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This book is dedicated to the memory of
Laura Arriaga Cabrera, Salvador Contreras-Balderas,
and Daniel Lluch Belda, caring colleagues,
great scientists, and exceptional human beings
to whom Baja California and the Gulf of California
owe so much.

Dedicamos este libro a la memoria
Laura Arriaga Cabrera, Salvador Contreras-Balderas y
Daniel Lluch Belda, colegas comprometidos,
grandes científicos, y seres humanos excepcionales,
a quienes Baja California y el Golfo de California
tanto les deben.

FLORISTIC ANALYSIS IN OASES AT CENTRAL BAJA CALIFORNIA SUR

José Luis León de la Luz*

One of the features of the Sierra de la Giganta Mountains is the existence of many small riparian wetlands (oases) along pluvial drainage channels. There are no geo-hydrological studies from which to determine their dynamics in their arid environment, but these areas confront increasing water extraction to satisfy demands of small local settlements. This study compiled a checklist of the hydrophytes from 12 representative oases, and discusses their current status on the basis of composition, richness, and plant species characteristics. We performed a classification of locations based in absence-presence of 57 species using UPGMA to represent a dendrogram of sites group cohesivity. Two major kinds of locations were revealed. By analyzing individual site characteristics, we found that one group fits to places under "low impact conditions" and the other composed of locations that are "impacted" in several ways. The former group contains oases that are relatively rich in species, including aquatic forms which seem to be the most sensitive to disturbance. Geographical affinity of the whole floristic list reveals that most species have a broad distribution, mostly in tropical America.

Keywords: Baja California, Sierra La Giganta, desert wetlands, hydrophytes.

1. INTRODUCTION

The southern half of the Baja California Peninsula is part of the southern Sonoran Desert Biotic Province (Shreve and Wiggins 1964). The Cape Region, at the southern tip of the Peninsula, has been floristically documented and is considered a separate region from the desert communities (Wiggins 1980, León de la Luz *et al.*

1999). The Sierra de La Giganta, northern neighboring region of the Cape Region, has been recently described by León de la Luz *et al.* (2008), concluding that it has sufficient characteristics to be considered a distinct eco-region of the desert (Shreve and Wiggins 1964, Wiggins 1980, Brown 1994).

The relative low altitude of the mountains and the narrow width of the southern Baja California Peninsula provide little surface area for hydrologic depressions. Annual rainfall ranges from 100 to 300 mm. A number of oasis, wetlands, or permanent waterways (springs, seeps) and seasonal reservoirs, locally called 'pozas' or 'tinajas,' occupy this land. No perennial river or lake is currently present (Grismer and McGuire 1993), although in the early 20th century, streams near San José del Cabo and Mulegé were considered "small rivers" (León de la Luz *et al.* 1997).

Currently, numerous small water bodies have been identified, some of them isolated and others occurring in close groups (Maya *et al.* 1997). The largest and best known oases are San Ignacio, Comondú, La Purísima, Mulegé, and San José del Cabo. Some of these are close to the sea; others are spring-fed from the mountains. There are no geo-hydrological studies from which to determine their dynamics. Several are vanishing in the last few decades because water is being extracted to satisfy demands of local settlements. It is likely that the demise of these wetlands results from the combination of primary extraction and increased aridity in the region during the very recent Holocene (Spaulding and Graumlich 1986, Díaz *et al.* 2001).

Most of the riparian habitats are located in an area of the Sierra de La Giganta (Maya *et al.* 1997) where only a few thousand people live and whose livelihood depends on this water supply. Primary activities of the population are extensive livestock ranching of cattle and goats, subsistence agriculture, and gathering mesquite logs (*Prosopis palmeri* S. Wats. and *P. articulata* S. Wats.) for making charcoal (León de la Luz and Domínguez 2005). In a hypothetical model, rainfall collected in upland basins enters aquifers that supply water to the lowlands for supporting scattered farms, rural settlements, and small agricultural areas. Increasing demands for water to satisfy local needs is usually pumped from these aquifers. The importance of these areas for local settlements is obvious.

These oases are attractive areas for vertebrate fauna. Álvarez *et al.* (1996a) found that nearly 65% of the mammalian species in the south-central part of the Peninsula visit the Sierra de La Giganta oases. At ten oases, Rodríguez-Estrella *et al.* (1997) found an edge effect, with resident and over-wintering migratory birds. Álvarez *et al.* (1996b) recorded 32 species of reptiles and amphibians, of which nine are endemic to the Peninsula and ten are adapted to mesic environments or live in association with water sources. Plants of the scrubland community are usually found along the stream

banks and weed-like plants arrive from nearby agricultural areas. Cultivated species, such as the date palm (*Phoenix dactylifera* L.) are also found at the wetland margins.

Since many aspects of oases vegetation are unknown, the main objectives of this study were to: 1. Compile a checklist of hydrophytes in a representative group of wetland locations in the Sierra de La Giganta; 2. Describe the current status of these wetlands, using composition, richness, and species characteristics; 3. Describe geographic relationships of the hydrophytes; and 4. Describe the threats to preserving native plant life, in contrast to the exotic plants species that are also present at the oases.

