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### Dwarf Giants, Guano, and Isolation: Vegetation and Floristic Diversity of San Pedro Mártir Island, Gulf of California, Mexico

Benjamin Theodore Wilder

*Department of Botany and Plant Sciences, 2150 Batchelor Hall,  
University of California, Riverside, California 92521; benjamin.wilder@email.ucr.edu*  
and  
*University of Arizona Herbarium, P. O. Box 210036, Tucson, Arizona 85721*

Richard Stephen Felger

*San Diego Natural History Museum, P. O. Box 121390, San Diego, California 92112*  
and  
*University of Arizona Herbarium, P. O. Box 210036, Tucson, Arizona 85721; rfelger@ag.arizona.edu*

**ABSTRACT.**—San Pedro Mártir Island, the most isolated island in the Gulf of California, is roughly dome shaped, covers 2.67 km<sup>2</sup>, and rises to 300 m. It is part of the Central Gulf Coast subdivision of the Sonoran Desert. The island has a low floristic diversity—24 species, 23 genera, 13 families—which has been documented by botanists since 1887. Despite the isolation there are no endemics, and all species are capable of dispersing long distances or over water. Factors limiting species diversity on the island are isolation, high levels of guano, aridity, relatively little habitat diversity, and competition with the seasonally abundant ephemeral vine *Vaseyanthus insularis*. The most striking aspect of the island's flora is the dense forest of "dwarf" cardón cacti (*Pachycereus pringlei*) that dominates the upper portion of the island. Two principal phytogeographic patterns characterize the island's flora: (1) species common to both sides of the Gulf of California and (2) species occurring otherwise only on the Baja California side of the gulf. We established permanent transects, a quadrat, and a cardón plot to serve as a baseline for monitoring change, including the effects of eradication of the introduced black rat (*Rattus rattus*), accomplished in 2007. The vegetation structure consists of seasonally dense ephemerals (annuals), scattered shrubs, and an overstory of cardons. The cardón plot contains 209 individuals, 63% of which are less than 1 m in height, making this the youngest cardón population recorded. No non-native plants occur on the island, but this situation has the potential to change rapidly, and vigilant monitoring is needed. In the 20th century three species may have been extirpated and one has immigrated. The isolation, relative absence of human influences, depauperate flora, and long collection history make San Pedro Mártir an ideal site for monitoring and documenting the effects of climate change.

**RESUMEN.**—La Isla San Pedro Mártir, la isla más aislada en el Golfo de California, tiene la forma de un domo con un área de 2.67 km<sup>2</sup> y se eleva aproximadamente 300 m. Forma parte de la subdivisión Costa Central del Golfo del Desierto Sonorense. La isla tiene poca diversidad florística, 24 especies en 23 géneros y 13 familias documentada por botánicos desde 1887. A pesar del aislamiento, no existen especies endémicas y todas las especies tienen la capacidad de dispersión a larga distancia o transoceánica. Los factores que limitan la diversidad de especies en la isla son el aislamiento, los altos niveles de guano, la aridez, la poca diversidad de hábitat, y la competencia con la abundante enredadera efímera *Vaseyanthus insularis*. El aspecto florístico más llamativo de la isla es la existencia de un bosque denso de cactus "enanos" de cardón (*Pachycereus pringlei*), el cuál domina la parte alta de la isla. Las especies en la isla presentan dos principales patrones fitogeográficos: (1) especies comunes a ambos lados del Golfo de California, y (2) especies que ocurren sólo en el lado de Baja California. Se establecieron transectos permanentes, un cuadrante, y una parcela de cardón como línea de base para monitorear los cambios en el tiempo, incluyendo los efectos producidos por la erradicación en el 2007, de la población introducida de rata negra (*Rattus rattus*). El análisis de la estructura de la vegetación muestra crecimiento denso de plantas anuales, arbustos dispersos, y una cobertura considerable de cardones. La parcela de cardón contiene 209 individuos, 63% de los cuales tienen menos de 1 m en la altura, siendo ésta, la población de cardón más joven registrada. No existen especies introducidas en la isla, pero ésta situación puede cambiar rápidamente, por lo que se requiere de un monitoreo constante. En el siglo veinte, tres especies muestran evidencias de extinción local y una inmigración reciente. El aislamiento, la relativa ausencia de influencia humana, la baja diversidad florística, y la larga historia de colecta, hacen de la isla San Pedro Mártir un sitio ideal para la observación y registro de cambios causados por el calentamiento global y cambio climático.

#### INTRODUCTION

San Pedro Mártir Island, lying in deep water in the central Gulf of California, is the most isolated island in the gulf (Figure 1) and is part of the Central Gulf Coast subdivision of the Sonoran Desert (Shreve 1951). The island lies roughly equally distant from Sonora and Baja

California (ca. 50 km) and from the nearest islands (San Esteban, ca. 40 km, and Dátil, ca. 35 km). San Pedro Mártir is volcanic in origin and has never been connected to any other landmass (Carreño and Helenes 2002). For its size and elevation the flora is the most impoverished of any island in the Gulf of California, having only 24 species. The shore rises abruptly to high sea cliffs, which are claimed by thousands of

noisy birds throughout the year. San Pedro Mártir is one of the most important seabird-nesting sites in Mexico; 85 species of birds have been recorded there, including eight of breeding seabirds (Tershy and Breese 1997). The colonies of the Brown Booby (*Sula leucogaster*) and Blue-footed Booby (*S. nebouxii*) are among the world's largest, and the colonies of the Brown Pelican (*Pelecanus occidentalis*) and Red-billed Tropicbird (*Phaethon aethereus*) are among the largest in Mexico (Tershy et al. 1997). There are no beaches, alluvial deposits, or outwashes, and consequently there is no development of shore vegetation.

The island is roughly triangular in shape, girdled by steep sea cliffs and rising as a dome. Its area is 2.67 km<sup>2</sup>, as calculated by Grupo de Ecología y Conservación de Islas, A.C. (GECI), on the basis of a Quickbird image, resolution 60 cm (Figure 2). Above the high sea cliffs, the topography shows relatively little relief and consists roughly of two main plateaus or mesas, one at about halfway, the other at the top and occupying the western portion of the island with a peak elevation of 300 m (Figure 3).

There are no meteorological records for the island, but the climate is certainly arid. It is hot most of the year, though winter nights are moderate, and years of extreme drought are most likely commonplace. We assume winters are frost free. Rainfall is undoubtedly unpredictable, the largest amounts coming in the form of tropical storms and hurricanes, which develop between July and October and occasionally strike the island. Rain also falls in winter, as attested by the species of ephemerals (cool-season short-lived or single-season annuals). Often in the early mornings during cooler seasons all but the lowest portion of the island is enveloped by fog, which remains until several hours after dawn, sometimes nearly all day (Figure 4). The vegetation receives significant moisture from this fog—the plants at such times are drenched with dew.

Riparian or semi-riparian canyons and arroyos are absent. There is no source of fresh water (Bowen 2009). Most of the surface of the island is exposed and offers little or no shelter from wind. The island is volcanic in origin and covered with rocks of varying size. Soil is poorly developed and shallow. At the island's west end, a rock headland about 75 to 100 m high juts out into the sea and is connected to the rest of the island by a low saddle. The principal landfall, although a poor one and occupied by California sea lions (*Zalophus californianus*), is at the southeast corner of the island (28.37207° N, 112.30181° W). Just above the southeast landing are the ruins of a village of rock-walled houses and shelters built by guano workers (Figure 5).

From 1885 to 1891, the Mexican Phosphate and Sulphur Company, under two different ownerships (1885–1888 as the U.S.-based International Company and 1888–1891 under British ownership), mined guano on the island intensively (Bowen 2000). One of the few observations of this period comes from ornithologist Nathaniel Goss, who visited the island from 15 to 28 March 1888 by means of a small steamer from Guaymas used to bring supplies to the workers on the island (Bowen 2000, Goss 1888). Goss observed a workforce of Yaqui Indians collecting guano, 135 on the payroll and many with their families. He reported that most of the valuable guano had been removed. This is the only report stating that the workers were Yaquis. Conditions must have been severe for the miners and their families, but the American and British companies would have paid wages, contrary to the popular belief that the workers were prisoners or slaves. As difficult as conditions may have been, the workers were likely safer on the island, given the pogroms and deportations to slave-condition henequen plantations in southern Mexico being inflicted on the Yaquis at the time (see Spicer 1980). Bowen (2000:134–136) provided the best overall discussion of the guano operation.

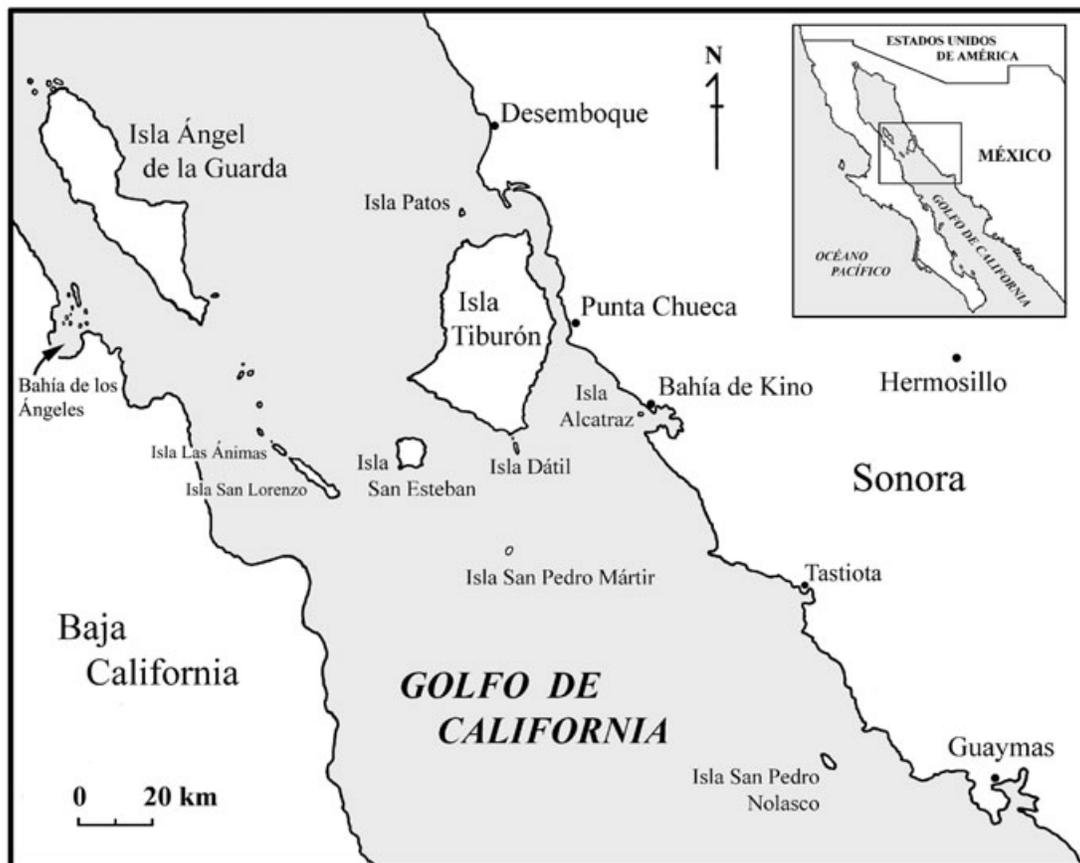


FIGURE 1. Midriff Islands, Gulf of California, Mexico. Map by Cathy Moser Marlett.

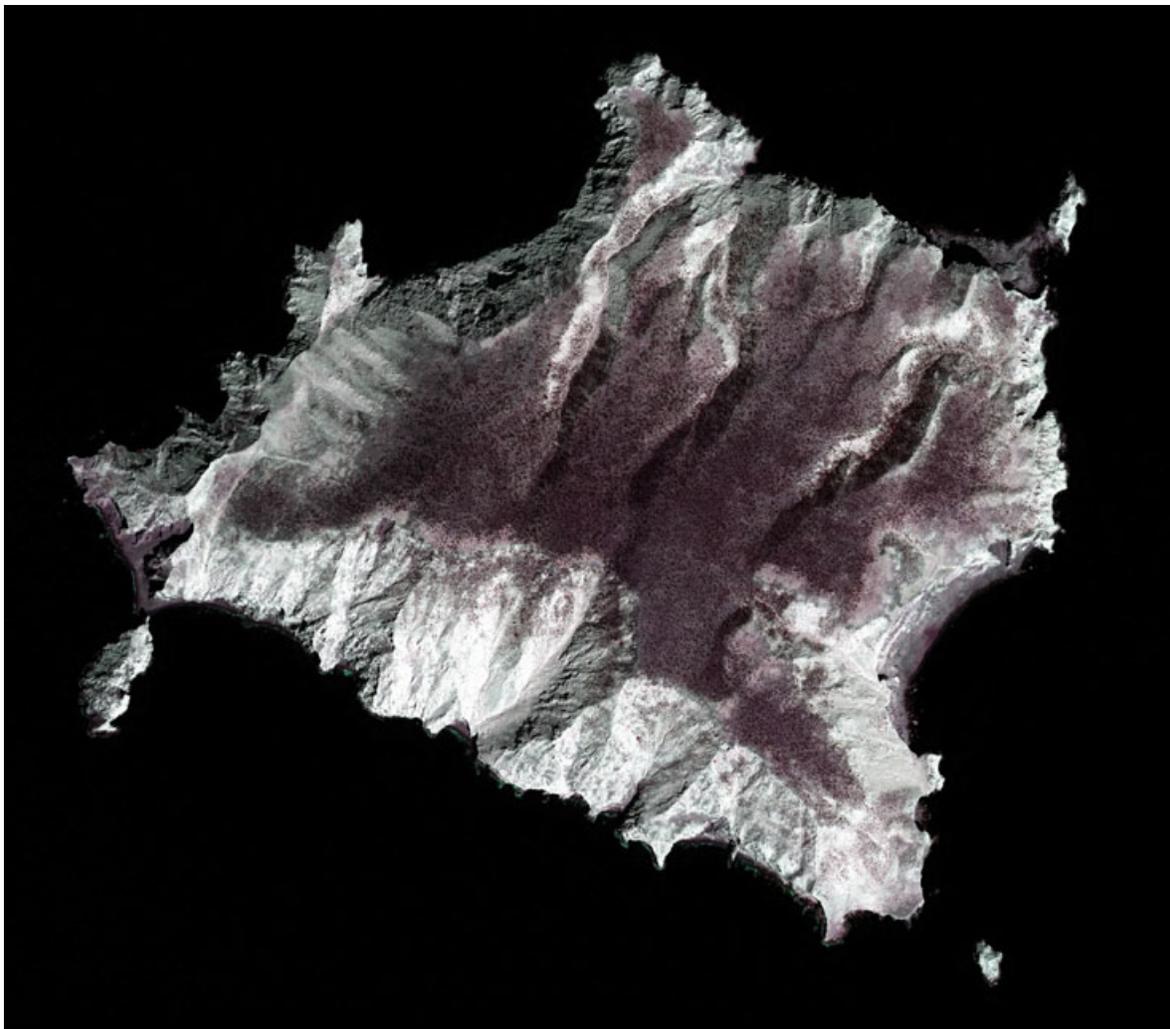


FIGURE 2. San Pedro Mártir Island. The white areas are guano-covered sea cliffs and lower elevations. The darker areas are the vegetated areas dominated by cardón. Image from Grupo de Ecología y Conservación de Islas. North at top.

