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**Flora Vascular Endémica de la Península de Baja California,
Patrones de Distribución y Escenarios de Conservación**

Tesis que para optar por el grado de:

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Presenta

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Resumen

Esta obra pretende su principal mérito en el aporte que hace a dos áreas del conocimiento científico: conservación y ecología.

En la primera parte de esta tesis se toma a las plantas vasculares endémicas de la península de Baja California para analizar su valor en las actuales áreas naturales protegidas y su posible redefinición o creación de nuevas áreas protegidas.

Por medio de un análisis GAP se identifican 6 regiones que presentan un elevado número de especies no protegidas. Las regiones con mayor número de endemismos ausentes de las áreas protegidas son la parte noroeste de la península donde se localizan las únicas comunidades mediterráneas del país y el extremo sur de la península que presenta comunidades de selva baja caducifolia. Se plantea que para alcanzar una exitosa conservación de los *taxa* raros o endémicos se requiere el establecimiento de un corredor de áreas protegidas a lo largo de la península, que incluya comunidades mediterráneas, junto con las elevaciones de las sierras en la parte media de la península, la sierra de La Giganta y las islas Magdalena y Margarita en la parte media-sur de la península, y una extensa área al este del meridiano de 110° 20' que complemente la actual Reserva de Biosfera de Sierra de La Laguna.

En la segunda parte de este trabajo se analizó la distribución de la flora endémica en 230 áreas cartográficas de 15' x 20'. La riqueza de endemismos vasculares se relacionó a la intensidad de colecta y al área terrestre de cada celda cartográfica. Al comparar de manera estadística la riqueza de especies en cada celda con la riqueza media de toda la península corregida por el efecto de área y el esfuerzo de colecta, se identificaron áreas con valores de riqueza y endemismo significativamente altos. Se construyó un dendrograma que describe la afinidad entre los 12 tipos de vegetación descritos aquí sobre la base de los endemismos vasculares compartidos. Se pudo identificar regiones de baja riqueza de especies, así como, diez regiones con un número significativamente alto de especies o hotspots.

INTRODUCCIÓN

La conservación de la biodiversidad es una responsabilidad que no podemos soslayar para que futuras generaciones de biólogos hagan de ésta una labor pionera. La preocupante pérdida de germoplasma a nivel mundial hace que esta sea una labor apremiante que no es posible postergar.

El incremento de la población y su demanda por una mejor calidad de vida, repercuten en la capacidad de los ecosistemas para suministrar bienes y servicios, así como en su capacidad de reserva para mantener la diversidad biológica en niveles mínimos de erosión genética.

En la conservación de su biodiversidad México enfrenta tan solo desde la perspectiva biológica, grandes desafíos. Su notable riqueza de especies, el desconocimiento de una importante proporción de su biota que aún no ha sido descrita, la escasez de recursos económicos y humanos, y la pobreza de colecciones y bases de datos, están entre las limitantes más importantes para poder identificar de manera precisa aquellas regiones que requieren de atención inmediata y sobre las que es importante establecer algún régimen de protección tal que permita un compromiso entre conservación y uso de los recursos (Sarukhán y Dirzo 1992).

Recientemente, se han dado importantes avances. Para el año de 1992 se tenían decretadas 111 áreas naturales protegidas de administración federal y 176 de administración estatal, representando 137,464.65 km² de superficie terrestre y marina (CONABIO 1998). Sin embargo, algunas de las áreas protegidas heredan de administraciones pasadas errores de delimitación y de régimen de protección y fueron creadas con un propósito distinto al de conservación, por lo que el área conservada efectiva en México está lejos del 10% de la superficie recomendada por la Unión

Internacional para la Conservación de la Naturaleza (IUCN) y en regiones de megadiversidad aún este porcentaje puede resultar insuficiente.

Esta investigación tiene como propósito aportar información básica y metodológica que permita establecer procedimientos de análisis para la delimitación de áreas naturales protegidas a partir de la información de colecciones.

Para el desarrollo de esta investigación se ha tomado como objeto de estudio a la flora vascular endémica de Baja California bajo los siguientes argumentos:

- 1 Los endemismos son una categoría importante en la delimitación de áreas protegidas. A causa de que los endemismos son dependientes de una sola área son grupos de especies muy sensibles a la modificación del entorno, especialmente por agentes de carácter antropogénico.
- 2 El área de estudio contiene una proporción importante de endemismos. Los endemismos vegetales de esta región representan al menos 23% del total de la flora de la región (Wiggins 1980).
- 3 En la península están representadas dos de las grandes regiones de biodiversidad mundiales: la región Californiana y la Mesoamericana (Mittermeier et al. 1998).
- 4 Al tomar como objeto de estudio a los endemismos vegetales vasculares se tienen representadas a más de la mitad de las familias de plantas y se abarcan las categorías taxonómicas desde variedad o subespecie hasta género. Se tiene con ello bien representada la diversidad de formas de vida, estrategias adaptativas, y comunidades.

Interrogantes que se plantean en esta tesis

A partir de la delimitación de la flora vascular endémica como objeto de estudio se plantean las siguientes interrogantes:

- i ¿Es posible evaluar por medio de los endemismos el valor real de las áreas naturales protegidas?.
- ii ¿Utilizando métodos biogeográficos, es posible plantear alternativas para la conservación de estas áreas?
- iii ¿Es posible predecir la riqueza de especies mediante la riqueza de endemismos?
- iv ¿Es posible detectar patrones de varianza significativa en la riqueza de especies colectadas en una zona y que estos puedan ser estadísticamente atribuibles a efectos o predictores específicos, tales como la Intensidad de colecta, el área, y factores ambientales y/o históricos?
- v ¿Las causas de la riqueza de especies pueden ser investigadas por separado y es posible detectar “hotspots” que no sean atribuibles a un artefacto de la colecta?

El empleo de las especies endémicas como elementos de análisis de los ecosistemas permite una aproximación al problema de conservación a una escala espacial que no sería factible por medio del estudio de grupos funcionales, o de especies dominantes especialmente en ecosistemas de los cuales se tiene un desconocimiento muy grande de su estructura, dinámica o aun de su composición florística ya que estos estudios se pueden hacer a partir del análisis de las colecciones incompletas pero con buena representatividad (Soberón and Llorente 1993, Burgess et al. 1995, Villaseñor et al. 1998, Nelson et al. 1990, Nichols et al. 1998, Polasky et al. 2000).

En esta investigación se define como endémicas a aquellas especies que no rebasan los límites de las fronteras políticas de los estados de Baja California y Baja California Sur y como casi endémicas aquellas especies que alcanzan a rebasar estos límites. Se tiene en el primer grupo, al menos 754 taxa de los cuales 565 corresponden a la categoría de especie. En total los endemismos representan 84 familias de plantas de un total de 155 de la flora nativa de la región.

La Región de Estudio

La península de Baja California que ocupa el extremo noroeste del país, se distribuye desde los 32° 45' de latitud norte hasta los 22° 52' de latitud sur y desde 117° 07', hasta 109° 24' de longitud oeste. Tiene una longitud de aproximadamente 1,300 km con un ancho que varía entre 40 y 250 km lo que le confiere una extensión territorial cercana a los 143,000 km². El área territorial de esta investigación está limitada por el territorio peninsular e insular administrado por los estados de Baja California y Baja California Sur. Por lo que a la cifra anterior se agregan aproximadamente 2,000 km² de territorio insular, de las islas del Golfo de California y en el Pacífico las islas costeras y las de carácter oceánico como las Islas San Benito, isla de Cedros e isla Guadalupe localizada a los 118° 16' de longitud oeste y 29° 02' de latitud norte (Fig.1).

La teoría más aceptada de la explicación de la formación de la península de Baja California supone la existencia de dos fallas que en el Mioceno separan del macizo continental grandes masas que se desplazan a lo largo de la costa del Pacífico Mexicano (Gastil et al. 1972). La región del actual estado de California (alta California) que se distribuye al oeste de la falla de San Andrés desde Santa Barbara a San Francisco, el territorio de la Península Californiana, al sur de la cordillera transversa de California junto con las islas del Golfo de California, las islas del sur de California y la isla Cedros forman parte del territorio que se desprendió del continente.

La alta California probablemente empezó su desplazamiento hace unos 20-25 millones de años, cuando se separó de la Baja California que entonces estaba localizada al sur de su actual ubicación en la costa Mexicana. La separación de la alta y baja Californias se dio desde la parte que actualmente corresponde a la Bahía de Sebastián Vizcaíno hacia el norte. Las islas costeras del Pacífico de Baja California Norte y de la Bahía de Vizcaíno, son muy probablemente fragmentos que resultaron de la separación de las dos Californias. La fecha de la separación de la California Peninsular del macizo continental es aún materia de controversia, el rango de fechas estimadas abarca todo el Terciario

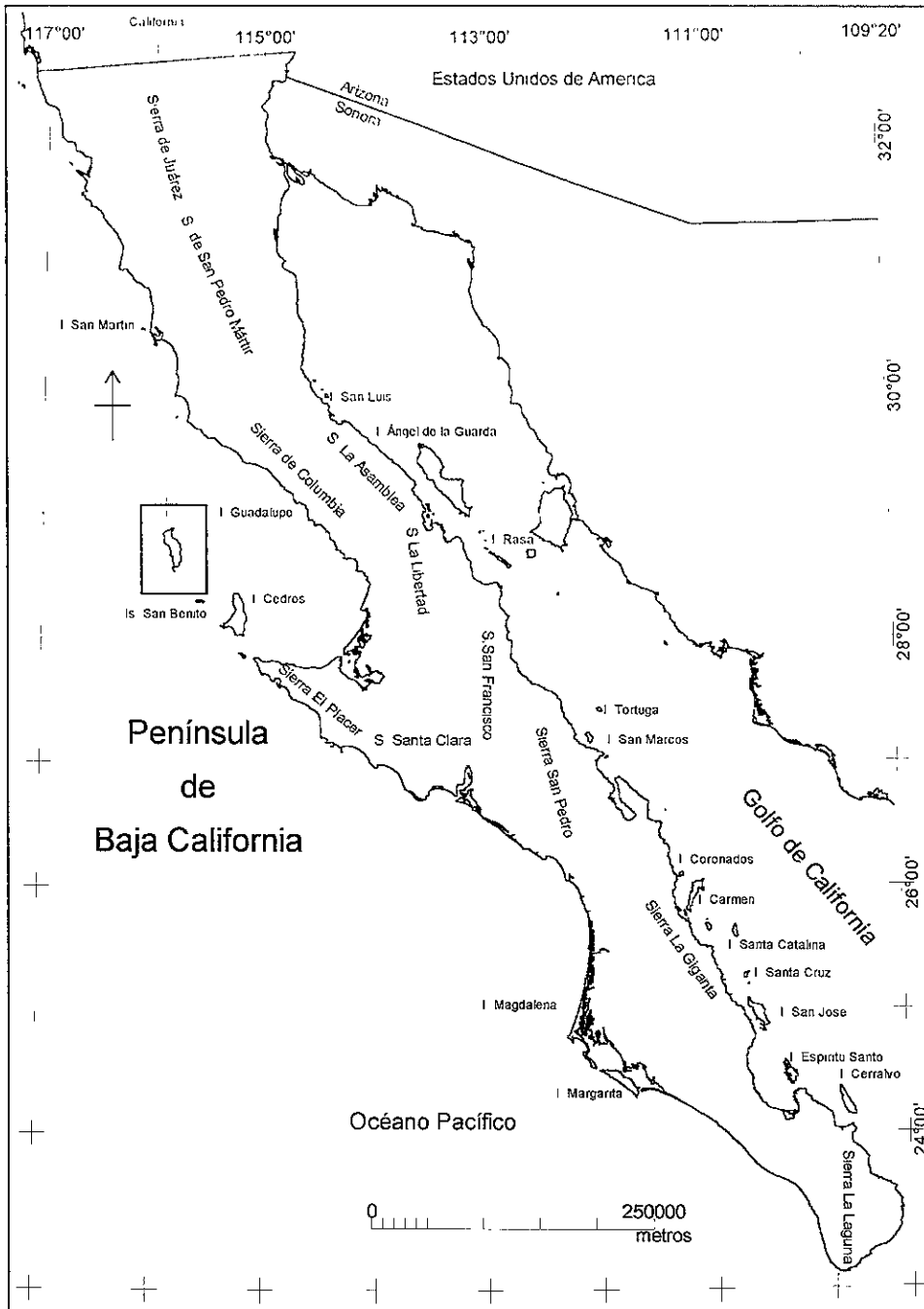


Figura 1. Región de estudio. Península de Baja California.

(Gastil et al. 1972, Moore 1973). La evidencia geológica sugiere que la parte sur de Baja California que corresponde a la región del Cabo se originó en el Mioceno Medio (12-14 M de años) de la costa Mexicana en el borde de Jalisco y Nayarit. Esta porción y las islas cercanas se desplazaron de manera simultánea en dirección noroeste desde el Mioceno Medio hasta el Plioceno tardío, a una localización que corresponde a la de las actuales islas Mariás 370 km al sureste de Cabo San Lucas (Gastil and Jansky 1973).

Al parecer a partir del Mioceno medio (14 M de años) gran parte de la California Peninsular existía como un archipiélago de islas, que incluía gran parte de la región del Cabo y las islas cercanas desde Santa Catalina hasta Cerralvo, así como también las partes elevadas de la actual península de Vizcaíno posiblemente incluyendo también a isla de Cedros. Durante este periodo y como resultado de un proceso de subducción emergen las cordilleras peninsulares del norte. Éstas, que en un principio no estaban totalmente separadas del oeste de México dieron origen a un proto Golfo de California que se empezó a formar hacia unos 14 millones de años atrás (Murphy 1983) y que no tomó carácter de rasgo geográfico permanente sino hasta la transición del Mioceno-Plioceno, 6 a 5 millones de años atrás. Durante este mismo periodo las cordilleras peninsulares centrales empezaron a emerger como resultado del vulcanismo (Durham and Allison 1960). Las sierras Madre Occidental, Madre Oriental y el altiplano mexicano también se elevaron como resultado de la tectónica miocénica, por tanto, la única porción geográficamente aislada de la península en el Mioceno Medio eran las islas del mencionado archipiélago. Durante el Mioceno tardío las islas del Cabo estuvieron conectadas temporalmente a porciones más norteñas de la península hasta el Mioceno-Plioceno, cuando esta conexión quedó inundada (Murphy 1983).

Anterior al Eoceno la flora del oeste de México estuvo dominada por elementos de origen neotropical. A partir de esta época, sin embargo, se dio un descenso de la temperatura y un incremento en las condiciones de aridez restringiendo la flora neotropical Terciaria a regiones más al sur. Para esta época se empezaron a desarrollar las asociaciones de la

flora Madro-Terciaria de pino-encino y de matorrales áridos, restringiéndose a las partes más elevadas de las montañas. Hacia finales del Oligoceno, la geoflora Madro-Terciaria ya predominaba a lo largo de las cadenas montañosas y del altiplano del centro de México. Las partes bajas de México al oeste de la Sierra Madre Occidental estaban aún dominadas por la flora neotropical.

Durante el Plioceno (5 millones de años atrás) la California Peninsular empieza un movimiento más rápido en dirección noroeste desde la actual localización de las islas Tres Marías a su presente ubicación (Moore 1973). La resurgencia de la interacción de placas y la unión de la California peninsular con la placa del Pacífico dio por resultado un subsecuente levantamiento de las cordilleras peninsulares. El vulcanismo continuó formando las cordilleras de la parte peninsular sur incluyendo en esto a la sierra de la Giganta. El proto Golfo de California ya se había formado por completo, hace 5 millones de años y se extendía como un archipiélago de islas cercanas desde la parte sur de California, hasta su abertura en el Pacífico entre las islas Tres Marías y la parte continental de México. Durante esta época la parte central y Sur de la Península, la Sierra de Vizcaíno, y posiblemente las islas del Cabo permanecieron aisladas de las Cordilleras peninsulares del Norte (Durham and Allison 1960). Durante el Plioceno la Bahía de Los Ángeles se sumergió en el Océano Pacífico. Esto, y la formación del proto Golfo de California, redujeron en gran medida el acceso terrestre a la parte norte de la península, de hecho muy probablemente quedó totalmente aislada (Murphy 1983). Los procesos de orogénesis del Plioceno, llevaron a la Sierra Madre Occidental, a la Sierra Madre Oriental y al altiplano mexicano casi a su actual elevación. Como resultado de esto, se presentó una parcial barrera de intercambio genético entre las poblaciones de organismos xerofílicos del proto chihuahuense y proto sonoreense, a ambos lados de la Sierra Madre Occidental.

Acompañada de la formación de regiones montañosas se acentúan las condiciones de aridez por efecto de sombra orográfica. A finales del Plioceno en las latitudes medias de

25° a 40°, los climas prevalecientes eran esencialmente equivalentes a los actuales, sin embargo, los desiertos tal como los conocemos ahora no se desarrollaron sino hasta el último periodo interglacial del Pleistoceno (Axelrod 1979).

Durante el Pleistoceno el proceso de cambio más importante desde el punto de vista de la distribución de la flora fueron las fluctuaciones en el nivel del mar que favorecieron el establecimiento de corredores temporales entre las islas. Los procesos tectónicos de esta época dieron ocasión a la separación de la península de las islas Ángel de la Guarda y San Lorenzo. Al mismo tiempo continuó el proceso de elevación de las cordilleras peninsulares completando el corredor costero de California y forzando el retroceso de la línea de costa del Golfo a su actual localización. Es en este periodo cuando la actual península de Vizcaíno y la región del proto Cabo quedan unidas a la península.

La flora del Pleistoceno de Baja California y regiones cercanas evidencian una tendencia hacia ambientes cada vez más secos y calientes, sólo alterados por los interglaciales. La evidencia de fósiles de vertebrados indica que en la parte sur de la península los ambientes continuaron siendo más húmedos que en la parte norte de la península con comunidades arboladas y de pastizales más abundantes que en el presente (Axelrod 1979). Con excepción de las comunidades desérticas, durante el Pleistoceno los cambios más notables en la vegetación corresponden a los desplazamientos de los pisos de vegetación ocasionados por los avances y retrocesos de las glaciaciones. La formación del desierto sonorense fue el resultado del gradual incremento en las condiciones de aridez que prevalecieron durante los interglaciales del Pleistoceno y que continuaron hasta el Holoceno. Al finalizar la glaciación del Wisconsiniano (aproximadamente 11,000 años antes del presente) la vegetación de la península era esencialmente la que prevalece actualmente (Axelrod 1979). La parte noroeste de la península con una vegetación de tipo mediterráneo con abundancia de elementos esclerófilos que se origina de la flora Madro-Terciaria. Elementos de esta flora en las Sierras de La Libertad, San Francisco, La Giganta y La Laguna, evidencian la presencia

de corredores durante el Plioceno y Pleistoceno (Cody et al. 1983). La formación del desierto sonorense en la región de estudio se explica por la combinación de tres factores: escasez de precipitación debida a su ubicación en la franja latitudinal de alta presión, por efecto de sombra orográfica y por el efecto de los vientos húmedos provenientes de las corrientes frías del Océano Pacífico que al entrar en contacto con la región terrestre aumentan su temperatura y producen una neblina que no llega a precipitar. Los tipos de vegetación mediterránea de matorral costero y chaparral tienen un origen paralelo a la desértica en las condiciones xerotérmicas del Cuaternario (Axelrod 1978). Por otro lado, la vegetación de origen neotropical de la región del Cabo y de la isla Cerralvo, tienen una clara afinidad con la flora neotropical de la costa de Jalisco-Nayarit (Cody et al. 1983).

Biogeografía

La obra pionera de Shreve (1951) establece cuatro tipos de vegetación para la fracción del desierto sonorense que ocupa la península. Posteriormente Wiggins (1980) en su flora de Baja California al integrar la vegetación mediterránea del norte y la tropical del sur reconoce ocho tipos de comunidades vegetales.

A raíz de la publicación del trabajo de Simpson (1964), donde propone un patrón de riqueza para las penínsulas que disminuye desde la parte basal de la península hacia la parte más distal del continente, Baja California fue objeto de varias investigaciones en donde se intentó someter a prueba esta hipótesis. En su publicación sobre la distribución de heterómidos en la península Taylor y Regal (1978) describen un gradiente de riqueza de tipo peninsular. Sin embargo, este ha sido puesto en duda por otros (Lawlor 1983). Por lo que respecta a otros grupos investigados, ninguno ha evidenciado el efecto de este patrón de riqueza. En algunos grupos el patrón es bimodal con máximos de riqueza en los extremos norte y sur de la península (lepidópteros, plantas y moluscos) en otros con un máximo de especies en la parte centro sur (escorpiones) y en otros el patrón no se distingue de la contraparte continental (reptiles) (Brown 1987, Burgess et al. 1995, Seib 1980, Due and Polis 1986, Smith et al. 1990). Por lo que los parámetros de diversidad de

esta región deben responder a factores históricos, a la diversidad climática y topográfica como en el caso de la vecina California y no a procesos de colonización y extinción análogos a la teoría de biogeografía de islas (Richerson and Lum 1980).

La región de las islas del Golfo de California y la costa de Sonora muestran evidencia de los desplazamientos de la vegetación durante las glaciaciones del Pleistoceno y principios del Reciente. En isla Ángel de la Guarda, se localizan Plagiobothris jonesii y Gutierrezia microcephalia, ambas especies características del desierto frío del Mojave y que no se localizan en la parte peninsular de Baja California. Es notable el hecho de que la colonización a través del puente de las islas de la parte media del Golfo de California se haya dado de manera preferente desde la península hacia la costa de Sonora siguiendo el avance de la aridez y no por la dirección de los vientos dominantes o a las corrientes marinas (Cody et al. 1983).

En los dos capítulos siguientes se desarrollan las interrogantes planteadas arriba. En el capítulo 1, se elaboran los argumentos de los puntos i y ii y en el capítulo 2, los tres restantes.

La presentación de estos capítulos 1 y 2, así como el hecho de que estén escritos en inglés responde al formato de edición solicitado por las revistas especializadas. El capítulo 1 ya está en proceso de dictamen en una revista de conservación. El capítulo 2, será sometido en fecha próxima a dictamen para su publicación.

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CAPÍTULO 1

**ENDEMISMOS VEGETALES Y ÁREAS NATURALES PROTEGIDAS EN LA
PENÍNSULA DE BAJA CALIFORNIA, MÉXICO**

**PLANT ENDEMISMS AND NATURAL PROTECTED AREAS IN THE
PENINSULA OF BAJA CALIFORNIA, MEXICO**

**PLANT ENDEMISMS AND NATURAL PROTECTED AREAS IN THE
PENINSULA OF BAJA CALIFORNIA, MEXICO**

ABSTRACT

The Peninsula of Baja California, Mexico has long been recognized as a hotspot for plant richness and endemism however, the number and position of existing protected areas in the region fail to protect its extraordinary diversity. We analyzed the distribution of the endemic vascular flora of the peninsula, and its presence or absence in protected areas. We also identified regions with greater numbers of endemic species not currently under protected status. From our analysis we determined that the 754 endemic taxa (including species and subspecies) within the political frontiers of the two states that occupy the peninsula, 40% are grouped in the families Asteraceae, Cactaceae, and Fabaceae. All the peninsular species within the Begoniaceae, Thymeleaceae, Araliaceae and Hippocastanaceae are endemic. Of the total number of endemic taxa in the region, 73.5% are present within protected areas. The endemic genera Adenothamnus, Carterothamnus, Faxonia, and Ornithostaphylos are all absent from protected areas. At the species level, 423 endemics (68% of the total number of endemic species) are present within protected areas, while 199 are not. At the subspecies level, 121 are present in protected areas while 24 have not been collected in them. The endemic genera have 13 species absent from all protected areas. A gap analysis identified that the areas with the highest number of unprotected endemic species are in the Mediterranean-type ecosystems of the northwest part of the peninsula and in the deciduous dry tropical communities of the cape region at the southernmost tip of Baja California. Our findings suggest that to achieve the successful conservation of rare and endemic taxa it is necessary to create a corridor of protected areas along the peninsula. This corridor should encompass a range of biogeographical units (including Mediterranean communities and montane habitats of the Sierras) in a north-south direction ending at the tip of the peninsula.

RESUMEN

La península de Baja California ha sido reconocida de tiempo atrás como una región con una elevada riqueza de especies vegetales y numerosos endemismos, sin embargo, un importante número de estos endemismos no están presentes en las existentes áreas protegidas. Analizamos la distribución de la flora vascular endémica de la península y su presencia o ausencia de las áreas protegidas. Identificamos aquellas regiones con mayor número de endemismos ausentes de áreas protegidas. De nuestro análisis encontramos que de los 754 taxa endémicos (que incluyen especies y subespecies), dentro de las fronteras políticas de los dos estados que ocupan la península, 40% se agrupa en las familias: Asteraceae, Cactaceae y Fabaceae. Las especies de las familias Begoniaceae, Thymeleaceae, Araliaceae e Hippocastanaceae son todas endémicas. Del total de endemismos, 73.5% está presente en las áreas protegidas. A nivel específico, 423 endemismos (68% del total de especies) están presentes en las áreas protegidas, mientras que 199 no han sido colectadas en ninguna de ellas. En cuanto a los taxa infraespecíficos 121 tienen presencia dentro de las áreas protegidas, mientras que los 24 restantes no han sido colectados al interior de éstas. Los géneros endémicos tienen 13 especies ausentes de las áreas protegidas. Un análisis GAP, permitió identificar que las regiones con mayor número de endemismos ausentes de las áreas protegidas son la parte noroeste de la península donde se localizan las únicas comunidades mediterráneas del país y el extremo sur de la península que presenta comunidades de selva baja caducifolia. Nuestros hallazgos sugieren que para alcanzar una exitosa conservación de los taxa raros o endémicos se requiere el establecimiento de un corredor de áreas protegidas a lo largo de la península. Este corredor debería abarcar la amplia gama de unidades biogeográficas (incluyendo comunidades Mediterráneas y los habitats presentes en las Sierras) en una dirección norte – sur que terminara en la punta de la península.

INTRODUCTION

Endemism in Baja California

One of the most important criteria used in the identification of high-priority areas for conservation is endemism, (i.e., species of local, ecoregional, or national distribution Olson & Dinerstein 1998; Mittermeier et al. 1998; Stattersfield et al. 1998). However in some areas a high number of endemics may not correspond to high species richness (Prendergast et al. 1993). In Mexico this low association between diversity and number of endemic species is noticeable in several groups, especially in vertebrates (Ceballos et al. 1998; Flores Villela 1993; Escalante et al. 1993). Mexico as a whole has a clear dissociation between plant species richness and endemism. For example, the species rich tropical forest in the southeast has a low proportion of endemic species, whereas there is a high proportion of endemic plants in the temperate and arid northern ecoregions.

Thus, in the drylands and temperate ecosystems of northern Mexico endemism should be a primary reason to designate protected areas. A case in point the Baja California peninsula and associated islands. Here, Wiggins (1980) described 2934 plant species, approximately 20% of which are endemic to the peninsula. The high number of endemic plant species in this region is possibly the result of two processes that favor biological speciation: (1) the landscape heterogeneity and (2) the isolation of the Baja California peninsula. According to Peinado et al. (1994), the process of adaptive radiation that gave rise to the Pleistocene neoendemics in this region was largely caused by the numerous boundaries and ecotones between zones of limited and insufficient rainfall. Alternatively, the Tertiary paleoendemics owe their presence to the long-term climatic stability of regions near, the Pacific Ocean (Peinado et al. 1994). Another possibility is that surviving species have gone extinct in other regions.

The purpose of this paper is to provide direction for future policies of conservation and sustainable use. We analyzed how well represented the endemics of Baja California are in protected areas. We identified regions with high endemism that are currently unprotected.

Protected Areas in Baja California

The Baja California peninsula and neighboring islands have been the subject of 14 decrees of protected areas. Several correspond to vague pronouncements declaring large forest reserves that were originally created for reasons other than biodiversity conservation and that have poorly defined boundaries. Therefore, 65,725 km² are currently under some effective protection regime, including six biosphere reserves, two national parks and two marine national parks. Of the total protected area, 85.3% correspond to terrestrial environments, representing 39.5% of the total land area of the region (Table 1 and Fig. 1).

In the northern part of the peninsula, two national parks are located in the heights of the Sierra de Juárez and Sierra de San Pedro Mártir that protect communities with pine, pine-oak, and chaparral. The Vizcaino biosphere reserve and Valle de Los Cirios flora and fauna protection area protects the desert ecosystems of the mid-peninsula, including the sarcophyllous (with fleshy leaves) communities of the Pacific Coast, the halophilic vegetation of the coastal marshes and lagoons, and the sarcocaulous communities near the coast of the Sea of Cortés. In the extreme south, the Sierra de La Laguna biosphere reserve encompasses communities ranging from lowland tropical deciduous forests at 400 m, to oak and pine forests above 1600 m. The reserve off the Islands of the Sea of Cortés protects sarcocaulous (with fleshy trunks) communities (the Gulf Island desert scrub), the Guadalupe Island reserve in the Pacific Ocean harbors Mediterranean coastal scrubs, and the Alto Golfo de California biosphere reserve, mostly a marine area, consists of coastal halophytes and microphyllous desert scrubs (Table 1).

The Study Area

The study region encompasses the Baja California peninsula, Guadalupe Island in the Pacific, and the islands of the Sea of Cortés that fall under the administration of the political states of Baja California and Baja California Sur (Fig. 1). The peninsula is approximately 1,300 km long and 45-250 km wide. The study area represents a region of approximately 143,000 km²,

spanning almost 10 degrees of latitude from 22° 53' N in the Cape Region to 32° 46' N in the Mexico-U.S. border.