2. MATERIAL AND METHODS

2.1. Study site

The Sierra de La Giganta is part of the geological backbone of the northern part of the Mexican state of Baja California Sur. It is an elongated and asymmetrically-shaped over its 150-km length and trends SE-NW. The crest or spine lies relatively close to the Gulf of California, with some peaks reaching more than 1,000 m (1,600 m Cerro Giganta, 1,200 m Cerro Mechudo) and many others reaching elevations over 800 m. The drainage divide averages less than 8 km from the eastern shoreline of the Peninsula, leading to precipitous escarpments and steep slopes along the Gulf of California. The western flank slopes more gradually, finally draining gently onto the Pacific coastal plain. Riparian wetlands appear sporadically along the western drainage channels. Some arroyos are about 100 km long (see Figure 1). Most of the Sierra de La Giganta structure is composed of repeating layers of volcano-clastic sandstones of Miocene age (Comondú Formation) and conglomerates of more recent epochs. Extensive alluvial slopes and plains occupy the western flanks.

The climate ranges from BWh to BSh (K√ppen classification). On the western side of the divide, Mission San Xavier (25º51'N, 111º32'W, 420 m), which is the highest weather station in the range, receives 300 mm rainfall (García 1973), while the next closest weather station at El Pilar (24º28'N, 111º00'W, 90 m) receives only 125 mm. Hastings and Turner (1965) consider this sector as transitional between the summer monsoonal-type rainfall regime, typical at the southern third of the Peninsula, and the winter cyclonic regime that prevails in the northern half of the Peninsula. This does not mean that the Sierra receives rainfall in the extreme seasons; on the contrary, this is a transitional region that usually receives little rainfall in summer or winter. Mean annual temperature ranges from 19 to 22ºC; winter temperatures are relatively mild, with a few days of frost (García 1973).

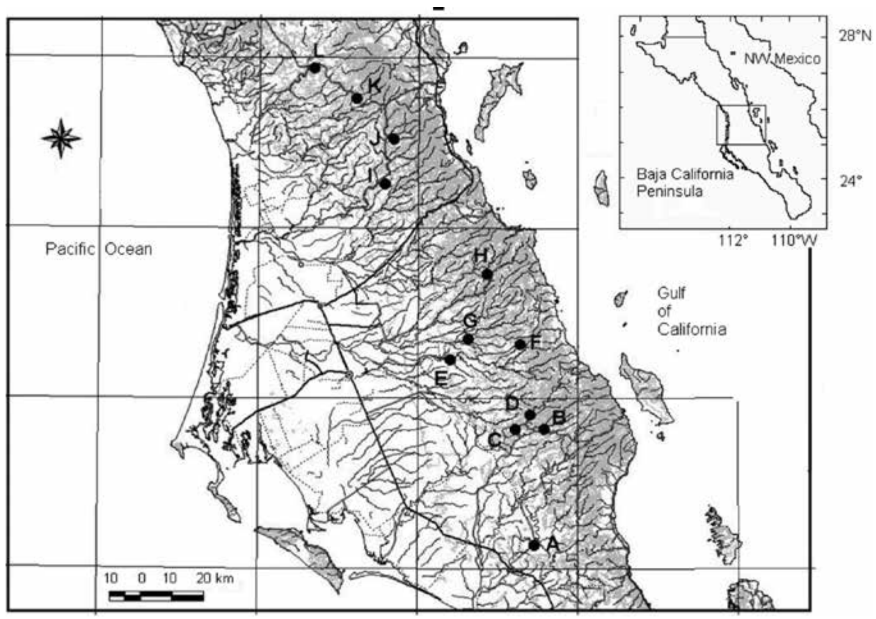

FIGURE 1. Location of 12 oases in the Sierra de la Giganta in the central Baja California Peninsula of Mexico. Names of oases are listed in Table 1. Note drainage systems.

In the entire Baja California Peninsula, 184 oases have been identified, 171 located in the southern half (Maya *et al.*1997). Each was assigned to one of seven groups. Group III (54), mostly in the Sierra de La Giganta, are intermittent, small water bodies within arroyos, ranging from 0.05 to 0.59 km^2 in area, and most of them contain fan palms *Washingtonia robusta Wendl*, and date palms *Phoenix dactylifera*.

2.2. Field inventory

We studied 12 of the larger riparian wetlands in the Sierra de la Giganta, all having a permanent water supply (see Figure 1). From March 2001 through July 2002, physical and biological characteristics of each wetland were inventoried. Several geographical factors (distance to the nearest human settlement, number of inhabitants, and size of water body) were also recorded in several ways (see Table 1). Some indicators of human impact were also recorded (see Table 2).

Riparian zone boundaries were defined according to Thompson *et al.* (2002) as the ecotone where facultative and obligate aquatic plants (the hydrophytes) comprised >50% of species present. This zone coincides with soil that remains moist during the driest season (March through July). Having delimited our sampling area, we

TABLE 1. Characteristics of 12 oases located in the Sierra de la Giganta in the central Baja California Peninsula of Mexico
*Based on nearest weather station.
**Distance from the nearest human settlement (rancho, village, or town).
@According to local informants.
‡Based on local distribution of hydrophytes.