The guano mining had significant effects on the island. Most breeding seabirds temporarily abandoned the island, failed to reproduce, or perished, and there was likely decreased plant cover and increased erosion (Tershy et al. 1992). The most significant long-term effect of the guano operation was the introduction of the ubiquitous Old World black rat (*Rattus rattus*). The rats preyed on bird eggs and chicks, especially those of the boobies, and are reported to have fed on some of the island plants when the seabirds were not reproducing (Tershy et al. 1992, 1997). The effects on the plant life, however, are difficult to determine. The area that was mined and where the workers lived is mostly below the major vegetated parts of the island, and there is little direct evidence of human disturbance at the higher elevations. Yet so much activity on this small island would have had effects throughout.

The island has been uninhabited since the end of mining. Human use, however, increased in the late 20th and early 21st centuries from commercial and sport fishing, private and commercial tourism, researchers, and other users (see Tershy et al. 1999). In 1978, along with the other islands of the Gulf of California, San Pedro Mártir was declared an Area de Protección de Flora y Fauna. In 1995 all the gulf's islands were made a Biosphere Reserve registered in the Man and Biosphere Program of UNESCO. In 2002 the Mexican Federal Government established San Pedro Mártir and the surround-

ing waters as a Mexican Biosphere Reserve encompassing 30,165 ha (Diario Oficial 2002). In July 2005 San Pedro Mártir and the other islands of the Gulf of California were made a UNESCO Natural Heritage Site (World Heritage Nomination 2004). The island is managed by the Guaymas office of the Comisión Nacional de Áreas Naturales Protegidas (CONANP) of the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) of the Mexican federal government. CONANP also works with Comunidad y Biodiversidad (COBI), World Wildlife Foundation (WWF), Prescott College, and Grupo de Ecología y Conservación de Islas, A.C. (GECI), to jointly address issues that face the island's management and conservation. Through these institutions and, in part, on the basis of the report by Tershy et al. (1992), a strategic plan was developed with six strategies: protection, management, restoration, knowledge, culture, and administration. In its final stage, this management plan is to be published in the official diary of the Mexican federal government as a legal instrument (Ana Luisa Figueroa-Carranza, personal communication 2009).

The terrestrial vertebrate fauna includes a rattlesnake (*Crotalus atrox*), a king snake (*Lampropeltis getula*), and two small endemic lizards, *Aspidoscelis martyr* (*Cnemidophorus martyr*) and *Uta palmeri* (Grismer 1999; Murphy and Aguirre 2002). There are no native land mammals.

The introduced population of black rats (*Rattus rattus*) was tar-



FIGURE 3. Aerial image of the high-elevation plateau of San Pedro Mártir Island, 9 October 1966. View is to the southwest. Photo by R. Felger, from Alexander Russell's airplane.

geted by a large-scale eradication program, which was successfully realized in the fall of 2007. The eradication plan was developed by GEI in coordination with Mexican government agencies (CONANP, SEMARNAT, SEMAR—Secretaría de Marina-Armada de Mexico, and SEGOB—Secretaría de Gobernación) and other institutions (e.g., Prescott College Kino Bay Field Station and Island Conservation; Samaniego-Herrera et al. 2008); it is one of several efforts on islands in western Mexico to eradicate invasive mammals (Aguirre-Muñoz et al. 2008). It is critical to have baseline data to gauge the effects of the rat eradication on the island's ecosystem. In order to assess the current and future vegetation of the island, in October 2007 we established permanent vegetation transects, quadrats, and photo points at its upper elevations.

This publication provides the first in-depth analysis of the flora and vegetation of San Pedro Mártir Island. First, the methods used in floristic and vegetational sampling are detailed to aid future monitoring. We then discuss the flora and vegetation, to impart a sense of the island's uniqueness. We point out the nuances of the flora and offer an explanation of the extreme dearth of floristic diversity and lack of endemic plant species. Next we present an assessment of the vegetation, including the impressive cardón forest, through the analysis of quadrat and transect studies, historic field notes, and photos. After a section focusing on the use of San Pedro Mártir as site for a long-term monitoring for understanding floristic and ecological changes in the coming decades, we elaborate on the history of botanical exploration and collection on the island. Finally we provide a specimen-based

discussion for each plant species on the island, including documentation of herbarium collections and information.

#### METHODS

The floristic listing for San Pedro Mártir Island presented here was compiled from collections from the island beginning with Edward Palmer in 1887 (see "Collectors" below) and previous species lists for the island (Felger and Lowe 1976; Moran 1983; Rebman et al. 2002; Tershy et al. 2002, appendix 1). We searched for specimens from the island at the herbaria of the University of Arizona (ARIZ), San Diego Natural History Museum (SD), and other regional collections. We also made use of pertinent information for specimens for San Pedro Mártir databased at SD and elsewhere. Information has also been provided for specimens of special interest housed at other herbaria, especially the California Academy of Sciences, San Francisco (CAS), and the University of California, Berkeley (UC). Specimens were collected by us under a Mexican federal collecting permit and are deposited at ARIZ with duplicate specimens variously distributed to the Herbarium of the Centro de Investigaciones Biológicas del Noroeste in La Paz, Baja California Sur (HCIB), the Instituto de Biología, Universidad Autónoma de México, Mexico City (MEXU), SD, the Universidad de Sonora (USON), and other herbaria in Mexico and the United States.

Quantitative field data were recorded in December 2007 by means of a quadrat, transects, and a cardón plot. A single 0.1-ha (50



FIGURE 4. *Pachycereus pringlei* in early morning fog, 6 December 2007. A moderate amount of *Vaseyanthus insularis* grows on juvenile cardons in the left foreground. Mature cardons in background and at right; note broken branches on right and elsewhere. Photo by B. Wilder.

m × 20 m) quadrat was established on the top of the island with angle iron stakes and GPS points for all four corners (Table 1). Within the quadrat all species were identified and recorded, and the number of individuals of each perennial species was tallied. Six 50-m line-intersect transects were established within the same area. The end of each transect was marked with a metal stake and a GPS point (Table 1). For each species encountered along the 50 m line, the distance covered was recorded and then summed. The assessment of the coverage looks at the contribution of each species to the total ground coverage, allowing coverage totals greater than 100%. Heights of species in the quadrat and along the transects were determined in one of three ways: the first was direct measurement in the field, though this was not done for all species. Second, height was sufficiently ascertained by notes of the species' height from those individuals collected, and third, by estimation from photographs of the transect and quadrat area, so that the average height of each species is known. (See the Cardón Plot section for method of the investigation of the cardón population.)

#### Floristic Diversity and Phytogeography

Twenty-four species of vascular land plants in 23 genera and 13 families are known for the island, and we predict that further investigation will yield few or no additional records (Table 2). The most striking floristic feature of the island is the massive and dense forest of the cardón (*Pachycereus pringlei*) that dominates the island

and casts a dark green hue over its surface that can be seen from afar (Figures 6 and 7). After each significant rainfall, except in summer, a thick blanket of the cucurbitaceous vine *Vaseyanthus insularis* covers the vegetated part of the island, forming 100% coverage in many areas, draping over the cardons and shrubs and painting the island bright green (Figure 8). After the vines dry, they impart a golden brown hue to the landscape. The island is otherwise marked by occasional shrubs. The sea cliffs and lower third of the island are thickly whitewashed in guano.

Two principal phytogeographic patterns are evident among the flora: (1) species common to both sides of the Gulf of California and (2) plants occurring otherwise only on the Baja California side of the gulf. Twenty species (83% of the flora) represent the former pattern, and, for these, colonization could have originated from either side of the gulf or from other islands. Within this group, spatial or geographic distributions vary. Three species are restricted mainly to the Gulf of California region: *Euphorbia petrina*, *Stegnosperma halimifolium*, and *Vaseyanthus insularis*. Seven are primarily Sonoran Desert species, seen in Sonora in the dry western or northwestern part of the state and more widespread in both states of the Baja California Peninsula: *Chylismia cardiophylla* subsp. *cardiophylla*, *Ficus palmeri*, *Mentzelia adhaerens*, *Pachycereus pringlei*, *Petalonyx linearis*, *Pleurocoronis laphamioides*, and *Viscainoa geniculata*. Ten species are widespread in the Sonoran Desert and regions beyond: *Abutilon palmeri*, *Aristida adscensionis*, *Baccharis sarothroides*, *Cyperus squarrosus*, *Digitaria californica*, *Lycium brevipes*,



FIGURE 5. Southeast part of San Pedro Mártir Island, 6 December 2007. Lower-elevation cardons above ruins of guano workers' village; note white guano-covered rock and soil. Photo by B. Wilder.

*Muhlenbergia microsperma*, *Nicotiana obtusifolia*, *Perityle emoryi*, and *Trixis californica*. The second pattern is represented by only four species (16% of the flora): *Cylindropuntia alcahes*, *C. cholla*, *Pelucha trifida*, and *Sphaeralcea hainesii*. *Pelucha trifida* and *S. hainesii* have distributions primarily in the arid northern part of the gulf. They occur on the gulf coast of the Baja California Peninsula, the adjacent peninsular islands, and some Midriff Islands, but are absent from the Sonora coast. Likewise, *Cylindropuntia alcahes* and *C. cholla* are absent from Sonora, but they are found through most of the Baja California Peninsula and often on the Pacific side, including at the southern extremity of the California Floristic Province near El Rosario, on Cedros Island, in the vicinity of Magdalena Bay, and commonly in Baja California Sur (Jon Rebman, personal communication).

Significantly, the plants on Mártir are small seeded or produce disseminules adapted to over-water colonization, both of which are features of long-distance dispersal. The fruits of *Vaseyanthus insularis* are lightweight structures with air-filled chambers readily suited to dissemination on the ocean (Gentry 1950). The sticky fruits of *Mentzelia adhaerens* and the aril-surrounded seeds of *Viscainoa geniculata* might readily be carried to the island by birds, while other plants such as *Ficus palmeri*, *Pachycereus pringlei*, and *Stegnosperma halimifolium* have edible seeds and fruits and may also have been introduced by birds. Lightweight cypselas ("achenes") of the composites might be wind-transported from neighboring landmasses and/or become entangled in bird feathers. It is interesting to note the relatively large representation of Asteraceae on the island: five species or 20% of the flora.

Is the flora of San Pedro Mártir depauperate because of the island's isolation? The entire flora consists of species that have mechanisms for long-distance dispersal. Those species not adapted to long-distance dispersal are probably effectively restricted from reaching San Pedro Mártir, greatly reducing the potential source pool of species. Yet, in contrast to the reptiles, there are no endemic plants on San Pedro Mártir. This lack of endemism indicates the island's plants retain significant genetic connectivity with sources on other islands and/or the mainland, reducing the island's isolation from the perspective of a wind- or water-dispersed plant. The role of vagrant birds (visitors and unsuccessful colonizers), which often carry seeds between areas and may serve as pollinators for various plants, is likely significant in creating a link to other genetic sources (Rose and Polis 2000).

There are also factors intrinsic to San Pedro Mártir that limit the number of species. Because of the large number of seabirds, concentrations of guano and associated nutrients, principally nitrogen and phosphorus, are extremely high. The large amount of guano on the island certainly limits the plant species that are able to establish themselves. However, the effects of guano are difficult to separate from those of the extreme aridity. Certain species are able to tolerate the soil conditions of guano islands and are commonly found on such islands in the gulf; six of these occur on San Pedro Mártir: *Cylindropuntia alcahes*, *C. cholla*, *Nicotiana obtusifolia*, *Pachycereus pringlei*, *Perityle emoryi*, and *Viscainoa geniculata*. On San Pedro Mártir, *Sphaeralcea hainesii* also extends into guano areas, but no other *Sphaeralcea* is found associated with guano habitats on other Sonoran islands in the Midriff region. The seasonally abun-

TABLE 1. GPS points that mark the corners of the permanent vegetation quadrat and transects, and the cardón plot. Datum for points is WGS 84.