The peninsula of Baja California was formed during the Tertiary (some 5-10 million years ago), when this narrow sliver of land was detached from the mainland by tectonic forces, creating the Sea of Cortés. A series of mountain ranges run north-south along the peninsula (Fig. 1). This steep mountain backbone separates the ecosystems sloping into the Sea of Cortés from those running into the Pacific, and creates a complex physiographic gradient with a large diversity of environments and landscapes so contrasting as the Mediterranean ecosystems and the sonoran desert in less than 100 km in a west east direction.

The peninsula is covered with 20 different types of climates (in Köppen's classification), that goes from very arid to temperate (García 1988). Most of Baja California has mean annual temperatures above 18° C and mean annual rainfall lower than 200 mm. The highest rainfall (500-700 mm) occurs in the high parts of the Sierras of San Pedro Mártir and La Laguna, in both latitudinal extremes of the peninsula. The most adverse climatic conditions occur along the coasts of the Upper Sea of Cortés, in the northeast, where the highest summer temperatures and lowest annual rainfall occur.

The peninsular territory is occupied by a diversity of plant communities from winter-rain Mediterranean scrubs and coniferous forests in the northwest and microphyllous scrub in the northeast to tropical deciduous forests of the cape region with a heterogeneous array of sarcophyllous, sarcocaulous, and crassicaulescent desert communities in the central deserts (Wiggins 1980).

METHODS

Information about endemic species was obtained from the literature and from herbaria. Because of the obvious association between the biogeographic definition of the peninsula of Baja California and the political boundaries of the two Mexican states that lie within it, we arbitrarily defined endemic species as those that had a distribution restricted to the insular and peninsular

territory administered by the states of Baja California and Baja California Sur. This operational criterion may introduce some error in the case of species that occur along the northern border of the peninsula, which may be classified as non-endemic when in reality they may have a narrow biogeographic distribution. However the funding obtained for this study forced us to impose this political, as opposed to natural, boundaries to our study area.

We consulted the herbaria at the San Diego Natural History Museum, Rancho Santa Ana at Claremont, University of California at Berkeley, and California Academy of Sciences. The information from the collections (taxa and locality) was geographically referenced by means of a topographic map, (1:250,000) (INEGI 1982). The georeferenced database which consisted of a file of 12,287 records corresponded to 3925 field sites. This database was transferred to a geographical information system (GIS) (ITC 1998). Repeated data points of the same species for the same site were excluded.

The following method was used to relate these digital data points to our study interests. First, we digitized the topographic cartography of the peninsula. Second, we used the database of collection sites to generate a map of collection points. Third, we digitized the boundaries of all protected areas in the published decrees. Fourth, we digitized the five major phytogeographic regions of the peninsula and neighboring islands from several sources (INEGI 1988; Wiggins 1980; Brown & Lowe 1982; SPP 1982) and also our own field experience. Thus, the GIS consisted of four maps and the corresponding databases. These data layers were transformed to a raster format with 150 m × 150 m pixels and reprojected to Lambert conformal conic projection. The lists of protected and unprotected endemic species were obtained by performing a gap analysis. This was done by overlapping the data points, protected areas and phytogeographic regions layers. The resultant map of this overlapping permitted us to identify the gap areas or regions rich in unprotected endemics (Scott et al. 1992).

A species-area model was fitted by means of principal axes regression, in order to allow for measurement errors in both variables (Sokal, & Rohlf 1981).

RESULTS

Taxonomic distribution of endemics

The literature review and the revision of existing collections yielded 3774 species. Of these, 20% are endemic to the peninsula and adjacent islands. About three-fourths (74%) of indigenous plants are also found outside Baja region, and the remaining 6% are introduced species.

Of the 155 indigenous plant families in the Baja California flora 85 contain endemic taxa (species or subspecies) and 23 of these have only one endemic taxon. Forty percent of the endemic taxa are concentrated in only three families: Asteraceae (143), Cactaceae (80), and Fabaceae (75). In Baja California all species in the families Begoniaceae, Thymeleaceae, Araliaceae, and Hippocastanaceae are endemic, and families Agavaceae, and Ebenaceae contain 86%, and 75% endemics.

Twenty of the 926 indigenous genera of Baja California are endemic and, of these, 15 are monospecific. The endemic genera families (Anacardiaceae, Asteraceae, Boraginaceae, Cactaceae, Ericaceae, Liliaceae, Onagraceae, Polemoniaceae, Polygonaceae, Scrophulariaceae and Sterculiaceae) contain in total 31 species. The Poaceae, the third family in number of species (329), has only 8 endemic taxa, and none at the genus level.

A total of 754 endemic taxa (species and subspecies) were found, including 565 species and 158 endemics below the species level (i.e., varieties or subspecies).

348 endemics are restricted to the peninsular mainland, 83 have strict insular distributions, 66 on the islands of the Pacific and 17 on the islands of the Sea of Cortés, while 323 occur in both the islands and the peninsula.

Representation of endemism in protected areas

We obtained location data for 719 of the 754 endemic taxa. In total, 558 taxa occur in protected areas (Table 1). The core areas of two of the three federally-decreed Biosphere Reserves (Vizcaíno, and Sierra de la Laguna) only contain 13.5% of the endemic flora. The core area of

the Ojo de Liebre Lagoon in the Vizcaíno BR and the core area of the Alto Golfo de California BR, jointly totaling 296 km², lack endemic plants.

Two hundred and fifty eight taxa belonging to 51 families have not been collected within the protected areas of the peninsula and neighboring islands. These unprotected taxa are widely scattered along the study region (Fig. 2). At the species level, 441 endemics are present in protected areas, while 133 have not been collected. Concerning the infraspecific taxa, 96 are present within protected areas while the remaining 20 have not been collected.

The endemic genera Adenothamnus, Carterothamnus, Faxonia, and Ornithostaphylos are all absent from protected areas. The endemic genus Cochemiea has three species and the endemic genus Harfordia have one subspecies each absent from protected areas (Appendix 1).

Of 161 georeferenced endemics not collected in protected areas, 78 have local distribution (i.e., micro-endemics whose distribution is equal or smaller than 1,000 km²); 80 have restricted distributions (i.e., meso-endemics ranging between 1,000 km² and 10,000 km²); and 3 have regional distributions, occupying a large part of the peninsula of Baja California (i.e., endemics with distributional areas exceeding 10,000 km²). The protected areas shelter a large proportion of the meso and macro-endemisms, over half of micro-endemisms at any level (genera, species, or subspecies) lies outside protected areas (Fig 3. and Appendix 1).

There are five major phytogeographic regions in Baja California (Fig. 4). The Lower Colorado Desert scrub showed the lowest number of endemics to the region, while endemism was very high in the San Lucan xeric scrub (Table 2). These tropical ecosystems also showed the highest percentage of regionally endemic species that have not been recorded within protected areas.

Based on our gap analysis, we recognized six gap-areas that harbor the highest number of unprotected taxa (Fig. 5).

Coastal Mediterranean. Along the Pacific coast, between parallels 30° 00' and 32° 15', the Californian bioregion (i.e., mediterranean scrubs) of Mexico is found. This area presents a high number of species of restricted or of local distribution (Villaseñor & Elias 1995). This narrow band of coastal sage and succulent-rosette scrubs, chaparrals, and temperate forest has 134

recorded endemics with 35 not found in protected areas (Fig. 5). Species such as Sanicula deserticola, Hazardia ferrisiae, H. orcutti, Hemizonia perennis, Ferocactus fordii fordii, Mammillaria brandegei, M. louisae, Astragalus anemophilus, A. sanctorum, Leucaena brandegeei, Chorizante inequalis, C. jonesiana, and Galvezia juncea pubescens are all restricted to this zone. Given the high intensity of land-use, this is the most threatened region of Baja California, agriculture, tourism, industry, and urban development increase, aim to a great risk of germplasm loss in the short term.

We developed a scenario of a hypothetical protected area in the Mediterranean lowlands of Baja California (including chiefly chaparral and coastal scrubs), stretching from the coast up to an altitude of 600 m and occupying 11,992 km². We found that this reserve, if created, would protect up to 176 taxa in addition to the 13 already mentioned, including the monospecific genera Bergerocactus and Adenothamnus (Fig. 6).

Montane Mediterranean. Another region with a high number of endemic taxa occurs in the heights of the Sierra de Juárez and San Pedro Mártir, where two national parks are located. These parks, however, are very small and their high perimeter-to-area ratio makes them highly vulnerable to adjacent agricultural activities. This is especially true in the case of Constitución de 1857 National Park (Sierra de Juárez), which has an area < 50 km². Additionally, many high-altitude temperate endemics do not occur within the boundaries of these two parks. With this in mind, we proposed another protected area in the Mediterranean uplands consisting primarily of temperate forests and chaparral, stretching from 800 to 3100 m elevation and occupying 12,836 km². This proposed reserve would protect at least 20 more endemic taxa including the endemic genus Ornithostaphylos, currently outside protected areas. Other researchers have previously highlighted the possibility of creating a reserve in the mountains of northern Baja California, potentially extending its influence across the U.S. border into Southern California (Franco-Vizcaíno & Sosa-Ramírez 1991).

Sierra de La Giganta. Farther south the Sierra de la Giganta also has an important concentration of endemism. It possesses 259 endemics and 43 of these not present within any

protected area. Galium carterae, Agave gigantensis, and Acacia kelloggiana are among the species restricted to this region. The endemic genus Carterothamnus occurs in the middle and southern part of this range.

San Lucan. Near the tip of the peninsula, east of the 110° 20' meridian, a low, deciduous tropical dry forest occurs (Rzedowski 1978). These communities intermingle gradually with nearctic elements at middle heights of the Sierra de La Laguna, where a temperate pine-oak relictual forest prevails at the highest elevations and includes local endemics such as Pinus lagunae. This southern portion of the peninsula shows the highest number of micro, and meso-endemics, (i.e., species with local or restricted distributions). The genera Clevelandia, Bessera, and Hermannia are restricted to this part of the peninsula. This portion of the peninsula harbors no less than 304 endemic species, 55 of which are not found within any protected area and 39 of which are restricted solely to this area.

Cedros Island. Located along the Pacific Coast, 22.5 km off shore between 28° 02' and 28° 22', Cedros, is also an important center of endemism. This small island of approximately 367 km² contains 121 endemic taxa. Of these, 23 are not under protection, including Rhus integrifolia cedrosensis, Encelia cedrosensis, Senecio cedrosensis, Cochemia pondii, Ferocactus chrysacanthus, Mammillaria goodridgei, Opuntia oricola, Dudleya cedrosensis, D. pachyphytum, Lotus cedrosensis, L. nudatus, Monardella thymipholia, Eriogonum molle, Harfordia macroptera, Mimulus stellatus, and Penstemon cedrosensis.

Magdalena and Margarita islands. Located near the Pacific coast between parallels 25° 16' and 24° 18', Magdalena and Margarita islands have a geological origin that differs from that of the neighboring coastline (Durham & Allison 1960). Possibly because of this, the islands shelter some rare micro-endemisms such as Agave margaritae, Asclepias masonii, Brickellia hastata, Ibervillea insularis, Cochemia halei, Echinocereus barthelowanus, Opuntia pycnantha, O. santamaria, Sphaeralcea coulteri margaritae, Gongylocarpus fruticosus fruticosus, G. fruticosus glaber, and Castela peninsularis. All these species are absent from protected areas.

Species-Area Analysis

As expected from the general theory of species-area relationships (e.g., Fisher et al. 1943; Preston 1960; Palmer & White 1994), the number of endemics in protected areas when plotted against area in a log-log scale, fall along a straight general line, with slope 0.50. As a general rule, the larger the reserve, the larger the number of endemics. The Alto Golfo de California br differs significantly ($p < 0.001$) from this trend, with fewer species than expected according to its size (Fig. 7). Two other reserves (Sierra de la Laguna and Islas del Golfo de California) fall on the edge of the 95% bivariate confidence ellipse, indicating a marginally significant tendency to show more species than the species-area model predicts. As for the five major phytogeographic regions, four fall inside the 95% confidence ellipse, and only the Lower Colorado falls on the edge with a tendency to show less species than the model predicts.

DISCUSSION

It is interesting to note that the regions with the highest level of endemism (Mediterranean and San Lucan), both form parts of larger areas recently singled-out by Myers et al, (2000) as global biodiversity hotspots: the Californian Floristic Province and the Mesoamerican Tropical Forests. In these communities there seems to be a closer association between diversity and number of endemics as is also the case in the neighboring southwestern part of the USA (Kerr 1997).

In a precedent research to our work Villaseñor and Elias (1995), who restricted their investigation to 552 species of endemic angiosperms identified the Mediterranean region, in the northwest part of the peninsula, as the richest in plant endemisms.

The data analyzed here assumes the current existence of all the endemics recorded for the region. However, in the consulted herbaria, however, we found that 74 endemics have not been collected during the last 32 years and some have failed to show up in the collections for almost 100 years. It is likely that even an intense collection effort may fail to encounter all the taxa included in this research. Some of the peninsular endemics, such as the genus Faxonia, are

solely represented in the collections by the type specimen. This stresses the importance of establishing protected areas in the region as soon as possible.

A possible source of error to our research may arise from the assumption that the absence of collection records within the protected areas presupposes the absence of the taxa in their interior. Although more intensive collecting may change the results of our study, it is unlikely it could change the qualitative conclusions. The presence of a taxon in low numbers within a protected area does not imply the existence of a healthy population, or a level of genetic variation adequate for the persistence of the species. Given the great latitudinal span of Baja California, it is unlikely that the protected areas that currently exist could harbor a significant proportion of the genetic variation of the endemic peninsular flora, especially those species that have not been detected to date in protected sites.

Although the peninsula has been surveyed for the last 150 years, especially by U.S. botanists, the region continues to be a territory for which a large part of the collection accessions still come from sites near the main roads. A greater collection effort would permit the discovery of new species or new records in regions that have had little collecting in the past and would allow confirmation of the distribution and condition of the endemic taxa, especially in those ecosystems suffering the greatest pressures from development projects.

Another threats such as cattle ranching, agriculture, mining, and the introduction of exotic animal and plant species have been increasing causes of environmental disturbance in the last decade. As a result of these, there is a wide distribution of weedy exotic taxa such as salt cedar or tumble weed, and a high number (78) of introduced species of the family Poaceae.

The concentration of agriculture and cattle ranching along the wetter habitats such as creeks and vernal pools has had a strong effect on these ecosystems. This is especially important to conservation policies since these communities are usually rich in species and high in endemism. Even in remote sites such as Guadalupe Island the introduction of exotic plants and animals has caused a serious modification of the native flora, there has been a failure to re-collect in recent times previously recorded endemics (Moran 1996).

To achieve the successful conservation of rare and endemic taxa it is necessary to take into account the distribution of regions rich in endemism. These regions should be of high priority for the creation of new protected areas, especially if the core areas of new reserves are to have a high level of protection.

We recommend that this is best achieved by means of a corridor of protected areas that would allow genetic flow along the peninsula. The size and status of this corridor should be the result of a compromise between the needs of development and those of conservation. This corridor should include extensive areas of the low and upland northwest Mediterranean communities, together with the highest parts of the mid-latitude sierras of La Libertad and Columbia, San Francisco, Santa Clara, and Tres Vírgenes in the middle of the peninsula. It should also include the Sierra de La Giganta and the islands of Magdalena and Margarita in the middle-south part of Baja California. Finally, the corridor should encompass an area to the east of the 110° 20' meridian that would complement the current Sierra de La Laguna br, to include lowlands and coastal vegetation.

Although the current system of terrestrial protected areas in the Peninsula of Baja California is worthy of praise for the recent efforts that have been done to decree comprehensive reserves, it is still far from meeting the ideal goal of protecting a large proportion of regional endemics. A large number of micro-endemic taxa, are distributed outside protected areas. This creates a challenge and an opportunity to rethink the existing system and to develop new alternatives, including that of a corridor of protected areas that would help effectively preserve the extraordinary endemism of this unique peninsula.

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| <i>Agave deserti</i> Engelmänn <i>pringlei</i> (Engelmänn ex Baker) Gentry | V | no | m | 1 |
| <i>Agave gigantensis</i> Gentry | S | no | s | 1 |
| <i>Agave margantae</i> Brandegeee | S | no | s | 1 |
| <i>Agave promontorii</i> Trelese | S | yes | s | 1 |
| <i>Agave sebastiana</i> E. Greene | S | yes | s | 1 |
| <i>Agave shawii</i> Engelmänn <i>goldmaniana</i> (Trelese) Gentry | S | yes | m | 1 |
| <i>Agave sobria</i> Brandegeee <i>frailensis</i> Gentry | S | no | s | 1 |
| <i>Agave sobria</i> Brandegeee <i>roseana</i> (Trelese) Gentry | S | yes | m | 1 |
| <i>Agave sobria</i> Brandegeee <i>sobria</i> Brandegeee | S | yes | m | 1 |
| <i>Agave vizcainoensis</i> Gentry | S | yes | s | 1 |
| <i>Hesperoyucca whipplei</i> Torrey <i>eremica</i> Epling & Haines | V | yes | m | 1 |
| <i>Yucca capensis</i> L. Lenz | S | no | s | 1 |
| <i>Yucca peninsularis</i> Mc Kelvey | S | yes | s | 1 |
| <i>Yucca valida</i> T. S. Brandegeee | S | yes | l | 1 |
| ALLIACEAE | | | | |
| <i>Allium eurotophilum</i> Wiggins | S | yes | m | 1 |
| AMARANTHACEAE | | | | |
| <i>Amaranthus lepturus</i> S. F. Blake | S | yes | m | 1 |
| <i>Celosia floribunda</i> A. Gray | S | yes | l | 1 |
| ANACARDIACEAE | | | | |
| <i>Cyrtoarpa edulis</i> (Brandegeee) Standley | S | yes | m | 1 |
| <i>Pachycormus discolor</i> (Bentham) Coville <i>discolor</i> (Bentham) Coville | G | yes | m | 1 |
| <i>Pachycormus discolor</i> (Bentham) Coville <i>pubescens</i> (S. Watson) Gentry | G | yes | m | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Pachycormus discolor</i> (Bentham) Coville <i>veatchiana</i> (Kellogg) Gentry | G | yes | m | 1 |
| <i>Rhus integrifolia</i> (Nuttall) Bentham & Hooker <i>cedrosensis</i> Barkley | V | no | s | 1 |
| <i>Rhus lentii</i> Kellogg | S | yes | m | 1 |
| APIACEAE | | | | |
| <i>Arracacia brandegeei</i> Coulter & Rose | S | yes | m | 1 |
| <i>Sanicula deserticola</i> C. R. Bell | S | no | s | 1 |
| APOCYNACEAE | | | | |
| <i>Macrosiphonia hesperia</i> I. M. Johnston | S | yes | m | 1 |
| <i>Vallesia laciniata</i> Brandegee | S | yes | m | 1 |
| ARALIACEAE | | | | |
| <i>Aralia scopulorum</i> Brandegee | S | yes | l | 1 |
| ARECACEAE | | | | |
| <i>Erythea armata</i> (S. Watson) S. Watson | S | yes | m | 1 |
| <i>Erythea brandegeei</i> Purpus | S | yes | m | 1 |
| <i>Erythea edulis</i> S. Watson | S | yes | m | 1 |
| <i>Washingtonia robusta</i> H. Wendl. | S | yes | m | 2 |
| ARISTOLOCHIACEAE | | | | |
| <i>Aristolochia monticola</i> Brandegee | S | no | s | 1 |
| ASCLEPIADACEAE | | | | |
| <i>Asclepias masonii</i> Woodson | S | no | s | 1 |
| <i>Cynanchum palmeri</i> (S. Watson) S. F. Blake | S | yes | m | 2 |
| <i>Cynanchum peninsulare</i> S. F. Blake | S | no | m | 1 |
| <i>Mateleia umbellata</i> (Brandegee) Woodson | S | no | s | 1 |
| <i>Sarcostemma arenarium</i> Decne. | S | yes | m | 1 |
| ASTERACEAE | | | | |
| <i>Adenothamnus validus</i> (Brandegee) Keck | G | no | m | 1 |

| | | | | |
|--|---|-----|---|---|
| <i>Alvordia brandegeei</i> A. Carter | S | no | m | 1 |
| <i>Alvordia fruticosa</i> Brandegee | S | no | m | 1 |
| <i>Alvordia glomerata</i> Brandegee <i>glomerata</i> Brandegee | S | yes | m | 1 |
| <i>Alvordia glomerata</i> Brandegee <i>insularis</i> Carter | S | yes | s | 1 |
| <i>Amauria brandegeana</i> (Rose) Rydberg | G | yes | m | 1 |
| <i>Amauria rotundifolia</i> Bentham | G | yes | m | 1 |
| <i>Amblyopappus pusillus</i> Hooker & Arn. | S | yes | m | 1 |
| <i>Ambrosia acuminata</i> (Brandegee) Payne | S | Yes | s | 2 |
| <i>Ambrosia bryantii</i> (Curran) Payne | S | Yes | m | 1 |
| <i>Ambrosia carduacea</i> (E. Greene) Payne | S | yes | m | 2 |
| <i>Ambrosia flexuosa</i> (A. Gray) Payne | S | no | m | 1 |
| <i>Archibaccharis peninsularis</i> S. F. Blake | S | yes | m | 1 |
| <i>Baeriosis guadalupensis</i> J. T. Howell | G | yes | s | 1 |
| <i>Bebbia atriplicifolia</i> (A. Gray) E. Greene | S | yes | l | 1 |
| <i>Bidens leptcephala</i> E. E. Sherff <i>hammerlyae</i> E. E. Sherff | V | yes | m | 1 |
| <i>Bidens nudata</i> Brandegee | S | yes | m | 1 |
| <i>Boeberastrum littoralis</i> (Brandegee) Rydb. | S | no | m | 1 |
| <i>Brickellia brandegeei</i> B. L. Robinson | S | yes | m | 1 |
| <i>Brickellia glabrata</i> (Rose) B. L. Robinson | S | yes | m | 1 |
| <i>Brickellia hastata</i> Bentham | S | no | m | 1 |
| <i>Brickellia macromera</i> B. L. Robinson | S | no | m | 1 |
| <i>Brickellia megaphylla</i> M. E. Jones | S | yes | m | 1 |
| <i>Brickellia peninsularis</i> Brandegee | S | yes | m | 1 |
| <i>Brickellia sessile</i> B. L. Robinson | S | no | s | 1 |
| <i>Carterothamnus anomalochaeta</i> R. M. King | G | no | m | 1 |
| <i>Chaenactis lacera</i> E. Greene | S | yes | m | 1 |

| | | | | |
|--|---|-----|---|---|
| <i>Cirsium trachylomum</i> S. F. Blake | S | yes | s | 1 |
| <i>Coreocarpus dissectus</i> (Bentham) S. F. Blake | S | yes | m | 2 |
| <i>Coreocarpus involutus</i> E. Greene | S | yes | m | 1 |
| <i>Coreocarpus parthenioides</i> Bentham <i>heterocarpus</i> (A. Gray) S. F. Blake | V | yes | m | 1 |
| <i>Coreocarpus parthenioides</i> Bentham <i>parthenioides</i> Bentham | S | yes | l | 2 |
| <i>Coulterella capitata</i> Vasey & Rose | G | yes | m | 1 |
| <i>Dyssodia anthemidifolia</i> Bentham | S | yes | l | 1 |
| <i>Dyssodia speciosa</i> A. Gray | S | no | m | 1 |
| <i>Encelia californica</i> Nuttall <i>asperifolia</i> S. F. Blake | V | yes | m | 1 |
| <i>Encelia cedrosensis</i> Rose | S | no | s | 1 |
| <i>Encelia conspersa</i> Bentham | S | yes | m | 1 |
| <i>Encelia densifolia</i> Clark and Kyros | S | yes | s | 1 |
| <i>Encelia farinosa</i> A. Gray <i>radians</i> Brandegee ex. S. F. Blake | V | yes | m | 1 |
| <i>Encelia laciniata</i> Vasey & Rose | S | yes | m | 1 |
| <i>Encelia palmeri</i> Vasey & Rose | S | yes | l | 2 |
| <i>Encelia ravenii</i> Wiggins | S | no | s | 1 |
| <i>Encelia stenophylla</i> E. Greene | S | yes | m | 1 |
| <i>Encelia ventorum</i> Brandegee | S | yes | m | 1 |
| <i>Ericameria cooperi</i> (A. Gray) H. M. Hall <i>bajacalifornica</i> Urbatsch & Wussow | V | no | s | 1 |
| <i>Ericameria juarezensis</i> (R. Moran) Urbatsch | S | no | m | 1 |
| <i>Ericameria martirensis</i> Wiggins | S | yes | m | 1 |
| <i>Ericameria parishii</i> (E. Greene) H. M. Hall <i>peninsularis</i> (Moran) G. Nesom | S | yes | m | 1 |
| <i>Eupatorium peninsulare</i> Brandegee <i>epipolium</i> | V | yes | s | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Eupatorium peninsulare</i> Brandegee <i>peninsulare</i> Brandegee | V | no | m | 1 |
| <i>Eupatorium purpusii</i> Brandegee | S | yes | m | 1 |
| <i>Gochnatia arborescens</i> Brandegee | S | yes | m | 1 |
| <i>Greenella ramulosa</i> E. Greene | S | yes | m | 1 |
| <i>Hazardia berberidis</i> (A. Gray) E. Greene | S | no | m | 1 |
| <i>Hazardia enormidens</i> (Moran) Clark | S | no | s | 1 |
| <i>Hazardia ferrisiae</i> (S. F. Blake) Clark | S | no | m | 1 |
| <i>Hazardia odontolepis</i> (Moran) Clark | S | yes | m | 1 |
| <i>Hazardia orcuttii</i> (A. Gray) E. Greene | S | no | m | 1 |
| <i>Hazardia rosarica</i> (Moran) Clark | S | yes | m | 1 |
| <i>Hazardia vernicosa</i> (Brandegee) Clark | S | yes | m | 1 |
| <i>Helianthus similis</i> (Brandegee) S. F. Blake | S | yes | m | 1 |
| <i>Heliopsis anomala</i> (M. E. Jones) Turner | S | yes | m | 1 |
| <i>Heliopsis parviflora</i> A. Gray <i>rubra</i> (Fish.) Wiggins | V | yes | m | 1 |
| <i>Hemizonia frutescens</i> A. Gray | S | yes | s | 1 |
| <i>Hemizonia greeneana</i> Rose <i>greeneana</i> Rose | S | yes | m | 1 |
| <i>Hemizonia greeneana</i> Rose <i>peninsulares</i> Moran | V | no | m | 1 |
| <i>Hemizonia martirensis</i> Keck | S | no | m | 1 |
| <i>Hemizonia palmeri</i> Rose | S | yes | s | 1 |
| <i>Hemizonia perennis</i> Keck | S | no | s | 1 |
| <i>Hemizonia streetsii</i> A. Gray | S | no | s | 1 |
| <i>Heterosperma coreocarpoides</i> Sherff. | S | yes | m | 1 |
| <i>Heterosperma xantii</i> A. Gray | S | yes | m | 1 |
| <i>Heterotheca martirensis</i> R. Moran | S | yes | m | 1 |
| <i>Hofmeisteria fasciculata</i> (Bentham) Walp. <i>fasciculata</i> (Bentham) Walp. | V | yes | m | 2 |

| | | | | |
|---|---|-----|---|---|
| <i>Hofmeisteria fasciculata</i> (Bentham) Walp. | V | yes | m | 1 |
| <i>pubescens</i> (S. Watson) B. L. Robinson | | | | |
| <i>Hofmeisteria fasciculata</i> (Bentham) Walp. <i>xantii</i> A. Gray | V | yes | m | 1 |
| <i>Hofmeisteria filifolia</i> I. M. Johnston | S | yes | m | 1 |
| <i>Hymenoclea platyspina</i> Seaman | S | no | m | 1 |
| <i>Isocoma menziesii</i> (Hooker & Arn.) G. Nesom | S | yes | m | 1 |
| <i>furfuraceus</i> (E. Greene) Hall | | | | |
| <i>Isocoma menziesii</i> (Hooker & Arn.) G. Nesom | S | no | m | 1 |
| <i>tridentatus</i> (E. Greene) Hall | | | | |
| <i>Isocoma veneta</i> (H.B.K.) E. Greene <i>oxyphylla</i> (E. Greene) Beauchamp | V | yes | m | 1 |
| <i>Machaeranthera arenaria</i> (Bentham) Shinnery | S | yes | m | 1 |
| <i>Machaeranthera crispa</i> (Brandege) Turner & Home | S | yes | m | 1 |
| <i>Machaeranthera wigginsii</i> (Blake) Hartman | S | yes | m | 1 |
| <i>Malacothrix carterae</i> Davis | S | yes | s | 1 |
| <i>Malacothrix xantii</i> A. Gray | S | yes | l | 1 |
| <i>Melampodium sinuatum</i> Brandege | S | no | s | 1 |
| <i>Nicolletia trifida</i> Rydb. | S | yes | l | 1 |
| <i>Palafoxia linearis</i> (Cav.) Lag. <i>glandulosa</i> | V | yes | s | 2 |
| <i>Parthenice mollis</i> A. Gray <i>peninsularis</i> Sauck | V | no | m | 1 |
| <i>Pectis multiseta</i> Bentham <i>ambigua</i> (Fernald) Keil | V | yes | m | 1 |
| <i>Pectis multiseta</i> Bentham <i>multiseta</i> Bentham | V | yes | m | 1 |
| <i>Pectis vollmeri</i> Wiggins | S | no | m | 1 |
| <i>Pelucha trifida</i> S. Watson | S | yes | m | 2 |
| <i>Perezia palmeri</i> S. Watson | S | yes | m | 1 |
| <i>Perezia pinetorum</i> Brandege | S | yes | m | 1 |
| <i>Perityle aurea</i> Rose | S | yes | m | 2 |