	Oases	Location NW	Arroyo	Elevation (m)	Rainfall* (mm)	Distance ** (m)	Inhabitants @	Surface‡ (km^2)	No. of species
A	El Pilar	24°28' 111°01'	El Pilar	140	125	20	16	0.25	20
B	San Pedro de la Presa	24°51' 110°59'	San Pedro	270	180	30	68	0.10	21
C	Cantar-ranas	24°51' 111°05'	San Pedro	250	180	500	12	0.17	33
D	Santa Ma. Toris	24°54' 111°02'	La Presa	250	170	400	26	0.16	25
E	Tepentú	25°05' 111°19'	La Picota	130	150	300	18	0.47	16
F	La Ensenada	25°08' 111°04'	La Ensenada	425	220	200	8	0.09	14
G	El Rosario	25°09' 111°15'	Batequi-tos	240	185	300	14	0.17	19
H	Poza del León	25°22' 111°11'	San Juan	410	220	100	6	0.19	34
I	El Edén	25°40' 111°33'	San Xavier	110	170	1000	8	0.28	34
J	La Fortuna	25°49' 111°31'	San Xavier	480	300	300	12	0.57	29
K	Palmar Las Bebelamas	25°57' 111°39'	San Venancio	400	285	300	8	0.68	28
L	San Miguel Comondú	26°03' 111°48'	Comondú	450	300	10	330	0.88	26

identified and recorded each plant species as obligate hydrophyte (aquatic plant) or facultative (plants from the adjacent scrubland).

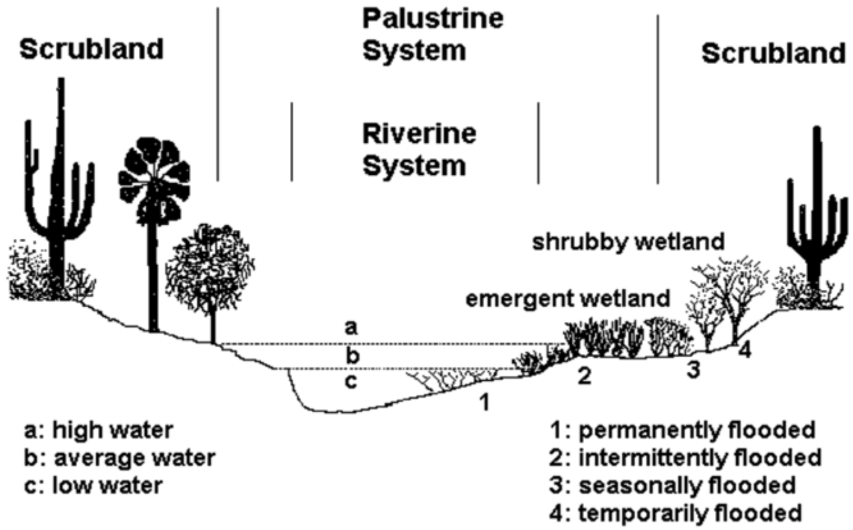

FIGURE 2. Distinguishing features, habitats, and vegetation in an idealized cross-section of an oasis in the Sierra de La Giganta (modified from the wetland classification of Cowardin *et al.* 1992).

Stem growth was used to classify hydrophytes species in eight classes (arborescent, simple, stoloniferous, rhizomatous, floating, rooted/submerged, rooted/emerged, or prostrate); stem form includes three classes (herbaceous, woody, or semi-woody); and growth phase includes two classes (perennial or seasonal). Most of the species were identified on site; but some plants were not readily identified in the field since they did not show flowers and/or fruit. These were preserved and later identified using published regional floras (Shreve and Wiggins 1964, Wiggins 1980, Gould and Moran 1981, Turner *et al.* 1995, Felger 1999, 2000).

2.3. Numerical analysis

We used a multi-variate analysis for a presence-absence or incidence matrix (57 species × 12 sites), each element containing a designation 1 (present) or 0 (absent). A classification based on floristic attributes at the sites was based on a hierarchical cluster analysis generated with MVSP v3.1 software (Kovach 2007); the clustering method was the UPGMA (unweighted pair-group using arithmetic averages). The Euclidean distance was used as the measure of similarity between sites.

2.4. Biogeographical analysis

Geographic affinity of 57 obligated hydrophytes, at the species level, was obtained from the natural distribution of the taxa cited in several floristic studies (Shreve and