	Latitude	Longitude
Vegetation quadrat		
SE corner (Q1)	28.38026	-112.30814
NE corner (Q2)	28.38071	-112.30812
NW corner (Q3)	28.38072	-112.30832
SW corner (Q4)	28.38028	-112.30838
Vegetation transects		
Line 1, from Q1 to Q2		
S end	28.38026	-112.30814
N end	28.38071	-112.30812
Line 2, middle of quadrat, from S to N		
S end	28.38024	-112.30826
N end	28.38074	-112.30818
Line 3, from Q4 to Q3		
S end	28.38028	-112.30838
N end	28.38072	-112.30832
Line 4, outside of quadrat, from S to N		
S end	28.38022	-112.30843
N end	28.38070	-112.30830
Line 5, outside of quadrat, from S to N		
S end	28.38030	-112.30859
N end	28.38073	-112.30856
Line 6, outside of quadrat, from S to N		
S end	28.38019	-112.30874
N end	28.38066	-112.30885
Cardón plot		
NW corner (corner 1)	28.37910	-112.30631
NE corner (corner 2)	28.37906	-112.30614
SE corner (corner 3)	28.37870	-112.30618
SW corner (corner 4)	28.37870	-112.30636

dant ephemeral vine *Vaseyanthus insularis* blankets the island with 100% coverage in large areas after strong rains, likely smothering and inhibiting the establishment of other species. The island also lacks topographic complexity that might provide niches for additional species. Thus, while San Pedro Mártir's isolation certainly limits those species that can become established, in addition, a high concentration of guano, intense aridity, *Vaseyanthus insularis*, and lack of topographic complexity compound the impediments species face on the island, resulting in one of the most depauperate floras in the Gulf of California.

Various species and growth forms are strangely absent from San Pedro Mártir. There are no legumes, present on nearly every other

island in the gulf. *Amaranthus watsonii*, with small edible seeds and so prevalent on most islands—even guano islands such as Alcatraz at Bahía Kino—and *Boerhavia*, with its small sticky fruits, would seem likely long-distance colonizers. Chenopods are also absent. *Chenopodium murale*, also with small edible seeds, is certainly tolerant of high guano concentrations and is the only plant on the guano-covered San Jorge Island southeast of Puerto Peñasco. *Cenchrus palmeri*, with its nasty, clinging burs, also seems a likely colonizer, and it is surprising that it evaded transportation during the years of guano mining. Smaller cacti such as *Mammillaria* are conspicuous in their absence, as is *Agave*.

The vegetation, aside from the dense population of cardons and seasonal ephemerals, is sparse throughout, and the major perennials are generally widely spaced. The guano-covered cliffs and lower slopes at the edge of the island are nearly devoid of plants. On ascending the island from its best apparent point of ingress at the southeast end, one is impressed by the strangeness of the pioneer community consisting of three species of divergent growth forms: *Pachycereus pringlei*, *Sphaeralcea hainesii*, and *Vaseyanthus insularis* (Figure 9). These species are concentrated along drainageways as they extend below the more vegetated plateau. The same species dominate much of the remaining landscape. The number of species and density of populations are greatest toward the top of the island and gradually diminish at lower elevations. Among the plants found above the region about 1/3 of the way up the island and concentrated at higher elevations are *Baccharis sarothroides*, *Ficus palmeri*, *Lycium brevipes*, *Pelucha trifida*, and *Viscainoa geniculata*. *Digitaria californica* is only found at the highest plateau of the island.

Major perennials consist of xerophytic succulents (cacti) and drought-deciduous shrubs. Especially common are species such as *Abutilon palmeri*, *Nicotiana obtusifolia*, and *Sphaeralcea hainesii* whose stems die back extensively during the dry season. It is noteworthy that the *Abutilon* and *Sphaeralcea*, among the most ubiquitous plants on the island, can respond to variable moisture by reproducing in their first season, thus acting like ephemerals, or persist as herbaceous perennials or shrubs (see Species Accounts). *Pelucha trifida* and *Trixis californica* likewise die back extensively in drought seasons. There are five growth forms on the island (Table 2): shrubs (10 species), ephemerals (short-lived annuals) (8), xerophytic succulents (3), herbaceous perennials (2), and a single vine that is also an ephemeral (*Vaseyanthus insularis*).

All members of the flora have simple leaves or are aphyllous. *Pelucha*, *Perityle*, and *Vaseyanthus* have dissected or lobed leaves, while the leaves of other species are mostly entire or shallowly lobed. Several growth forms common on the opposite shores are conspicuously absent, e.g., leaf succulents and leaf-bearing trees other than



FIGURE 6. San Pedro Mártir Island in view to the west, 14 April 2007. Photo by B. Wilder.



FIGURE 7. Cardón forest at the top of San Pedro Mártir Island, in view to the northwest, 5 December 2007. Permanent quadrat and transects are on the plateau at the right side of the image. Photo by B. Wilder.

*Ficus*, which is the largest-leaved plant on the island and in the Gulf of California (Figure 10). Also absent are plants with bulbs, stolons, rhizomes, or tuberous roots. Winter–spring ephemerals, the most common of which are *Aristida adscensionis*, *Muhlenbergia microsperma*, and *Perityle emoryi*, constitute about 30% of the flora. Most of the winter–spring ephemerals are capable of growth again during the summer–fall rains.

No non-native plants are known to occur on the island. There is no evidence that any plant species were introduced in the late 1800s during guano mining, with the possible exception of *Baccharis sarothroides*. During those years there was ample opportunity for the introduction of weedy species, as a small supply boat went between Guaymas and the island at least weekly (Bowen 2000). Despite the absence of noxious plants on the island, aggressive monitoring and quick responses to discoveries of non-natives are needed. Rates of visitation to the island are again high, mostly through commercial tourism and commercial fishers (Tershy et al. 1997, 1999). Tershy et al. (1997) reported at least 448 boat visits between 1990 and 1992, originating from 12 different ports in the four states that share the Gulf of California; these visits brought 5577 people to the island, 669 of whom went ashore. These numbers are likely higher today and again present substantial opportunity for the introduction of weedy, invasive species.

Since about 2005, responsible tour groups, such as Lindblad Expeditions, heed the legal conservation ethics by not landing on the island (e.g., Tershy et al. 1997). The occasional researchers and others who do go ashore should take special care to have people clean their belongings of possible stowaway seeds before depart-

ing the mainland and the boat. Shoes and sandals, especially fabric shoes, are prone to harboring weed seeds and disseminules, such as the tack-shaped mericarps of the goathead, *Tribulus terrestris*, which can long remain embedded in the soles. “Clean shoes” should be the motto for all visitors before embarking. The coastal camps used by fisherman should be regularly monitored for new introductions. Researchers and photographers need to be extra careful to be sure their equipment is free of seeds of non-native plants, since they often spend prolonged times on the island and visit the more remote areas that are more difficult to monitor. Especially troublesome invasives that might become established, all of which occur in ports on both sides of the gulf, include *Mesembryanthemum crystallinum* (crystalline ice plant, *hielitos*; Aizoaceae), *Cenchrus ciliaris* (buffelgrass, *zacate buffel*; Poaceae), and *Tribulus terrestris* (goathead, puncture vine, *torito*, *toboso*; Zygophyllaceae; Wilder et al. 2007). Even native species from sources off the island could have severe effects on the San Pedro Mártir ecosystem.

#### Vegetation Structure

In 2007, we assessed the vegetation quantitatively via transects and quadrats at the highest plateau, about 270 m elevation and 200 m to the northwest of the summit. Thirteen species, perennials and annuals, were present in the 0.1-ha quadrat, totaling 122 individuals of perennial plants (Table 2). *Pachycereus pringlei* (cardón) was the most abundant perennial with 67 individuals, the majority of which were adult plants. The dominance of cardón reflects the fact that the higher elevations—the majority of the island—is covered in a cardón forest (see Cardón

TABLE 2. Growth forms and seasons of the 24 plant species recorded from San Pedro Mártir Island.

Family	Species	Growth form	Growth season
Asteraceae	<i>Baccharis sarothroides</i>	shrub	
Asteraceae	<i>Pelucha trifida</i>	shrub	
Asteraceae	<i>Perityle emoryi</i>	ephemeral	winter–spring
Asteraceae	<i>Pleurocoronis laphamioides</i>	shrub	
Asteraceae	<i>Trixis californica</i>	shrub	
Cactaceae	<i>Cylindropuntia alcahes</i>	xerophytic succulent	
Cactaceae	<i>Cylindropuntia cholla</i>	xerophytic succulent	
Cactaceae	<i>Pachycereus pringlei</i>	xerophytic succulent	
Cucurbitaceae	<i>Vaseyanthus insularis</i>	ephemeral/vine	fall–winter–spring
Cyperaceae	<i>Cyperus squarrosus</i>	ephemeral	nonseasonal
Euphorbiaceae	<i>Euphorbia petrina</i>	ephemeral	nonseasonal
Loasaceae	<i>Mentzelia adhaerens</i>	ephemeral	nonseasonal
Loasaceae	<i>Petalonyx linearis</i>	shrub	
Malvaceae	<i>Abutilon palmeri</i>	shrub/ephemeral	
Malvaceae	<i>Sphaeralcea hainesii</i>	ephemeral/shrub	nonseasonal
Moraceae	<i>Ficus palmeri</i>	shrub/tree	
Onagraceae	<i>Chylismia cardiophylla</i>	ephemeral	winter–spring
Phytolaccaceae	<i>Stegnosperma halimifolium</i>	shrub	
Poaceae	<i>Aristida adscensionis</i>	ephemeral	nonseasonal
Poaceae	<i>Digitaria californica</i>	herbaceous perennial	
Poaceae	<i>Muhlenbergia microsperma</i>	ephemeral	nonseasonal
Solanaceae	<i>Lycium brevipes</i>	shrub	
Solanaceae	<i>Nicotiana obtusifolia</i>	herbaceous perennial	
Zygophyllaceae	<i>Viscainoa geniculata</i>	shrub	

Plot section below). The next most abundant were chollas, *Cylindropuntia alcahes* with 19 individuals and *C. cholla* with 5, followed by 28 shrubs roughly evenly divided among three species, *Lycium brevipes*, *Trixis californica*, and *Viscainoa geniculata*. The vegetation is composed of a thick layer of ephemeral species whose combined coverage averaged 123%, scattered shrub species whose combined coverage averaged 19%, and an overstory of cardons with an average coverage of 9% (Table 3, Figure 11). These data were recorded during a dry period, and both coverage and number of shrubs and herbaceous perennials (especially *Abutilon palmeri* and *Sphaeralcea hainesii*) are likely to be higher during seasons of favorable rains.

In an attempt to assess or predict vegetative change on the island, two external factors that have altered the vegetation, both associated with the guano mining, should be considered. Tershy et al. (1992:41) wrote, “It is likely that guano-mining activities decreased the total amount of plant cover on the island, perhaps even causing the extinction of some species.” It is known that the vegetation of other Gulf of California islands used for guano mining was cleared to enhance guano removal, e.g., Patos Island to the north of Tiburón (Felger and Lowe 1976), but there is no direct evidence for this activity on San Pedro Mártir. More than 100 years since any possible vegetation removal or clearing, the vegetation density has likely recovered. It is important to note that without baseline information prior to mining, we can only speculate about local extirpations. The collections of Edward Palmer in 1887, however, indicate vegetation and flora basically similar to what we found.

The second effect on the vegetation is that of the introduced rats. Tershy et al. (1992:43) wrote, “On Isla San Pedro Mártir, rats reproduce during the seabird breeding season when food is abundant. This plentiful food source may boost the rat population above what can be seasonally supported by the island’s plants, which probably represent a more important food source when seabirds are not breeding (for example, rat damage to the island’s globemallow [*Sphaeralcea hainesii*] was widespread at the beginning of the sea bird breeding season in 1991). Thus, the impact of rats on the plant community may be severe.” With the rat population now exterminated, following the observations of Tershy et al. (1992), we might expect an increase in

the density of the vegetation—unless the recurring severe droughts exert a stronger influence on limiting the vegetation. The permanent quadrats and transects will serve as a means of gauging the effect of the rat eradication as well as the long-term dynamics that are at play on the island.

#### Cardón Plot

The cardón population on San Pedro Mártir has been reported as special by various biologists beginning with Ivan Murray Johnston. “There is considerable variation in habit of growth. The common form is one with a distinct trunk 1–2 m. high, which supports a crown of very thick upright branches. The whole plant is 3–9 m. high. . . . The most pronounced variation in habit is that characteristic of the plants on San Pedro Martir island. . . . These are trunkless or nearly so, the branches starting from the ground and making the plant appear like monstrous specimens of *Lemaireocereus* [sic] *thurberi* [*Stenocereus thurberi*, organpipe cactus]. This trunkless form was seen on most of the northern Gulf islands” (Johnston 1924:1118). Several other scientists who have visited Gulf of California islands have noted this phenomenon. George Lindsay, an avid student of Baja Californian and gulf island cacti, reported from a 1966 expedition, “There are not many kinds of plants on the island [San Pedro Mártir], but abundant dwarf cardón cacti look like a piñon forest from a distance” (Lindsay 1966:8). Reid Moran, who has known gulf island plants better than perhaps anyone else, wrote in a fascinating popular article on cardón, “those of some of the gulf islands tend to be dwarfed,” and in the caption of a photo, “Cardonal (cardón forest) on San Pedro Mártir Island. On this and some other islands, cardons are dwarfed” (Moran 1968:7, 9). In their chapter on plants of the gulf islands in *Island Biogeography of the Sea of Cortés*, Cody et al. (1983:80) stated, “Differentiation among the columnar cacti on gulf islands seems restricted to growth form, and in particular *Pachycereus pringlei* can occur on islands in a remarkably short and almost trunkless form.”