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|--|---|-----|---|---|
| <i>Perityle crassifolia</i> Brandegee <i>crassifolia</i> Brandegee | V | no | s | 1 |
| <i>Pentyle crassifolia</i> Brandegee <i>robusta</i> (Rydb.) Eyerly | V | yes | l | 1 |
| <i>Perityle cuneata</i> Brandegee | S | yes | m | 1 |
| <i>Perityle incana</i> A. Gray | S | yes | s | 1 |
| <i>Perityle incompta</i> Brandegee | S | yes | m | 1 |
| <i>Perityle lobata</i> (Rydb.) I. M. Johnston | S | no | m | 1 |
| <i>Pluchea adnata</i> (Humb. & Bonpl.) Mohr <i>parvifolia</i> | S | no | m | 2 |
| <i>Porophyllum confertum</i> E. Greene | S | yes | m | 2 |
| <i>Porophyllum crassifolium</i> S. Watson | S | yes | m | 2 |
| <i>Porophyllum maritimum</i> Brandegee | S | no | m | 1 |
| <i>Porophyllum ochroleucum</i> Rydb. | S | yes | m | 1 |
| <i>Porophyllum porfyreum</i> Rose & Standley | S | no | m | 1 |
| <i>Porophyllum tridentatum</i> Benthham | S | yes | m | 1 |
| <i>Rumfordia connata</i> Brandegee | S | yes | m | 1 |
| <i>Senecio californicus</i> DC. <i>ammophilus</i> | V | no | m | 1 |
| <i>Senecio cedrosensis</i> E. Greene | S | no | s | 1 |
| <i>Senecio palmeri</i> A. Gray | S | yes | s | 1 |
| <i>Sphaeromeria martirensis</i> (Wiggins) Holmgren Schultz & Lowery | S | yes | s | 1 |
| <i>Stenotus pulvinatus</i> R. Moran | S | yes | s | 1 |
| <i>Stephanomeria guadalupensis</i> Brandegee | S | yes | s | 1 |
| <i>Stephanomeria monocephala</i> R. Moran | S | yes | s | 1 |
| <i>Tagetes lacera</i> Brandegee | S | yes | m | 1 |
| <i>Trixis californica</i> Kellogg <i>peninsularis</i> (S. F. Blake) C. Anderson | S | yes | l | 1 |
| <i>Verbesina erosa</i> Brandegee | S | yes | m | 1 |
| <i>Verbesina hastata</i> Kellogg | S | yes | s | 1 |

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|--|---|-----|---|---|
| <i>Verbesina oligocephala</i> I. M. Johnston | S | no | m | 1 |
| <i>Verbesina palmeri</i> S. Watson | S | yes | m | 2 |
| <i>Verbesina peninsularis</i> S. F. Blake | S | yes | m | 1 |
| <i>Verbesina pustulata</i> M. E. Jones | S | no | s | 1 |
| <i>Viguiera chenopodina</i> E. Greene | V | yes | l | 1 |
| <i>Viguiera deltoidea</i> A. Gray | S | yes | m | 1 |
| <i>Viguiera lanata</i> (Kellogg) A. Gray | S | yes | m | 1 |
| <i>Viguiera lanciniata</i> A. Gray | S | yes | l | 1 |
| <i>Viguiera microphylla</i> Vasey & Rose | S | yes | l | 1 |
| <i>Viguiera purissimae</i> Brandegeee | S | yes | m | 1 |
| <i>Viguiera subincisa</i> Bentham | S | no | s | 1 |
| <i>Viguiera tomentosa</i> A. Gray | S | yes | l | 1 |
| <i>Viguiera triangularis</i> M. E. Jones | S | yes | l | 2 |
| <i>Xylothamnia diffusa</i> (Bentham) Nesom | S | yes | m | 1 |

BEGONIACEAE

| | | | | |
|---------------------------------------|---|-----|---|---|
| <i>Begonia californica</i> Brandegeee | S | yes | s | 1 |
|---------------------------------------|---|-----|---|---|

BORAGINACEAE

| | | | | |
|---|---|-----|---|---|
| <i>Antiphytum peninsulare</i> (Rose) I. M. Johnston | G | yes | s | 1 |
| <i>Bourreria sonorae</i> S. Watson | S | yes | m | 2 |
| <i>Cryptantha angelica</i> I. M. Johnston | S | yes | m | 2 |
| <i>Cryptantha echinosepala</i> J. F. MacBr. | S | yes | m | 1 |
| <i>Cryptantha fastigiata</i> I. M. Johnston | S | yes | l | 2 |
| <i>Cryptantha foliosa</i> (E. Greene) E. Greene | S | yes | s | 1 |
| <i>Cryptantha grayi</i> (Vasey & Rose) MacBr. | V | yes | l | 1 |
| <i>cryptochaeta</i> (MacBr.) I. M. Johnston | | | | |
| <i>Cryptantha grayi</i> (Vasey & Rose) MacBr. <i>grayi</i> (Vasey & Rose) MacBr. | V | yes | m | 1 |

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|--|--------------------|---|-----|---|---|
| <i>Cryptantha grayi</i> (Vasey & Rose) MacBr | <i>nesiotica</i> I | V | yes | m | 1 |
| M. Johnston | | | | | |
| <i>Cryptantha maritima</i> (E. Greene) E. Greene | | V | yes | m | 1 |
| <i>cedrosensis</i> (E. Greene) I. M. Johnston | | | | | |
| <i>Cryptantha patula</i> E. Greene | | S | no | s | 1 |
| <i>Pectocarya peninsularis</i> I. M. Johnston | | S | yes | m | 1 |
| BRASSICACEAE | | | | | |
| <i>Dithyrea californica</i> Harv. <i>clinata</i> (MacBr & Payson) | | V | yes | m | 1 |
| Wiggins | | | | | |
| <i>Draba corrugata</i> S. Watson <i>demareei</i> (Wiggins) C. | | V | yes | m | 1 |
| L. Hitchcock | | | | | |
| <i>Dryopetalon crenatum</i> (Brandege) Rollins | | S | no | m | 1 |
| <i>Dryopetalon crenatum</i> (Brandege) Rollins | | S | yes | s | 1 |
| <i>racemosum</i> Rollins | | | | | |
| <i>Dryopetalon purpureum</i> Rollins | | S | no | m | 1 |
| <i>Erysimum moranii</i> Rollins | | S | yes | s | 1 |
| <i>Lepidium lasiocarpum</i> Nuttall in Torrey & Gray | | V | yes | m | 1 |
| <i>palmeri</i> (S. Watson) C. L. Hitchcock | | | | | |
| <i>Lesquerella peninsularis</i> Wiggins | | S | yes | s | 1 |
| <i>Lyrocarpa coulteri</i> Hooker & Harv. ex Harv. <i>apiculata</i> | | V | yes | m | 1 |
| Rollins | | | | | |
| <i>Lyrocarpa linearifolia</i> Rollins in Gentry | | S | yes | s | 1 |
| <i>Lyrocarpa xantii</i> Brandege | | S | no | m | 1 |
| <i>Sibara angelorum</i> (S. Watson) E. Greene | | S | yes | m | 1 |
| <i>Sibara brandegeana</i> (Rose) E. Greene | | S | yes | m | 1 |
| <i>Sibara laxa</i> (Rose) E. Greene | | S | yes | l | 1 |
| <i>Sibara pectinata</i> (E. Greene) E. Greene | | S | yes | m | 1 |

BROMELIACEAE

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|--|---|----|---|---|
| <i>Tillandsia ferrisiana</i> L. B. Smith | S | no | s | 1 |
|--|---|----|---|---|

BUDDLEJACEAE

| | | | | |
|--|---|-----|---|---|
| <i>Buddleja corrugata</i> M. E. Jones <i>corrugata</i> M. E. | S | yes | m | 1 |
|--|---|-----|---|---|

Jones

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|-------------------------------------|---|-----|---|---|
| <i>Buddleja crotonoides</i> A. Gray | S | yes | m | 2 |
|-------------------------------------|---|-----|---|---|

BURSERACEAE

| | | | | |
|--------------------------------------|---|-----|---|---|
| <i>Bursera cerasifolia</i> Brandegee | S | yes | s | 1 |
|--------------------------------------|---|-----|---|---|

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|---|---|-----|---|---|
| <i>Bursera laxiflora</i> S. Watson <i>filicifolia</i> (Brandegee) | V | yes | m | 1 |
|---|---|-----|---|---|

Felger & Lowe

CACTACEAE

| | | | | |
|--|---|----|---|---|
| <i>Bergerocactus emoryi</i> (Engelmann) Britton & Rose | G | no | m | 2 |
|--|---|----|---|---|

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|---|---|----|---|---|
| <i>Cochemiea halei</i> (Brandegee) Walton | G | no | s | 1 |
|---|---|----|---|---|

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|--|---|----|---|---|
| <i>Cochemiea pondii</i> (E. Greene) Walton | G | no | s | 1 |
|--|---|----|---|---|

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|--|---|-----|---|---|
| <i>Cochemiea poselgeri</i> (Hildmann) Britton & Rose | G | yes | m | 1 |
|--|---|-----|---|---|

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|---|---|-----|---|---|
| <i>Cochemiea setispina</i> (Coulter) Walton | G | yes | m | 1 |
|---|---|-----|---|---|

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|--|---|----|---|---|
| <i>Echinocereus barthelowanus</i> Britton & Rose | S | no | s | 1 |
|--|---|----|---|---|

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|--|---|-----|---|---|
| <i>Echinocereus brandegeei</i> (Coulter) K. Schum. | S | yes | l | 1 |
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|--|---|-----|---|---|
| <i>Echinocereus ferreirianus</i> Gates | S | yes | m | 1 |
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|--|---|-----|---|---|
| <i>Echinocereus grandis</i> Britton & Rose | S | yes | s | 2 |
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|---|---|-----|---|---|
| <i>Echinocereus maritimus</i> (M. E. Jones) K. Schum. | S | yes | m | 2 |
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|---|---|-----|---|---|
| <i>Echinocereus pensilis</i> (K. Brandegee) J.A. Purpus | S | yes | m | 1 |
|---|---|-----|---|---|

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|---|---|----|---|---|
| <i>Echinocereus sciurus</i> (K. Brandegee) Britton & Rose | S | no | m | 1 |
|---|---|----|---|---|

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|---|---|----|---|---|
| <i>Ferocactus chrysacanthus</i> (Orcutt) Britton & Rose | S | no | s | 1 |
|---|---|----|---|---|

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|---|---|-----|---|---|
| <i>Ferocactus cylindraceus</i> (Engelmann) Orcutt | V | yes | m | 1 |
|---|---|-----|---|---|

tortulospinus (Gates) Lindsay

| | | | | |
|---|---|-----|---|---|
| <i>Ferocactus diguetii</i> (Weber) Britton & Rose <i>diguetii</i> | V | yes | s | 1 |
|---|---|-----|---|---|

(Weber) Britton & Rose

| | | | | |
|---|---|-----|---|---|
| <i>Ferocactus fordii</i> (Orcutt) Britton & Rose <i>fordii</i> (Orcutt) Britton & Rose | V | yes | s | 1 |
| <i>Ferocactus fordii</i> (Orcutt) Britton & Rose <i>grandiflorus</i> Lindsay | V | yes | m | 1 |
| <i>Ferocactus gatesii</i> Lindsay | S | yes | s | 1 |
| <i>Ferocactus gracilis</i> Gates <i>coloratus</i> (Gates) Lindsay | S | yes | m | 1 |
| <i>Ferocactus gracilis</i> Gates <i>gracilis</i> Gates | S | no | s | 1 |
| <i>Ferocactus johnstonianus</i> Britton & Rose | S | yes | s | 1 |
| <i>Ferocactus peninsulare</i> (Engelmann ex A. Weber) Britton & Rose <i>peninsulae</i> | S | yes | m | 1 |
| <i>Ferocactus peninsulare</i> (Engelmann ex A. Weber) Britton & Rose <i>viscainensis</i> (Gates) Lindsay | S | yes | m | 1 |
| <i>Ferocactus rectispinus</i> (Engelmann) Britton & Rose | S | yes | m | 1 |
| <i>Ferocactus townsendianus</i> Britton & Rose <i>townsendianus</i> Britton & Rose | S | no | m | 1 |
| <i>Lophocereus gatesii</i> M. E. Jones | S | no | m | 1 |
| <i>Lophocereus schottii</i> (Engelmann) Britton & Rose <i>australis</i> (K. Brandegee) Borg. | V | yes | m | 1 |
| <i>Lophocereus schottii</i> (Engelmann) Britton & Rose <i>monstruosus</i> Lindsay | V | yes | m | 1 |
| <i>Mammillaria albicans</i> (Britton & Rose) Berger | S | yes | m | 2 |
| <i>Mammillaria angelensis</i> Craig | S | yes | m | 1 |
| <i>Mammillaria armillata</i> K. Brandegee | S | yes | m | 1 |
| <i>Mammillaria baxteriana</i> (Gates) Boed. | S | yes | s | 1 |
| <i>Mammillaria blossfeldiana</i> Boedeker <i>shurliana</i> (Gates) Wiggins | S | yes | m | 1 |
| <i>Mammillaria brandegeei</i> (Coulter) K. Brandegee | S | no | s | 1 |
| <i>Mammillaria capensis</i> (Gates) Craig | S | no | s | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Mammillaria cerralboa</i> (Britton & Rose) Orcutt | S | yes | s | 1 |
| <i>Mammillaria estabanensis</i> Lindsay | S | yes | s | 1 |
| <i>Mammillaria evermanniana</i> (Britton & Rose) Orcutt | S | yes | s | 2 |
| <i>Mammillaria fraileana</i> (Britton & Rose) Boed. | S | yes | m | 1 |
| <i>Mammillaria goodridgei</i> Scheer <i>goodridgei</i> Scheer | S | yes | m | 1 |
| <i>Mammillaria goodridgei</i> Scheer <i>rectispina</i> Dawson | S | no | s | 1 |
| <i>Mammillaria hutchinsoniana</i> (Gates) Boed. | S | yes | m | 1 |
| <i>Mammillaria insularis</i> Gates | S | yes | s | 2 |
| <i>Mammillaria lewisiana</i> Gates | S | yes | s | 1 |
| <i>Mammillaria louisae</i> Lindsay | S | no | s | 1 |
| <i>Mammillaria neopalmeri</i> Craig | S | no | s | 1 |
| <i>Mammillaria peninsularis</i> (Britton & Rose) Orcutt | S | no | s | 1 |
| <i>Mammillaria schumannii</i> (Hildmann) Britton & Rose | S | no | s | 1 |
| <i>Myrtillocactus cochal</i> (Orcutt) Britton & Rose | S | yes | l | 2 |
| <i>Opuntia alcahes</i> F.A.C. Weber <i>alcahes</i> F.A.C. Weber | S | yes | m | 1 |
| <i>Opuntia alcahes</i> F.A.C. Weber <i>burrageana</i> (Britton et Rose) J. Rebman | S | yes | m | 1 |
| <i>Opuntia bravoana</i> E. M. Baxter | S | yes | m | 2 |
| <i>Opuntia brevispina</i> Gates | S | yes | s | 1 |
| <i>Opuntia californica</i> (Torrey & Gray) Cov. <i>rosarica</i> (Lindsay) J. Rebman | S | yes | m | 1 |
| <i>Opuntia cedrosensis</i> J. Rebman | S | no | s | 1 |
| <i>Opuntia cholla</i> F.A.C. Weber | S | yes | l | 1 |
| <i>Opuntia cineracea</i> Wiggins | S | yes | m | 1 |
| <i>Opuntia echinocarpa</i> Engelmann & J. Bigelow <i>echinocarpa</i> Engelmann et Bigelow | V | yes | m | 1 |
| <i>Opuntia invicta</i> T. S. Brandegee | S | yes | m | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Opuntia lagunae</i> Baxter | S | yes | m | 1 |
| <i>Opuntia molesta</i> K. Brandegee | S | yes | l | 2 |
| <i>Opuntia oricola</i> Philbrick | S | no | s | 1 |
| <i>Opuntia prolifera</i> Engelman | S | yes | m | 2 |
| <i>Opuntia pycnantha</i> Engelman in Coulter | S | no | m | 1 |
| <i>Opuntia santamaria</i> (Baxter) Bravo | S | no | s | 1 |
| <i>Opuntia tapona</i> Engelman in Coulter | S | yes | m | 1 |
| <i>Opuntia tesajo</i> Engelman in Coulter | S | yes | l | 1 |
| <i>Pachgerocereus orcuttii</i> (K. Brandegee) Moran | G | yes | s | 1 |
| <i>Peniocereus johnstonii</i> Britton & Rose | S | yes | s | 1 |
| <i>Stenocereus eruca</i> (K. Brandegee) Gibson & Horak | S | no | m | 1 |
| <i>Stenocereus gummosus</i> (Engelman) Gibson & Horak | S | yes | l | 2 |
| CAMPANULACEAE | | | | |
| <i>Githopsis diffusa</i> A. Gray <i>guadalupensis</i> | V | yes | s | 1 |
| <i>Heterotoma aurita</i> Brandegee | S | yes | m | 1 |
| <i>Lobelia dunnii</i> E. Greene <i>dunnii</i> E. Greene | V | yes | m | 1 |
| <i>Nemacladus glanduliferus</i> Jepson <i>australis</i> (Munz) McVaugh | V | yes | m | 1 |
| CARYOPHYLLACEAE | | | | |
| <i>Drymaria arenarioides</i> Willd. <i>peninsularis</i> (Blake) J. Duke | S | yes | m | 1 |
| <i>Drymaria debilis</i> Brandegee | S | yes | m | 1 |
| <i>Drymaria glandulosa</i> Presl. | S | yes | m | 1 |
| <i>Drymaria holosteoides</i> Benth <i>crassifolia</i> (Benth) J. Duke | V | yes | l | 1 |
| <i>Drymaria viscosa</i> S. Watson | S | yes | l | 2 |

| | | | | |
|---|---|-----|---|---|
| <i>Paronychia mexicana</i> Hemsl. <i>monandra</i> (Brandegee) Chaudhri | | no | s | 1 |
| <i>Silene laciniata</i> Cav. <i>brandegeei</i> Hitchcock & Maguire | V | yes | m | 1 |
| CHENOPODIACEAE | | | | |
| <i>Atriplex barclayana</i> (Bentham) D. Dietr. <i>dilatata</i> (E. Greene) Hall & Clements | V | yes | s | 1 |
| <i>Atriplex barclayana</i> (Bentham) D. Dietr. <i>lurida</i> (Brandegee) Hall & Clements | V | yes | m | 1 |
| <i>Atriplex julacea</i> S. Watson | S | yes | l | 2 |
| <i>Atriplex magdalenae</i> T. S. Brandegee | S | yes | m | 1 |
| <i>Chenopodium flabellifolium</i> Standley | S | no | s | 1 |
| CISTACEAE | | | | |
| <i>Helianthemum nutans</i> Brandegee | S | yes | m | 1 |
| COMMELINACEAE | | | | |
| <i>Gibasis heterophylla</i> (T. S. Brandegee) Reveal & Hess | S | yes | m | 1 |
| <i>Tinantia modesta</i> T. S. Brandegee | S | yes | s | 1 |
| <i>Tradescantia peninsularis</i> T. S. Brandegee | S | yes | m | 1 |
| CONVOLVULACEAE | | | | |
| <i>Calonyction tastense</i> (Brandegee) House | S | yes | s | 1 |
| <i>Calystegia macrostegia</i> (E. Greene) Brummitt <i>tenuifolius</i> Abrams | V | no | m | 1 |
| <i>Cuscuta veatchii</i> Brandegee | S | yes | m | 1 |
| <i>Ipomoea jicama</i> Brandegee | S | no | m | 1 |
| <i>Ipomoea peninsularis</i> Brandegee | S | yes | s | 1 |
| <i>Jacquemontia abutiloides</i> Bentham <i>abutiloides</i> Bentham | V | yes | l | 1 |

Jacquemontia abutiloides Bentham *eastwoodiana* V yes m 2
(I. M. Johnston) Wiggins

Merremia aurea (Kellogg) O'Donnell S yes l 1

CRASSULACEAE

Dudleya acuminata Rose S yes m 1

Dudleya albiflora Rose S yes m 1

Dudleya anomala (Davidson) Moran S no m 1

Dudleya campanulata R. Moran S no s 1

Dudleya candida Britton S yes s 1

Dudleya cedrosensis R. Moran S no s 1

Dudleya gatesii Johansen S yes m 1

Dudleya guadalupensis R. Moran S yes s 1

Dudleya ingens Rose S no m 1

Dudleya linearis (E. Greene) Britton & Rose S yes s 1

Dudleya nubigena (Brandege) Britton & Rose S yes s 1

cerralvensis Moran

Dudleya pachyphytum R. Moran S no s 1

Dudleya pauciflora Rose S yes s 1

Dudleya rubens (Brandege) Britton & Rose S no m 1

Dudleya virens (Rose) Moran S yes s 1

CUCURBITACEAE

Cucurbita cordata S. Watson S yes l 1

Cucurbita cylindrata Bailey S yes s 1

Echinopepon minimus (Kellogg) S. Watson S yes l 1

Echinopepon peninsularis Gentry S yes m 2

Ibervillea insularis Brandege S no s 1

Ibervillea sonorae (S. Watson) E. Greene V yes m 2

peninsularis I. M. Johnston

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|---|---|-----|---|---|
| <i>Marah guadalupensis</i> (S. Watson) E. Greene | S | yes | s | 1 |
| <i>Sicyos peninsularis</i> Brandegee | S | no | s | 1 |
| <i>Vaseyanthus brandegee</i> (Cogn.) Rose | S | yes | m | 1 |
| <i>Vaseyanthus insularis</i> (S. Watson) Rose <i>inermis</i> I. M. Johnston | S | yes | m | 1 |
| <i>Vaseyanthus insularis</i> (S. Watson) Rose <i>insularis</i> (S. Watson) Rose | S | yes | m | 1 |
| CUPRESSACEAE | | | | |
| <i>Cupressus arizonica</i> E. Greene <i>montana</i> (Wiggins) Little | S | yes | m | 1 |
| <i>Cupressus guadalupensis</i> S. Watson <i>guadalupensis</i> S. Watson | S | yes | s | 1 |
| CYPERACEAE | | | | |
| <i>Cyperus dioicus</i> I. M. Johnston | S | yes | m | 1 |
| DRACAENACEAE | | | | |
| <i>Nolina beltingii</i> T. S. Brandegee | S | yes | l | 1 |
| <i>Nolina palmeri</i> S. Watson <i>palmeri</i> S. Watson | V | yes | l | 1 |
| EBENACEAE | | | | |
| <i>Diospyros californica</i> (Brandegee) I. M. Johnston <i>californica</i> | V | yes | m | 1 |
| <i>Maba intricata</i> (A. Gray) Hiern | S | yes | m | 1 |
| ERICACEAE | | | | |
| <i>Arbutus peninsularis</i> Rose & Goldman | S | yes | m | 1 |
| <i>Arctostaphylos australis</i> Eastwood | S | no | m | 1 |
| <i>Arctostaphylos patula</i> E. Greene <i>platyphylla</i> (A. Gray) P. Wells | V | yes | m | 1 |
| <i>Arctostaphylos peninsularis</i> Wells | S | yes | l | 1 |
| <i>Ornithostaphylos oppositifolia</i> (C. Parry) Small | G | no | m | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Xylococcus bicolor</i> Nuttall | G | yes | m | 1 |
| EUPHORBIACEAE | | | | |
| <i>Acalypha comonduana</i> Millsp. | S | yes | l | 1 |
| <i>Acalypha saxicola</i> Wiggins | S | no | m | 1 |
| <i>Andrachne ciliato-glandulosa</i> (Millsp.) Croizat | S | yes | m | 1 |
| <i>Bernardia lagunensis</i> (M. E. Jones) L. C. Wheeler | S | yes | m | 1 |
| <i>Croton boregensis</i> M. E. Jones | S | yes | m | 1 |
| <i>Croton caboensis</i> Croizat | S | yes | m | 1 |
| <i>Croton magdalenae</i> Millsp. | S | yes | l | 2 |
| <i>Ditaxis brandegeei</i> (Millsp.) Rose & Standley | V | yes | m | 1 |
| brandegeei | | | | |
| <i>Euphorbia apicata</i> L. C. Wheeler | S | yes | m | 1 |
| <i>Euphorbia bartolomaei</i> E. Greene | S | yes | m | 1 |
| <i>Euphorbia brandegeei</i> Millsp. | S | yes | m | 1 |
| <i>Euphorbia californica</i> Bentham <i>hindsiana</i> (Bentham) | V | yes | m | 1 |
| Wiggins | | | | |
| <i>Euphorbia dentosa</i> I. M. Johnston | S | yes | m | 1 |
| <i>Euphorbia heterophylla</i> L. <i>eriocarpa</i> Millsp. | V | yes | m | 1 |
| <i>Euphorbia lagunensis</i> Huft. | S | yes | m | 1 |
| <i>Euphorbia magdalenae</i> Bentham | S | yes | l | 2 |
| <i>Euphorbia peninsularis</i> I. M. Johnston | S | yes | m | 1 |
| <i>Euphorbia polycarpa</i> (Bentham) Millsp. <i>carmenensis</i> | V | yes | m | 2 |
| (Rose) L. C. Wheeler | | | | |
| <i>Euphorbia polycarpa</i> (Bentham) Millsp. <i>johnstonii</i> L. | V | yes | m | 1 |
| C. Wheeler | | | | |
| <i>Euphorbia polycarpa</i> (Bentham) Millsp. <i>mejamia</i> L. | V | yes | m | 1 |
| C. Wheeler | | | | |
| <i>Euphorbia pondii</i> Millsp. | S | yes | m | 1 |

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|---|---|-----|---|---|
| <i>Jatropha vernicosa</i> Brandegee | S | yes | m | 1 |
| FABACEAE | | | | |
| <i>Acacia brandegeana</i> I. M. Johnston | S | no | l | 1 |
| <i>Acacia goldmanii</i> (Britton & Rose) Wiggins | S | yes | l | 1 |
| <i>Acacia kelloggiana</i> Carter & Rudd | S | no | s | 1 |
| <i>Acacia mcmurphyi</i> Wiggins | S | yes | m | 1 |
| <i>Acacia pacensis</i> Rudd & Carter | S | yes | m | 1 |
| <i>Acacia peninsularis</i> (Britton & Rose) Standley | S | no | m | 1 |
| <i>Aeschynomene nivea</i> Brandegee | S | yes | l | 1 |
| <i>Aeschynomene vigil</i> Brandegee | S | no | m | 1 |
| <i>Amorpha apiculata</i> Wiggins | S | yes | m | 1 |
| <i>Astragalus anemophilus</i> E. Greene | S | no | m | 1 |
| <i>Astragalus circumdatus</i> E. Greene | S | yes | m | 1 |
| <i>Astragalus douglasii</i> (Torrey & A. Gray) A. Gray | V | yes | m | 1 |
| <i>glaberrimus</i> M. E. Jones | | | | |
| <i>Astragalus fastidius</i> (Kellogg) M. E. Jones | S | yes | m | 1 |
| <i>Astragalus francisquitensis</i> M. E. Jones <i>lagunensis</i> M. E. Jones | S | yes | m | 1 |
| <i>Astragalus francisquitensis</i> M. E. Jones | S | yes | m | 1 |
| <i>Astragalus gruinus</i> Barneby | S | yes | m | 1 |
| <i>Astragalus harbisonii</i> Barneby | S | yes | m | 1 |
| <i>Astragalus homii</i> A. Gray <i>minutiflorus</i> M. E. Jones | S | yes | m | 1 |
| <i>Astragalus idrietorum</i> Barneby | S | yes | m | 1 |
| <i>Astragalus insularis</i> Kellogg <i>harwoodii</i> Munz & McBurney | V | yes | m | 1 |
| <i>Astragalus insularis</i> Kellogg <i>insularis</i> Kellogg | V | yes | l | 1 |
| <i>Astragalus insularis</i> Kellogg <i>quintinensis</i> M. E. Jones | V | yes | m | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Astragalus orcuttianus</i> S. Watson | S | yes | m | 1 |
| <i>Astragalus piscinus</i> (M. E. Jones) Barneby | S | yes | s | 1 |
| <i>Astragalus prorifer</i> M. E. Jones | S | yes | l | 1 |
| <i>Astragalus sanctorum</i> Hooker & Arn. | S | no | s | 1 |
| <i>Brongniartia peninsularis</i> Rose | S | no | m | 1 |
| <i>Brongniartia trifoliata</i> Brandegee | S | yes | m | 1 |
| <i>Caesalpinia arenosa</i> Wiggins | S | yes | l | 1 |
| <i>Caesalpinia californica</i> (A. Gray) Standley | S | yes | m | 1 |
| <i>Caesalpinia pannosa</i> Brandegee | S | yes | l | 1 |
| <i>Caesalpinia peninsularis</i> (Britton) Eifert | S | no | m | 1 |
| <i>Caesalpinia placida</i> Brandegee | S | yes | m | 1 |
| <i>Calliandra brandegeei</i> (Britton & Rose) Gentry | S | yes | m | 1 |
| <i>Calliandra californica</i> Bentham | S | yes | l | 2 |
| <i>Calliandra peninsularis</i> Rose | S | yes | m | 1 |
| <i>Cercidium floridum</i> Bentham ex. A. Gray <i>peninsulare</i> (Rose) Carter | V | yes | l | 1 |
| <i>Dalea brandegeei</i> (Rose) Bullock | S | yes | m | 1 |
| <i>Dalea juncea</i> (Rydb.) Wiggins | S | yes | m | 1 |
| <i>Dalea megalostachys</i> (Rose) Wiggins | S | yes | l | 1 |
| <i>Dalea orcuttii</i> S. Watson | S | yes | m | 1 |
| <i>Dalea peninsularis</i> (Rose) Bullock | S | yes | m | 1 |
| <i>Dalea purpusii</i> Brandegee | S | yes | m | 1 |
| <i>Dalea trochilina</i> Brandegee | S | yes | m | 1 |
| <i>Dalea vetula</i> Brandegee | S | yes | l | 2 |
| <i>Desmanthus fruticosus</i> Rose | S | yes | l | 2 |
| <i>Desmanthus oligospermus</i> Brandegee | S | no | m | 1 |
| <i>Desmodium prostratum</i> Brandegee | S | yes | m | 1 |
| <i>Errazurizia benthami</i> (Brandegee) I. M. Johnston | S | yes | m | 1 |