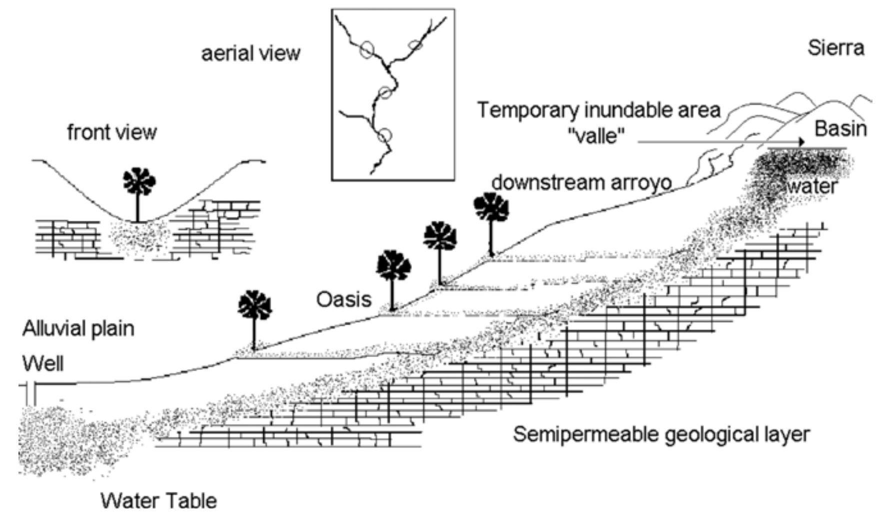

FIGURE 3. Idealized geohydrological scheme of the Sierra de la Giganta oases in the central Baja California Peninsula in Mexico. Rainfall is captured in elevated closed basins, where it percolates to the subsoil. By artesian pressure or cracks, water emerges in the oases intermittently until reaching phreatic surface in the alluvial plains.

Wiggins 1964, Wiggins 1980, Gould and Moran 1981, Felger 2000). The geographical range of each species was classified as either: regional endemism, peninsular, northwestern Mexico, Mexico, North America, continental America, tropical America, pantropical, or cosmopolitan.

3. RESULTS

3.1. General assessments

Figure 2 is an idealized profile diagram of a Sierra de La Giganta oasis, which is based on a wetlands nomenclature found in Cowardin *et al.* (1992). Figure 3 is a schematic representation of the geo-hydrological model of oases. Thus, each oasis is part of a discontinuous series of slightly depressed relief along a rocky arroyo bed having a 3–5° slope and the oases appear near the outlet of an artesian spring. Water level in oases vary throughout the year, depending on current rainfall and occurrence of rainfall in previous years, evaporation rates, runoff from the upslope drainage basin, and extraction for farming and other human activities. Characteristics of the oases are shown in Table 1. The size of the oases was obtained from Maya *et al.* (1997) or by our field surveys. Extent of the oasis site depends on the distribution of hydrophytes, particularly palm groves. Disturbance in an oasis is assessed by using

TABLE 2. Indicators of human disturbance in 12 oases in the Sierra de La Giganta in the Baja California Peninsula of Mexico. (Location codes are identified in Table 1).

Oases												
Type of human disturbance	A	B	C	D	E	F	G	H	I	J	K	L
1. Associated agricultural practices	x	x			x	x	x					x
2. Evidence of cattle ranching	x	x	x	x	x	x	x	x	x	x	x	x
3. Water extracted by pumping		x			x							x
4. Aggressive exotic plants present	x	x					x					x

TABLE 3. Stem growth forms of hydrophytes at 12 oases in the Sierra de la Giganta of the central Baja California Peninsula of Mexico.
*All seasonal or annual /biennial.
**Four perennials, one annual.

Environment	Growth form	Number of species	%
Terrestrial	Underground stolon	8	14.1
	Rhizomatous	11	19.3
	Herbaceous simple*	15	26.3
	Ligneous (Tree/ shrubby)	2	3.5
	Prostrate/ decumbent**	6	10.6
Aquatic	Floating	3	5.2
	Stem emergent	3	5.2
	Stem submerged	9	15.8
Total		57	100.00

four management conditions, of which some were observed during the fieldwork. Table 2 summarizes the evaluation of each oasis.

3.2. Vegetation

Species that are widely occurring in scrublands areas grow opportunistically on moist soil near the oases; these facultative hydrophytes include: cardon *Pachycereus pringlei* (S. Wats.) Britt. & Rose, choya *Cilyndropuntia cholla* Weber, and otatave *Vallesia glabra* (Cav.) Link, lomboy *Jatropha cinerea* (Ortega) Muell.-Arg., mezquite

Prosopis articulata S. Wats., vinorama *Acacia farnesiana* (L.) Willd., bledo *Celosia floribunda A. Gray*, apan *Bebbia juncea* (Benth.) Greene, and several other species. The obligate hydrophytes and the oases where they occur are listed in Table 4. The list includes 57 vascular plants (30 dicotyledons, 26 monocotyledons, and one fern). The survey of Arriaga *et al.* (1997) contains a list of 184 species in eight oases, but only 24 are obligate hydrophytes (according to our classification); all of them were found in this survey.

Of the 57 vascular species, 35 are perennial and 22 are seasonal (annual). Table 3 organizes the flora by life form. Most of the annuals are weeds, probably some of them came from nearby agricultural fields (Santo Domingo Valley). Based on consistence of the stem, 47 species are herbaceous, 7 are partly woody, and 3 are woody. The best represented families, in terms of species, are: Cyperaceae (12), Compositae (7), Scrophulariaceae (4), Onagraceae (4), and Potamogetonaceae (3). Of the Cyperaceae, seven species occur in the genus Cyperus. Table 3 displays this flora according to a classification of the form of stem growth, with 28% living in standing water and 72% in moist and wet soil.