On the basis of our observations, however, the “trunkless” growth habit is not the usual situation on most northern islands, at least not



FIGURE 8. *Vaseyanthus insularis* blanketing the areas between the cardons after Hurricane John of September 2006. Photo by J. A. Soriano/Grupo de Ecología y Conservación de Islas archive.

on other Sonoran islands (Tiburón, San Esteban, Patos, Dátil, Cholludo, Alcatraz in Bahía Kino, and San Pedro Nolasco) and not on the Sonora mainland and the Baja California Peninsula. The “dwarfed” and “trunkless” growth form is documented for certain from San Pedro Mártir and Partida Norte (a small island to the south of Ángel de la Guarda, also known as Cardonosa) islands in the Midriff region (e.g., Medel-Narvaez et al. 2006; Thomas Bowen, personal communication 2008). Lindsay (1948:17) reported that on Partida Norte, “Lynne and I went ashore, to find only *Pachycereus pringlei* in the common dwarfed insular form, and two cylindropuntias.” Cholludo Island, a tiny isle off the south shore of Tiburón Island, also has a dense “forest” of relatively short cardons, but their branching is not basal—the majority of branches arise well above ground level, like those on Tiburón.

We established a permanent cardón plot in 2007 in order to gain insights into this unique insular population and begin tracking its dynamics. The plot, 775 m<sup>2</sup>, is located on the south slope of the peak at about 265 m elevation and contains 209 cardons (see Table 1 for coordinates of the plot corners). The results from this plot and the 0.1-ha quadrat at the top of the island document the cardón population as having two different age structures. The quadrat contains mostly adult individuals, whereas the cardón plot has mostly small plants or “babies.” The population in the cardón plot is representative of the population found over the majority of the island. Following both of these populations through time will provide a better picture of the dynamics of this species on the island. The discussion in this section is based on results from the cardón plot rather than the summit quadrat. The work of Medel-Narvaez et al. (2006), who looked at the density and size structure of *Pachycereus pringlei* at 26 sites throughout its range, serves as an excellent source to which we can compare our

results and better understand the unique aspects of the cardón population of San Pedro Mártir. Extrapolating from the population census in the San Pedro Mártir plot yields a density of 2697 individuals per hectare. This is an order of magnitude greater than the density of any population on the Baja California Peninsula or the Sonora mainland recorded by Medel-Narvaez et al. (2006). Yet, two populations on islands in Guaymas Bay have higher densities (extrapolated to 1 ha): one of the Mellizas Islands (ca. 7907 individuals/ha; Turner et al. 2003) and on Tío Ramón Island (10,250 individuals/ha; Medel-Narvaez et al. 2006). In addition, Cholludo Island, south of Tiburón, is likely to have a density on par with that of these two islands (Wilder et al. 2008). Medel-Narvaez et al. (2006) concluded that islands sustain greater population densities than do the mainland and peninsula but stated that the mechanism generating such great differences in abundance between island and mainland populations is not known.

We obtained the following information for each cardón in the plot: height, vertical distance to the first branch, basal diameter of the trunk, and number of broken arms (in part to gain insights into the reported ailment “flat top decay”; Bashan et al. 1995). In addition, each individual was mapped so that in the future the fate of each individual can be tracked to determine the dynamics of the population. The population is made up of 63% “babies” (<1 m in height), 10% juveniles (1–2.5 m tall), and 27% adults (>2.5 m tall). This size distribution shows that the cardón population is exceedingly healthy. A regeneration index (the percent of the population <1 m) of 63% is higher than that reported by Medel-Narvaez et al. (2006) for all 26 sites they studied throughout the range of *P. pringlei*: the Baja California Peninsula (14 sites, average 24% ± 9%), gulf islands (Tío Ramón 12%, Catalina 61%, and Cerralvo 51%), and Sonoran mainland (9 sites, average 19% ± 10%).



FIGURE 9. Pioneer community of first-season plants of *Sphaeralcea hainesii*, with *Vaseyanthus insularis* on guano-rich soil in foreground, 11 April 2007. Photo by B. Wilder.

Our quantitative results for the growth form of the cardón population were within the range of the findings of Medel-Narvaez et al. (2006) with respect to basal diameter of the trunk, but the San Pedro Mártir cardons have much shorter trunks, measured by the distance to the first branch, and total height. The trunks of the San Pedro Mártir population range in height from 0 to 63 cm and average only about 20 cm (average  $0.19 \text{ m} \pm 0.16 \text{ m}$ ,  $n = 73$ ; 18 individuals had no effective or measurable trunk; Figure 12). This is substantially shorter than the range of 0.9–2.0 m among all populations measured by Medel-Narvaez et al. (2006) and the range of 0.7–1.95 m, average  $0.83 \text{ m} \pm 0.39 \text{ m}$  ( $n = 49$ ), for a population just inland from Bahía Kino, Sonora (Felger and Wilder, unpublished data). These data directly support the observations of previous scientific explorers to the island that the cardón population is nearly trunkless (e.g., Johnston 1924). The San Pedro Mártir population of branched individuals (adult plants, 73 out of 209 individuals in the plot) has an average height of  $3.6 \text{ m} \pm 1.6 \text{ m}$ , which is shorter than that of any peninsular or mainland population measured by Medel-Narvaez et al. (2006). The San Pedro Mártir cardons are also slightly shorter than those on the three islands, Tío Ramón, Catalina, and Cerralvo, which were significantly shorter than those on the peninsula or mainland, supporting the “dwarf” label.

We observed a number of cardons on San Pedro Mártir that had stem tips, or ends of arms, broken off. Bashan et al. (1995) reported on the widespread occurrence of a condition called flat-top decay, which causes detachment of the upper portion of an arm and a characteristic flat top. Whether its cause is biotic or abiotic is unknown. For all branched individuals in the cardón plot, we counted the number of

broken arms per individual. Out of 73 branched plants, 18 had broken stems (26%; only three plants had three or more broken arms). The average number of broken arms we observed is comparable to the results of Bashan et al. (1995). Of the 13 sites they investigated in Baja California Sur, they found 6 sites with little or no decay (0–7%), five sites with medium amounts of decay (24–62%), and two sites with significant levels of decay—the islands of Partida Sur just north of Espíritu Santo Island and El Conejo, which is on the Pacific side of the peninsula west of La Paz (91 and 99% respectively). Our results best correspond to what Bashan et al. (1995) observed at the south end of Bahía Concepción south of Mulegé in Baja California Sur (32% decay), what they termed as a second form of the condition, “an initial circular crack on the branch without decay. Later, the green branch above the crack detaches, creating the characteristic flat top” (Bashan et al. 1995:683). Interestingly, Moran (1968:4) wrote, “cardones are sometimes seen, especially southward, with branches looking chopped off above. In the cardonal (cardón forest) at the south end of Conception Bay in 1961, many were newly topless, the tops of varying lengths all lying on the ground pointing with remarkable regularity to the northwest. It was clear that they must have been snapped off by the chubasco, or hurricane, of the previous summer.” When we visited San Pedro Mártir in early 2007, a few months after Hurricane John slammed into the Sonoran Midriff Islands in early September 2006, we observed many freshly broken arms and multiple large individuals toppled over (Figure 13). This damage seems due to strong winds and storms punishing overly turgid, healthy or old stems and plants, not to the flat-top decay syndrome.



FIGURE 10. *Ficus palmeri* among guano-covered rocks on mid-elevation sea cliff on south side of San Pedro Mártir Island, 7 December 2007. Photo by B. Wilder.

One of the most significant factors that permits such a dense and healthy succulent forest on San Pedro Mártir is the absence of native rodents and other terrestrial herbivores that are known to prey on seedlings and young columnar cacti (Medel-Narvaez et al. 2006; Steenbergh and Lowe 1983; Turner et al. 1969). Similar cardón forests are seen on the islands of Cholludo (a 0.1-km<sup>2</sup> island to the south of Tiburón; Wilder et al. 2008), Las Mellizas (small islands in Guaymas Bay; Turner et al. 2003), and Tío Ramón (another small island in Guaymas Bay; Medel-Narvaez et al. 2006), all of which lack rodents as well as other mammalian herbivores. Turner et al. (2003) showed that the Mellizas population increased through the 20th century whereas mainland populations did not. Our San Pedro Mártir data and those from two of the three islands investigated by Medel-Narvaez et al. also indicate increasing populations. These islands have extremely large numbers of small individuals (high regeneration indices; ca.  $\frac{2}{3}$  of the population), many of which Turner et al. (2003) showed to survive and lead to a dense cardón forest. In addition, the fog that often envelops San Pedro Mártir (Figure 4) is probably a significant factor aiding the successful germination, establishment, and continued growth of the cardons.

Why is the San Pedro Mártir population dwarfed and trunkless? Cardons are massive plants, the island has an unstable rocky surface and shallow soil, and from time to time violent tropical storms and hurricanes strike the island. From 1949 to 2008, 15 out of 52 hurricanes that struck the Baja California Peninsula crossed the Midriff Islands (Wikipedia contributors 2008). The selection pressure on the island for this massive columnar cactus to maintain a low center of gravity is difficult to quantify yet certainly should be considered

when the dwarfing of the cardón on gulf islands is assessed. In addition, the root system of *P. pringlei* is extensive, and such a high population density may be limiting the resources any one individual is able to uptake (Medel-Narvaez et al. 2006; Niklas et al. 2002). A unique factor influencing the San Pedro Mártir cactus forest is the high concentration of guano, which is not seen in this species' distribution except on some gulf islands. The high levels of nitrogen and phosphorus also may limit the growth of plants on San Pedro Mártir and other islands.

*Summary of cardón plot results:* Remarkably dense populations of cardón have been documented for several gulf islands (Medel-Narvaez et al. 2006; Turner et al. 2003). These two studies also show mainland populations to be substantially sparser. The lack of native rodents on the islands is likely the most significant factor shaping this distinction. In addition, favorable growing conditions on the islands likely aid the observed healthy dense populations. The dwarfing of the San Pedro Mártir plants seems to be due to a selection for shorter individuals to survive fierce tropical storms, possible root competition in such a dense forest, and the undefined effect of high levels of nitrogen and phosphorus from the abundant guano that might stunt growth. Genetic studies have not been undertaken, and insular and terrestrial populations may differ genetically, despite the species' capability for long-range dispersal. In addition, the role of differences in pollinators has not been investigated and may be significant (Rodrigo Medellín, personal communication 2008). Continued census of the established cardón plots on San Pedro Mártir, Mellizas, and the mainland will significantly increase our knowledge of the dynamics of these different populations. As Medel-Narvaez et al. (2006) sug-

TABLE 3. Number of individuals in 0.1-ha quadrat and average coverage, by species. Near the summit of San Pedro Mártir Island; 6 Dec 2007, ca. 275 m elevation, level terrain with shallow rocky soil.

Species	Number	Average coverage (%) <sup>a</sup>
<i>Abutilon palmeri</i>	NC <sup>b</sup>	1.85
<i>Aristida adscensionis</i> , <i>Muhlenbergia microsperma</i> <sup>c</sup>	NC	70.4
<i>Cylindropuntia alcahes</i>	19	4.63
<i>Cylindropuntia cholla</i>	5	0.96
<i>Digitaria californica</i>	3	1.20
<i>Lycium brevipes</i>	14	6.45
<i>Mentzelia adhaerens</i>	NC	12.08
<i>Pachycereus pringlei</i>	67	9.00
<1 m; babies	14	
1–2.5 m; juveniles	11	
>2.5 m; adults	42	
<i>Perityle emoryi</i>	NC	0.00
<i>Sphaeralcea hainesii</i>	NC	38.91
<i>Trixis californica</i>	9	5.28
<i>Viscainoa geniculata</i>	5	0.65
Total individuals/Total coverage	122	151.41%

<sup>a</sup>These values are an average of six 50-meter transects.

<sup>b</sup>Ephemeral/annual species were not counted (NC).

<sup>c</sup>These two species are grouped because they formed a dense blanket of ephemeral coverage that was mostly dead and to distinguish between them was nearly impossible.

gested, experimental studies with transplanted seeds and seedlings on the island and nearby mainland would test the leading hypothesis of the role of rodents in the substantial differences in abundance between islands and the mainland.

Change: San Pedro Mártir as an Opportunity for Study

There is perhaps no better place to monitor the effects of climate change and island biogeography than San Pedro Mártir Island. The island has a small and now well-known flora with over a century of documentation that makes future new discoveries or lack of detection direct evidence of change, either new immigrations or extirpations. Furthermore, the island’s baseline vegetation structure has been described, and permanent plots and transects have been established. The island is as remote and removed from human influence as any desert site can be and has the advantage of a finite and significantly small area, as well as legal conservation protection.

Historic collections and observations provide evidence of change on the island. Three species have not been seen on the island since

they were collected at the latest in 1962. *Cyperus squarrosus* was collected on the island only once, by Palmer in 1887. It is a short-lived plant that may have been established and extirpated from the island. *Petalonyx linearis* was collected only by Palmer in 1887 and Johnston in 1921. *Stegnosperma halimifolium* was collected by Palmer in 1887 and again in 1962 by Moran, who noted only two were seen—one a massive individual 4 m tall—but none have been recorded on the island since then. A few individuals of all three of these species could still exist on the island, though the possibility of their extirpation is more likely and intriguing.