| | | | | |
|--|---|-----|---|---|
| <i>Errazurizia megacarpa</i> (S. Watson) I. M. Johnston | S | yes | l | 2 |
| <i>Eysenhardtia peninsularis</i> Brandegee | S | yes | m | 1 |
| <i>Indigofera fruticosa</i> Rose | S | yes | m | 2 |
| <i>Indigofera nelsonii</i> Rydb. | S | yes | s | 1 |
| <i>Leucaena brandegeei</i> Britton & Rose | S | no | s | 1 |
| <i>Lotus bryantii</i> (Brandegee) Ottley | S | yes | l | 1 |
| <i>Lotus cedrosensis</i> E. Greene | S | no | s | 1 |
| <i>Lotus distichus</i> E. Greene | S | yes | m | 1 |
| <i>Lotus nudatus</i> E. Greene | S | no | s | 1 |
| <i>Lotus oroboides</i> (H.B.K.) Ottley <i>ramulosus</i> (M. E. Jones) Ottley | V | yes | m | 1 |
| <i>Lupinus andersonii</i> S. Watson <i>sublinearis</i> C. P. Smith | V | yes | m | 1 |
| <i>Lupinus arizonicus</i> (S. Watson) S. Watson | S | yes | l | 2 |
| <i>lagunensis</i> (M.E. Jones) Christ. & Dunn | | | | |
| <i>Lupinus niveus</i> S. Watson | S | yes | s | 1 |
| <i>Lupinus sparsiflorus</i> Bentham <i>insignitus</i> C. P. Smith | V | yes | m | 1 |
| <i>Lysiloma candidum</i> T. S. Brandegee | S | yes | l | 1 |
| <i>Marina catalinae</i> Barneby | S | yes | s | 1 |
| <i>Marina chrysorrhiza</i> (A. Gray) Barneby | S | no | m | 1 |
| <i>Marina divaricata</i> (Bentham) Barneby <i>anthonyi</i> (Brandegee) Wiggins | V | yes | m | 1 |
| <i>Marina divaricata</i> (Bentham) Barneby <i>divaricata</i> Bentham | V | yes | m | 1 |
| <i>Marina maritima</i> (Brandegee) Barneby | S | no | m | 1 |
| <i>Marina oculata</i> (Rydb.) Barneby | S | yes | s | 1 |
| <i>Mimosa margaritae</i> Rose in Britton & Rose | S | yes | m | 1 |
| <i>Nissolia setosa</i> Brandegee | S | no | s | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Petalostemon evanescens</i> (Brandege) Rose | S | no | m | 1 |
| <i>Prosopidastrum mexicanum</i> (Dressler) Burkart | S | yes | m | 1 |
| <i>Prosopis palmeri</i> S. Watson | S | no | l | 1 |
| <i>Psorothamnus emoryi</i> (A. Gray) Rydb. <i>arenarius</i> (Brandege) Barneby | V | yes | m | 1 |
| <i>Senna confinis</i> (E. Greene) Irwin & Barneby | S | yes | l | 2 |
| <i>Senna purpusii</i> (Brandege) Irwin & Barneby | S | yes | l | 1 |
| <i>Tephrosia cana</i> Brandege | S | yes | m | 1 |
| <i>Trifolium wigginsii</i> J. M. Gillett | S | yes | m | 1 |
| FAGACEAE | | | | |
| <i>Quercus brandegei</i> Goldman | S | yes | m | 1 |
| <i>Quercus cedrosensis</i> C. H. Müller | S | yes | l | 1 |
| <i>Quercus comelius-mulleri</i> Nixon & K. Steele | S | no | m | 1 |
| <i>Quercus devia</i> Goldman | S | yes | m | 1 |
| <i>Quercus peninsularis</i> Trelease | S | yes | l | 1 |
| FOUQUIERIACEAE | | | | |
| <i>Fouquieria burragei</i> Rose | S | yes | m | 1 |
| GARRYACEAE | | | | |
| <i>Garrya grisea</i> Wiggins | S | yes | l | 1 |
| <i>Garrya salicifolia</i> Eastwood | S | yes | m | 1 |
| GENTIANACEAE | | | | |
| <i>Centaurium nudicaule</i> (Engelmann) Robinson | S | yes | s | 2 |
| GERANIACEAE | | | | |
| <i>Geranium flaccidum</i> Small. | S | yes | m | 1 |
| GROSSULARIACEAE | | | | |
| <i>Ribes brandegei</i> Eastwood | S | yes | m | 1 |
| <i>Ribes tortuosum</i> Bentham | S | yes | l | 1 |
| <i>Ribes viburnifolium</i> A. Gray | S | yes | m | 1 |

GUTTIFERAE

| | | | | |
|--|---|-----|---|---|
| <i>Hypericum peninsulare</i> A. Eastwood | S | yes | m | 1 |
|--|---|-----|---|---|

HIPPOCASTANACEAE

| | | | | |
|--------------------------------|---|-----|---|---|
| <i>Aesculus parryi</i> A. Gray | S | yes | m | 1 |
|--------------------------------|---|-----|---|---|

HYDROPHYLLACEAE

| | | | | |
|--|---|----|---|---|
| <i>Eriodictyon sessilifolium</i> E. Greene | S | no | l | 1 |
|--|---|----|---|---|

| | | | | |
|---|---|-----|---|---|
| <i>Nama demissum</i> A. Gray <i>lineare</i> C. L. Hitchcock | V | yes | m | 1 |
|---|---|-----|---|---|

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|----------------------------------|---|-----|---|---|
| <i>Phacelia cedrosensis</i> Rose | S | yes | m | 1 |
|----------------------------------|---|-----|---|---|

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|----------------------------------|---|-----|---|---|
| <i>Phacelia hirtuosa</i> A. Gray | S | yes | m | 1 |
|----------------------------------|---|-----|---|---|

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|--------------------------------|---|-----|---|---|
| <i>Phacelia ixodes</i> Kellogg | S | yes | m | 1 |
|--------------------------------|---|-----|---|---|

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|--------------------------------------|---|-----|---|---|
| <i>Phacelia pauciflora</i> S. Watson | S | yes | l | 1 |
|--------------------------------------|---|-----|---|---|

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|--------------------------------------|---|-----|---|---|
| <i>Phacelia phyllomanica</i> A. Gray | S | yes | s | 1 |
|--------------------------------------|---|-----|---|---|

| | | | | |
|------------------------------------|---|-----|---|---|
| <i>Phacelia scariosa</i> Brandegee | S | yes | l | 2 |
|------------------------------------|---|-----|---|---|

KRAMERIACEAE

| | | | | |
|--|---|-----|---|---|
| <i>Krameria parvifolia</i> Bentham <i>parvifolia</i> Bentham | V | yes | m | 1 |
|--|---|-----|---|---|

LAMIACEAE

| | | | | |
|---------------------------------------|---|-----|---|---|
| <i>Hedeoma martirensense</i> R. Moran | S | yes | s | 1 |
|---------------------------------------|---|-----|---|---|

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|---------------------------------|---|----|---|---|
| <i>Hyptis collina</i> Brandegee | S | no | s | 1 |
|---------------------------------|---|----|---|---|

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|-------------------------------------|---|-----|---|---|
| <i>Hyptis decipiens</i> M. E. Jones | S | yes | m | 1 |
|-------------------------------------|---|-----|---|---|

| | | | | |
|--|---|----|---|---|
| <i>Hyptis emoryi</i> Torrey <i>amplifolia</i> I. M. Johnston | V | no | m | 1 |
|--|---|----|---|---|

| | | | | |
|---|---|-----|---|---|
| <i>Hyptis emoryi</i> Torrey <i>palmeri</i> (S. Watson) I. M. Johnston | V | yes | l | 1 |
|---|---|-----|---|---|

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|---------------------------------|---|-----|---|---|
| <i>Hyptis laniflora</i> Bentham | S | yes | l | 1 |
|---------------------------------|---|-----|---|---|

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|--|---|-----|---|---|
| <i>Lepechinia hastata</i> (A. Gray) Epling | S | yes | m | 1 |
|--|---|-----|---|---|

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|--|---|----|---|---|
| <i>Monardella thymifolia</i> E. Greene | S | no | s | 1 |
|--|---|----|---|---|

| | | | | |
|------------------------------------|---|-----|---|---|
| <i>Pogogyne tenuiflora</i> A. Gray | S | yes | s | 1 |
|------------------------------------|---|-----|---|---|

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|-------------------------------------|---|-----|---|---|
| <i>Salvia californica</i> Brandegee | S | yes | m | 1 |
|-------------------------------------|---|-----|---|---|

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|-------------------------------------|---|-----|---|---|
| <i>Salvia cedrosensis</i> E. Greene | S | yes | m | 1 |
|-------------------------------------|---|-----|---|---|

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|---|---|-----|---|---|
| <i>Salvia chionocephala</i> Epling | S | yes | m | 1 |
| <i>Salvia marci</i> Epling | S | yes | m | 1 |
| <i>Salvia munzii</i> Epling | S | yes | l | 1 |
| <i>Salvia peninsularis</i> Brandegee | S | yes | m | 1 |
| <i>Salvia platycheila</i> A. Gray | S | yes | m | 1 |
| <i>Salvia similis</i> Brandegee | S | yes | m | 2 |
| <i>Satureja ganderi</i> Epling | S | yes | m | 1 |
| <i>Satureja palmeri</i> (A. Gray) Briq. | S | yes | s | 1 |
| <i>Stachys tenerrima</i> Epling | S | yes | m | 1 |
| LILIACEAE | | | | |
| <i>Bessera tenuiflora</i> E. Greene | G | yes | m | 1 |
| <i>Calochortus weedii</i> Wood <i>peninsularis</i> Ownbey | V | yes | m | 1 |
| <i>Triteleia guadalupensis</i> L. Lenz | S | yes | s | 1 |
| LOASACEAE | | | | |
| <i>Eucnide aurea</i> (A. Gray) Thompson & Ernst | S | yes | m | 1 |
| <i>Eucnide tenella</i> (I. M. Johnston) Thompson & Ernst | S | no | s | 1 |
| <i>Mentzelia adhaerens</i> Bentham | S | yes | l | 1 |
| <i>Mentzelia hirsutissima</i> S. Watson <i>hirsutissima</i> S. Watson | V | yes | m | 2 |
| LYTHRACEAE | | | | |
| <i>Lythrum bryantii</i> Brandegee | S | no | m | 1 |
| MALPIGHACEAE | | | | |
| <i>Malpighia diversifolia</i> Brandegee | S | yes | m | 1 |
| MALVACEAE | | | | |
| <i>Abutilon aurantiacum</i> S. Watson | S | no | s | 2 |
| <i>Abutilon carterae</i> Kearney | S | yes | s | 1 |
| <i>Abutilon xantii</i> A. Gray | S | yes | m | 1 |
| <i>Gossypium armourianum</i> Kearney | S | yes | m | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Gossypium harknessii</i> Brandegee | S | yes | m | 1 |
| <i>Hibiscus ribifolius</i> A. Gray | S | no | m | 2 |
| <i>Lavatera lindsayi</i> R. Moran | S | yes | s | 1 |
| <i>Lavatera occidentalis</i> S. Watson | S | yes | s | 1 |
| <i>Lavatera venosa</i> S. Watson | S | yes | s | 1 |
| <i>Sphaeralcea axillaris</i> S. Watson <i>axillaris</i> S. Watson | V | yes | m | 1 |
| <i>Sphaeralcea axillaris</i> S. Watson <i>violacea</i> (Rose) | V | yes | m | 1 |
| Wiggins | | | | |
| <i>Sphaeralcea coulteri</i> (S. Watson) A. Gray <i>californica</i> (Rose) Kearney | V | yes | l | 1 |
| <i>Sphaeralcea coulteri</i> (S. Watson) A. Gray <i>margaritae</i> (Brandegee) Kearney | V | no | s | 1 |
| <i>Sphaeralcea fulva</i> E. Greene | S | yes | m | 1 |
| <i>Sphaeralcea hainesii</i> Brandegee | S | yes | m | 2 |
| <i>Sphaeralcea palmeri</i> Rose | S | yes | s | 1 |
| <i>Sphaeralcea sulphurea</i> S. Watson | S | yes | s | 1 |
| MORACEAE | | | | |
| <i>Ficus brandegeei</i> Standley | S | no | m | 1 |
| NYCTAGINACEAE | | | | |
| <i>Abronia carterae</i> Ferris | S | yes | m | 1 |
| <i>Abronia gracilis</i> Bentham <i>gracilis</i> Bentham | V | yes | l | 1 |
| <i>Abronia gracilis</i> Bentham <i>platyphylla</i> (Standley) | V | yes | m | 1 |
| Ferris | | | | |
| <i>Abronia maritima</i> Nuttall ex Watson <i>capensis</i> A. F. Johnson | V | no | s | 1 |
| <i>Commicarpus brandegeei</i> Standley | S | yes | m | 1 |
| <i>Mirabilis exserta</i> Brandegee | S | yes | m | 1 |
| <i>Mirabilis heimerlii</i> (Standley) MacBr. | S | yes | s | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Pisonia flavescens</i> Standley | S | yes | m | 1 |
| OLACACEAE | | | | |
| <i>Schoepfia californica</i> Brandegee | S | yes | l | 2 |
| OLEACEAE | | | | |
| <i>Forestiera macrocarpa</i> Brandegee | S | yes | s | 1 |
| <i>Forestiera pubescens</i> Nuttall | S | no | m | 1 |
| <i>Fraxinus trifoliata</i> (Torrey) Lewis & Epling | S | yes | l | 1 |
| <i>Hesperelaea palmeri</i> A. Gray | S | yes | s | 1 |
| ONAGRACEAE | | | | |
| <i>Camissonia angelorum</i> (S. Watson) Raven | S | yes | l | 1 |
| <i>Camissonia cardiophylla</i> (Torrey) Raven <i>cedrosensis</i> (E. Greene) Raven | V | yes | m | 1 |
| <i>Camissonia crassifolia</i> (E. Greene) Raven | S | yes | l | 1 |
| <i>Camissonia guadalupensis</i> (S. Watson) Raven <i>guadalupensis</i> (S. Watson) Raven | V | yes | s | 1 |
| <i>Camissonia proavita</i> Raven | S | yes | m | 1 |
| <i>Camissonia sceptrostigma</i> (T. S. Brandegee) Raven | S | yes | m | 1 |
| <i>Gongylocarpus fruticulosus</i> (Bentham) T. S. Brandegee <i>fruticulosus</i> | V | no | m | 1 |
| <i>Gongylocarpus fruticulosus</i> (Bentham) T. S. Brandegee <i>glaber</i> (Thomas) Raven | V | no | s | 1 |
| <i>Lopezia clavata</i> T. S. Brandegee | S | yes | m | 1 |
| <i>Oenothera drummondii</i> Hooker <i>thalassaphila</i> (Brandegee) Munz | V | no | m | 1 |
| <i>Oenothera wigginsii</i> W. Klein | V | yes | m | 1 |
| <i>Xylonagra arborea</i> (Kellogg) Donnell Smith & Rose <i>arborea</i> | G | yes | m | 1 |

| | | | | |
|--|---|-----|---|---|
| <i>Xylonagra arborea</i> (Kellogg) Donnell Smith & Rose <i>wigginsii</i> Munz | G | yes | m | 1 |
| ORCHIDACEAE | | | | |
| <i>Arethusa rosea</i> Bentham | S | yes | s | 1 |
| <i>Epipactis gigantea</i> (Douglas) Hooker | S | yes | m | 2 |
| PAPAVERACEAE | | | | |
| <i>Argemone subintegrifolia</i> G.P. Owenby | S | yes | m | 1 |
| <i>Eschscholzia palmeri</i> Rose | S | yes | s | 1 |
| PASSIFLORACEAE | | | | |
| <i>Passiflora arida</i> (Mast, & Rose) Killip <i>cerralbensis</i> Killip | V | yes | m | 2 |
| <i>Passiflora arida</i> (Mast, & Rose) Killip <i>pentachista</i> Killip | V | no | m | 1 |
| <i>Passiflora fruticosa</i> Killip | S | yes | m | 1 |
| <i>Passiflora palmeri</i> Rose | S | yes | i | 2 |
| PINACEAE | | | | |
| <i>Pinus contorta</i> Loudon <i>murrayana</i> (Grev. & Balf.) Critchf. | V | yes | s | 1 |
| <i>Pinus lagunae</i> (Passini & Bailey) Passini | S | yes | s | 1 |
| <i>Pinus radiata</i> D. Don <i>binata</i> (Engelmann in Watson) Lemmon | V | yes | m | 1 |
| POACEAE | | | | |
| <i>Aristida adscensionis</i> L. <i>decolorata</i> (E. Fourn.) Beetle | V | no | s | 1 |
| <i>Bouteloua annua</i> Swallen | S | yes | m | 1 |
| <i>Cenchrus palmeri</i> Vasey in Brandegees | S | yes | i | 2 |
| <i>Chloris brandegei</i> (Vasey) Swallen | S | yes | m | 1 |
| <i>Muhlenbergia brandegei</i> C. Reeder | S | no | s | 1 |

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|-----------------------------|---|----|---|---|
| <i>Setaria palmeri</i> Hem. | S | no | m | 2 |
|-----------------------------|---|----|---|---|

POLEMONIACEAE

| | | | | |
|---|---|-----|---|---|
| <i>Acanthogilia gloriosa</i> (Brandege) Day & Moran | G | yes | m | 1 |
|---|---|-----|---|---|

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|-------------------------------------|---|-----|---|---|
| <i>Gilia mexicana</i> A. & V. Grant | S | yes | m | 2 |
|-------------------------------------|---|-----|---|---|

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|---|---|-----|---|---|
| <i>Gilia palmeri</i> S. Watson <i>palmeri</i> S. Watson | V | yes | m | 1 |
|---|---|-----|---|---|

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|--|---|-----|---|---|
| <i>Gilia palmeri</i> S. Watson <i>spectabilis</i> A. Day | V | yes | s | 1 |
|--|---|-----|---|---|

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|---|---|-----|---|---|
| <i>Ipomopsis effusa</i> (A. Gray) Moran | S | yes | m | 1 |
|---|---|-----|---|---|

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|--|---|----|---|---|
| <i>Ipomopsis guttata</i> (A. Gray) Moran | S | no | m | 1 |
|--|---|----|---|---|

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|--|---|----|---|---|
| <i>Leptodactylon veatchii</i> (Parry ex Gray) Wherry | S | no | m | 1 |
|--|---|----|---|---|

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|--------------------------------------|---|----|---|---|
| <i>Linanthus jamauensis</i> R. Moran | S | no | m | 1 |
|--------------------------------------|---|----|---|---|

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|--|---|----|---|---|
| <i>Linanthus laxus</i> (Vasey & Rose) Wherry | S | no | m | 1 |
|--|---|----|---|---|

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|--|---|-----|---|---|
| <i>Linanthus melingii</i> (Wiggins) V. Grant | S | yes | m | 1 |
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| <i>Linanthus uncialis</i> (Brandege) E. Greene | S | yes | m | 1 |
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|--|---|-----|---|---|
| <i>Linanthus viscainensis</i> R. Moran | S | yes | s | 1 |
|--|---|-----|---|---|

POLYGALACEAE

| | | | | |
|--|---|-----|---|---|
| <i>Polygala apopetala</i> T. S. Brandege | S | yes | m | 1 |
|--|---|-----|---|---|

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|---|---|-----|---|---|
| <i>Polygala desertorum</i> T. S. Brandege | S | yes | m | 1 |
|---|---|-----|---|---|

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|---|---|----|---|---|
| <i>Polygala magdalenae</i> T. S. Brandege | S | no | m | 1 |
|---|---|----|---|---|

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|--------------------------------|---|-----|---|---|
| <i>Polygala xantii</i> A. Gray | S | yes | s | 1 |
|--------------------------------|---|-----|---|---|

POLYGONACEAE

| | | | | |
|--|---|----|---|---|
| <i>Chorizanthe chaetophora</i> Goodman | S | no | m | 1 |
|--|---|----|---|---|

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|-----------------------------------|---|-----|---|---|
| <i>Chorizanthe flava</i> Brandege | S | yes | m | 1 |
|-----------------------------------|---|-----|---|---|

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|-------------------------------------|---|-----|---|---|
| <i>Chorizanthe inequalis</i> Stokes | S | yes | m | 1 |
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|--|---|-----|---|---|
| <i>Chorizanthe interposita</i> Goodman | S | yes | l | 1 |
|--|---|-----|---|---|

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|--------------------------------------|---|----|---|---|
| <i>Chorizanthe jonesiana</i> Goodman | S | no | s | 1 |
|--------------------------------------|---|----|---|---|

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|---------------------------------------|---|-----|---|---|
| <i>Chorizanthe mutabilis</i> Brandege | S | yes | m | 1 |
|---------------------------------------|---|-----|---|---|

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|---------------------------------------|---|-----|---|---|
| <i>Chorizanthe pulchella</i> Brandege | S | yes | l | 1 |
|---------------------------------------|---|-----|---|---|

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|--------------------------------------|---|-----|---|---|
| <i>Chorizanthe turbinata</i> Wiggins | S | yes | m | 1 |
|--------------------------------------|---|-----|---|---|

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|--|---|-----|---|---|
| <i>Eriogonum angelense</i> R. Moran | S | yes | s | 1 |
| <i>Eriogonum austrinum</i> (Stokes) Reveal | S | yes | m | 1 |
| <i>Eriogonum elongatum</i> Bentham <i>areorivum</i> Reveal | S | yes | m | 1 |
| <i>Eriogonum elongatum</i> Bentham <i>vollmeri</i> (Wifg.) Reveal | V | yes | m | 1 |
| <i>Eriogonum encelioides</i> Reveal & Hanson | S | yes | m | 1 |
| <i>Eriogonum fasciculatum</i> Bentham <i>emphereium</i> Reveal | S | yes | m | 1 |
| <i>Eriogonum fastigiatum</i> Parry <i>taxifolium</i> | V | yes | m | 1 |
| <i>Eriogonum galioides</i> I. M. Johnston | S | yes | m | 1 |
| <i>Eriogonum grande</i> E. Greene <i>testudinum</i> Reveal | S | no | m | 1 |
| <i>Eriogonum hastatum</i> Wiggins | S | yes | m | 1 |
| <i>Eriogonum intricatum</i> Bentham | S | yes | m | 1 |
| <i>Eriogonum molle</i> E. Greene | S | no | s | 1 |
| <i>Eriogonum moranii</i> Reveal | S | yes | m | 1 |
| <i>Eriogonum orcuttianum</i> S. Watson | S | yes | m | 1 |
| <i>Eriogonum pilosum</i> Stokes | S | yes | m | 1 |
| <i>Eriogonum pondii</i> E. Greene | S | yes | m | 1 |
| <i>Eriogonum preclarum</i> Reveal | S | yes | m | 1 |
| <i>Eriogonum repens</i> (Stokes) Reveal | S | yes | m | 1 |
| <i>Eriogonum scalare</i> S. Watson | S | yes | m | 1 |
| <i>Eriogonum wrightii</i> Bentham <i>oresbium</i> Reveal | S | yes | m | 1 |
| <i>Eriogonum zapatoense</i> R. Moran | S | yes | s | 1 |
| <i>Harfordia macroptera</i> (Bentham) E. Greene & Parry <i>fruticosa</i> (E. Greene) Reveal | G | no | s | 1 |
| <i>Harfordia macroptera</i> (Bentham) E. Greene & Parry <i>galioides</i> (E. Greene) Reveal | G | yes | l | 1 |

| | | | | |
|---|---|-----|---|---|
| <i>Harfordia macroptera</i> (Bentham) E. Greene & Parry | G | yes | l | 1 |
| <i>macroptera</i> | | | | |

POLYPODIACEAE

| | | | | |
|---|---|-----|---|---|
| <i>Asplenium blepharodes</i> D. C. Eaton | S | yes | m | 1 |
| <i>Cheilanthes brandegeei</i> D. C. Eaton | S | yes | m | 1 |
| <i>Cheilanthes peninsularis</i> Maxon <i>peninsularis</i> Maxon | S | no | s | 1 |
| <i>Notholaena peninsularis</i> Maxon & Weatherby | S | yes | s | 1 |

PORTULACACEAE

| | | | | |
|--|---|-----|---|---|
| <i>Cistanthe guadalupensis</i> (Dudley) Carolin in Hershkovitz | S | yes | s | 1 |
|--|---|-----|---|---|

RANUNCULACEAE

| | | | | |
|---|---|-----|---|---|
| <i>Ranunculus harveyi</i> (T. S. Brandegee) L. Benson | S | yes | s | 1 |
| <i>australis</i> (Brandegee) L. Benson | | | | |
| <i>Thalictrum peninsulare</i> Rose | S | yes | s | 1 |

RHAMNACEAE

| | | | | |
|--|---|-----|---|---|
| <i>Ceanothus verrucosus</i> Nuttall | S | yes | m | 1 |
| <i>Condalia brandegei</i> I. M. Johnston | S | yes | m | 1 |
| <i>Condaliopsis rigida</i> (Wiggins) Wiggins | S | no | s | 1 |
| <i>Rhamnus crocea</i> Nuttall in Torrey & Gray <i>insula</i> (Kellogg) C.B. Wolf | V | yes | s | 1 |

ROSACEAE

| | | | | |
|----------------------------------|---|-----|---|---|
| <i>Rosa minutifolia</i> Engelman | S | yes | l | 1 |
|----------------------------------|---|-----|---|---|

RUBIACEAE

| | | | | |
|---|---|-----|---|---|
| <i>Carterella alexanderae</i> (A. Carter) Terrell | S | no | s | 1 |
| <i>Chiococca pubescens</i> Standley <i>peninsularis</i> Wiggins | S | yes | s | 1 |
| <i>Galium angulosum</i> A. Gray | S | yes | s | 1 |
| <i>Galium carterae</i> Dempster | S | no | s | 1 |

| | | | | |
|--|---|-----|---|---|
| <i>Galium coronadoense</i> Dempster | S | no | s | 1 |
| <i>Galium diabloense</i> Dempster | S | yes | m | 1 |
| <i>Galium martireense</i> Dempster & Stebbins | S | yes | l | 1 |
| <i>Galium mechudoense</i> Dempster | S | no | s | 1 |
| <i>Galium moranii</i> Dempster <i>aculeolatum</i> Dempster | V | yes | m | 1 |
| <i>Galium moranii</i> Dempster <i>moranii</i> Dempster | V | no | m | 1 |
| <i>Galium volcanense</i> Dempster | S | yes | m | 1 |
| <i>Galium wigginsii</i> Dempster | S | yes | m | 1 |
| <i>Houstonia arenaria</i> Rose | S | yes | m | 1 |
| <i>Houstonia asperuloides</i> (Bentham) A. Gray | V | yes | m | 1 |
| <i>asperuloides</i> (Bentham) A. Gray | | | | |
| <i>Houstonia asperuloides</i> (Bentham) A. Gray | V | no | m | 1 |
| <i>brandegeana</i> (Rose) Wiggins | | | | |
| <i>Houstonia australis</i> I. M. Johnston | S | yes | m | 1 |
| <i>Houstonia brevipes</i> Rose | S | yes | m | 1 |
| <i>Houstonia gracilentia</i> I. M. Johnston | S | yes | m | 1 |
| <i>Houstonia mucronata</i> (Bentham) Robinson | S | yes | m | 1 |
| <i>Houstonia peninsularis</i> Brandegee | S | no | s | 1 |
| <i>Mitracarpus linearis</i> Bentham | S | yes | m | 1 |
| <i>Randia megacarpa</i> Brandegee | S | yes | m | 1 |
| RUTACEAE | | | | |
| <i>Cneoridium dumosum</i> (Nuttall) Baillon | S | yes | l | 1 |
| <i>Esenbeckia flava</i> T. S. Brandegee | S | yes | m | 1 |
| <i>Ptelea aptera</i> Parry | S | no | m | 1 |
| SALICACEAE | | | | |
| <i>Populus brandegeei</i> Schneider <i>brandegeei</i> | S | yes | m | 1 |
| Schneider | | | | |
| <i>Populus brandegeei</i> Schneider <i>glabra</i> Wiggins | S | yes | m | 1 |

SAPINDACEAE

| | | | | |
|--------------------------------------|---|-----|---|---|
| <i>Cardiospermum spinosum</i> Radlk. | S | yes | s | 1 |
| <i>Cardiospermum tortuosum</i> Benth | S | yes | m | 1 |
| <i>Serjania californica</i> Radlk. | S | yes | s | 1 |

SAPOTACEAE

| | | | | |
|---|---|-----|---|---|
| <i>Sideroxylon leucophyllum</i> S. Watson | S | yes | m | 1 |
| <i>Sideroxylon peninsulare</i> (Brandegee) Pennington | S | yes | m | 1 |