3.3. Statistical analysis

The phenogram of these sites is derived from the UPGMA analysis (see Figure 4). Because the paired and grouped clusters in the phenogram result in linkages at different levels of similarity, an ecologically meaningful classification is not automatically indicated. UPGMA analysis indicates that distances between locations are strongly related to the heterogeneity of the matrix of distance, with the threshold of 5.1 linkage distance defines two large clusters. Cluster I contains oases C, I, H, J, and K, and Cluster II contains oases A, B, D, E, G, F, and L.

Cluster I contains 28 to 34 species at each oases; Cluster II contains 14 to 26 species at each oases. Also, analysis of the list reveals that a group of 33 species appear between one to five times in the records and another group of 24 species appear between six to eleven times in the records.

Some sites in each cluster constitute tight pairs. Locations C and I have almost the same number (33 and 34) and types of species. Locations E and L have different numbers of species (16 and 26), but all records from location E are practically included in location L (see Table 4).

Clusters I and II have another pair of sites that form well-differentiated subgroups, each pair with almost the same number of species, but only ~50% are the same species. These are locations J (29 species) and H (28 species) in Cluster I. Locations A (20 species) and B (21 species) occur in Cluster II. Site D in Cluster II is an

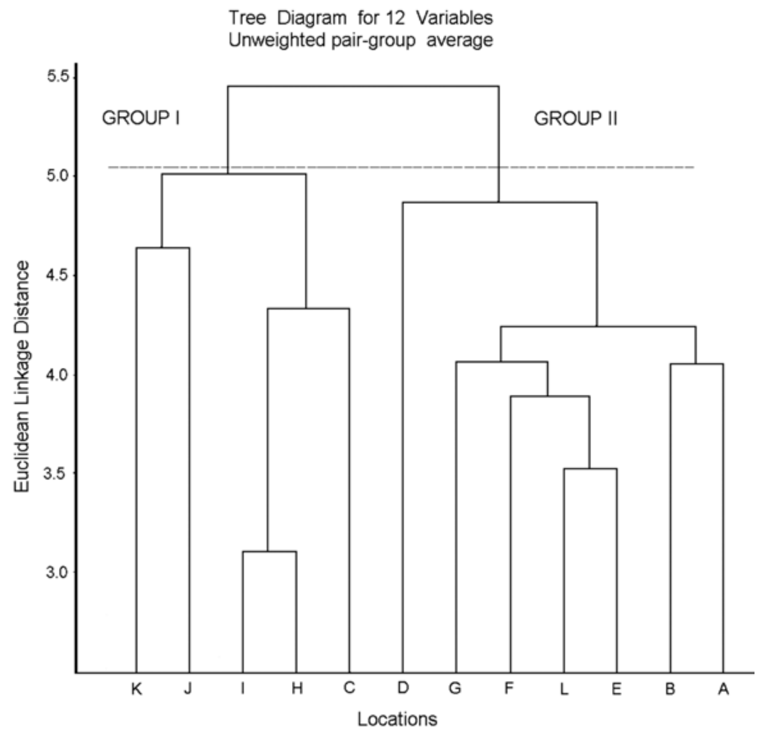

FIGURE 4. UPGMA phenogram based on a distance matrix comparison among several oases (A to L). Names of oases (locations) are listed in Table 1. See text for explanation.

interesting location, distantly linked to other sites in the cluster (high dissimilarity), yet suggesting an intermediate position between the two clusters.

3.4. Floristic interpretation

From the total number of species (57), Cluster I contains 49 and Cluster II contains 50 species. Species that consistently appear in the five locations of Cluster I are yerba-santa *Anemopsis californica* (Nutt.) Hook. & Arn., *Bacopa monieri* (L.) Wettst., *Mimulus dentilobus* Rob. & Fern., *Stemodia pussilla* Benth., *Echinodorus berteroi* (Spreng) Fasset, and *Polygonum hydropiperoides* Michx. Also, six combinations of four species appear jointly among the five locations and five possible combinations of three species appear together. At the seven locations in Cluster II, there are only two common species: buena mujer *Chloracantha spinosa* Benth. and the fan palm (palma real) *Washingtonia robusta*. In this cluster, a couple of species appear jointly in six locations and another two in two locations.

TABLE 4. Floristic list of obligated hydrophytes in 12 oases in the Sierra de La Giganta in the central Baja California Peninsula, Mexico. Names of the oases (A to L) are listed in Table 1.