The collection histories of two species show evidence of their being recent immigrants. *Viscainoa geniculata* was not collected by Palmer (in 1887 and 1890) or Johnston (in 1921), and Johnston (1924) specifically listed it as being absent from San Pedro Mártir. It was first encountered by Moran in 1962, who noted seeing only one plant, and the following year Felger noted that it was rare on the island. In 2007 and 2008, we found it scattered at lower elevations and common at higher elevations. In December 2008, we found *Digitaria californica* at the top of the island, the first confirmation of this species on the island. In Moran’s (1983) floristic checklist for the islands, he indicated that *Digitaria californica* is on San Pedro Mártir, a report not duplicated by Rebman et al. (2002). The only potential record of this species on the island prior to our discovery is an entry in Wiggins’ field notebook (on file at CAS) for number 17191 as “*Triodia*.” We have not seen the specimen, and attempts to locate it have not been successful. *Triodia* in this case could equal *Dasyochloa pulchella* or *Tridens muticus*. *Dasyochloa* is present on Tiburón, San Esteban, Dátil, Angel de la Guarda, and San Lorenzo but is unlikely on San Pedro Mártir because of the habitat. In the gulf region, *Tridens muticus* is known only from the higher elevations of Tiburón and from a canyon on Dátil Island (Wilder et al. 2007). Perhaps Wiggins’ “*Triodia*” in his field notebook is *Digitaria californica* and the basis for Moran’s 1983 listing. Early collectors who botanized at upper elevations did not report this species, and it is likely a recent establishment on the island.

In his field notes for his 1971 trip to the island (in the possession of Ray Turner), Rod Hastings gives insight into the dynamics of the cardón population. He noted, “But virtually the entire stand [of *Pachycereus pringlei*] is even-aged, about 3–4 m in ht. Only in north slopes was I able to find any individuals under 1 dm in ht; very few of them. A scattering between 1 dm and 3 m.” Hastings’ observations came after the widespread mid-century drought and differ from ours. Medel-Narvaez et al. (2006) found that all the cardón populations they measured, including those on islands, showed evidence of pulse recruitment typical of other columnar cacti.

The long and detailed history of observations and collections by careful and desert-savvy botanists for over a century, combined with permanent vegetation plots and transects, position San Pedro Mártir

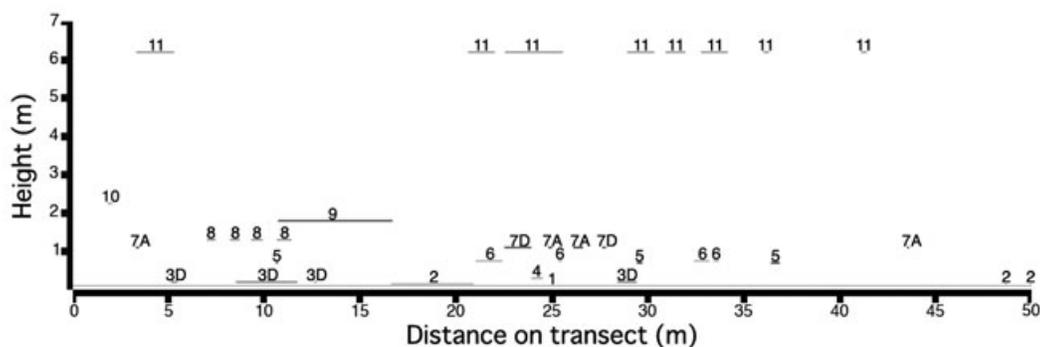


FIGURE 11. Vegetation structure on the top of San Pedro Mártir Island, representing transect 4, ca. 273 m elevation, level terrain, shallow rocky soil, 6 December 2007. The symbol # signifies a height measured directly in the field. (1) *Aristida adscensionis*, dead annual grasses. (2) *Muhlenbergia microsperma*. (3D) Dead *Mentzelia adhaerens*. (4) #*Digitaria californica*. (5) *Abutilon palmeri*. (6) *Trixis californica*. (7) *Sphaeralcea hainesii*: (A) living; (D) dead *Sphaeralcea hainesii*. (8) *Cylindropuntia alcahes*. (9) *Lycium brevipes*. (10) *Viscainoa geniculata*. (11) #*Pachycereus pringlei*.



FIGURE 12. “Trunkless” cardón, with new growth following a tropical storm in 2006 indicated by Felger, 11 April 2007. Photo by B. Wilder.

to be a premier locality for monitoring climate change.

#### THE FLORA

The awe of a desert island in the middle of the Vermillion Sea (Gulf of California) has attracted many of the most knowledgeable scientists of the Sonoran Desert region; we are fortunate to have a collection history that spans more than 120 years, beginning with Edward Palmer. Through these 120 years, careful observations and/or collections have been made at least every two decades, providing a robust body of knowledge of the flora. We present a summary of the botanists who made these collections, and a few associated scientists, followed by accounts of the species known from the island. We stress that this work is specimen-based, anchored to actual preserved material from the island.

#### Collectors and associates

##### Thomas Bowen

Bowen is an anthropologist and the author of *Unknown Island* (Bowen 2000), the first comprehensive ethnohistory of the Gulf of California. He has conducted archaeological and historical research on most of the Midriff Islands and has visited most of the larger islands elsewhere in the gulf. He was ashore briefly on San Pedro Mártir in May 1984 and on other occasions has studied the island from the sea near the shore. His *Record of Native People on Gulf of California Islands* (Bowen 2009) is essential for understanding

long-term human interactions on gulf islands.

##### Richard Felger

My first time on San Pedro Mártir, while I was a student at the University of Arizona, was on 25 January 1963, with Alexander “Ike” Russell (see Bowen 2002). At Guaymas we obtained passage on a shrimp boat. The crew trawled for shrimp all night and rested during the day offshore at San Pedro Mártir. Some of the crew members took us ashore in a dinghy. We were able to spend most of the day exploring the island for plants, from the ruins of the guano miners’ village to the summit. The island was green from recent rains. I collected 20 numbers (6346 to 6366).

The nighttime trawls yielded enormous, bulging nets of marine life scoured from the sea floor. The whole wet, writhing mass was dumped onto the deck; only a small fraction consisted of large, succulent shrimps, which were picked out by hand, put in large baskets, and stored on ice below deck. A few edible fish were saved, but the vast majority of the catch, now crushed, mangled, and dead or dying, was shoveled overboard.

11 April 2007, with Miguel Durazo, Exequiel Ezcurra, Jesús Ventura-Trejo, and Benjamin Wilder. We catalogued 16 numbers (Felger 07-09 to 07-24) at the southeast end of the island and from the guano miners’ village site to the plateau near the summit. Near the top of the island, we photographed a large, black kingsnake (*Lampropeltis getula*), which had not been documented on the island for 40 years. We also encountered several large, very fat, and light-colored rattlesnakes (*Crotalus atrox*).

5 to 7 December 2007, with Miguel Durazo, Andrea Galindo, Benjamin Wilder, and two crew members. I catalogued five numbers on 5 December, at the highest elevations of the island (07-194 to 07-198). Collections from 6 and 7 December were catalogued by Wilder. On this trip we obtained quantified vegetation data and detailed observations. We camped at the old village site. Dawn and dusk were especially noisy times, with thousands of seabirds whirling overhead and jostling for a roosting place. On the second day, we awoke to dense fog that did not lift until late in the day. Our return to the mainland in the early evening of 7 December was marred by rough weather in open water, resulting in a very challenging night at sea.

##### James Rodney Hastings (1923–1974)

Rod Hastings obtained his Ph.D. at the University of Arizona, where he later became professor of atmospheric science. His dissertation, *Historical Changes in the Vegetation of a Desert Region*, completed in 1963, became the basis for *The Changing Mile*, co-authored with Ray Turner (Hastings and Turner 1965), his former major professor. Their joint efforts included establishing permanent study plots for the cardón in Sonora and on the Baja California Peninsula.

Hastings went on a substantial tour of many of the Gulf of California islands from 12 to 28 March 1971 on the ship *San Agustín II*, owned and operated by Antero Díaz of Bahía de Los Angeles. Hastings was on San Pedro Mártir on 17 March 1971. In addition to collecting 10 numbers (71-58 to 71-67), he made perceptive observations preserved in his field notebook, graciously provided to us by Ray Turner:

“Proceed then to San Pedro Martir, a giant rookery for the blue-footed booby. The island is extremely mountainous and rocky with only 2 fairly level spots. See that birdshit! A curious flora, evidently selected for its ability to tolerate high P and N levels. PAPR [*Pachycereus pringlei*] is the dominant, and superficially the island resembles the *Islas Melisas* [*sic*] in PAPR density. But virtually the entire stand is even-aged, about 3–4 m in ht. Only in north slopes was I able to find any individuals under 1 dm in ht; very few of them. A scattering between 1 dm and 3 m. The second dominant is *Sphaer-*



FIGURE 13. Fallen cardón, 6 December 2007. Note several broken branches on cardons in background. Photo by Andrea Galindo.

*alcea hainesii*!; a woody perennial. *Ficus palmeri* occurs as widely scattered individuals. Comps comprise most of the species list.”

Ivan Murray Johnston (1898–1960)

Johnston served as the botanist on the California Academy of Sciences expedition to the Gulf of California from 13 April to 13 July 1921, during which “collections were made on all the 30-odd important islands in the gulf, at five localities in Sonora, and at 14 localities on the peninsula of Lower California” (Johnston 1924:951). Johnston’s publication remains one of the finest treatises on the botany of the islands of the Gulf of California.

The party made a one-day visit, 18 April 1921, to San Pedro Mártir. This date should have been in the middle of the seabird nesting season, but, as Slevin (1923:57) reported in the expedition’s general account, “It was formerly a great sea-bird rookery but appears to have been long deserted, probably due to the depredations of the guano hunters.” Johnston collected at least 20 numbers of 15 species with another species observed. These are listed with the page where treated by Johnston (1924):

- 3145, *Sphaeralcea hainesii* (page 1094)
- 3146, *Vaseyanthus insularis* (1180–1182)
- 3147, *Chylismia cardiophylla* (1121) [*Oenothera cardiophylla*]
- 3148, *Perityle emoryi* (1205)
- 3149, *Trixis californica* (1213. On this page Johnston says 3149

is from San Pedro Nolasco Island, but the actual specimen is labeled as San Pedro Mártir Island and the number sequence is for San Pedro Mártir)

- 3150, *Nicotiana obtusifolia* (1156) [*N. trigonophylla*]
- 3151, *Pelucha trifida* (1193)
- 3153, *Ficus palmeri* (1006)
- 3154, *Lycium brevipes* (1153) [*L. richii*]
- 3155, *Euphorbia petrina* (1072–1073)
- 3156, *Mentzelia adhaerens* (1103)
- 3157, *Pleurocoronis laphamioides* (1187) [*Hofmeisteria pluri-seta* var. *laphamioides*]
- 3158, *Abutilon palmeri* (1090)
- 3159, *Baccharis sarothroides* (1192–1193)
- 3160, *Pachycereus pringlei* (1118)
- 3162, *Pleurocoronis laphamioides* (1187) [*Hofmeisteria pluri-seta* var. *laphamioides*]
- 3162, *Ficus palmeri* (1006; number 3162 was used for two species)
- 3164, *Petalonyx linearis* (1104)
- 4386, *Vaseyanthus insularis* (1180–1182)
- 4387, *Vaseyanthus insularis* (1180–1182)
- 4398, *Muhlenbergia microsperma* (986)
- Observation, *Cylindropuntia alcahes* (1115) [*Opuntia burrageana*]

The three out-of-order numbers (4386, 4387, 4398) are curious

since Johnston otherwise kept consecutive numbers on the expedition, and he visited San Pedro Mártir only once. The species for which there is no record of Johnston having collected are *Aristida adscensionis*, *Cylindropuntia cholla*, *Cyperus squarrosus*, *Digitaria californica*, *Stegnosperma halimifolium*, and *Viscainoa geniculata*.

John Kipping

20 June 1975. We have seen only one collection by Kipping: *Sphaeralcea hainesii* (CAS).

George Edmund Lindsay (1916–2002)

He earned his undergraduate and doctoral degrees at Stanford University. He was the first director of the Desert Botanical Gardens in Phoenix (1939–1940), director of the San Diego Natural History Museum (1956–1963), and subsequently director of the California Academy of Sciences (1963–1982). In the 1950s and 1960s he organized a series of explorations of gulf islands (Lindsay 1955, 1966) and helped lay groundwork for major conservation efforts by the Mexican federal government. He published a number of works on cacti and succulents, especially of the Baja California Peninsula and Gulf of California islands. He collected many cactus specimens on the gulf islands but apparently not on San Pedro Mártir. His observations and his facilitating the work of other researchers, however, are noteworthy.

Emily J. Lott and Thomas Harris Atkinson

Emily is a botanist, her husband Tom Atkinson an entomologist. At the time of their collections on San Pedro Mártir and other islands in the gulf, they were at the Instituto de Biología in Mexico City. On 22 July 2009, Emily wrote to Felger, “We were on an Instituto de Biología UNAM trip (on a Mexican Coast Guard ship) with a bunch of other biologists—herps, ornith, fish people. Several trips were made but Tom and I only went on one. The project was organized in conjunction with the establishment of seabird preserves. Enriqueta Velarde was the leader.” It was early summer during drought conditions, and the specimens thus are not in excellent condition.

Lott and Atkinson were on San Pedro Mártir on 4 May 1985, collection numbers 2426 to 2438. The collections are mainly at MEXU; some duplicates are at UC and CAS.

Reid Venable Moran (1916–2010)

Moran was the single most intrepid botanical collector ever to work on the gulf islands and Baja California Peninsula. During the early 1950s, Moran was at the L. H. Bailey Hortorium, Cornell University. His extensive collections are primarily at SD, where he was curator of the herbarium from 1957 to 1982. Numerous duplicates of his specimens are at other herbaria, including ARIZ. He published extensively on the flora of the region, describing numerous species new to science. On many expeditions to the islands, he climbed to the highest peaks to search for interesting specimens. His notebooks are at SD and available online (Moran 1936–1993).