SCROPHULARIACEAE

| | | | | |
|---|---|-----|---|---|
| <i>Antirrhinum watsonii</i> Vasey & Rose | S | yes | m | 1 |
| <i>Asarina flaviflora</i> (I.M. Johnston) Pennell | S | no | s | 1 |
| <i>Castilleja bryantii</i> Brandegee | S | yes | m | 1 |
| <i>Castilleja fruticosa</i> R. Moran | S | yes | s | 1 |
| <i>Castilleja guadalupensis</i> Brandegee | S | yes | s | 1 |
| <i>Clevelandia beldingii</i> (E. Greene) E. Greene | G | yes | m | 1 |
| <i>Conobea polystachya</i> (Brandegee) Minod | S | no | s | 1 |
| <i>Cordylanthus involutus</i> Wiggins | S | yes | m | 1 |
| <i>Cordylanthus orcuttianus</i> A. Gray | S | yes | m | 1 |
| <i>Galvezia juncea</i> (Benth) Ball <i>foliosa</i> I. M. Johnston | V | yes | l | 1 |
| <i>Galvezia juncea</i> (Benth) Ball <i>juncea</i> (Benth) Ball | V | yes | m | 1 |
| <i>Galvezia juncea</i> (Benth) Ball <i>pubescens</i> (Brandegee) I. M. Johnston | V | yes | s | 1 |
| <i>Mecardonia exilis</i> (Brandegee) Pennell | S | yes | s | 1 |
| <i>Mimulus stellatus</i> (Kellogg) Grant | S | no | s | 1 |
| <i>Ophiocephalus angustifolius</i> Wiggins | G | yes | m | 1 |
| <i>Penstemon cedrosensis</i> Kellogg | S | no | s | 1 |
| <i>Penstemon clevelandii</i> A. Gray <i>clevelandii</i> A. Gray | V | yes | m | 2 |

| | | | | |
|--|---|-----|---|---|
| <i>Penstemon eximius</i> Keck | S | yes | m | 1 |
| <i>Penstemon spectabilis</i> Thurber <i>subinteger</i> Keck | V | yes | m | 1 |
| <i>Russelia grandidentata</i> Carlson | S | yes | m | 1 |
| SELAGINELLACEAE | | | | |
| <i>Selaginella cinerascens</i> Maxon | S | no | m | 1 |
| SIMAROUBACEAE | | | | |
| <i>Castela peninsularis</i> Rose | S | yes | m | 1 |
| <i>Castela polyandra</i> Moran & Felger | S | yes | m | 2 |
| SOLANACEAE | | | | |
| <i>Lycium densifolium</i> Wiggins | S | yes | s | 1 |
| <i>Lycium fremontii</i> A. Gray <i>viscidum</i> Wiggins | V | yes | m | 1 |
| <i>Lycium megacarpum</i> Wiggins | S | yes | m | 1 |
| <i>Physalis crassifolia</i> Bentham <i>infundibularis</i> I. M. Johnston | V | yes | l | 1 |
| <i>Physalis glabra</i> Bentham | V | no | m | 1 |
| <i>Solanum palmeri</i> Vasey & Rose | S | no | s | 1 |
| STERCULIACEAE | | | | |
| <i>Ayenia peninsularis</i> T. S. Brandegee | S | yes | m | 1 |
| <i>Hermannia palmeri</i> Rose | G | yes | m | 1 |
| THYMELAEACEAE | | | | |
| <i>Daphnopsis lagunae</i> Breedlove & León de la luz | S | yes | m | 1 |
| VERBENACEAE | | | | |
| <i>Aloysia barbata</i> (Brandegee) Moldenke | S | yes | m | 1 |
| <i>Burroughsia fastigiata</i> (Brandegee) Moldenke | S | no | s | 1 |
| <i>Citharexylum roxanae</i> Moldenke | S | yes | m | 1 |
| <i>Lippia formosa</i> Brandegee | S | no | s | 1 |
| <i>Verbena bajacalifornica</i> Moldenke | S | no | s | 1 |
| <i>Verbena lilacina</i> E. Greene | S | yes | m | 1 |

| | | | | |
|--|---|-----|---|---|
| <i>Verbena macrodonta</i> Perry | S | yes | s | 1 |
| <i>Verbena orcuttiana</i> Perry | S | yes | m | 1 |
| <i>Verbena shrevei</i> Moldenke | S | no | s | 1 |
| VIOLACEAE | | | | |
| <i>Viola purpurea</i> Kellogg <i>pupurea</i> Kellogg | V | yes | m | 1 |
| VISCACEAE | | | | |
| <i>Phoradendron riberense</i> Wiggins | S | yes | m | 1 |
| VITACEAE | | | | |
| <i>Vitis peninsularis</i> M. E. Jones | S | yes | m | 1 |
| ZYGOPHYLLACEAE | | | | |
| <i>Fagonia densa</i> I. M. Johnston | S | yes | m | 2 |
| <i>Fagonia palmeri</i> Vasey & Rose | S | yes | m | 2 |
| <i>Fagonia villosa</i> D. M. Porter | S | yes | l | 1 |
| <i>Kallstroemia peninsularis</i> D. M. Porter | S | yes | m | 1 |
| <i>Viscainoa geniculata</i> (Kellogg) E. Greene <i>geniculata</i> (Kellogg) E. Greene | S | yes | l | 1 |
| <i>Viscainoa geniculata</i> (Kellogg) E. Greene <i>pinnata</i> I. M. Johnston | S | yes | l | 2 |

Table 1. Terrestrial protected areas in the peninsula of Baja California and neighboring islands.

| Natural protected area | Category | Area (ha) | Genera | species | subspecies | Communities |
|---|----------|-------------|--------|---------|------------|---|
| Guadalupe Island. | AR | 25,000.0 | 1 | 34 | 4 | Pacific coastal scrub. |
| Sierra de San Pedro Mártir. | NP | 63,000.0 | 1 | 33 | 9 | Chaparral and pine-oak forest. |
| Constitución de 1857. | NP | 5,009.5 | 0 | 7 | 2 | Pine forest |
| Sea of Cortés Islands, including Isla Rasa. | AR | 150,061.0 | 5 | 143 | 41 | Sonoran & Gulf island scrub |
| Valle de los Círios | FFPA | 2,521,776.0 | 9 | 164 | 52 | Desert scrub, |
| El Vizcaino (BA) | BR | 2,546,790.0 | 6 | 168 | 34 | Desert scrub, |
| El Vizcaino (CA) | | | 2 | 53 | 11 | coastal dunes, halophilic scrub, mangroves. |
| Alto Golfo de California y Delta del Colorado. ^(a) | BR | 179,266.0 | 0 | 6 | 2 | Sand dunes, halophilic scrub. |
| Alto Golfo de California y delta del Colorado (CA) | | | 0 | 0 | 0 | |
| Sierra de La Laguna (BA) | BR | 112,437.0 | 2 | 109 | 17 | Pine-oak forest, tropical dry forest, |
| Sierra de La Laguna (CA) | | | 3 | 90 | 14 | palm oases, columnar cacti and desert scrub |

(a) This area represents only the terrestrial and peninsular section of the reserve. (BA) buffer area, (CA) core area.

Categories: BR: Biosphere Reserve (*Reservas de la Biosfera*); NP: National Park (*Parque Nacional*); FFPA: Flora and Fauna Protection Area (*Área de Protección de Flora y Fauna*); AR: Area currently under re-categorization (*Área en Recategorización*). Sources: SEMARNAP 1996, DOF June/07/2000.

Table 2. Phytogeographic regions of Baja California and number of endemic species in them.

| Phytogeographic region | Number of endemic species | | |
|------------------------|---------------------------|----------|-----------------|
| | Baja Calif. | Regional | unprotected (%) |
| Mediterranean | 268 | 93 | 39 (42) |
| Lower Colorado | 116 | 4 | 3 (75) |
| Central Gulf | 326 | 33 | 17 (52) |
| Vizcaino | 399 | 52 | 23 (44) |
| San Lucan | 315 | 102 | 38 (37) |

Numbers in parentheses indicate the percentage of the regional endemics that have not been found within existing protected areas.

FIGURE CAPTIONS.

Figure 1. Natural protected areas in Baja California and adjacent islands. Although some reserves include marine ecosystems, this study only took into consideration their land areas.

Figure 2. Distribution of endemic taxa: Taxa not found in the interior of protected areas (closed circles), taxa with populations inside the protected areas (+).

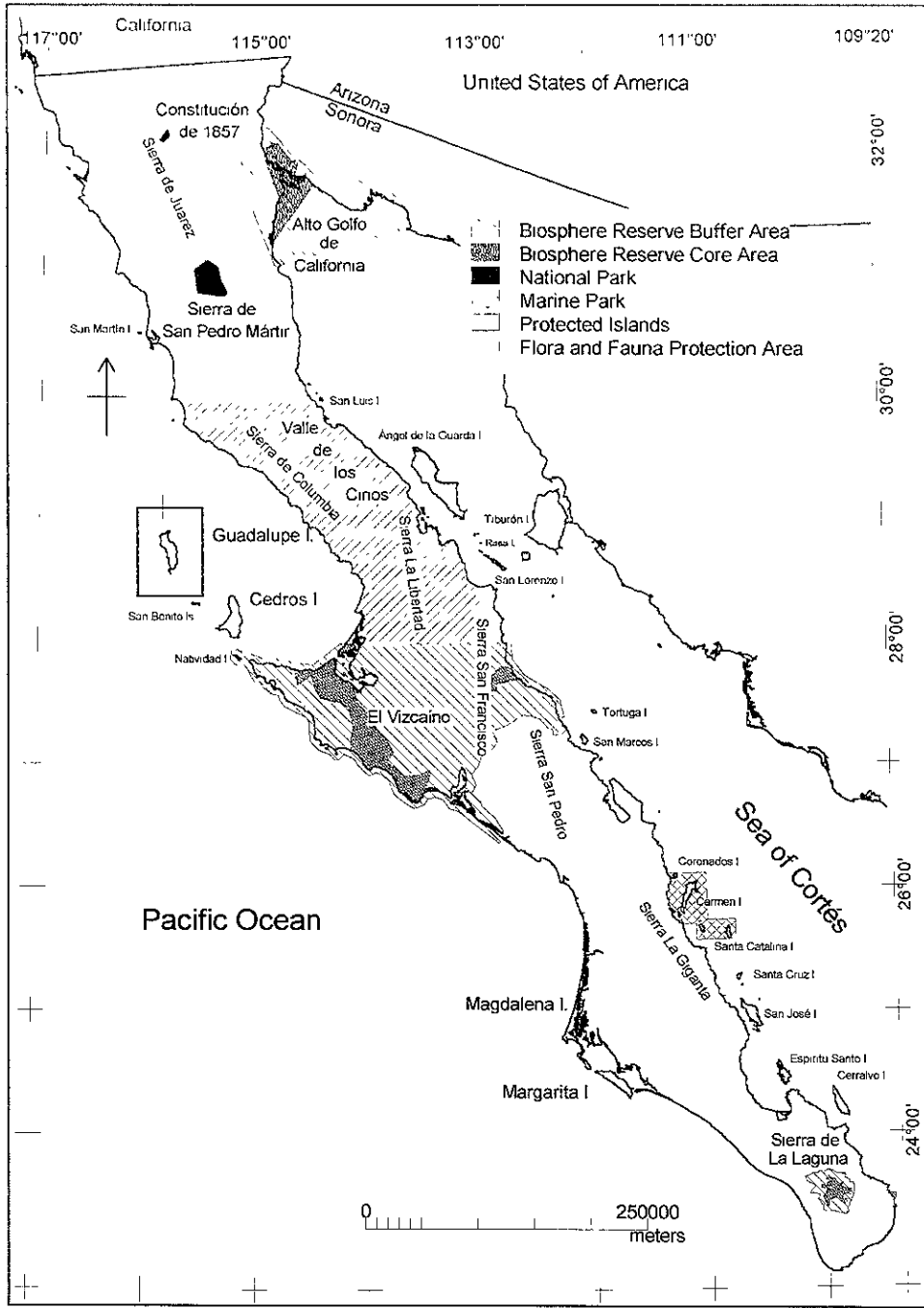
Figure 3. Distribution of endemic taxa in Baja California classified according to their geographic range (see definitions in main text): (a) endemic genera, (b) endemic species, and (c) endemic subspecies. Black bars indicate taxa collected inside one or more protected areas, and hatched bars indicate taxa not collected inside a protected area. The "rare" column indicates taxa that have been collected poorly and do not have geo-reference locations.

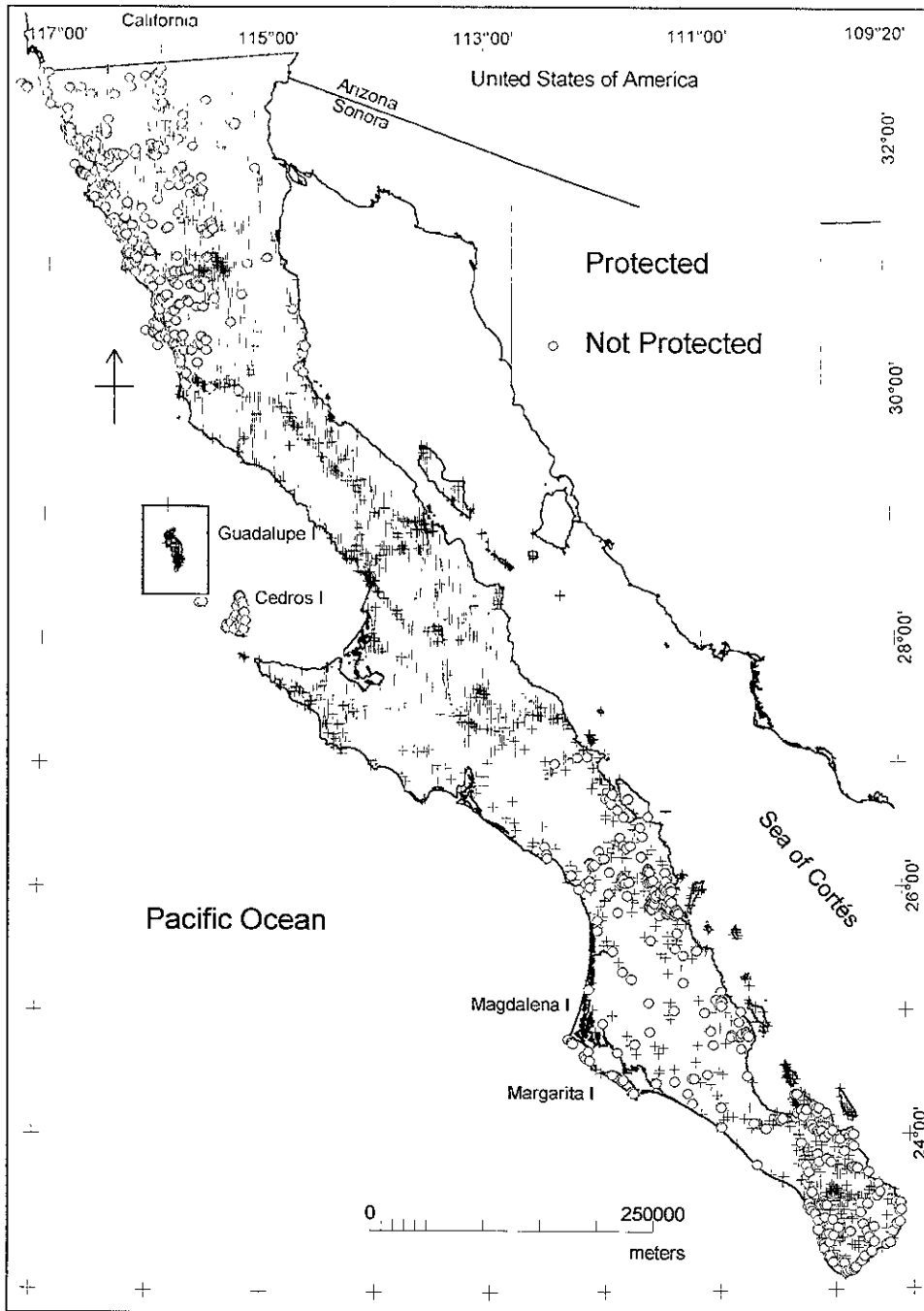
Figure 4. Major phytogeographic regions in Baja California.

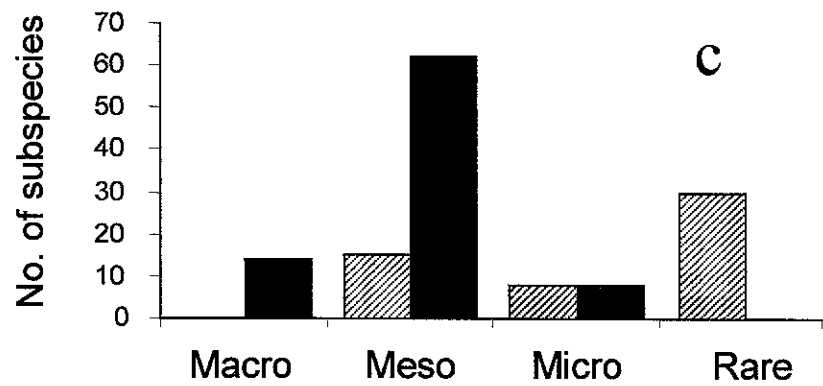
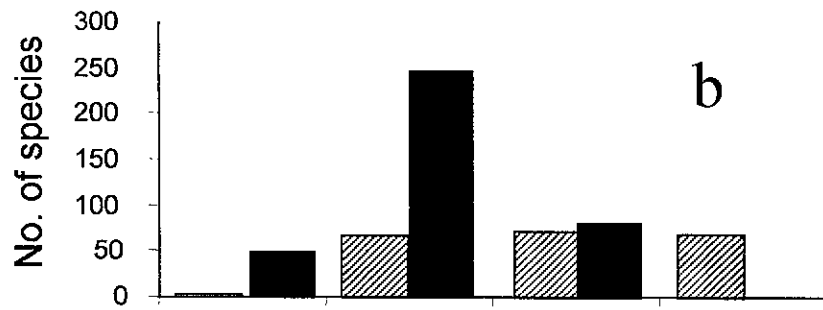
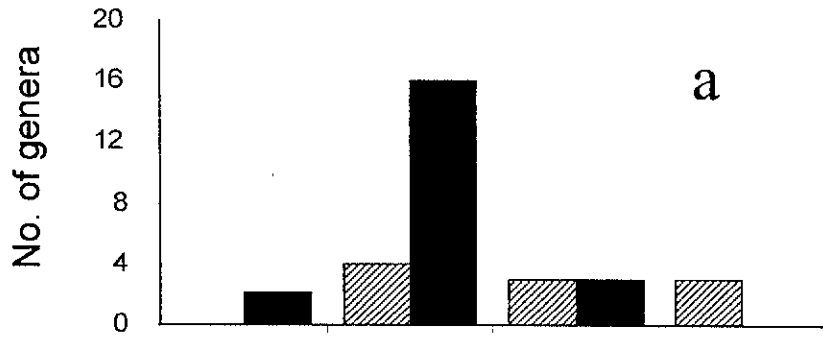
Figure 5. Major gap areas in Baja California.

Figure 6. Distribution of endemic genera in Baja California. The shape of the symbols indicates the number of taxa within the genera: circle, monospecific genera, diamond, genera containing 2 taxa, triangle, genera with 3 taxa, squares, genera with 5 taxa.

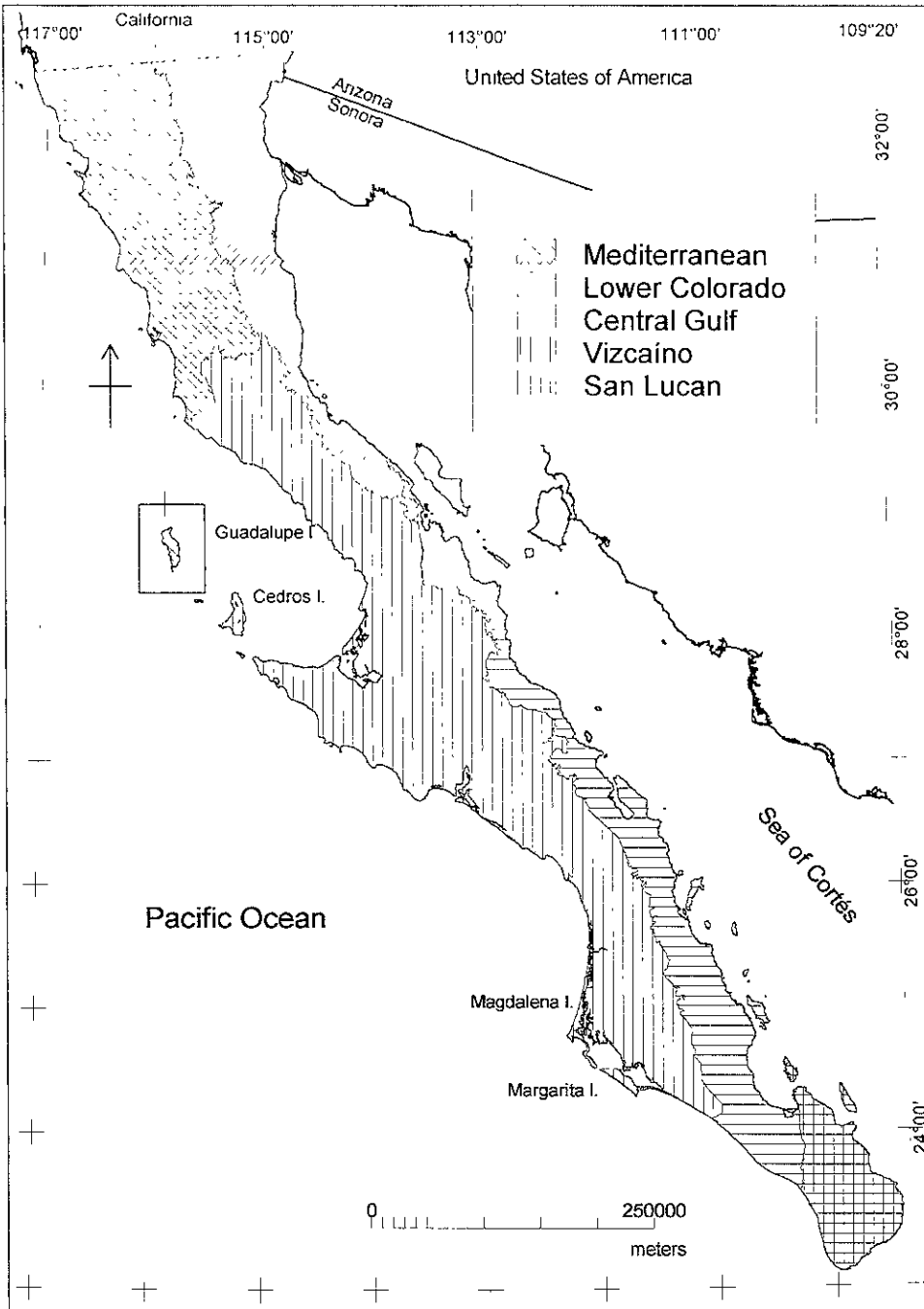
Figure 7. Species-area relationship for the endemic species of Baja California and the protected areas that shelter them, on a log-log scale. The line was fitted by principal axes regression. The ellipse corresponds to the 95% confidence interval of the Normal bivariate distribution. The fitted model was: $\log_{10} S = a + b \log_{10} A$, where S = species richness, A = area, b = slope, and a = intercept. Symbols are as follows: PNC = Parque Nacional Constitución de 1857, GI = Guadalupe Island, SLC = Sierra de la Laguna core area, PNM = Parque Nacional San Pedro Mártir, SL = Sierra de La Laguna BR (buffer area), IG = Sea of Cortés Islands, AG = Alto Golfo de California BR, VC = El Vizcaíno BR (core area), VB = El Vizcaíno BR (buffer area), VR = Valle de Los Cirios FPPA. Open circles = phytogeographic regions (not used in the regression).

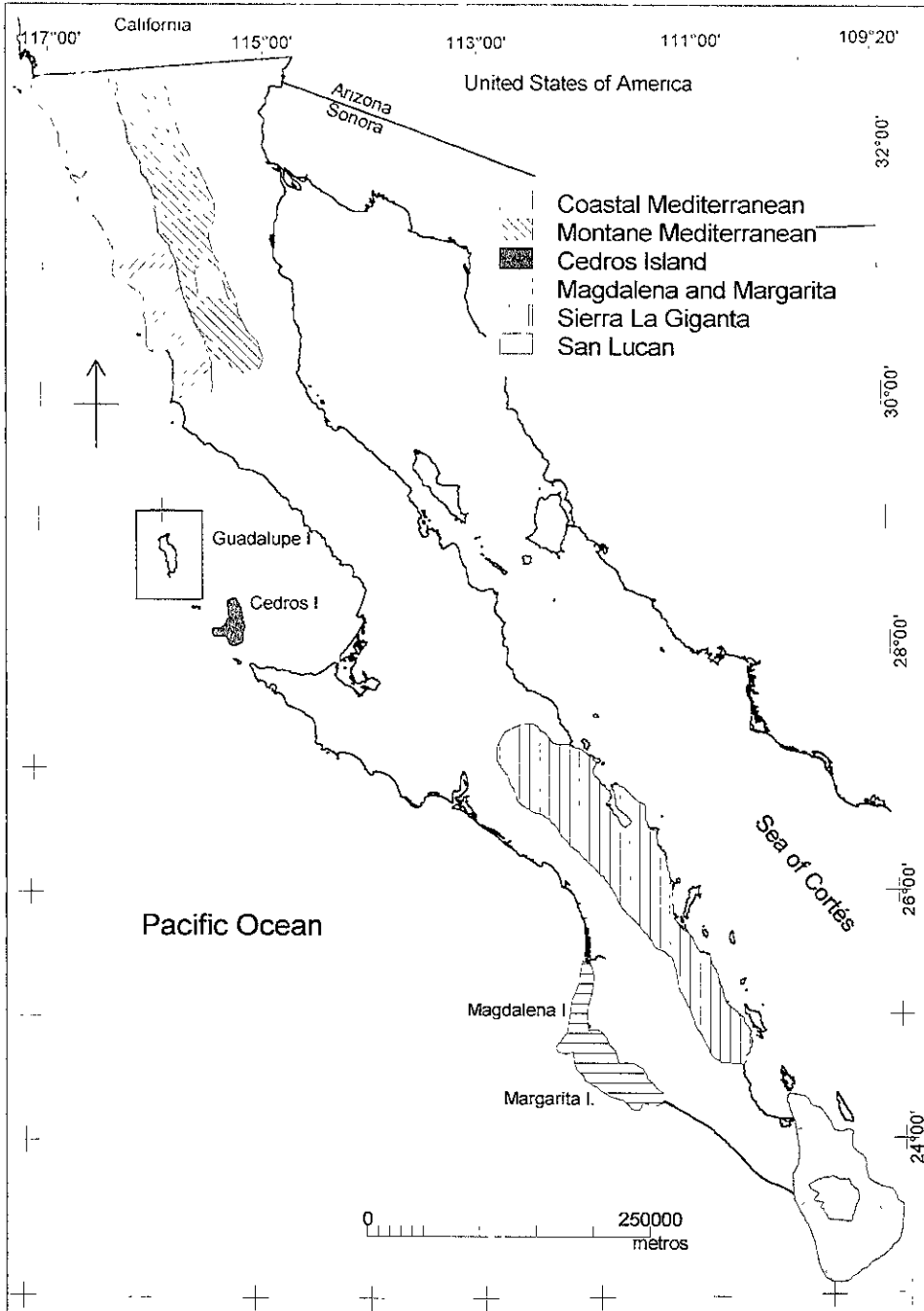


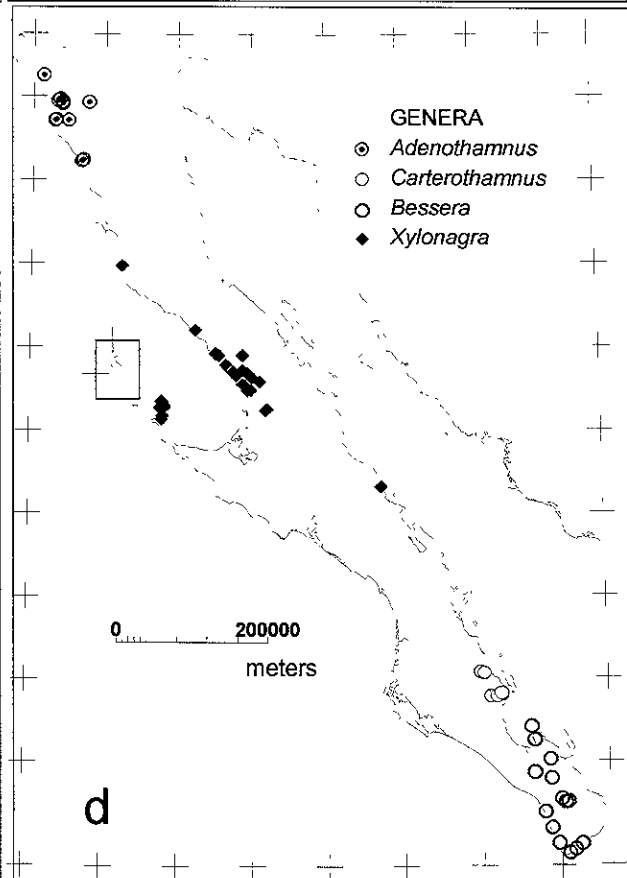
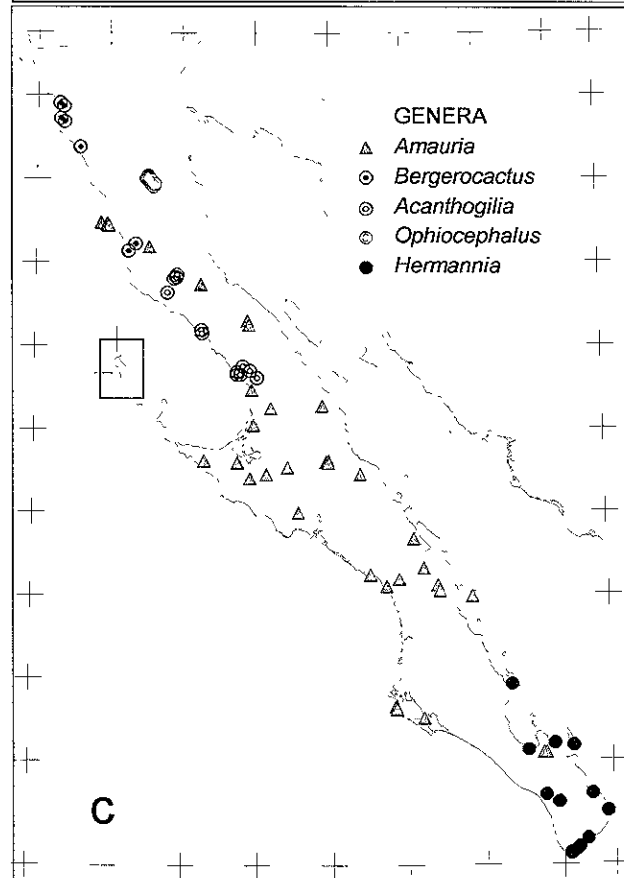
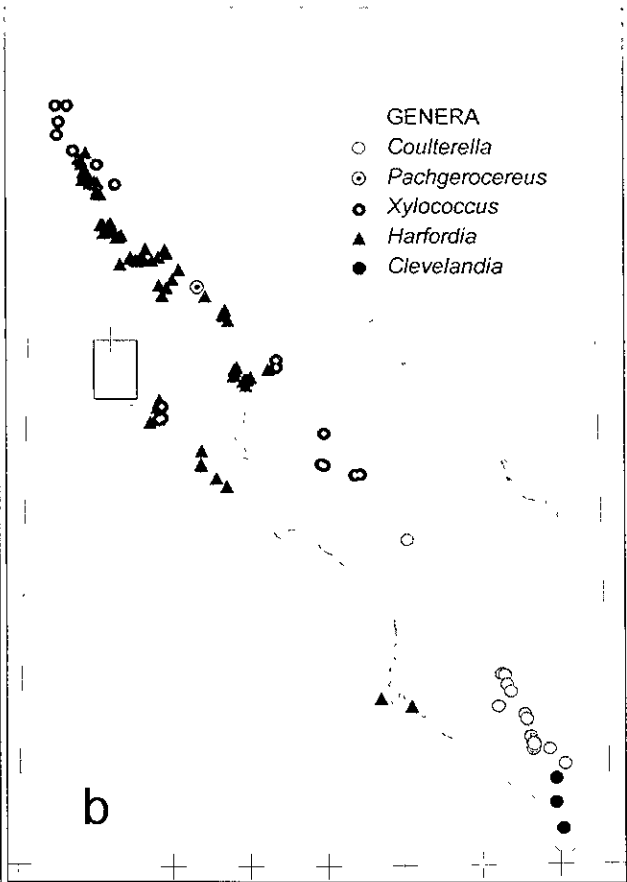
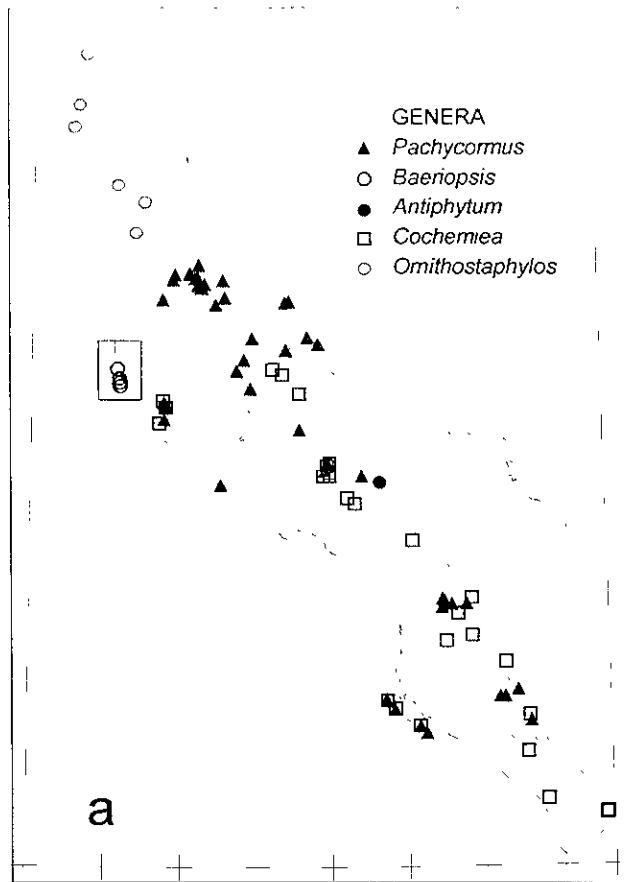