Oasis	I	C	H	J	K	L	D	P	A	G	E	F
Ferns												
Marsilea vestita Hooker & Grev. (Marsiliaceae)	0	1	1	0	0	0	0	1	1	0	0	1
Dicotyledons												
Ambrosia ambrosioides (Cav.) Payne (Compositae)	1	1	1	0	0	1	1	0	1	0	1	0
Ammania coccinea Rottb. (Onagraceae)	1	1	0	0	1	0	0	0	0	1	0	0
Anagallis arvensis L. (Primulaceae)	1	0	1	0	0	0	0	0	0	0	0	0
Anemopsis californica (Nutt.) Hook. et Arn. (Saururaceae)	1	1	1	1	1	1	0	0	0	0		0
Baccharis glutinosa Pers. (Compositae)	1	0	1	1	1	1	0	1	1	1	0	1
Bacopa monieri (L.) Wettst. (Scrophulariaceae)	1	1	1	1	1	1	1	1	1	1	1	0
Centaurium capense Broome (Gentinaceae)	1	1	1	1	0	0	0	1	0	0	0	0
Centunculus minimus L. (Primulaceae)	0	0	0	0	1	0	0	0	0	0	0	0
Chloracantha spinosa (Benth.) Nesom var. *spinosa* (Compositae)	1	1	0	0	0	1	1	1	1	1	1	1
Eclipta alba (L.) Hassk. (Compositae)	0	0	0	0	0	1	0	1	0	1	1	1
Epilobium adenocaulon Haussk (Onagraceae)	0	0	0	0	0	0	0	0	0	1	0	0
Eustoma exaltatum (L.) Griseb (Gentianaceae)	1	0	1	1	1	0	1	1	1	1	0	0
Heimia salicifolia H.B.K. (Lythraceae)	0	1	0	1	0	1	0	0	1	1	0	1
Heliotropim procumbens Mill. (Boraginaceae)	1	1	1	0	1	1	0	1	0	1	1	0
Hydrocotyle umbellata L. (Apiaceae)	1	1	1	0	0	0	0	0	0	0	0	0
Hymenoclea monogyra Torr. et A. Gray (Compositae)	0	0	0	0	0	1	1	0	1	1	1	1
Kosteletzkya digitata A. Gray (Malvaceae)	0	0	0	0	0	1	0	0	0	1	1	1

Oasis	I	C	H	J	K	L	D	P	A	G	E	F
Ludwigia octovalvis (Jacq.) Raven (Onagraceae)	0	0	0	1	1	0	1	0	1	1	0	0
Ludwigia peploides (H.B.K.) Raven (Onagraceae)	1	1	1	0	0	0	0	0	0	0	0	1
Mecardonia vandellioides (H.B.K.) Pennell (Scrophulariaceae)	0	1	0	1	1	0	0	1	0	0	0	0
Mimulus dentilobus Rob. et Fernald (Scrophulariaceae)	1	1	1	1	1	1	1	1	1	0	1	0
Petunia parviflora Juss. (Scrophulariaceae)	0	0	1	0	0	1	0	1	1	0	0	0
Pluchea odorata (L.) Cass. (Compositae)	1	1	0	0	1	1	0	0	0	1	0	1
Polygonum hydropiperoides Michx. (Polygonaceae)	1	1	1	1	1	0	0	0	0	0	0	0
Roripa palustris (L.) Bess. (Cruciferae)	0	1	1	0	0	0	1	0	0	0	0	0
Salix bonplandiana H.B.K. (Salicaceae)	0	0	0	0	0	0	0	1	1	0	1	0
Samolus ebracteatus H.B.K. (Primulaceae)	0	0	0	0	0	1	0	0	0	0	0	0
Stemodia pusilla Benth. (Scrophulariaceae)	1	1	1	1	1	0	1	0	0	0	0	0
Tillaea erecta Hook subsp. *erecta*	0	0	0	0	0	0	0	0	0	0	1	0
Xanthium strumarium L.	0	0	0	1	0	0	1	0	0	0	0	0
Monocotyledons												
Cyperus cuspidatus H.B.K. (Cyperaceae)	1	0	1	0	0	1	1	0	0	0	0	0
Cyperus dioicus I.M. Jhtn. (Cyperaceae)	0	1	1	1	0	0	0	1	0	1	0	0
Cyperus esculentus L. (Cyperaceae)	0	1	0	1	1	0	1	1	1	0	0	1
Cyperus laevigatus L. (Cyperaceae)	1	0	1	1	1	1	0	0	0	1	0	0
Cyperus perennis (M.E. Jones) O'Neill (Cyperaceae)	1	1	0	1	0	0	1	0	1	0	0	0
Cyperus surinamensis Rottb. (Cyperaceae)	0	0	1	0	1	1	1	0	0	0	1	0

Oasis	I	C	H	J	K	L	D	P	A	G	E	F
Cyperus tenuis Swartz (Cyperaceae)	1	1	0	1	1	1	0	1	0	0	0	0
Echinodorus berteroi (Spreng.) Fasset (Alismataceae)	1	1	1	1	1	0	1	0	0	0	0	0
Eleocharis geniculata (L.) R. et S. (Cyperaceae)	1	1	1	0	0	1	1	1	1	0	1	1
Eleocharis montevidensis Kunth (Cyperaceae)	0	1	0	1	0	1	1	0	0	0	1	1
Fuirena simplex Vahl (Cyperaceae)	1	0	1	0	1	0	0	0	0	0	0	0
Hemicarpha micrantha (Vahl) Pax (Cyperaceae)	0	1	1	1	1	0	0	0	0	0	0	0
Juncus acutus L. (Juncaceae)	0	0	0	1	1	0	0	1	0	0	0	0
Juncus mexicanus Willd. (Juncaceae)	1	0	1	0	1	1	0	1	1	1	1	0
Lemna minor L. (Lemnaceae)	1	1	1	1	0	0	1	0	0	1	0	0
Naias guadalupensis (Spreng.) Morong (Najadaceae)	1	1	0	1	1	0	0	0	1	0	0	0
Naias marina L. (Najadaceae)	1	1	1	1	0	1	1	0	0	0	0	0
Phragmites australis (Cav.) Steud. (Gramineae)	0	0	0	1	1	1	1	1	1	0	1	1
Potamogeton illinoensis Morong (Potamogetonaceae)	1	1	1	1	0	0	0	0	1	0	0	0
Potamogeton pectinatus Raf. (Potamogetonaceae)	1	1	1	0	1	0	1	0	0	0	0	0
Ruppia maritima L. (Ruppiaceae)	1	1	0	1	0	0	1	0	0	0	0	0
Scirpus americanus Pers. (Cyperaceae)	1	0	1	0	1	0	1	0	0	0	0	0
Typha dominguensis Pers. (Typhaceae)	0	1	1	1	1	0	0	1	0	0	0	1
Typha latifolia L. (Typhaceae)	0	0	0	0	0	1	1	0	1	1	0	0
Washingtonia robusta Wendl. (Arecaceae)	1	1	1	0	1	1	1	1	1	1	1	1
Zannichellia palustris L. (Potamogetonaceae)	1	1	1	1	0	0	0	0	0	0	0	0