4 May 1952. He collected 5 numbers (4053 to 4057) on San Pedro Mártir as a member of the Sefton–Stanford Gulf of California Expedition (Lindsay 1955). “Sailed at 0500 [from San Pedro Nolasco Island] for San Pedro Mártir Island. We got ashore at noon and had to be back by 1400. This is a thousand-foot dome of rock with sheer cliffs on most sides, well whitewashed below. The top and the more gently sloping east side are forested with cardón. We landed on a broad sheltered ledge on the south end and found a trail thence to a deserted village of stone houses or half houses. It was very hot. I climbed to the top and collected a few plants, leaving half an hour

to get back down. On the way down, I heard a rattlesnake buzz, and managed to capture it with a couple of cardón sticks. I got down almost in time and apologized for being late, saying that since there were no snakes on the island I knew nobody would believe me unless I brought this one. The herpetologists had come back early, saying that they had gotten all the reptiles of the island” (Moran field book 3:111–112).

21 March 1962, 20 numbers (8801 to 8820). “With an early start we landed at 07:45 in a cove on the north side of San Pedro Mártir Island [Perhaps he actually went ashore at the northeast cove]. We climbed the trail remaining from guano-harvesting days, up the steep lower slope, into the canyon above. There were many nesting pelicans and boobies. I found three rattlesnakes. . . . I went to the top of this rather dome-shaped island, where middle slopes cut off any view of the shore on most sides. We were to be back at noon, but I got in the wrong canyon and was well down before I was sure of my error. . . . I was down by 12:10 with rest of the stragglers” (Moran field book 7:24–25).

16 April 1975, 3 numbers (21745 to 21747). On this trip Moran and others shipped out of Bahía de Los Angeles on 13 April aboard Antero Diaz’s boat. He wrote, “We circumnavigated ISPM in a panga from 9:30 to 11:30. Our 1952 landing place turns out to be on the NW side [undoubtedly this is an error on Moran’s part and their 1952 landing spot was indeed the SE side]. At 13:50 I went ashore at the usual landing cove on the north side and climbed up to the top” (Moran field book 14:78).

Edward Palmer (1831–1911)

During summer and fall of 1887, Edward Palmer, an intrepid plant collector, focused on the poorly known flora of the Gulf of California region at Guaymas, Mulegé, Bahía de Los Angeles, and San Pedro Mártir Island (Watson 1889; McVaugh 1956). Of the 415 native species collected, 89 were deemed new to science in Sereno Watson’s (1889) report on the collection. Palmer spent 8 days on San Pedro Mártir, 24 October to 5 November, and collected 18 species (listed below). He called the island San Pedro Martin.

Palmer collected all but five species of the known flora of San Pedro Mártir, lacking *Aristida adscensionis*, *Cylindropuntia alcahes*, *Digitaria californica*, *Lycium brevipes*, and *Viscainoa geniculata*. Did he miss or overlook these species? Or were some or all of them not present? He certainly covered the island, as evidenced by the diversity of specimens, labels, and reports. Palmer made numerous sets (duplicates) to sell, and perhaps his time was largely occupied in preparing the collections, or maybe he ignored plants he deemed less interesting or not specimen-worthy, such as those without flower or fruit, etc. He revisited the island in 1890 and collected three more numbers. His collections are as follows:

1887:

- 400, *Stegnosperma halimifolium*
- 401, *Abutilon palmeri* [*A. aurantiacum*]
- 402, *Mentzelia adhaerens*
- 403, *Chylismia cardiophylla* [*Oenothera cardiophylla*]
- 404, *Sphaeralcea hainesii* [as *Sphaeralcea* ?]
- 405, *Sphaeralcea hainesii* [as *S. ambigua*]
- 406, *Pleurocoronis laphamoides* [as *Laphamia* ?]
- 407, *Pelucha trifida* [type specimen]
- 408, *Trixis californica*
- 409, *Vaseyanthus insularis* [*Echinopepon insularis*, type specimen]
- 410, *Nicotiana obtusifolia* [*N. trigonophylla*]
- 411, *Petalonyx linearis*
- 412, *Euphorbia petrina* [type specimen]
- 413, *Ficus palmeri* [type specimen]
- 414, 415, *Baccharis sarothroides*

416, *Muhlenbergia microsperma* [as *M. tenella*]

417, *Cyperus squarrosus* [*C. aristatus*]

418, *Pachycereus pringlei* [*Cereus pringlei*]

419, *Cylindropuntia cholla* [*Opuntia* sp.]

1890. Palmer spent one day (13 February) on the island and collected three species of Asteraceae (Vasey and Rose 1890):

148, *Pleurocoronis laphamioides* [*Hofmeisteria laphamioides*]

149, *Perityle emoryi*

150, *Pelucha trifida*

Pedro Tenorio L. and Alfonso Valiente-Banuet

9 August 1985, with Fernando Chiang-Cabrera et al., Tenorio and Valiente made a small collection on the island; we have seen two of their specimens (*Tenorio 9491* and *Valiente 604*). They were on a ship that visited a number of islands in the gulf. Pedro Tenorio has been a collector of botanical specimens for MEXU and works on invasive plants in Mexico. Valiente-Banuet is a noted researcher at the Instituto de Ecología, Universidad Nacional Autónoma de México.

Ira Loren Wiggins (1899–1987)

Wiggins was the curator of the Dudley Herbarium (now incorporated into CAS) at Stanford University. He was on the island on 21 March 1962 (see entry for Reid Moran) and collected 16 numbers (17176 to 17191), representing 12 species, as determined from his field notebook on file at CAS. Wiggins (1964) wrote *Flora of the Sonoran Desert*, which continues to be the foremost botanical work of the region.

Benjamin Wilder

11 April 2007, with Miguel Durazo, Exequiel Ezcurra, Richard Felger, and Jesús Ventura-Trejo. After circumnavigating the island we went ashore, and from above the guano miners' village climbed to the upper plateau of the island. Collections from the day are cataloged under Felger's numbers.

5 to 7 December 2007, with Miguel Durazo, Richard Felger, Andrea Galindo, and two crew members. After arriving at the island on the 5th, we spent the 6th establishing and taking data from the vegetation quadrat and transects on the top of the island. A dense fog covered the island all day, and a constant stiff wind made for rather cold conditions. The next day was spent censusing the cardón plot. Seven specimens were collected (07-601 to 07-607) on 6 and 7 December at the highest elevations of the island. Collections from the 5th are cataloged as Felger's.

## SPECIES ACCOUNTS

The nomenclature represents our interpretation of the literature and identifications of experts as indicated for specimens cited. The accepted scientific name is in boldface, and selected synonyms are listed in brackets. Four species are described from specimens collected on San Pedro Mártir by Palmer in 1887—we provide publication information for these species. Selected common names are given first in Spanish (in italics) and then in English. Unless otherwise stated, the brief descriptions including measurements are based on specimens or populations as they occur on San Pedro Mártir. We summarize the distributions and information on the plants as they occur on the island, followed by the general geographic distribution. Information for occurrences on other gulf islands is listed by latitude and is based on Rebman et al. (2002) and our knowledge of the flora of the Sonoran islands (Tiburón, San Esteban, Dátil, Cholludo, Patos, Alcatraz, and San Pedro Nolasco). We have seen all specimens cited unless noted as “not seen.” Specimens seen by us as digital images are indicated

as “image.” Specimens are listed in order of date of collection. All specimens cited are at ARIZ unless otherwise indicated by the abbreviations for herbaria in Index Herbariorum (2009). If a specimen is at ARIZ, we generally do not cite duplicates at other herbaria. In cases where more than one collector is listed on the label, we generally cite only the first collector's name, associated with the collection number. To avoid confusion, in a few cases the herbarium accession number follows the herbarium abbreviation, especially in the case of multiple specimens of type collections.

ASTERACEAE—Aster or Sunflower Family

***Baccharis sarothroides*** A. Gray. *Romerillo*; desert broom.

Broomlike shrubs ca. 0.5–1.5 m tall. Leaves sparse, small, and quickly drought deciduous. Male and female flowers on separate plants. Flowers inconspicuous. Cypselas (“achenes”) ca. 2.5 mm long, the pappus bristles feathery, to ca. 10 mm long.

Widely scattered and rather rare on the island, mostly at higher elevations. Palmer reported it as “yerba del pasmo.” “The twigs are used as a remedy for toothache. Rarely over 2 feet high” (Watson 1889:55). Johnston (1924:1192–1193) reported that it is “occasional in draws where it forms a bright-green, compact shrub 12–15 dm high. It is reported (Proc. Am. Acad. 24:55, 1889) as growing only 6 dm high on the island, but all plants seen there were considerably taller.”

Various resinous and bushy composites are called *hierba de pasmo* in northwestern Mexico and the southwestern United States and are highly esteemed for medicinal purposes (e.g., Felger 2007, Felger and Moser 1985). Yoemem (Yaquis) have used desert broom for roofing, and the branches would also serve well as roofing for the tiny rock-walled huts on San Pedro Mártir. Did Yoeme guano workers bring it to the island for medicinal purposes and/or roofing material? It is the only dioecious species on the island, and there is a hint that the plants increased in size between 1887 and 1921.

General distribution: Sinaloa to southwestern United States and both states of Baja California, often in disturbed habitats.

Other islands: Angel de la Guarda (observation), San Lorenzo, San Ildefonso (observation).

1887, *Palmer 415* (UC, pistillate). Occasional in draws, a bright green compact shrub 4 or 5 feet high, 18 Apr 1921, *Johnston 3159* (CAS). Only 2 seen, on top of island, shrub 1.5 m high, 4 May 1952, *Moran 4054* (CAS). 300 m, occasional, 21 Mar 1962, *Moran 8818* (SD). 21 Mar 1962, *Wiggins 17181* (CAS). Near top of island, rare, two large shrubs seen, ca. 4–5 ft high, 25 Jan 1963, *Felger 6356*. Elevation 125 m, 17 Mar 1971, *Hastings 71-59* (pistillate). Small canyon at base of SE-facing slope that leads to island summit, only one plant seen [here], about 1.2 m tall, sheltered at the NE base of a large cardón, 11 Apr 2007, *Felger 07-24*.

***Pelucha trifida*** S. Watson, Proc. Amer. Acad. Arts 24:55, 1889.

Pungently aromatic, scarcely woody shrubs or bushy perennials, 0.3–1 m tall. Herbage thinly gray-woolly to white-woolly. Leaves often semisucculent and three-toothed or three-lobed. Flower heads in terminal inflorescences; flowers discoid and golden yellow. Cypselas 2 mm long, silky haired; pappus of many bristles, the larger ones 5.5 mm long and minutely barbed. Palmer recorded that “it has a very strong aroma as of cloves and cinnamon, and so powerful is this at times that it causes persons to sneeze and cough” (Vasey and Rose 1890:78).

Scattered and moderately common at higher elevations, with one record at ca. 50 m elevation; often on rock outcrops.

General distribution: Gulf coast of the southern part of the state of Baja California and some Midriff Islands. Johnston (1924) pointed out that it seems to require open exposure to sea breezes and that it was very common in rocky ground along the crest of San Pedro Mártir. Palmer reported it growing “in crevices of rocks near the sea” (Watson 1889:55). “The shrubby habit of *Pelucha* is unusual in the

otherwise mostly herbaceous Helenieae s.s. and is conceivably the result of evolution on islands in the Gulf of California" (Baldwin and Wessa 2000:522). Their studies demonstrate that *Pelucha* is in a clade with *Psathyrotes* and *Trichoptilium*, small annuals of the drier, winter-rainfall regions in the northwestern parts of the Sonoran Desert (e.g., Felger 2000).

Other islands: Ángel de la Guarda, Tiburón, San Esteban.

1887, *Palmer 407* (holotype, GH 10992, information from data base; isotype, US 47511, image). 13 Feb 1890, *Palmer 150* (UC 84228). Common along the rocky crest of the island, open irregularly branched shrub 2–3½ ft high, 18 Apr 1921, *Johnston 3151* (CAS, UC). Top of island, occasional, smelly shrub 4–8 dm tall, 4 May 1952, *Moran 4053* (UC). Summit, 300 m, occasional, few in flower, 21 Mar 1962, *Moran 8805* (SD). Usually along shallow arroyos, not common, 25 Jan 1963, *Felger 6358*. Elevation 125 m, 17 Mar 1971, *Hastings 71-65*. Steep N slope, common above landing, ca. 50 m elev, shrub ½ m high, with turpentine odor, heads yellow,  $2n = 19$  pairs fide A.M. Powell, 16 Apr 1975, *Moran 21745*. Ridge, 285 m, uncommon, seen only at upper elevations, 5 Dec 2007, *Felger 07-194*.

***Perityle emoryi*** Torrey. Desert rock daisy.

Cool-season annuals, highly variable in size. Rays white, the disk yellow. Cypselas thin, 2.1–3.0 mm long.

Seasonally common across the island.

General distribution: Both Baja California states and Sonora from the Guaymas region to southwestern United States, and Peru and Chile. This is one of the few species of *Perityle* found in South America and the only amphitropical species in the genus.

Other islands: Ángel de la Guarda, San Lorenzo, Patos, Tiburón, Cholludo, Dátil, Alcatraz, San Esteban, San Pedro Nolasco, Tortuga, San Marcos, San Ildefonso, Coronados, Carmen, Monserrat, Santa Cruz, San Francisco, Espíritu Santo, Cerralvo.

S end of island, 13 Feb 1890, *Palmer 149* (not seen, cited by Vasey and Rose 1890:79). Common along crest, growing between loose rocks, 18 Apr 1921, *Johnston 3148* (UC, CAS, det. M. Powell 1970). 21 Mar 1962, *Wiggins 17184* and *17180* (CAS, det. M. Powell 1968). Abundant at higher elevations, 25 Jan 1963, *Felger 6359* (duplicate at SRSC det. by A.M. Powell). Elevation 125 m, 17 Mar 1971, *Hastings 71-60*. Small canyon at base of SE-facing slope that leads to island summit, most of the plants nearly smothered by *Vaseyanthus*, 11 Apr 2007, *Felger 07-20*. Plateau NW of highest point of island, 275 m, 6 Dec 2007, *Wilder 07-603*.