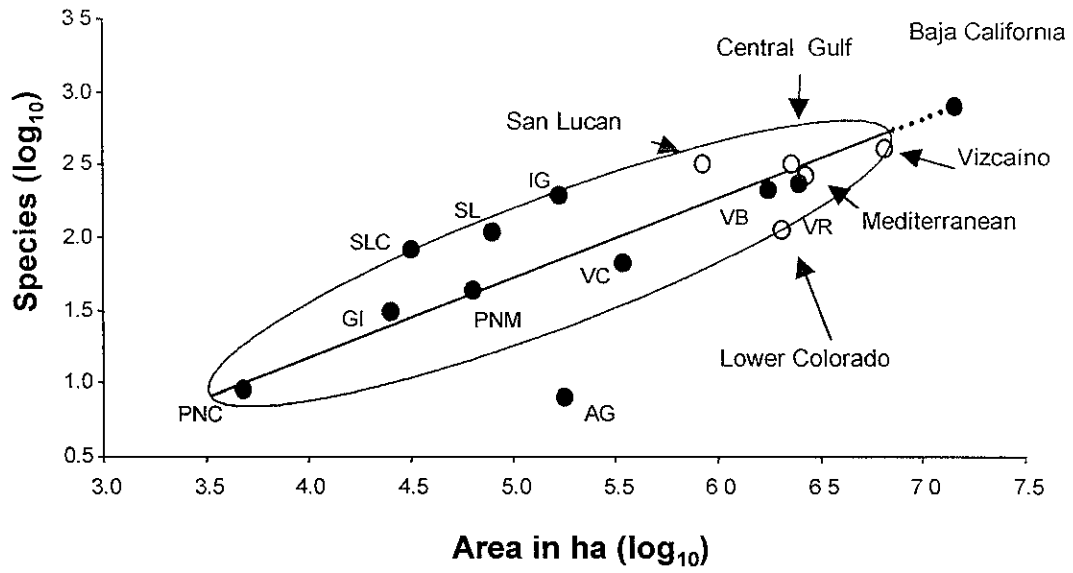


Geographic range









CAPÍTULO 2

**PATRONES DE DISTRIBUCIÓN Y “HOTSPOTS” DE LA FLORA VASCULAR ENDÉMICA
DE LA PENÍNSULA DE BAJA CALIFORNIA, MÉXICO**

**DISTRIBUTION PATTERNS AND *HOTSPOTS* OF THE VASCULAR ENDEMIC FLORA OF
THE PENINSULA OF BAJA CALIFORNIA, MEXICO**

DISTRIBUTION PATTERNS AND *HOTSPOTS* OF THE VASCULAR ENDEMIC FLORA OF THE PENINSULA OF BAJA CALIFORNIA, MEXICO

SUMMARY

We analyzed the distribution of the endemic vascular plants in the peninsula of Baja California and neighboring islands (totaling 702 species) distributed in 230 cartographic cells 15' × 20' in size. The richness of vascular endemics was related to the collection intensity and to the land area in each cell. By statistically comparing the species richness in each cell with the mean richness of the whole peninsula corrected by the collection effort and land surface, we identified areas with significantly high species richness and high endemism values. We constructed a dendrogram describing the affinities between the 12 ecoregions of Baja California as described by the endemic taxa of the peninsula. We were able to identify regions of low species richness, as well as areas with significantly high numbers of endemics. One of the principal achievements of this research is that permits to identify those regions that have been poorly collected as well as to identify those areas with high numbers of local and/or regional endemics. Finally, we identified for the Peninsula of Baja California 10 hotspots that define a working agenda for future conservation efforts.

RESUMEN

Analizamos la distribución de la flora vascular endémica en la península de Baja California y sus islas vecinas (un total de 702 especies) en 230 áreas cartográficas de 15' × 20'. La riqueza de endemismos vasculares se relacionó a la intensidad de colecta y a el área terrestre de cada celda cartográfica. Comparando de manera estadística la riqueza de especies en cada celda con la riqueza media de toda la península corregida por el efecto de área y el esfuerzo de colecta, identificamos áreas con valores de riqueza y endemividad significativamente altos. Construimos un dendrograma que describe la afinidad entre los 12 tipos de vegetación

descritos aquí sobre la base de los endemismos vasculares compartidos. Pudimos identificar regiones de baja riqueza de especies, así como, regiones con un número significativamente alto de endemismos. Uno de los principales logros de esta investigación es que permite identificar aquellas regiones que han sido pobremente colectadas, así como identificar aquellas áreas con alto número de endemismos locales y/o regionales. Finalmente, identificamos 10 *hotspots* para la península de Baja California, que sientan las bases para una agenda de trabajo de futuros esfuerzos de conservación.

INTRODUCTION

The peninsula of Baja California flora contains no less than 3,700 species of vascular plants, one fifth of which are endemic to this region. Although there are only 20 endemic genera and no endemic families, in Baja California endemism at the species and subspecies levels is found in 85 of its 155 native plant families, and is especially high the Asteraceae, Cactaceae, and Fabaceae, which jointly account for 40% of the endemism. The high number of endemic plant species in this region is possibly the result of landscape heterogeneity and isolation, two factors that favor biological speciation. Additionally, the presence of Tertiary paleoendemism may be the result of the long-term climatic stability of regions near to, and buffered by, the Pacific Ocean (Peinado et al. 1994). Finally, the peninsula forms an elongated land-bridge that stretches from the Nearctic Realm in the north into the Neotropical Realm in the South.

The ecotonal nature of the region also contributes to the coexistence of species of different origin, and hence to its high biological diversity (Rzedowski 1978). The extension of the peninsula comprises almost 10° latitude. The numerous landscapes, climates, and landforms promote a mosaic of communities that traverse such extreme gradients as coastal scrubs to mountain coniferous forest to desert vegetation in less than 80 km of east-west distance. The Sierras that stretch along the peninsula form “sky island” refuges, where numerous Pleistocene endemics are found (Axelrod 1979).

Although the peninsula has been collected for more than a hundred years, the real number of vascular plants inhabiting it is still unknown. Most of the accessions in the herbaria come from sites near the main roads. Although in a previous paper we identified seven GAP areas in the study region (Riemann and Ezcurra, in press), the geographic distribution of plant endemism in the peninsula still calls for a detailed analysis. The purpose of this investigation is (a) to make an analysis of the distribution of the vascular plant endemism in the peninsula of Baja California and nearby islands, (b) to relate the distribution patterns to vegetation types and other predictors, and (c) to identify regions with greatest abundance of endemisms –i.e., *hotspots*– as well as those regions that are still in need of more intense collection effort.

The Study Region

The study region encompasses the Baja California peninsula, Guadalupe Island in the Pacific, and the islands of the Sea of Cortés that fall under the administration of the political States of Baja California and Baja California Sur. The peninsula is approximately 1,300 km long and a 45-250 km wide. The study region represents an area of approximately 143,000 km², spanning almost 10° in latitude from 22° 53' N in the Cape Region to 32° 46' N in the Mexico-US border.

The peninsula of Baja California was formed during the Tertiary (some 5-10 My ago), when a narrow section of Mexico's mainland was separated northwest by tectonic forces, giving place in the process to the Gulf of California, also known as the Sea of Cortés. A series of ranges run in succession along the peninsula from north to south. This steep mountain backbone separates the ecosystems sloping east into the Gulf from those running west into the Pacific, and creates a complex landscape gradient with a large diversity of environments.

Twenty different types of climates (in Köppen's classification) cover the peninsula (Garcia 1988). Seven of these are arid (BS), and are located mainly in the Cape region and in the slopes of the mountain ranges in the mid-peninsula, ten correspond to variants of the very arid (BW) climates, two are temperate, and one is a cold climate found in the high mountain zones of San Pedro Mártir. Most of the territory has mean annual temperatures above 18°C and mean annual rainfall lower than 200 mm. The highest rainfalls (500-700 mm) occur in the high parts of the Sierras of San Pedro Mártir and La Laguna, in both extremes of the peninsula. The most adverse climatic conditions occur in the coasts of the Upper Sea of Cortés, in the northeast part of the territory, where the highest temperatures and lowest annual rainfall occur. The peninsular territory is occupied by a diversity of plant communities that goes from winter-rain Mediterranean chaparrals, coastal sage scrubs and coniferous forests in the northwest and microphyllous scrub in the northeast, to tropical deciduous dry forests in the Cape Region with a heterogeneous array of desert scrubs communities in the central deserts, in which fleshy stemmed trees, giant columnar cacti, and succulent rosette species prevail.

METHODS

Geographic information

The information about endemic species was obtained from the literature and from herbaria. Following a previous paper (Riemann and Ezcurra, in press) and because of the obvious association between the biogeographic definition of the peninsula of Baja California and the political boundaries of the two Mexican States that lie within it, we arbitrarily defined endemic species as those that had a distribution restricted to the insular and peninsular territory administered by the States of Baja California and Baja California Sur. Although this operational criterion may introduce some error in the case of species that occur along the northern border of the peninsula, which may be classified as non-endemic when in reality they may have a narrow biogeographic distribution, we were restricted in our project scope and funding to the Mexican territory.

The literature consulted was Wiggins (1980), Turner et al. (1995), Perry (1991), Moran (1996), Lenz (1992), Gentry (1978), Gould and Moran (1981), León and Coria (1992), and Delgadillo (1992). The lists from these publications were compared with Beauchamp (1986), Martin et al. (1998), and Hickman (1993), in order to exclude those species that are present outside the study region. The consulted herbaria were San Diego Natural History Museum (SD), Rancho Santa Ana at Claremont (RSA and POM), University of California at Berkeley (UC), and California Academy of Sciences (CAS and DS). From these sources of information it was possible to obtain location data for 702 of the 754 endemic taxa.

The information from the collections was geographically referenced by means of a topographic map, scale 1:250,000 (INEGI 1982). This initial database consisted of a file of 12,287 records related to 3,925 field sites, representing 702 endemic taxa. With the original database we formed a species \times sites data matrix of 702 endemic species and 230 cells, or cartographic units, covering the whole study region. Each cell stretched 15' latitude by 20' longitude. We organized the matrix in two ways: On the one hand, we organized the matrix as a presence-

absence dataset (matrix **A**), disregarding repeated collections of the same species for the same cell, totaling 5,116 presence records. On the other, we also counted all collection records for each species in each cell, giving rise to a quantitative matrix (matrix **B**) describing the number of taxonomic collections in each cartographic cell totaling 12,287 collection records.

To relate the physical geography of the region with the database matrix, and with the location of natural vegetation areas (i.e., ecological regions), we used a geographic information system (GIS), following the procedures described below:

- (a) Firstly, we digitized the land area, coastlines, and islands of the peninsula,
- (b) secondly, we constructed for the study region a polygon map consisting of the 230 cartographic cells described above, and
- (c) lastly, we elaborated a map of 12 major vegetation types, within five major biogeographic regions. For this purpose, we combined ecological maps from several sources (SPP 1984, Wiggins 1980, Brown and Lowe 1980, SPP 1982, Riemann and Ezcurra in press) that were modified according to our own field observations.

Thus, the geographic information system (GIS) consisted of three maps and of the corresponding databases: the physical map, the cartographic-cells map, and the map of vegetation and ecological regions.

The maps were transformed to a raster format with $150\text{ m} \times 150\text{ m}$ pixels. All the spatial information was transformed to Lambert conformal canonic projection, which is commonly used in large-scale maps in Mexico. Overlapping of the physical area and the vegetation maps with the cells map it was possible to calculate the land area (i.e., the area of the cell minus the area within the cell occupied by water or falling outside our study region) and the vegetation types in the interior of each cell.

The calculation of species richness and turnover

From the data matrix, we calculated the overall α , β , and γ diversity parameters by means of the following procedure: Let us consider a region the presence-absence matrix \mathbf{A} with dimensions $s \times n$ that describes the incidence (presence-absence) of s species in n cartographic cells.

$$\mathbf{A} = \{a_{ij}\} \quad \forall \{1 \leq i \leq s, 1 \leq j \leq n\}$$

Let us now define the marginal totals of the incidence matrix \mathbf{A} as a_i for the s row-totals, and as

a_j for the n column totals. Thus, $a_i = \sum_j^n a_{ij}$ represents the number of cells in which species i

is found, and $a_j = \sum_i^s a_{ij}$ represents the number of species that are present in cell j .

Obviously, $\{1 \leq a_i \leq s\}$ and $\{0 \leq a_j \leq n\}$. That is, there may exist cells without species, but each listed species must be at least present in one cell (otherwise it would be pointless to include it).

Species richness or α -diversity

The species richness (α -diversity) of cell j , represented by the symbol α_j , is obviously equal to the column total a_j . The mean α -diversity for the whole region will then be

$$\bar{\alpha} = \sum_j^n a_j / n \quad (1)$$

As, by definition, $\sum_j^n a_j = \sum_j^n \sum_i^s a_{ij} = a_{..}$, the variance of $\bar{\alpha}$ can be calculated as:

$$\text{var}(\bar{\alpha}) = \sum_j^n (a_j - (a_{..}/n))^2 / (n-1) \quad (2)$$

Species turnover or β -diversity

The species richness of the whole region (γ -diversity, in Whittaker's 1972 nomenclature) is equal to the number of rows (species) in \mathbf{A} . That is, $\gamma = s$. Obviously, $\gamma \leq \bar{\alpha}$. The difference

between γ and $\bar{\alpha}$ is due to the effect of environmental heterogeneity on diversity, also known as species turnover or β -diversity. Let us now define the mean number of cells occupied by each species (an inverse measure of endemism) as:

$$\bar{\epsilon} = \sum_i a_i / s \quad (3),$$

which can also be written as $\bar{\epsilon} = a / s$. It can be seen that

$$\bar{\alpha} / \bar{\epsilon} = (a_{..} / n) (s / a) = s / n$$

Remembering that $\gamma = s$, it is now clear that $\gamma = n \bar{\alpha} (1/\bar{\epsilon})$. Let us now define

$$\beta = 1 / \bar{\epsilon} = s / \left(\sum_i a_i \right) \quad (4),$$

and we reach Whittaker's (1972) equation relating α , β and γ -diversity:

$$\gamma = n \bar{\alpha} \beta \quad (5)$$

The variance of β can be calculated from the general equation for the variance of a ratio (Bulmer 1979):

$$\text{var}(\beta) = (1 / \bar{\epsilon})^2 \cdot \text{var}(\bar{\epsilon}) / \bar{\epsilon}^2 \quad (6).$$

Hence,

$$\text{var}(\beta) = \beta^4 \cdot \text{var}(\bar{\epsilon}) = \beta^2 \cdot \text{cv}(\bar{\epsilon})^2 \quad (7)$$

where var stands for variance and cv for coefficient of variation.

In short, for a given region β -diversity is an inverse measure of the mean number of cells colonized by the species. As the number of occupied cells is in turn proportional to the distributional area, it follows that as the distribution area decreases the degree of endemism increases and so does the value of β -diversity. Thus, β -diversity or species turnover is directly related to the mean level of endemism. The product $n \cdot \beta$ measures how many times larger is the total area compared to the mean area of the species. It is also easy to see that $1/n \leq \beta \leq 1$. Obviously, if $\beta = 1/n$, (that is, if $n \cdot \beta = 1$), then all the species occupy 100% of the cells, covering

the whole potential distribution area, and it follows that under this condition $\gamma = \bar{\alpha}$; that is, there is no species turnover.

In this model, the species richness of the cells (i.e., α -diversity) depend on the marginal totals of the columns of the data matrix **A** (i.e., the a_j values), whereas the variation in species composition between cells (i.e., the species turnover, or β -diversity) depend on the marginal totals of the rows of the data matrix **A** (i.e., the a_i values). The statistical properties of these values can be inferred from their distributional characteristics.

Mapping of species richness patterns, endemism, and collection effort

Species richness patterns. To map the spatial distribution of species richness, we simply plotted in each map cell j the species richness calculated for that cell from the data matrix **A**, i.e., we plotted the value of α_j for all cells.

Endemism. We also calculated the level of endemism (e) in each cell, by giving to each species a weight factor (w) inversely proportional to the land area covered by the cells occupied by the species. That is, the weight factor for species i was simply calculated as $w_i = 1 / \text{area}(i)$. The factor, an estimate of the geographic rarity of each species, was then used to weigh the species richness count for each cell. That is, $e_j = \sum_i^s a_{ij} \cdot w_i$, where the a_{ij} values correspond to the presence-absence records in matrix **A**.

Collection effort. Finally, we calculated for each cell the collection effort, represented by the number of specimens collected in that cell. These were obtained from the cell- or column-totals of the quantitative matrix (matrix **B**) describing all collection records for each species in each cell. As with the other parameters, the collection effort values were plotted in the corresponding map cells.

Testing hypotheses on species richness patterns

The variation in species richness observed between cells was tested statistically to see whether the observed patterns can be attributed to random variation (our null hypothesis), or if contrariwise they should be ascribed to non-random causes (i.e., "hotspots"). Because species richness values are frequency counts, our null model was based on the Poisson distribution. One interesting property of the Poisson is that the mean equals the variance. Thus, if we have an expected value of species richness for each cell, we can calculate the Pearson residual difference between the observed and the expected value $r_j = (o_j - e_j) / \sqrt{e_j}$. Because e_j is the expected value, then it follows that, if the data is randomly (Poisson) distributed, $\sqrt{e_j}$ is the standard deviation. Hence the values of the Pearson residuals are normalized deviates and their probability of occurrence can be calculated from the Normal distribution. However, because species distribution is normally autocorrelated in space, the values in each cell are not independent (Lyons and Willig 1999). To compensate for this bias, we used a Bonferroni correction, establishing a rejection threshold for each cell at $P = 0.000223$ and $P = 0.0000437$, in order to obtain a global probability of a type-I error in non-independent 230 simultaneous tests of $P = 0.05$ and $P = 0.01$, respectively.

Our first test was done by comparing the observed species richness in each cell (α_j) against the mean species richness of all cells (i.e., the $\bar{\alpha}$ value). This test rapidly showed that the cells with small land area had significantly less species than could be expected by chance. Hence, we decided to compensate for this fixed effect by including in the analysis the effect of the land area of each cell.

The effect of area

It is well-known that the number of species in an area increases non-linearly with the size of the area. Among many models that have been tested (He and Legendre 1996), one of the most common is Preston's (1960) model: $\alpha_j = c \cdot A_j^z$, where α_j is the species-richness of site j , A_j is

the cell's land-surface, z is the exponent or logarithmic slope (normally showing values between 0.6 and 0.2, and frequently showing Preston's "canonical" value of ≈ 0.23), and c is a coefficient of proportionality. In our dataset, we had already calculated the value of z (see Riemann and Ezcurra in press), which for the endemics of Baja California showed a log-slope value of 0.57.

Thus, we corrected the number of species expected in each cell by increasing or decreasing the

mean species richness according the cell's land area: $\hat{\alpha}_j = c \cdot A_j^z \cdot \bar{\alpha}_j$. If we impose the

restriction that the sum of the expected values over all cells equals the sum of the observed

species richness values (i.e., $\sum_j^n \hat{\alpha}_j = n \bar{\alpha}_j$, a requisite necessary for the calculation of the

Pearson residuals), then it is easy to show that $c = 1 / \sum_j^n A_j^z$. Finally, we tested for all cells the

observed values of species richness against the area-corrected predictor by means of the

Bonferroni-corrected test of residuals (see above). The cells departing significantly from the

predictions of the area-corrected random model were plotted in the regional map.

The effect of collection effort

In addition to the effect of the cell's land-surface, some cells showing-up as areas of significantly

high, or significantly low, species richness may appear to be so merely because they have been

better collected than the rest, or may have been undercollected. For this reason, we decided to

introduce a second correction to our calculation of the expected species richness, based on the

known properties of taxonomic accumulation functions (Soberón and Llorente 1993). Indeed, it

is known that as the collection effort increases within a given area, the number of species in the

collection increases non-linearly, in a manner rather similar to the species-area relationship

described above. One of the models most often used to represent this relationship is Clench's

equation: $\alpha_j = a \cdot b \cdot x_j / (a + b \cdot x_j)$, where x_j is the number of specimens collected in an area j , a is

the asymptote of the equation (i.e., an extrapolation estimate of the true species richness of the

area when the collection effort is sufficiently large), and b is a parameter that measures the

initial rate at which new species are accumulated in the collection and that depends on the relative abundance distribution of the species in the community (see Soberón and Llorente 1993, Clench 1979).

We initially fitted our data to Clench's model, and analyzed which cartographic cells had significantly more or significantly less species than predicted by the model. However, we found that there is a circularity in the model used in this way to compare different cells: the total species richness is indeed a result of the collection effort, but also the collection effort devoted to different areas depends on the species richness of each area. That is, botanists naturally tend to collect more on areas where species richness is high, and shorten their collection in areas where richness is low. To compensate for this circularity, we developed a new indicator of the sufficiency or insufficiency of the collection, based on Clench's model.

We first define an index of collection taxonomic intensity, or redundancy: $\rho_j = (x_j - \alpha_j) / x_j = 1 - \alpha_j/x_j$. That is, the taxonomic intensity ρ_j measures how many more specimens there are in the collection than species. It is easy to see that $0 < \rho_j < 1$. If the collection effort is high, most species are redundantly represented by many specimens, and $\alpha_j/x_j \rightarrow 0$. Thus, in areas where the collection effort is intense ($x_j \rightarrow \infty$), the redundancy of the collection is also high and $\rho_j \rightarrow 1$. In areas where the collection is poor, the redundancy is low and $\rho_j \rightarrow 0$.

Now, we solve for x_j in Clench's equation, to obtain $x_j = a.\alpha_j / b.(a - b.\alpha_j)$. It can easily be seen that this equation can be also written as $\alpha_j = [a(b - 1)/b] + (a/b) \rho_j$, a simple linear equation that can be re-parameterized as $\alpha_j = k + d\rho_j$. In short, the number of species in a given site should increase as a linear function of the taxonomic intensity of the collection for that site. Thus, we fitted a linear function for all the pairs of α_j vs. ρ_j data points and calculated the parameters of the linear equation.

Finally, we corrected the number of species expected in each cell by taking into account simultaneously the intensity of the collection and the cell's land area. As described in the previous section, we used a multiplicative model incorporating both effects. The final equation

was $\hat{\alpha}_j = c \cdot A_j^z \cdot (k + d\rho) \cdot \bar{\alpha}_j$. As in the previous case, the parameter c was calculated so that the restriction that the sum of the expected equals the sum of the observed values was met. Finally, through a Bonferroni-corrected test of residuals we tested for all cells the observed values of species richness against the predicted values, corrected by both the collection effort and land area. The cells departing significantly from the predictions of the random model corrected for these two fixed effects were plotted in the regional map.

Floristic relationships of natural regions

We made a cluster analysis for the 12 vegetation types recognized in the map analysis (Fig.1), and based on the endemic taxa shared between regions. For this analysis, we constructed a 702 species \times 12 natural regions incidence matrix describing the presences of each species in each of the natural regions. This biogeographic data matrix was analyzed by means of a clustering algorithm (unweighted pair group average linkage, or UPGMA), using the Sorensen's index of similarity (Kovach 1999).

Hotspots recognition

From the map of high and low diversity cartographic cells we digitized in a freehand way, polygons engulfing contiguous high diversity areas – *hotspots* – as well as polygons of low diversity areas. We overlap these polygons over the vegetation map in order to extract the vegetation information associated to each area.

RESULTS

Geographic information

We recognized 12 vegetation types for Baja California. Chaparral and Coastal Scrub represent the two typical mediterranean sclerophyllous scrubs, which appear in the NW of the peninsula and are dominated by winter rains. Montane Temperate forest occurs in the high mountains that divide the mediterranean region from the Sonoran Desert, and possibly represent relictual Nearctic Pleistocene vegetation. The Sierra de la Laguna Pine-Oak Forest, an isolated and uniquely endemic temperate forest, occurs in the mountains of the Cape Region. The lowlands of the Cape Region are occupied by two Neotropical vegetation types: the Tropical Dry Forest and San Lucan Xeric Scrub (Fig. 1). The Pacific side of the middle of the peninsula is occupied by Halophytic Vegetation in the low Vizcaíno mudflats, and by a Montane Sclerophyllous Scrub in the highest peaks. The rest of the regional vegetation is formed by three large subdivisions of the Sonoran/Baja Californian deserts: the Lower Colorado, the Vizcaíno and the Central Gulf Desert (Shreve and Wiggins 1964).

Species richness and turnover

Each cartographic cell, occupying less than 1000 km², had a mean of 23 endemic species (Table 1). The variance of this value, however, was very high, indicating that the spatial distribution of endemic plant species is significantly clumped in space. The mean species turnover (β) was 0.137, i.e., almost 14% of the endemic flora is replaced from one cell to the next. This high turnover value is responsible for the high total species richness of the peninsula ($\gamma = 702$), more than 30 times higher than the mean species richness of each cell. Finally, we found that each species occupies on average 7.3 cells. The distribution of these spatial occupancies, however, is highly skewed: while most species occupied less than 6 cells, a few widely distributed endemics occupied a large proportion of Baja California. As discussed and

predicted by Rapoport (1975) the distribution of species in the cells did not differ significantly from the lognormal (Fig.2).

Patterns of species richness, endemism, and collection effort

The highest richness of endemics tended to occur in some well-defined areas: (a) the whole of the Cape region, (b) the southern and mid-coast of the Central Gulf Desert, (c) the islands in the Sea of Cortés and in the Pacific, (d) the mediterranean region of the NW, and (e) the Baja California "sky islands", including Sierra de Juárez and San Pedro Mártir in the north, Sierra de La Libertad and San Francisco at the mid-peninsula, and Sierra de La Giganta along the southern Gulf Coast (Fig.3).