TABLE 5. Geographical affinity of hydrophytes from 12 oases in the Sierra de La Giganta of the central Baja California Peninsula of Mexico, based on data from relevant floras (Shreve & Wiggins 1964, Wiggins 1980, Gould & Moran 1981, Turner *et al.* 1995)

Geographical region of affinity	Number of species	%
Baja California Sur	1	1.7
Baja California Peninsula	2	3.5
Northern Mexico	7	12.2
Mexico	4	7.1
North America	10	17.5
Tropical America	17	29.9
Pantropical	2	3.5
Cosmopolitan	14	24.6
Total	57	100.0

A subset of seven species appears only at oases in Cluster I and do not occur in Cluster II: *Anagallis arvensis* L., *Fuirena simplex* Vahl, *Hydrocotyle umbellata* L., *Centunculus minimus* L., *Polygonum hydropiperoides* Michx., *Hemicarpha micrantha* (Vahl) Pax, and *Zannichelia palustris* L. Another subset of eight species appears only at oases in Cluster II and do not occur in Cluster I: *Eclipta alba* (L.) Hassk., *Epilobium adenocaulon* Hausk, *Samolus ebracteatus* H.B.K., *Hymenoclea monogyra*, *Kosteletzkya digitata* A. Gray, *Salix bonplandiana* H.B.K., *Typha latifolia* L., and *Tillea erecta* Hook subsp. *erecta*. The most common species in these oases are *Mimulus dentilobus* Rob. & Fern., which grows at all five Cluster I oases and six of seven Cluster II oases, and *Washingtonia robusta*, growing at the seven Cluster II oases and four of the five Cluster I oases.

Table 5 shows the geographical affinities of the 57 species, according to comments in the regional floras. The degree of geographical affinity demonstrates the expected results: that the broader the geographic area, the greater the number of species it contains. Tropical regions of the Americas and the cosmopolitan element contribute the largest number of hydrophytes. The most restricted plant, *Centaurium capense* Broome, is an herbaceous annual that occurs statewide.

4. DISCUSSION

A revision of the of Sierra de La Giganta oases is required within the ample concept of wetlands. These central Baja California Sur oases are found in intermittent stream channels that are subject to periodic flooding, as well as receiving year-round spring

or seep water (see Figures 2 and 3). Small wooded areas with emergent marsh-like vegetation arise under those conditions. In a general classification, these areas are called wetlands (humedales by many Mexican conservationists working on the Baja California Peninsula). In central Baja California Sur, arroyo wetlands are characterized by the regional endemic fan palm *Washingtonia robusta* and the non-native date palm *Phoenix dactylifera*, considered by conservationists as invasive in riparian habitats of the Sonoran Desert.

These oases are environmentally different from those described by Ezcurra *et al.* (1988) for coastal sand dune oases in the central Sonoran Desert, but seem to be similar in some grade to the wetlands in canyons described by Wehncke *et al.* (2009) in the northern Baja California Peninsula, as well with those cited by Felger (1999) in locations in the Sonoran Desert of mainland Mexico where they are called xero-riparian habitats. While they are in the same biotic province, these four situations are separated by hundreds of kilometers and are decidedly different from each other in floristics, micro-climatic and geo-hydrological conditions. In this sense, the wetlands of the Sierra de La Giganta seem to be unique in the Sonoran Desert Biogeographical Region.

In a general classification of wetlands, Lugo *et al.* (1988) and Cowardin *et al.* (1992) mention that regular catastrophic floods and ecological limitations are common in these riparian wetlands, leading to low species diversity and a relatively simple structure, compared to adjacent plant communities. Moreover, establishment and growth of plants are limited by environmental factors that seem to control composition and other processes in the vegetation. Among these factors are: periodicity of floods and droughts, occasional high kinetic energy of flood water, and low concentrations of nutrients in the soil. Hence, the fundamental niche for each species is largely affected by water dynamics and nutrients. Flooding from heavy rains, particularly from hurricanes and tropical storms that encounter the mountain range are the most drastic events affecting the oases. Human disturbances over the last three centuries should be included in the study of these habitats, especially in the last few decades when fuel-powered water pumps made water uptake easier, including developing small-scale agricultural activities (see Table 2).