***Pleurocoronis laphamioides*** (Rose) R.M. King & H. Robinson [*Hofmeisteria laphamioides* Rose].

Globose small shrubs or bushy perennials, gradually and tardily drought deciduous; minutely glandular-pubescent. Leaf blades semisucculent, becoming sparsely glandular with age. Flowers white to pale yellow with purple stigmas; reproductive at various seasons, especially in warmer weather.

Moderately common across the island, especially at higher elevations and on high sea cliffs; occasional on sea cliffs at low elevations. On 13 February 1890, Palmer recorded it as "very common over the summit" (Vasey and Rose 1890), and Johnston (1924:1186) noted "on San Pedro Mártir Island it is most abundant in the cactus forest crowning the island and forms an erect-growing shrub 5–10 dm high." Flowers at various seasons.

General distribution: Western Sonora, from east of the Pinacate region and nearby Arizona south to the Guaymas region, gulf islands, and both Baja California states.

Other islands: Tiburón, Dátil, Alcatraz, San Esteban, San Pedro Nolasco, Tortuga, San Marcos, San Ildefonso, Danzante.

Oct 1887, *Palmer 406* (GH, image). 13 Feb 1890, *Palmer 148* (not seen). 18 Apr 1921, talus at foot of sea-cliff about 20 ft above high tide, only 2 seen here, *Johnston 3162* (CAS, 2 sheets, images); Abundant along crest of island, *Johnston 3157* (CAS, image). Common in canyon, ca. 300 m, 21 Mar 1962, *Moran 8804* (CAS). 21 Mar 1962, *Wiggins 17182* (CAS). Common shrub, 25 Jan 1963, *Felger 6360*. Canyon on N side of isla, 150 m, 16 Apr 1975, *Moran 21746* (SD, UC). Small canyon at base of SE-facing slope that leads to summit, 11 Apr 2007, *Felger 07-23*.

***Trixis californica*** Kellogg var. *californica*. *Plumilla, arnica*; *trixis*.

Small shrubs or subshrubs, to 1 m tall, essentially glabrous. Leaves gradually drought deciduous, thin and semipersistent after drying. Flowers bright yellow; reproductive at various seasons, especially spring. Cypselas 8–10 mm long, with a pappus of numerous soft, barbellate bristles about as long as the cypselas. Flowers at various seasons.

Occasional and widely scattered on the island, seen mostly at higher elevations. Palmer reported it "common upon the summit" (Watson 1889:59).

General distribution: Southeastern California to western Texas and southward to Baja California Sur, Sinaloa, and north-central Mexico.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, Dátil, San Esteban, San Pedro Nolasco, Tortuga, San Marcos, Coronados, Carmen, Danzante, Monserrat, San Francisco.

Summit, 1887, *Palmer 408* (GH, UC, images). One of the most common plants on the island, 2½ ft high, 18 Apr 1921, *Johnston 3149* (CAS, image). Canyon on N slope, 100 m, occasional, 21 Mar 1962, *Moran 8801*. 21 Mar 1962, *Wiggins 17178* (CAS). Frequent near top of island, 25 Jan 1963, *Felger 6349*. Elevation 125 m, 17 Mar 1971, *Hastings 71-64*. N slope of isla, 200 m, 16 Apr 1975, *Moran 21747* (SD, not seen, verified in data base). Above ruins of guano workers' village, about 1/3 way up island, scattered, rather rare, 11 Apr 2007, *Felger 07-13*. Summit, 290 m, not common, 5 Dec 2007, *Felger 07-197*.

#### CACTACEAE—Cactus Family

***Cylindropuntia alcahes*** (F.A.C. Weber) F.M. Knuth var. *alcahes* [*Opuntia alcahes* F.A.C. Weber var. *alcahes*] Choya.

Staghornlike chollas, often 0.7–1.5 m tall. The terminal cladodes (joints) sometimes fall away and form new plants, although the cladodes are not nearly so fragile as those of *C. cholla*. Flowers yellowish and with a full complement of tepals. Fruits fleshy and yellow, apparently persisting up to several months; seeds presumably fertile.

Infrequent to locally common at higher elevations on the island. Often grows intermixed with *C. cholla*.

General distribution: This species occurs through most of the Baja California Peninsula, adjacent gulf islands, and on San Esteban Island. There are four intergrading varieties; var. *alcahes* is the most widespread one, extending across most of the range of the species.

Other islands: (var. *alcahes*): Ángel de la Guarda, San Lorenzo, San Esteban, Tortuga, San Ildefonso, Carmen, Danzante, Monserrat, Santa Catalina, Santa Cruz, San Diego, San José, San Francisco, Espíritu Santo, Cerralvo (observation).

18 Apr 1921, *Johnston*, observation (cited by Johnston 1924:1115). Erect to 1 or rarely 2 m tall, stems to 6 cm in diameter, petals green, erect, 4 May 1952, *Moran 4056* (SD, CAS). Top of island, occasional, 8 dm tall, stem to 5 cm diameter, 21 Mar 1962, *Moran 8815* (SD). Small canyon at base of SE-facing slope that leads to island summit, scattered, nearly all are draped with *Vaseyanthus* vines, no fruits seen, 11 Apr 2007, *Felger 07-18* (USON).

***Cylindropuntia cholla*** (F.A.C. Weber) Knuth [*Opuntia cholla* F.A.C. Weber] Choya; chain-link cholla.

Chollas to about 1.5 m tall. Cladodes (joints) and fruits green, highly succulent, readily detached, potentially forming new plants and clonal colonies. Flowers pink, with relatively few tepals. Fruits globose, persistent, and solitary or proliferating into pendent chains.

Infrequent to locally common at higher elevations. Palmer reported it as "Choyer"; "common on S. Pedro Martin [*sic*] Island" (Watson 1889:52).

General distribution: Widespread through the Baja California Peninsula including various Pacific and gulf islands. *Cylindropuntia cholla* is closely related to *C. fulgida* of the mainland and Sonoran islands, the distinctions being subtle (see Rebman 1995). The seeds of both species are likely not viable (Felger and Zimmerman 2000; Rebman 1995).

Other islands: Ángel de la Guarda, San Lorenzo (observation), Tortuga, San Marcos (observation), San Ildefonso (observation), Coronados, Carmen, Danzante, Monserrat (observation), Santa Catalina, Santa Cruz, San Diego, San José, San Francisco, Espíritu Santo, Cerralvo. Reports of this species from Tiburón and San Esteban islands (e.g., Rebman et al. 2002) as well as other Sonoran Islands appear to be of *C. fulgida* or possibly plants with intermediate morphology.

1887, *Palmer 419* (not seen, cited by Watson 1889:52). Top of island, occasional, ca. 6 dm high, broad yellowish papery sheaths, very spiny, 21 Mar 1962, *Moran 8814* (CAS, SD). Lower (first) "plateau," ca. 500 ft, not common, 25 Jan 1963, *Felger 6357*. Summit, 300 m, localized, 7 Dec 2007, *Wilder 07-607* (USON).

***Pachycereus pringlei*** (S. Watson) Britton & Rose. *Cardón, saguero*.

Columnar cacti with multiple thick stems, to about 5 m tall (10–15 m tall elsewhere in its range, e.g., Felger et al. 2001; Felger and Moser 1985; Turner et al. 1995); trunkless or with a very short trunk. Juvenile plants densely spiny with distinct areoles; the upper or reproductive stem portions are spineless with coalesced areoles. The stems show constrictions and color differences for each growth increment, probably representing a single year or season except during extreme droughts. Exposed, cut surfaces (cortex and pith) of stems quickly turn orange-brown, then blackish. Flowers large and white; plant presumably flowers in late spring and fruits in early summer.

This cactus is the dominant feature of the landscape across the island. The largest ones are at higher elevations, where the majority of the island surface is a veritable cardón forest. In 2007 we found juvenile to adult plants abundant throughout the island. Seedlings and small plants were found in the open, growing among rocks; nurse plants were not present. Upon reaching maturity with many massive branches, the plants seem prone to toppling over, probably because of the loose rock and the effects of strong winds when the plants are well hydrated. Uprooted behemoths are seen across the island. (See Cardón Plot above.)

Palmer reported the cardón forming a forest on the island's summit. "The dead wood is much used for fuel and other purposes, and the seedy fruit is an article of food" (Watson 1889:52). The Yoeme guano workers probably used the stem ribs in house construction.

In 1971 Rod Hastings saw few juvenile plants. He observed virtually the entire stand to be even-aged, about 3–4 m tall. Only on the north slopes did he find any individuals less than 10 cm tall and there very few, and only a scattering of plants between 10 cm and 3 m tall.

On 11 April 2007, we noted, especially at the lower elevations and at the bases of slopes, that the short trunks were often buried in rock rubble, indicating that the land surface is rather unstable. Smaller, young plants were fairly common, especially at higher elevations, and most of them were at least partially covered by *Vaseyanthus* vines. Here and there we saw quite a few still "living" and green large cardons that had fallen over, probably as a result of the last hurricane.

General distribution: Endemic to the Sonoran Desert and Cape Region of Baja California Sur: most of the Baja California Peninsula and Sonora from near Empalme (southeast of Guaymas) north along the coast to Puerto Lobos and inland to Pitiquito, and on most of the islands in the gulf. It would be interesting to know if the dwarf, trunkless forms on San Pedro Mártir and Partida Norte are genetically distinctive and thus warrant subspecific status.

The extensive research of Ted Fleming and colleagues has shown that this cactus has complex breeding systems, but the situation on San Pedro Mártir, site of the most isolated population, is unstudied. Although the cardón is normally slow growing and long-lived (Turner et al. 2003), our observations of cultivated plants show it can grow considerably faster than the saguaro.

Other islands: Ángel de la Guarda, Partida Norte, Las Ánimas ("San Lorenzo Norte"), San Lorenzo (observation), Patos, Tiburón,

Cholludo, Dátil, Alcatraz, San Esteban, San Pedro Nolasco, Tortuga, San Marcos (observation), San Ildefonso (observation), Coronados (observation), Carmen, Danzante (observation), Monserrat (observation), Santa Catalina, Santa Cruz (observation), San Diego (observation), San José, San Francisco (observation), Espíritu Santo, Cerralvo.

Summit, 1887, *Palmer 418* (GH, image). Forming a forest over upper part of island, branching from base, 18 Apr 1921, *Johnston 3160* (CAS, image). Very common, 25 Jan 1963, *Felger 6347*. "Forming forest on summit. . . . Branching mostly near the ground, the branches 2–5 dm diameter, with 13–15 ribs. Buds sometimes within 1–2 m of the ground, 7½–8 × 3½–4 cm. Some mature buds placed in a paper sack in my pack began to open well before any on the plant; in fact, when I reached the shore at 1850 (just before dark), none were yet seen open. On one small plant even small buds had stigmas exerted; in most plants stigmas not exerted before anthesis" (Moran, field notebook 9:119), 15 Apr 1966, *Moran 13038* (SD, UC, image). Small canyon at base of SE-facing slope that leads to island summit, the specimen is taken from a fallen branch, 11 Apr 2007, *Felger 07-19* (USON).

#### CUCURBITACEAE—Gourd Family

***Vaseyanthus insularis*** (S. Watson) Rose [*Echinopepon insularis* S. Watson, Proc. Amer. Acad. Arts 24:51, 1889. *E. palmeri* S. Watson. *Brandegea palmeri* (S. Watson) Rose. *Vaseyanthus insularis* var. *palmeri* (S. Watson) Gentry. *V. insularis* var. *inermis* I. M. Johnston].

Annual vines, herbaceous and often robust, growing luxuriantly with fall to spring rains, not known to survive pre-summer heat and drought. Pedro Tenorio collected what appears to be a young plant on 9 August 1985, the only record of this stage of the life cycle during the hot summer anywhere in the Gulf of California region. The plant produces a thick, carrot-shaped, fleshy, white taproot, which seems unusual for a short-lived annual. Stems slender, the tendrils usually forked. Leaves pale green, the blades relatively thin and highly variable in size, shape, and thickness depending on age of the vine, shading, position on the vine, and moisture; leaf blades palmately five-lobed, the lobes broad and shallow to notably slender and deeply parted.

Male and female flowers occur on the same plant; flowers small. Male flowers white, in slender panicles in leaf axils. Female flowers solitary, green, on slender pedicels from the same leaf axil as male panicles. Fruits have a globose, variously echinate (prickly) or sometimes smooth body and a slender, smooth, seedless beak longer than the body or base. Newly or nearly ripe fruits are bright green and fleshy, the body 12.7–14.3 × 11–12.4 mm, the beak green and succulent. As the fruits mature, the beak falls away, leaving a dry and brown, globose and corky structure with large air pockets and one or two lightweight seeds. The fruits readily float and are thus well adapted to dispersal by sea.

This is one of the most abundant and widespread plants on the island. During favorable seasons it carpets otherwise barren rocky slopes, forming dense, intertwining, sprawling mats, and festoons cacti and shrubs in green curtains, excluding other plants from growing. At such times, the island appears green when viewed from the sea, though after the *Vaseyanthus* dries, the island will be brown. We observed the vines generally to be absent or at least only sparse and infrequent in guano-covered places, such as the lower elevations, on sea cliffs and the precipitous margins of the island, and in some high, exposed places. We observed that seabirds do not nest in areas of dense *Vaseyanthus* cover.

General distribution: Coastal Sonora from the vicinity of El Desemboque San Ignacio to the vicinity of Guaymas, most islands in the Gulf of California, and Baja California Sur and the southern part of the state of Baja California.

Gentry (1950) recognized three varieties: var. *inermis* is based on smooth-fruited specimens, whereas var. *insularis* has echinate fruits. Both smooth and prickly fruits may occur on the same plant. Variety

*palmeri*, with thin, sparsely pubescent to glabrate leaves and mostly lanceolate, acuminate, and aristate lobes, seems to be based on plants responding to high soil moisture and perhaps shade. These varieties do not seem worthy of taxonomic recognition (Felger et al. 2010). A second but rather weakly distinguished species of *Vaseyanthus* occurs in the southern part of Baja California Sur.