The patterns of endemism followed a similar trend, but in this case the highest values were found the Pacific islands, especially in San Benito, as a result of its small size (Fig.4). High endemism was also found in the southern part of the Central Gulf Desert and the tropical tip of the peninsula, including the Sierra de Juárez and San Pedro Mártir, in the north, the north and south extremes of Sierra de La Giganta, and the Cape Region, at the extreme south of the peninsula, which was consistently occupied by high endemism and species of local distribution. In general, the cells with more number of species of local distribution (higher endemism values) were associated with high biological isolation: Sky islands, highly distinctive local floras, and true marine islands.

Comparing figures 3 (species richness) and 5 (collection effort), it became evident that an association exists between number of species in each cell and the collection effort. Indeed, a good fit was found between our dataset and Clench's equation (Fig.6a). As expected in our model (see reasoning in the Methods section above) an overall linear fit was found between the species richness in each cell and the intensity, or redundancy, of the collection (Fig.6b). Both models (Clench and redundancy) showed a basically similar pattern: The better-collected cells can be found at the right of the plot, and the departure of a cell from the regression line can be used as a measure of high, or low, species richness. In the redundancy model, however, the

southern group, the Vizcaíno and Central Gulf deserts showed high affinities. Finally, in spite of the sharing of common genera in their dominant canopy species (pines and oaks), the Sierra de la Laguna and the northern Montane Forests showed very low similarity in the endemic floras, a fact that suggests that their mapping as different vegetation types is indeed correct.

We identified ten high diversity areas or *hotspots*, and three low diversity areas (Fig. 10). The *hotspots* are distributed all over the study region representing 43% of the area. All the vegetation types, except the lower Colorado desertscrub are represented in the hotspots.

DISCUSSION

This research has two main contributions: the first one oriented to the knowledge of high diversity areas in the peninsula of Baja California. The second methodologically oriented to analyze diversity of large areas from collections information.

Methodological contribution of this research

One of the main strengths of our redundancy model, lays in the simplicity of information needed that can be obtained from any reliable and large data collection, while other spatial models based on cartographic cells are constructed using several biotic and non-biotic indicators (Pearson and Carroll 1998). Although we analyzed heterogeneous cartographic cells when applied to homogeneous polygons for example with the same type of vegetation its inference capabilities should be more evident. Although the redundancy model is derived from the Clench's accumulation function model, it seems to be more sensibly to catch high and low diversity areas than the former one. While the redundancy method adds to others proposed

Biological contribution of this research

The flora of Baja California shows a high level of endemism. This may be the result of the combination of several factors. Firstly, the presence of Pleistocene relictual temperate forests may account for an important fraction of the paleoendemisms. Secondly, arid and mediterranean vegetation appeared in the peninsula only after the last glaciation, adding diversity to the preexisting vegetation matrix (Axelrod 1978, 1979). Thirdly, the diversity in climates, soils and topography promotes the presence of relatively fragmented communities and within them speciation process, as has been described for California (Stebbins and Major 1965, Richerson and Lum 1990). Lastly, short distance gradients along mesic-semiarid-arid environments generate abrupt ecotones that allow the survival of ecotonal species and that stimulate speciation (Shreve 1936, Stebbins 1952).

As stated above we identified in our study region ten high biodiversity areas or *hotspots* (Fig. 10). In the northwest of the peninsula, the mediterranean *hotspot* extends from the international border to the south, below the 30° parallel, and from the highest parts of the sierras to the Pacific coast. This area includes Montane Temperate Forest, Chaparral, and Coastal Scrubs. These last two vegetation types extend from California into Baja California, and it is in the latter where the transition into the desert promotes the presence of numerous ecotonal endemics (Shreve 1936). The endemic genera Bergerocactus (Cactaceae), Adenothamnus (Asteraceae), Ophiocephalus (Scrophulariaceae), and Ornithostaphylos (Ericaceae) are restricted to this hotspot. At species level Amblyopappus pusillus, Ambrosia flexuosa (Asteraceae) and Amorpha apiculata (Fabaceae) are some of the species restricted to this hotspot.

The second hotspot, the Sierra de La Libertad region located at the middle peninsula, includes three vegetation types and several endemic genera. The heights of the Sierra La Libertad include the southernmost Mediterranean (Chaparral) vegetation in Baja California. The Sierra shows a steep east-west vegetation gradient that goes in less than 30 km from a warm desert scrub, to Chaparral, to a more mesic desert influenced by Pacific fog. Characteristic endemic genera of this hotspot are Acanthogilia (Polemoniaceae) and Xylonagra (Onagraceae).

Between latitudes 26° and 28° three *hotspots* are found. The first one is the Vizcaíno peninsula in the Pacific side of Baja California. This section of the Baja California peninsula became detached from the mainland during the Eocene and stayed as an island through most of the Neogene period (Durham and Allison 1960). Even at the Present it is relatively floristically isolated from the rest of the peninsula by the halophytic vegetation that surrounds it. Most of the endemics found in this area are located at the extreme west tip and at the Sierras El Placer and Santa Clara. Some of the distinctive species in this area are Agave vizcainoensis (Agavaceae) Astragalus piscinus (Fabaceae), *Camissonia sceptrostigma* (Onagraceae), and Eriogonum encelioides (Onagraceae). To the east of this the Sierra de San Francisco *hotspot* is found. Located inside the Vizcaíno Biosphere Reserve, this sky island has a distinct sclerophyllous scrub on its highest parts. The third mid-peninsular hotspot, Bahía Concepción, is found in the coast of the Sea of Cortés. This region has a volcanic origin and includes the lava field of Tres Vírgenes and the island of Tortuga. Described by a high collection effort, this region shows a high richness and a rather low endemism. The monotypic genus Antiphytum peninsulare (Boraginaceae) is restricted to this region.

To the south of this region, between 24° 45' and 26° 30' and along the coast of the Sea of Cortés, another high diversity area forms a fragmented insular/coastal hotspot encompassing all the southern Gulf Islands and the Sierra La Giganta. The Sierra, also of volcanic origin, stretches along 200 km. Even though, it has a good collection effort, especially at its north and south extremes, and harbors several local endemics at the species and genera level, its middle part is largely undercollected and it would likely render new taxa if explored in more detail. The monotypic genus Carterothamnus anomalochaeta (Asteraceae) is restricted to this Sierra.

The tropical origin of the Cape Region hotspot accounts for its high diversity. Floristically separated from the rest of the study region (León de la Luz et al. 2000), this region presents also high levels of endemism. In the heights of Sierra La Laguna, a relictual Pleistocene vegetation of pine–oak forest is present, while the lowlands harbor a tropical dry forest and a xeric tropical scrub. The monotypic genera Clevelandia beldingii (Scrophulariaceae) and Bessera tenuifolia (Liliaceae) are restricted to this hotspot. Some of the distinctive species of

this hotspot are Sideroxylon peninsulare (Sapotaceae) Verbesina pustulata, V. palmeri (Asteraceae), and Yucca capensis (Agavaceae).

As a rule, all the islands showed high endemism. As expected, those islands farther from the mainland were richer in local endemics. One notable exception, however, was found in Magdalena and Margarita islands, two small coastal islands located off Bahía Magdalena. These island hotspots show not only high species richness but also high endemism values. This is most likely the result of isolation processes related to their older geological age with respect to the near peninsular shore (Durham and Allison 1960). Some of the distinctive species of these islands are Cochemiea halei (Cactaceae), Abronia carterae (Nyctaginaceae), Agave margaritae (Agavaceae), and Asclepias masonii (Asclepiadaceae).

Although endemics plants are distributed all over the study region, we identified three, very low richness areas (Fig. 10). All of them belong to the poorly-collected group in Fig 6. Two factors are associated with these areas of low species richness. Firstly, they possibly present an intrinsic low richness that it is not attractive for collectors. This is especially true for the Lower Colorado and the Magdalena plains, two flat regions with agricultural development that seem to show low species richness even in cells that are moderately collected. Another factor is the difficulty to reach some areas of the peninsula. Most of the herbaria accessions come from sites near the main roads. There were in our data 11 cells void of any collection data and, since some of them are surrounded by high-endemism cells and lack easy access, presumably they have been scarcely visited by botanists. Very likely, this is the case of the cell in front of Ángel de la Guarda Island in the Gulf Coast or the one immediately below latitude 24° near the Cape region. Low collection effort could be the explanation for the low richness area of Sierra San Pedro. In the middle of the peninsula, this heterogeneous range presents a montane sclerophyllous scrub in its peaks, it has many canyons and arroyos as well as refuge areas that are still waiting to be collected.

The similarity analysis provided some unanticipated findings. Although very distant, we expected more affinity between the north and south coniferous forests, which, in spite of being

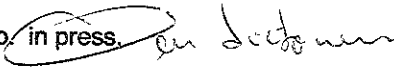
dominated by species of the same genera (Pinus and Quercus) showed substantial differences in their endemic flora. That is, although the physiognomically dominant species in these two forests are related at the generic level and may be indicating the existence of a paleorefuge (Nekola 1999), many understory species seem to be more related to the local floras and constitute microendemisms of more recent origin and of local distribution.

Two important points are derived from this research. Firstly, the results allowed us to gain information on the distribution of endemic plants, and to identify areas with high levels of endemism and high species richness. This information is important to plan and prioritize new protected areas in the peninsula. We perceive this as a very important point, since this region is the only part of Mexico that forms part of two larger areas recently singled-out by Myers et al. (2000) as global biodiversity *hotspots*: the Californian Floristic Province and the Mesoamerican Tropical Forests. These two phytogeographic regions lie in the extremes of the peninsula and are currently under increasing land-use pressure. Secondly, the study allowed us to identify undercollected areas and in general highlighted the need for a higher collection effort, especially in targeted areas. At the scale of our study, most of the cells analyzed showed some degree of undercollection. In spite of the problem of under collection, the geographic patterns found in our study seem to be quite consistent with both the predictions of ecological theory (endemism increases in fragmented or insular habitats) and with our own field experience. The hotspots identified in this work for the Peninsula of Baja California define a working agenda for future conservation efforts.

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Tables

Table 1. Estimates of mean species richness per cell (α diversity), species turnover (β diversity), total richness (γ diversity), and range ($\bar{\epsilon}$, or mean number of cells occupied by each species).

| Parameter | Value | Variance | st. dev. | st. error |
|------------------|-------|----------|----------|-----------|
| $\bar{\alpha}$ | 22.24 | 520.76 | 22.82 | 1.51 |
| β | 0.137 | 0.020 | 0.142 | 0.005 |
| γ | 702 | - | - | - |
| $\bar{\epsilon}$ | 7.29 | 56.56 | 7.52 | 0.28 |

Figure Captions

Figure 1. Vegetation map of the Peninsula of Baja California and neighboring islands. The map was elaborated from various sources (Brown and Lowe 1977, CONABIO, WWF, and CCE. 1998, INEGI 1982, SPP 1980) and our own field observations.

Figure 2. (a) Statistical distribution of species richness in cartographic cells. Vertical bars show the number of cells containing a given species richness. The continuous line shows the Poisson distribution, expected under the assumption of random fluctuations in species richness. Both series differed very significantly ($P \ll 0.0001$). (b) Statistical distribution of species geographic range. Vertical bars show the number of species occupying a given number of cartographic cells. The continuous line represents the lognormal distribution. Both series did not differ significantly.

Figure 3. Species richness of Baja California endemic plants. The radius of each circle represents the number of endemics.

Figure 4. Degree of endemism of Baja California plants. The area of each circle is proportional to the level of endemism in each cell.

Figure 5. Collection effort for Baja California endemic plants. The area of each circle is proportional to the number of specimens collected in each cell.

Figure 6. (a) Number of species against number of specimens collected in each cell. The line corresponds to the fitted values of Clench's equation, with parameters $a = .704$, $se(a) = .032$, $b = 159.3$, $se(b) = 11.4$ ($r^2 = 0.94$, $P \ll 0.00001$). Black circles represent cells that deviate significantly ($P < 0.01$) from the Clench values. (b) Number of species vs. collection intensity in each cell ($r^2 = 0.25$, $P \ll 0.00001$). Black circles represent cells that deviate significantly from the model. Numbers in both plots represent cells located at: 1 = Cape Region in front of Cerralvo Island, 2 and 3 = temperate forest at Sierra de San Pedro Mártir, and 4 = Guadalupe Island.

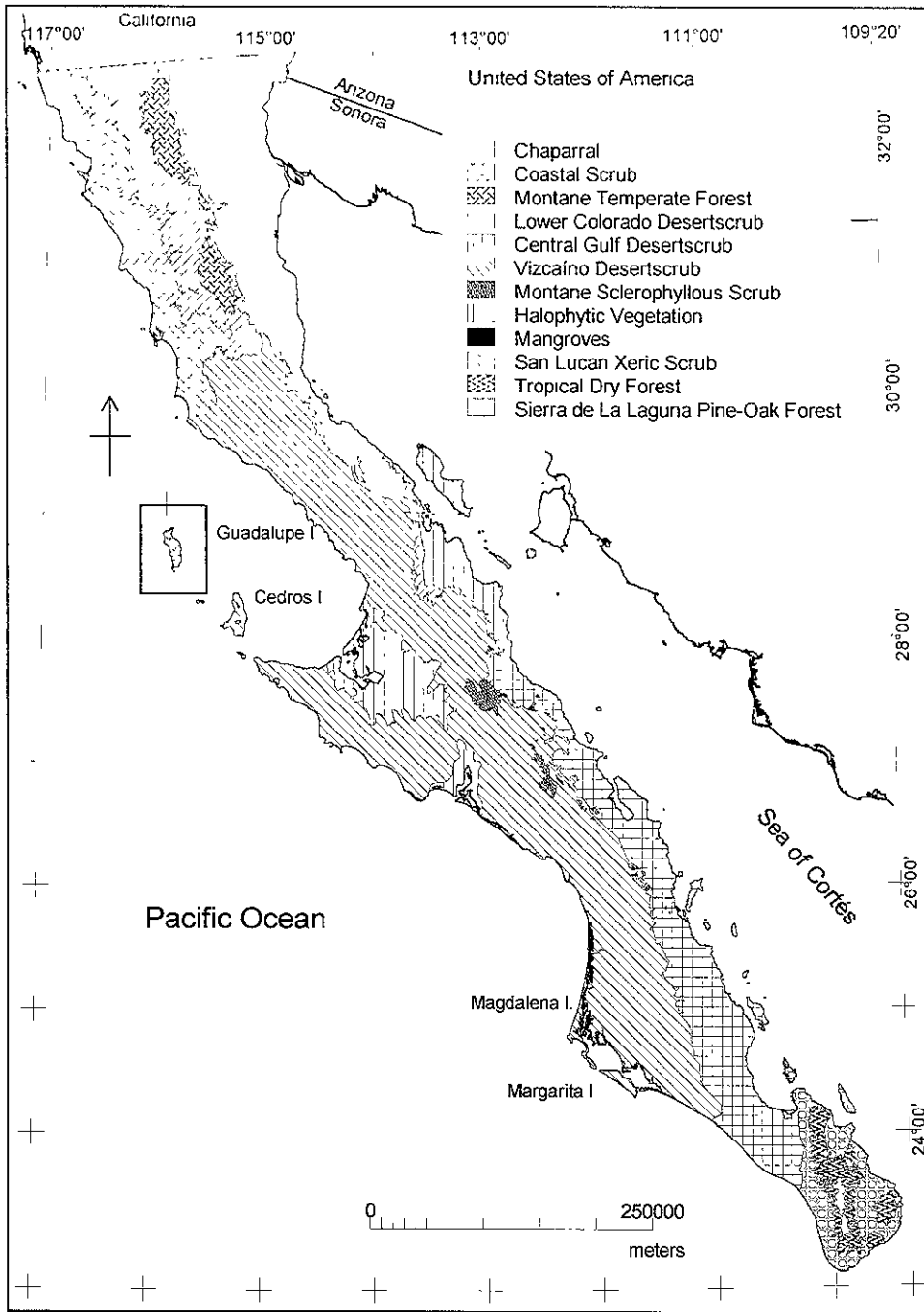
Figure 7. High and low-diversity cells corrected by the land area of the cell. Black and gray circles represent cells with significantly high and low number of endemics, respectively. Full

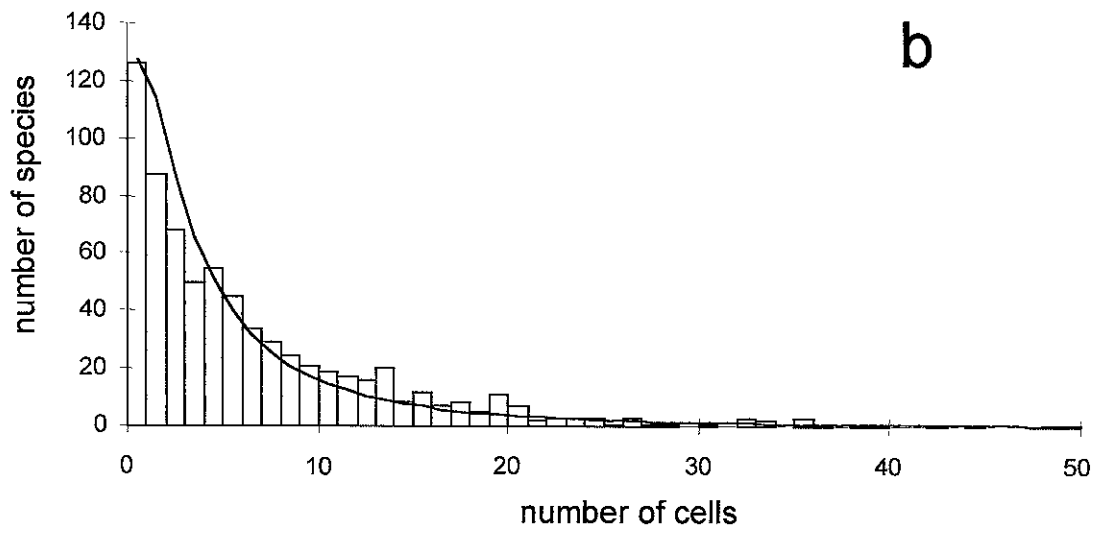
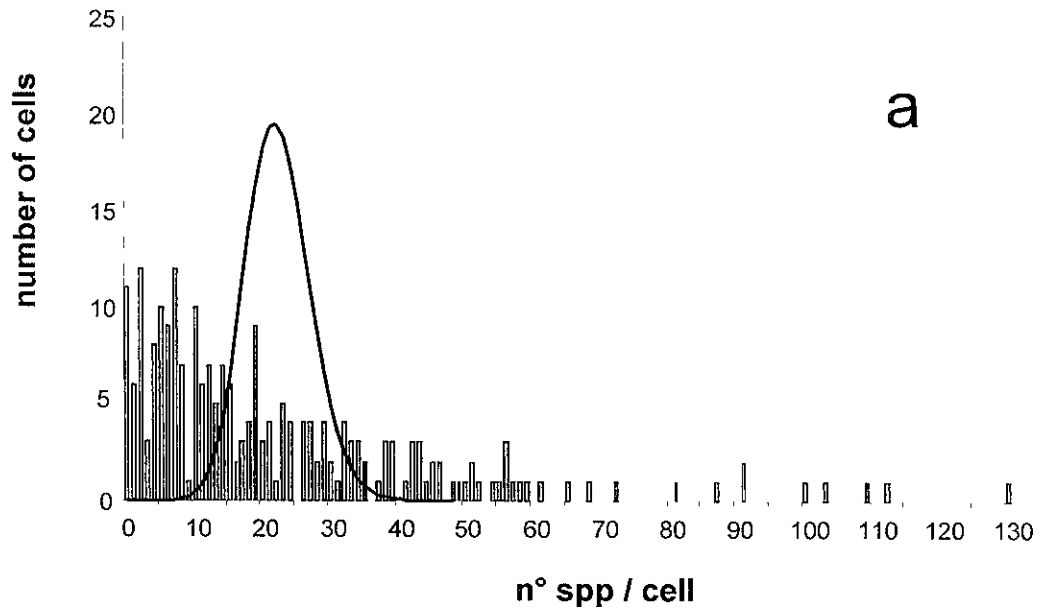
circles represent cells with a Bonferroni-corrected significance of 5%; white-dotted circles represents cells with a Bonferroni-corrected significance of 1%. Cells without circles do not differ from the expected mean value.

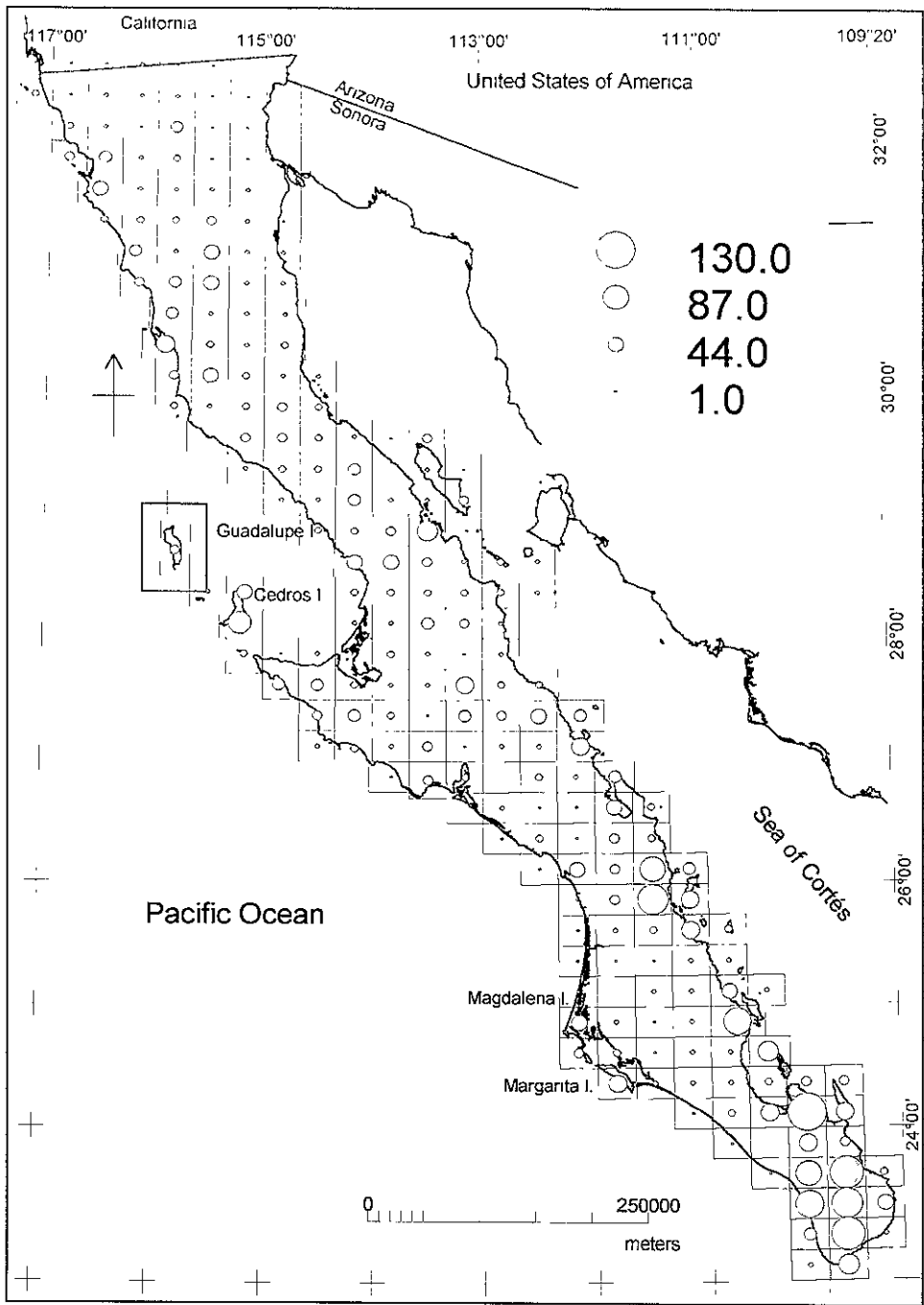
Figure 8. High and low-diversity cells corrected by both the land area and the collection intensity of the cell. Symbols as in Fig. 7.

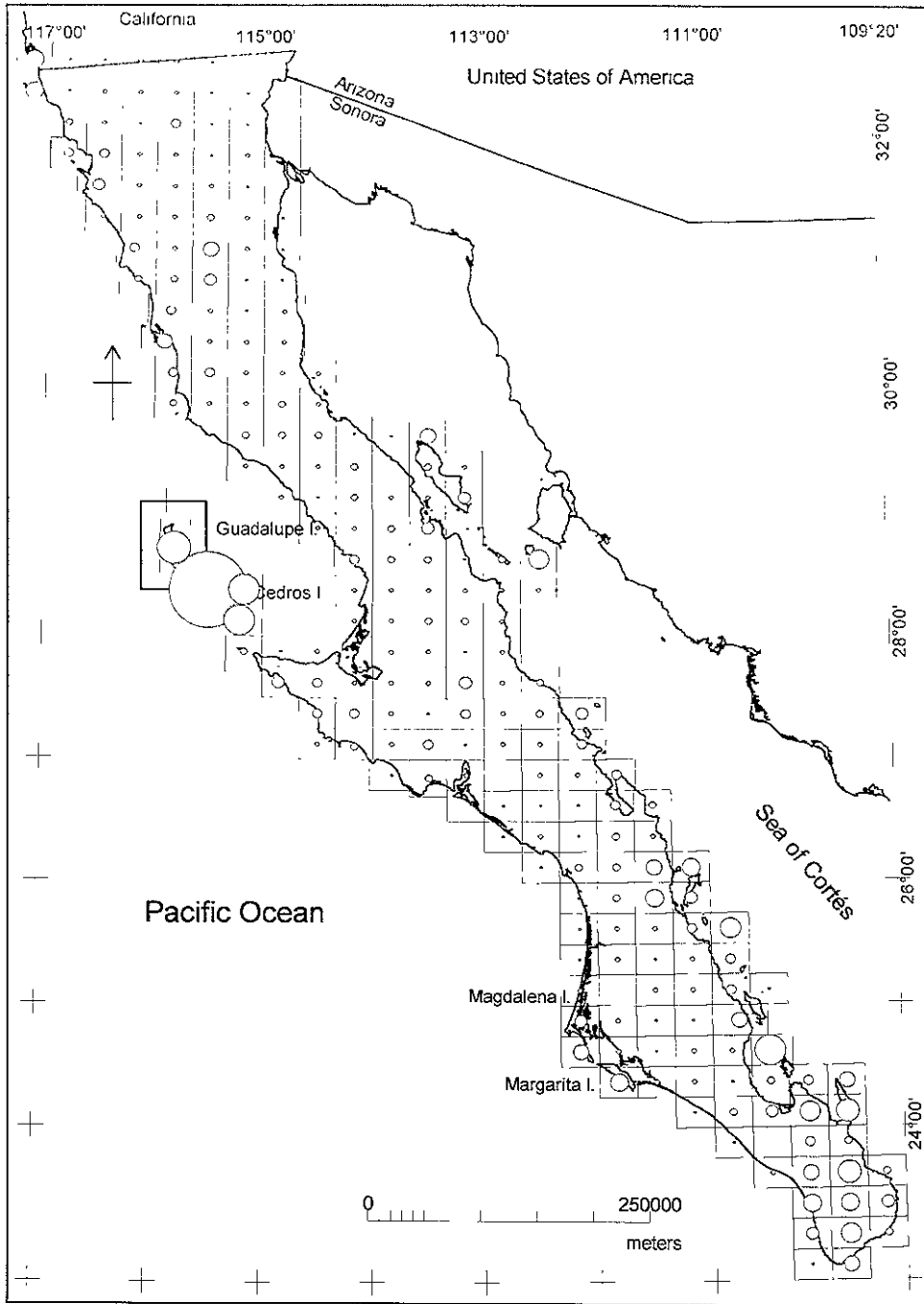
Figure 9. Similarity dendrogram for the 12 vegetation types of Baja California as described by their endemic plant species.

