archeological data from the area (Moore 1981, Figueroa-Beltrán 2009) that also provides significant justification for conservation.

Shell middens: The shell middens of Greater San Quintín should be mapped and evaluated as conservation targets. Of particular priority should be the midden in Ejido Nueva Odisea that has a large population of *Cylindropuntia californica* var. *rosarica*, several individuals of *Lophocereus schottii*, and seven other species of cacti.

Clay mesa of Vicente Guerrero: The clay mesa, just north of the Santa Maria Escarpment, in Colonia Vicente Guerrero, is used as a village commons by the local ejidatarios. The area is often used as a latrine and as a trash dump. Working with the local ejidos to clean-up and conserve this open space should be considered as part of a community outreach and education effort. Restoration of the vernal pools here may be feasible but would require protection and monitoring. Although small in size, they could serve as a re-introduction site for species extirpated elsewhere in Greater San Quintín.

Broader conservation concerns

The threat of continued unsustainable agricultural practices should be addressed as part of the long-term conservation planning for this region, including its impacts on the region's hydrology. Aquaculture may be a more sustainable alternative (Aguirre et al 2001).

The majority of vernal pool habitat in San Quintín has already been lost to agriculture. The plants found only after the heavy rains of 2010 occur in small numbers in the vernal pool-like habitats offered by drainage ditches in Ejido El Papalote that are unlikely to persist. Efforts in other parts of the state should focus on protection of vernal pools that remain intact. The vernal pools of Colonet Mesa remain in good condition (Harper et al. in press) and should be targeted for conservation.

Conservation of the maritime succulent scrub that occurs on clay soils outside the volcanic field should include land beyond the boundaries of this study where this habitat occurs in larger intact areas.

Conclusions

San Quintín is home to a diverse assemblage of CFP and desert taxa. Almost one in three taxa in Greater San Quintín is a sensitive species, here documented as rare and/or locally endemic, and many resident taxa have not been evaluated for rarity. All habitats in Greater San Quintín are threatened by human activity. There is a pressing need for conservation of the natural areas that remain in this unique but heavily impacted region. The El Socorro Dunes should be prioritized for inclusion in the Area Natural Protegida. The volcanic field should be protected. The shell middens should be evaluated as conservation targets. The clay mesa of San Vicente is a possible target for a restoration project in collaboration with the community. The flora of the area forms a rich heterogeneous patchwork that has already suffered substantial habitat loss. As a transitional area in a global biodiversity hotspot, Greater San Quintín may be key to species conservation in times of global climate change and should be conserved.

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