Cluster analysis suggests a relative cohesivity among several hydrophytes. There are prevalent species associated with each cluster, each with a core of associated species. Sites that are part of Cluster I seem to be better conserved than those in Cluster II because they have larger surface areas, support fewer inhabitants, and are located farther from larger settlements (see Table 1). Also, analyses of data in Table 2 show fewer impacts to sites in Cluster I.

The 16 aquatic plants suggest less impacted conditions. An oasis with aquatic forms, such as the strictly hydrophytes, indicates some or all of the following conditions: sporadic cattle grazing, limited agricultural activity, no pumping of water, and a sufficient distance from settlements to make exploitation unattractive. Cluster I sites have hydrophytes, such as: *Echinodorus berteroi* (Spreng) Fasset, *Hydrocotyle umbellata* L., *Zannichellia palustris* L., *Typha latifolia* L., *Naias guadalupensis* (Spreng.) Morong, *N. marina* L., *Potamogeton illinoensis* Morong, *P. pectinatus* Raf., and *Ruppia maritima* L. Cluster II have hydrophytes such as *Chloracantha spinosa* (Benth.) Nesom var. *spinosa*, *Washingtonia robusta* Wendl., and *Typha dominguensis* Pers. Three aquatics are shared: *Marsilea vestita* Hooker & Grev., *Roripa palustris* (L.) Bess., and *Baccharis glutinosa* Pers.

Biogeographically, these oases contain hydrophytes with broad geographic distributions, having geographical affinity with the American tropics and worldwide; hence, these hydrophytes possess a relative broad environmental tolerance, but they need fresh water as a primary condition of survival.

Interestingly, the fan palm *Washingtonia robusta*, a native of this habitat, is now cultivated in subtropical and Mediterranean climates worldwide. This palm has great importance as the primary source of fronds for rustic roofing (palapas) in much of the Baja California Peninsula because the leaves are waterproof and sun resistant. Exotic plants growing at the oases that deserve mention are "carrizillo" *Phragmites australis*, used as a rustic building material, and date palm *Phoenix dactylifera*, introduced by Jesuit missionaries in the 17th century. Currently, almost all oases have some date palm groves, and scattered palms are seen along many watercourses. So far, no management plan exists for enhancing quality and quantity of date palms to diversify the economic base of the local inhabitants.

Some of the annual species are considered native weeds in this region, such as the huizapol grass *Cenchrus palmeri* Vasey that occur as scattered bunches within the oases, as well as dangerous exotics of recent arrival, such as the invasive buffel grass *Pennisetum ciliare* (L.) Link. Although these plants displace native species, they provide significant forage for livestock. The most aggressive exotic plant is the rubber vine *Cryptostegia grandiflora* (Roxb.) R. Br. (Asclepiadaceae), a serious threat to all Sierra de La Giganta oases. It is a fast-growing, climbing perennial that propagates by comose seeds and rhizomes. Although a native of Madagascar, in Australia it is considered one of the most dangerous exotics because it displaces native plants along waterways. It is currently being controlled by an expensive eradication program (ADA 2001).

5. CONCLUSIONS

Cluster analysis reveals that the hydrophytes are usually found in two distinct groups. Species within Cluster I occupy relatively better preserved habitats. Floating and stem-emergent aquatic life forms are included in this group. Species within Cluster II occupy impacted sites of several types and aquatic life forms are almost absent.

The high threshold of dissimilarity used to define the two clusters indicates floristic heterogeneity among the oases, although there are a small set of species typical to each group. Floristically, the wetlands suggest enduring dynamically-changing composition and structure, a condition that is being strongly modified by contemporary environmental impacts.

The oases of the Sierra de La Giganta are regularly affected by disturbances of different magnitudes, some of them catastrophic, particularly extraordinary floods from major storms and hurricanes that strike the mountains, but also extreme droughts, livestock trampling, and overgrazing. Water extraction, fire, and other human disturbances are associated with small-scale agriculture and extensive ranching. In this survey, there was no opportunity to find two oases that were similar in physiognomy. The pattern we found suggests that the floristic composition is a result of their particular history of disturbance.

A large proportion of these hydrophytes have broad geographical distribution, mainly in the American tropics. Mexican civil authorities should develop management plans to preserve and regulate water use in these areas. Particularly important for conserving species diversity is exclusion of cattle from these wetlands and encouraging primary activities that are sustainable. Date palm cultivation could be one of the most compatible activities. Also, there is an urgent need to develop a control and eradication plan for the invasive rubber vine *Cryptostegia grandiflora*, which is displacing all types of native plants.

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Exploring Mexico's northwest, the Baja California Peninsula, its surrounding oceans, its islands, its rugged mountains, and rich seamounds, one feels diminished by the vastness and the greatness of the landscape while consumed by a sense of curiosity and awe. In a great natural paradox, we see the region's harsh arid nature molded by water through deep time, and we feel that its unique lifeforms have been linked to this desert and sea for thousands of years, as they are now.

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