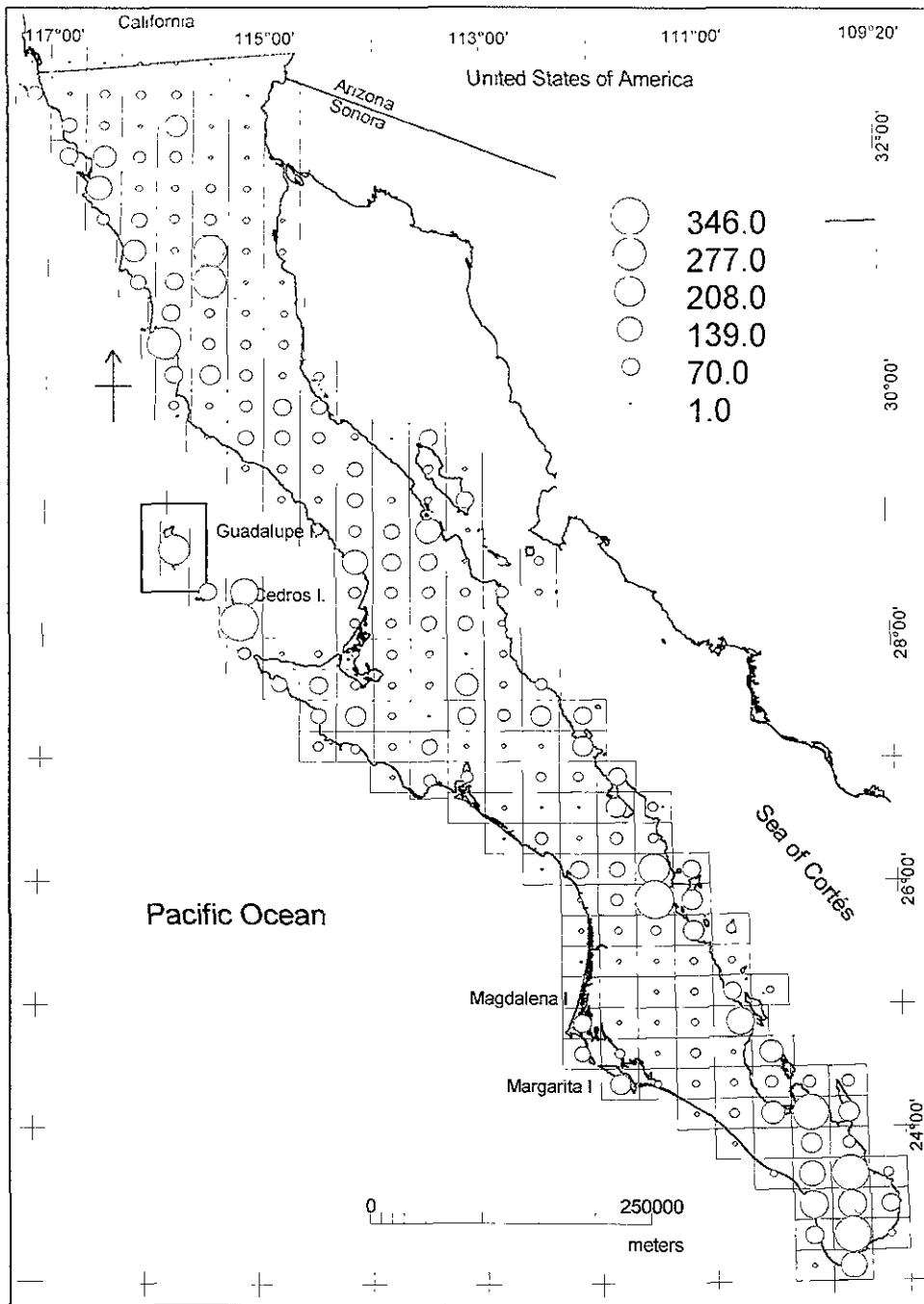
Figure 10. High and low-diversity areas in Baja California. Continuous lines represent high biodiversity hotspots, broken lines highlight low diversity areas. a = Mediterranean, b = Oceanic Islands of the Pacific, c = Sierra de la Libertad and Central Desert, d = Midriff Gulf Islands, e = Vizcaíno Peninsula, f = Sierra San Francisco, g = Bahía Concepción, h = Magdalena Bay Islands, i = South Gulf Islands, j = Cape Region. 1 = Lower Colorado Region, 2 = Sierra de San Pedro Region, 3 = Magdalena Plains Region.

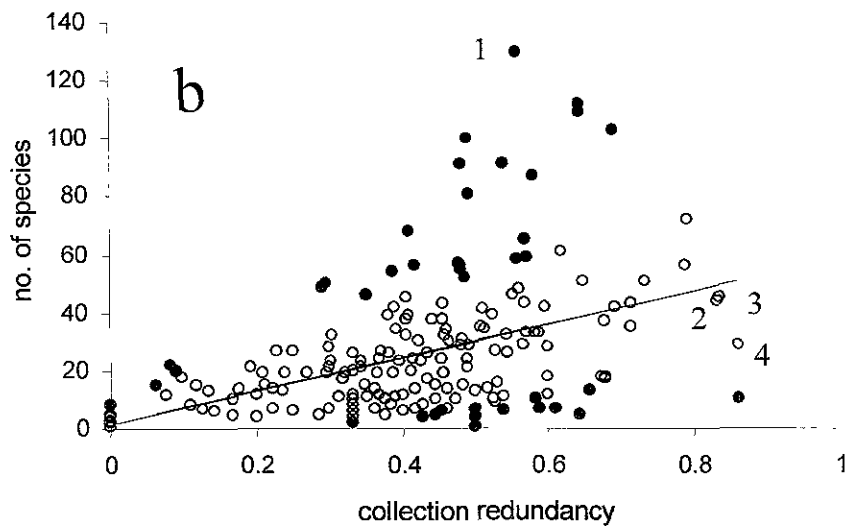
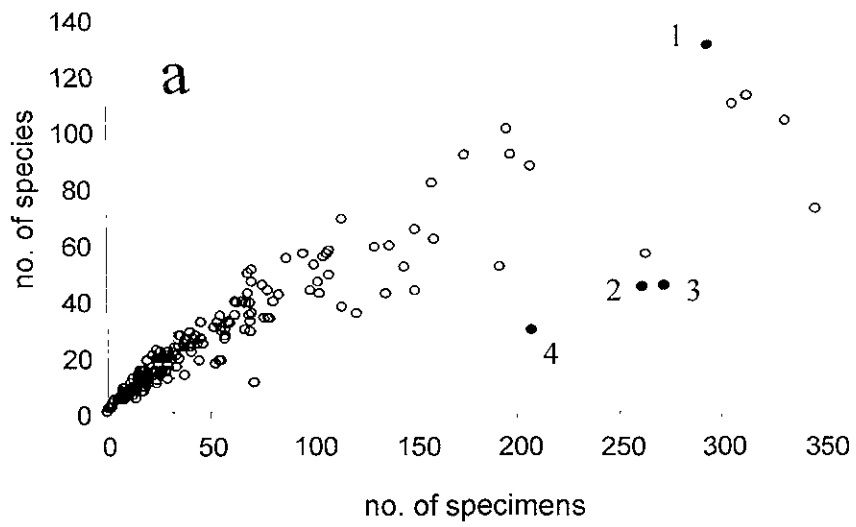


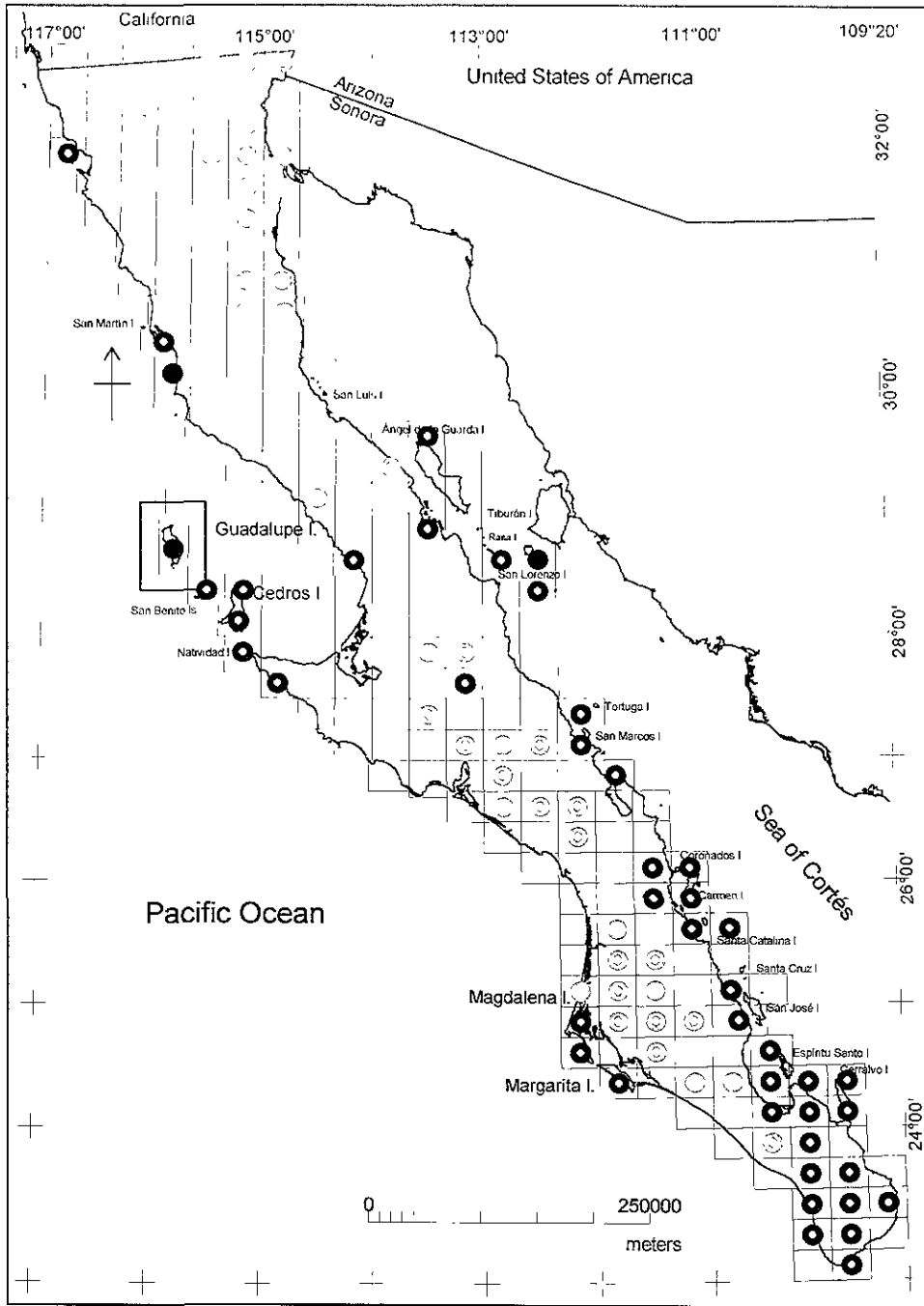


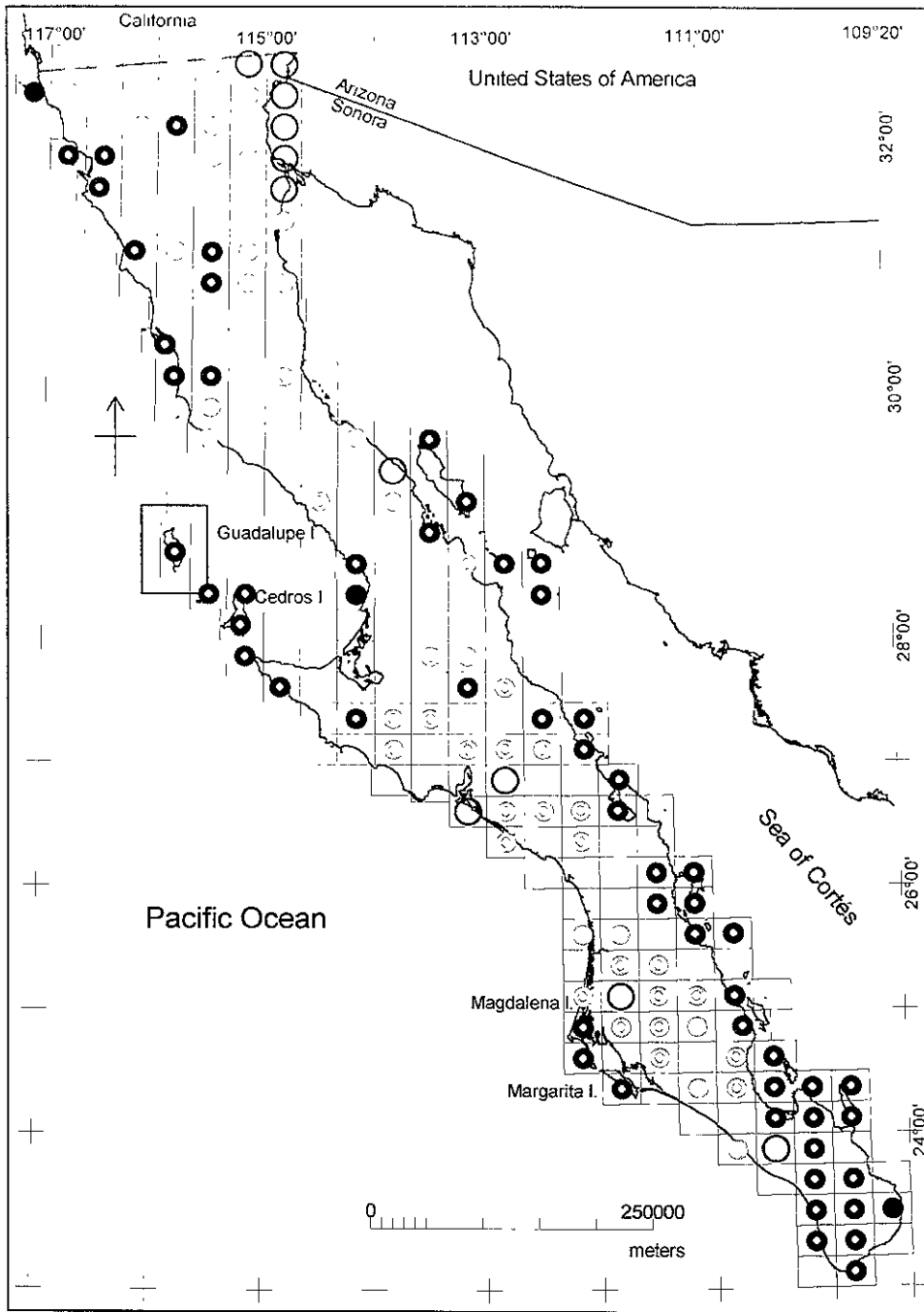


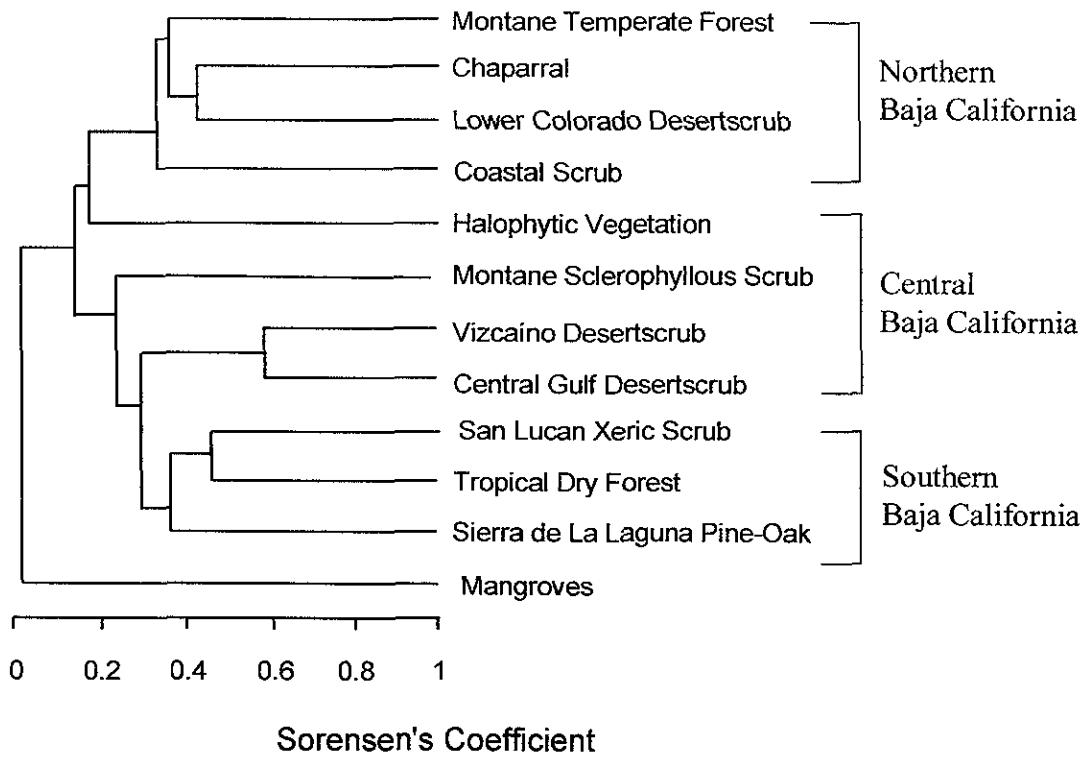


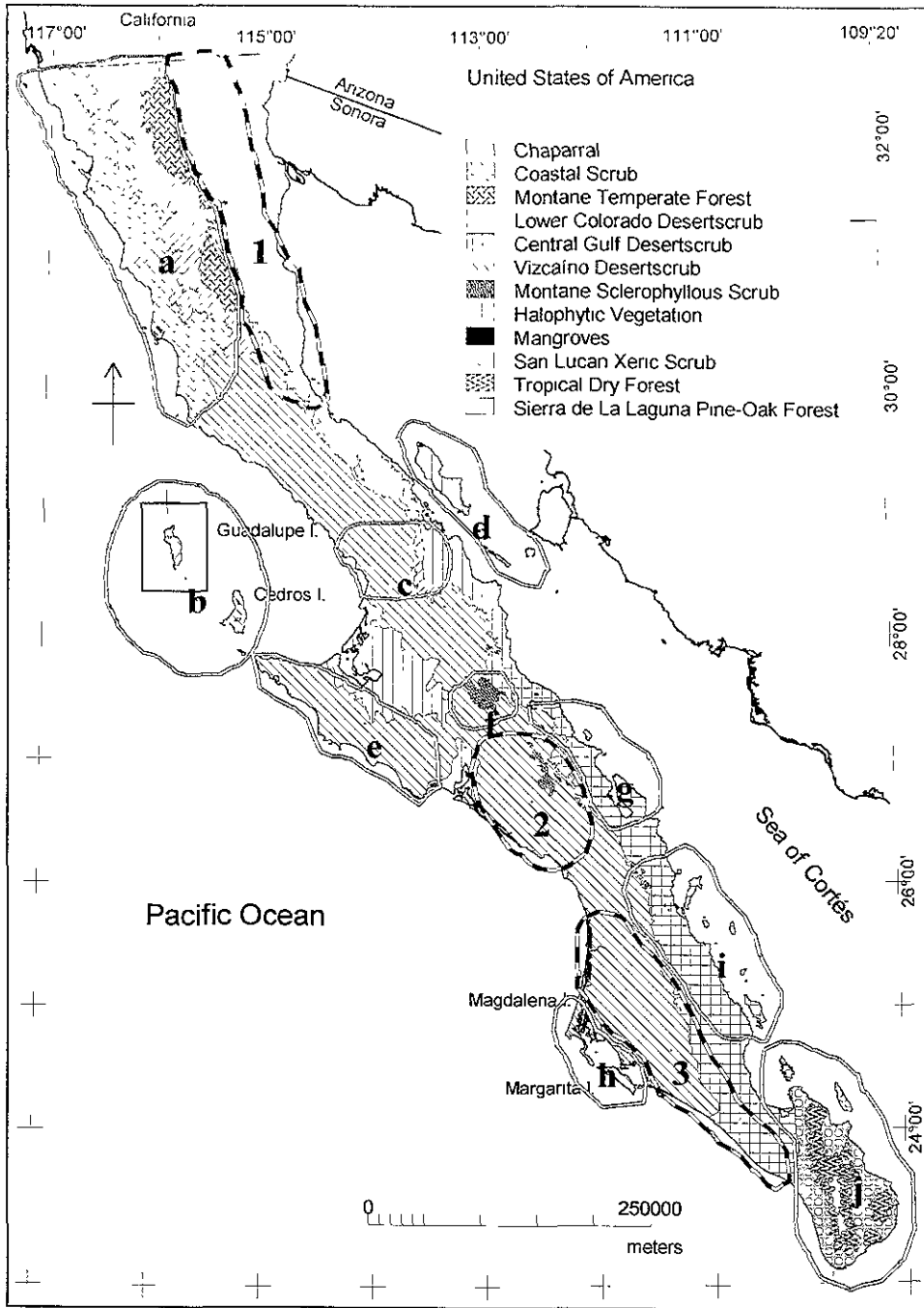












Conclusiones generales

Probablemente una de las responsabilidades más grandes que en materia de conservación de los recursos bióticos enfrentemos en el ámbito nacional y mundial sea establecer con el mayor acierto posible las áreas destinadas para la protección. El crecimiento de la población y la demanda por parte de ésta de una mejor calidad de vida inevitablemente llevan a rebasar la capacidad de oferta de bienes y servicios de los ecosistemas, con la consecuente degradación del ambiente.

Ante la paradoja de que la mayor riqueza biológica ocurre en las regiones de menor desarrollo y mayor tasa de crecimiento - de lo cual México es un claro ejemplo - debemos ser excesivamente cuidadosos al delimitar áreas de conservación (Chapin et al. 2000). Sabemos que inevitablemente seguiremos perdiendo una gran cantidad de especies, y aun, comunidades enteras. Para minimizar este impacto debemos ser capaces de identificar la contribución de cada región a la diversidad total y de esta manera establecer la extensión de las áreas a proteger. La necesidad de llevar a cabo esta tarea con recursos limitados y en el corto y mediano plazo requieren de procedimientos indirectos y confiables. Es en este sentido que esta investigación tiene uno de sus mayores méritos. Se ha demostrado aquí, la factibilidad de identificar estas regiones a partir de información de colecciones, en este caso tomando como objeto de análisis un grupo de especies diverso y clave en la conservación. Se logró también la identificación de áreas de alta diversidad y endemidad (*hotspots*) de una región que representa poco más del 7% de la superficie del país y en la cual están representadas de manera única dos de las regiones de alta biodiversidad del planeta la región Californiana y la Mesoamericana (Myers et al. 2000). Se identificó un importante número de especies endémicas no presentes en las actuales áreas protegidas, poniendo en duda su efectividad como áreas de protección, al menos para el grupo estudiado.

Por último, pero no por ello menos importante, se establecieron procedimientos de análisis para determinar parámetros de diversidad, a partir de datos de presencia y ausencia.

Al hacer una sobreposición de las áreas identificadas como de alta diversidad (*hotspots*) sobre las áreas naturales protegidas de Baja California se puede observar que si bien existe un alto grado de concordancia entre ambos grupos, también se presentan notables discrepancias (Figura 1). En la región mediterránea se localizan dos pequeños parques que protegen de manera parcial a la vegetación de pino-encino. El chaparral y el matorral costero que ocupan la mayor parte de esta área no tienen representación en las áreas protegidas. Estas comunidades están en alto riesgo de desaparecer como consecuencia de la intensificación en el uso del suelo en esta región.

Al sur, entre las latitudes 28° y 29° se localiza la región de Sierra de La Libertad y desierto central. Ésta es abundante en géneros endémicos de distribución local. En la parte alta de la Sierra de La Libertad, se localiza el último reducto al sur de vegetación de chaparral.

La región que aquí llamamos península de Vizcaíno se localiza dentro de la Reserva de la Biosfera del mismo nombre. El origen de esta región se remonta al Eoceno y permaneció aislada de Baja California hasta el Plioceno lo que puede ser un factor para explicar su alta riqueza de endemismos (Durham and Allison 1960). En un escenario que contemple la modificación de las áreas protegidas de la península debería considerarse incluir dentro de la actual área núcleo a las Sierras de El Placer y Santa Clara. De la misma manera la región de la Sierra de San Francisco por su abundancia de endemismos podría ser elevada a categoría de área núcleo. En la región de Bahía Concepción se localiza otra área de alta diversidad. Esta que abarca en su extremo norte parte de la Reserva del Vizcaíno en la región volcánica de Las Tres Vírgenes y se extiende hacia el sur englobando a la península de Bahía Concepción y la vertiente Golfo de la región montañosa. Al oeste de esta región se localiza la Sierra de San Pedro, una región que se ha marcado como de baja diversidad (capítulo 2). Sin embargo, del análisis de los datos se entrevé que el carácter de baja diversidad de esta región puede deberse más a la falta de colecta que a la baja diversidad. Por ello un escenario que

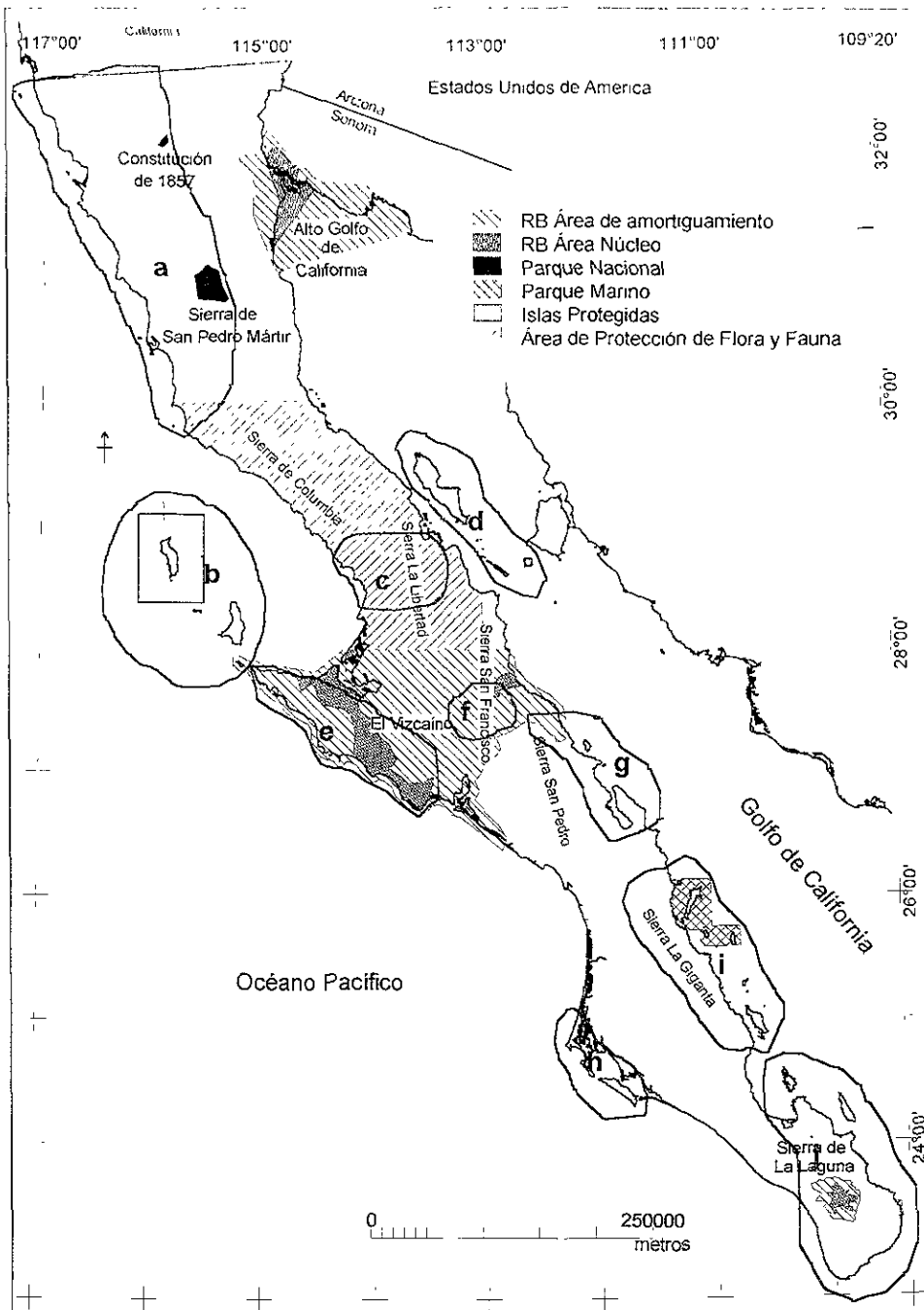


Figura 1. Regiones de alta diversidad y áreas naturales protegidas.

a = Mediterránea, b = Islas Oceánicas del Pacífico, c = Sierra de la Libertad y desierto central, d = Islas del Centro del Golfo, e = Península de Vizcaíno, f = Sierra San de Francisco, g = Bahía Concepción, h = Islas de Bahía Magdalena, i = Islas del Sur del Golfo, j = Región del Cabo.

contemplara la creación de la reserva de la región de Bahía Concepción debería considerar englobar la región de la Sierra de San Pedro, ya que es altamente probable que un estudio detallado de ésta revele una alta diversidad y riqueza de endemismos, como es el caso del resto de las Sierras de Baja California. La presencia de numerosas pinturas rupestres en esta sierra agrega un elemento más de interés para la protección de esta región (Crosby 1997).

El hecho de que la región aquí llamada islas del sur del Golfo incluya al parque marino de Bahía de Loreto y varias islas del Golfo resalta su importancia como área de conservación de la que ha quedado excluida la Sierra de La Giganta. Esta sierra, que alberga un número importante de endemismos locales, no está del todo explorada por lo que es muy probable que en el futuro con el hallazgo de nuevas especies se acentúe aún más su importancia como área de conservación de germoplasma de distribución local.

Las islas de Bahía Magdalena, al igual que la península de Vizcaíno tienen un origen que se remonta a principios del Neogeno (Durham and Allison 1960). En ellas se localizan especies de distribución local e inclusive especies vicariantes de las Poligonáceas de origen Neártico que en la parte peninsular tienen su límite de distribución muy al norte.

La región del Cabo se distingue del resto de la península por su vegetación. En esta se presentan dos tipos de vegetación de origen Neotropical, la Selva Baja Caducifolia y el Matorral Xerófilo San Lucano y un tercero de origen Neártico que representa una vegetación relictual del Pleistoceno. Probablemente debido a su origen, diversidad y localización geográfica extrema de relativo aislamiento del resto de la península, esta región presenta la mayor aglomeración de endemismos de distribución local. La creación de la Reserva de la Biosfera Sierra de La Laguna ha significado un importante avance en la protección de los ecosistemas del Cabo, sin embargo, ésta es aún insuficiente pues deja desprotegidas la vegetación de matorral xerófilo y la vegetación costera. Ambos tipos de vegetación muy expuestos a alteración por efecto de factores de alto impacto como pueden ser crecimiento urbano, aumento en la oferta de servicios turísticos y actividades extractivas.

Este trabajo enfatiza la importancia de las islas del centro del Golfo como región de alta diversidad, misma que ya ha sido reconocida de tiempo atrás al ser decretadas como áreas protegidas. En el Pacífico, sólo las ya mencionadas Margarita y Magdalena y las islas de Cedros y San Benito quedarían como regiones en espera de algún régimen de protección.

Cualesquiera que sean los regímenes de protección que en el futuro rijan las áreas protegidas no podrán dejar de lado la necesidad de mantener al máximo la diversidad del mayor grupo de organismos y simultáneamente mantener la máxima productividad del sistema. El fracaso en el régimen de protección adecuado para determinada área puede llevar a situaciones de malestar social, que vuelvan vano o inclusive reviertan cualquier esfuerzo de conservación.

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