It seems strange that *Vaseyanthus* is generally restricted to the Gulf of California region and the Pacific shore of Baja California Sur. The ocean-dispersed fruits should allow wider dispersal. The distribution may relate to the species' need for winter–spring or cool-season rains and the apparent inability of the plants to survive or germinate during the hot summers. Cool-season rains are greatly reduced south of the Guaymas region in Sonora, but suitable conditions seem available farther north on the Baja California Peninsula, where *Vaseyanthus* likewise does not occur.

Other islands: Ángel de la Guarda, Partida Norte, San Lorenzo, Tiburón, San Esteban, San Pedro Nolasco, Tortuga, San Marcos, Coronados, Monserrat, Santa Catalina, Santa Cruz, San Diego, San José, Espíritu Santo, Cerralvo.

Common, 1887, *Palmer 409* (type collection of *Echinopepon insularis*, US 228679, image). 18 Apr 1921, common, running up creosote trunks or matting rocks, *Johnston 3146* (CAS, image). Trailing over rocks and cacti, *Johnston 4386* (CAS, image). Trailing over rocks and cacti, *Johnston 4387*, (CAS, image). Common near summit, 300 m, 21 Mar 1962, *Moran 8803* (SD). Scrambling over rocks and shrubs, 25 Jan 1963, *Felger 6350*. N-central part of island, localized in arroyo, 400 ft elev, covering rocks and shrubs, 25 Jan 1963, *Felger 6361*. 500 ft, on rocks and shrubs, 25 Jan 1963, *Felger 6366*. Elevation 125 m, 17 Mar 1971, *Hastings 71-67*. 28° 22' 00" N, 112° 20' 00" W, hierba postrada, abundante, fl. blanca, fr. inmaduro, vegetación matorral xerófilo, primaria, 9 Aug 1985, *Tenorio 9491*. Small canyon at base of SE-facing slope that leads to island summit, 11 Apr 2007, *Felger 07-21*.

#### CYPERACEAE—Sedge Family

*Cyperus squarrosus* Linnaeus. [*C. aristatus* Rottbøell. *Mariscus squarrosus* (Linnaeus) C.B. Clarke] Dwarf sedge.

Small, nonseasonal annuals, the smallest *Cyperus* in the Sonoran Desert. Leaves few, soft, basal or nearly so, usually less than 1 mm wide. Each spikelet scale has a prominent recurved awnlike tip giving a fringed appearance to the spikelets.

Known from San Pedro Mártir only by Palmer's collection.

General distribution: Widespread in the Sonoran Desert in permanently to temporarily wet soils. Worldwide in temperate and tropical regions.

Other islands: San Pedro Nolasco (Wilder et al. 2007; Felger et al. 2010), Espíritu Santo (Tucker 1994:90).

On the summit of the island, small grassy annual, 1887, *Palmer 417* (UC, US, both cited by Tucker 1994:201 and seen by him).

#### EUPHORBIACEAE—Spurge Family

*Euphorbia petrina* S. Watson, Proc. Amer. Acad. Arts. 24:75, 1889 [*Chamaesyce petrina* (S. Watson) Millspaugh] *Golondrina*.

Nonseasonal annuals, the plant reddish brown. Seeds ca. 1 mm long, mucilaginous when wet and adhering tenaciously upon drying.

Seasonally common, especially at higher elevations. Watson (1889:75) reported it as "common among rocks at summit."

General distribution: Vicinity of the Río Colorado delta south in western Sonora to Sinaloa, gulf islands, and the Baja California Peninsula.

Other islands: Ángel de la Guarda, Tiburón, Alcatraz, San Esteban, San Francisco, Espíritu Santo.

San Pedro Island, October 1887, *Palmer 412* (holotype GH; type collection, UC 110399). There also are four sheets of *Palmer 412* in 1887 at US (images): three are labeled San Pedro Martín (US 47790, 798887, 7988880), and one (US 47789) bears two labels, one with "Flora of Lower California," the other with "Los Angeles Bay." Very common in the cordonada [cardón

area?] crowning the island, where it grows between the loose rocks, 18 Apr 1921, *Johnston 3155* (CAS, image). Top of island, 300 m, rather common, 21 Mar 1962, *Moran 8809* (SD; UC, image). 21 Mar 1962, *Wiggins 17189* (CAS). Among rocks, very common, 25 Jan 1963, *Felger 6348*.

#### LOASACEAE—Stickleaf or Loasa Family

*Mentzelia adhaerens* Benth. *Pega pega*.

Nonseasonal annuals, often best developed after summer–fall rains. Herbage and capsules stick like Velcro to surfaces because of intricately barbed (glochidiate) hairs. Flowers yellow-orange, opening early in the morning. Capsules 8–14 mm long, the seeds ca. 2.7 mm long.

Seasonally common to abundant across most of the island. Johnston (1924) reported that it grew in every sheltered place on the island.

General distribution: Western Sonora south to the Guaymas region, gulf islands, and the Baja California Peninsula.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, Dátil, San Esteban, Tortuga, San Marcos, Coronados, Carmen, Danzante, Monserrat, Santa Catalina, Santa Cruz, San José (observation), San Francisco, Espíritu Santo, Cerralvo.

Summit, among cactus and rocks, 1887, *Palmer 402* (GH, image). Frequent over higher part of island, 18 Apr 1921, *Johnston 3156* (CAS, image). Top of island, 300 m, rather common, 21 Mar 1962, *Moran 8808* (SD, UC, CAS). Common, 25 Jan 1963, *Felger 6363*. Small canyon at base of SE-facing slope that leads to island summit, 11 Apr 2007, *Felger 07-22*. High-elevation plateau, NW of highest point of island, 275 m, 6 Dec 2007, *Wilder 07-602*.

*Petalonyx linearis* Greene. Narrow-leaf sandpaper plant.

Perennials; often flowering during the first season, forming a small, woody-based bush. Leaves tardily drought deciduous. Flowers white. Fruits one-seeded, enclosed in clasping bracts, which act as the dispersal unit; the bracts cling tenaciously by means of complex hooked hairs.

Known from the island only by Palmer's (1887) and Johnston's (1921) collections.

General distribution: Southeastern California to northern Baja California Sur, gulf islands, southwestern Arizona, and northwestern Sonora.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, San Esteban, Tortuga, San Marcos.

In shade of *Cereus* and rocks, Oct 1887, *Palmer 411* (CAS, UC; GH image). A single plant at foot of sea-cliff on E side of island, 18 Apr 1921, *Johnston 3164* (CAS, image; entire young plant, annual or first season).

#### MALVACEAE—Mallow Family

*Abutilon palmeri* A. Gray [*A. aurantiacum* S. Watson].

Open and scarcely woody shrubs or subshrubs, sparsely branched, highly variable in size to 1+ m tall, probably not long-lived. Often flowering in the first season as a facultative annual, this plant quickly forms a deep tap root. Flowers pale orange. Fruits 1.3–1.5 cm wide, the mericarps about 10. Flowering nonseasonal. "One of the common plants in rocky ground over the higher parts of San Pedro Martín Island (3158) where it grows as a loosely branched perennial 7–12 dm high" (Johnston 1924:1090).

One of the most abundant and widespread plants on the island but generally not at lower elevations.

General distribution: Southwestern Arizona to Sinaloa, southeastern California to the Cape Region of Baja California Sur, and islands in the Gulf of California; disjunct in Tamaulipas.

Other islands: Ángel de la Guarda, Tiburón, Tortuga, Coronados, Carmen, Santa Cruz, San José, Espíritu Santo (from Moran 1983).

1887, *Palmer 401* (UC). Very common on upper part of island, 2½ ft high, 18 Apr 1921, *Johnston 3158* (UC); branches few ascending, 2½–4 ft high, *Johnston 3158* (CAS). Summit, 300 m, 21 Mar 1962, *Moran 8806* (SD,

UC). Abundant, 25 Jan 1963, *Felger 6352*. 125 m elevation, 17 Mar 1971, *Hastings 71-62*. Above ruins of the guano workers' village, ca. 100 m elev, 11 Apr 2007, *Felger 07-11*.

### *Sphaeralcea hainesii* Brandegee.

Mostly shrubs to 1.8+ m tall, probably not long lived. Some individuals flower in the first season as an ephemeral; these have a well-developed tap root. Flowers orange; nonseasonal. Mericarps two-seeded or three-seeded, the wings (dehiscent segment) larger than the body (indehiscent part).

One of the most widespread and abundant plants on the island, from low elevations in guano-white soils, where it is one of the pioneer plants, to the summit. The plants are unusual in the genus because of their often large, shrub-sized stature and often relatively large and somewhat thick leaves.

General distribution: Gulf of California islands and both Baja California states.

Other islands: Ángel de la Guarda, San Lorenzo, Tortuga, San Marcos, Carmen, Danzante, Monserrat, San José.

Stony ravines, Oct 1887, *Palmer 404, 405* (GH, images). Most abundant herbaceous perennial on island, 18 Apr 1921, *Johnston 3145* (CAS, UC). Shrub 1.5 m tall, 4 May 1952, *Moran 4057* (SD, CAS). Near summit, 300 m, abundant, 21 Mar 1962, *Moran 8802* (SD). Summit, 300 m, one seen with white flowers, 21 Mar 1962, *Moran 8813* (CAS). 21 Mar 1962, *Wiggins 17177* (CAS). One of the most abundant plants on the island, ca. 6 ft high, 25 Jan 1963, *Felger 6346*. 125 m elev, 17 Mar 1971, *Hastings 71-61*. S end, small landing below guano terraces, growing in a guano- and rock-filled canyon about 100 m above sea level, 20 June 1975, *Kipping s. n.* (CAS). Arbusto 0.5–1 m, flores anaranjadas, 4 May 1985, *Lott and Atkinson* (CAS). Above ruins of the guano workers' village, ca. 75 m elev., abundant, 11 Apr 2007, *Felger 07-10*. Summit of island, 290 m, abundant, 5 Dec 2007, *Felger 07-198*.

## MORACEAE—Mulberry Family

*Ficus palmeri* S. Watson, Proc. Amer. Acad. Arts 24:77, 1889 [*F. petiolaris* Kunth subsp. *palmeri* (S. Watson) Felger & Lowe] *Tes-calama*; cliff fig. Figure 10.

Large shrubs to 3, rarely 4, m tall and often as much as twice as wide, with adventitious roots grasping and growing over rock. Root and stem bark whitish. Twigs, leaves, and figs densely to sparsely pubescent. Leaves tardily drought deciduous, the plants ultimately leafless during extended drought; leaves mostly 7.5–18 cm long, the blades often relatively firm, broadly ovate, and mostly cordate at base; stipules often 1.8–2.7 cm long. Figs ca. 1.5 cm long, globose-obovoid, paired or one may fail to develop or fall off, peduncles usually 11.5–21.5 mm long, rarely as short as 8 mm. Figs subtended by two scales or sometimes appearing as three because of the splitting of one of the scales as the fig develops; the terminal pore (ostiole) usually obscured by short, broad, thick, overlapping, and ascending reddish scales.

*Ficus palmeri* is the largest-leaved plant on the island. Probably several hundred or more are thinly scattered along ridges and sea cliffs, mostly at higher elevations at the periphery of the island. In April 2007 we saw pelicans nesting on top of many *Ficus* shrubs and other seabirds nesting in the sheltered shade beneath the shrubs. Palmer reported *Ficus* as rare on the island and the fruit edible (Watson 1889).

General distribution: Endemic to the Sonoran Desert: western Sonora, gulf islands, and the Baja California Peninsula. This is the only fig that truly ranges into the desert. It is closely related to the more widespread *F. petiolaris*, which extends through much of subtropical Mexico.

Other islands: Ángel de la Guarda, Tiburón, Cholludo, Dátil, Alcatraz, San Esteban, San Pedro Nolasco, San Marcos, San Ildefonso, Carmen, Danzante, Monserrat, Santa Catalina, Santa Cruz, San Diego, San José, San Francisco, Espíritu Santo, Cerralvo.

Island of San Martin [sic], 1887, *Palmer 413* (type collection, US 796147, image; isotype, UC 11624). 18 Apr 1921, in a rock-hewn draw in mid-part of

island, *Johnston 3153* (CAS, image). Tree on high sea cliffs, *Johnston 3162* (CAS, UC). Shrub or small tree, 3–4 m high, on cliffs and large rocks along ridge at N side of island, and near the top, 200+ m elev, population estimated at 100 mature plants, 25 Jan 1963, *Felger 6354* (2 sheets). 125 m elev., 17 Mar 1971, *Hastings 71-63*. Arbusto de 1.2 m, rizomas germinados de color verde, látex blanco, lechoso, poco abundante, 9 Aug 1985, *Valiente-Banuet 604*. Small canyon at base of SE-facing slope that leads to island summit, shrub ca. 2.5 m tall and twice as wide, widely scattered, on rock, 11 Apr 2007, *Felger 07-17*.

## ONAGRACEAE—Evening Primrose Family

*Chylismia cardiophylla* (Torrey) Small subsp. *cardiophylla* [*Camissonia cardiophylla* (Torrey) P. H. Raven subsp. *cardiophylla*. *Oenothera cardiophylla* Torrey].

Annuals to short-lived perennials, growing and flowering during the cooler seasons. Flowers bright yellow, often drying pink. Seeds numerous and minute. Known from the island by four collections, from 1887 to 1962.

General distribution: Northern Baja California Sur to southeastern California, southwestern Arizona, and northwestern Sonora. Two other subspecies occur in western Sonora, Tiburón Island, and the state of Baja California. Members of this species are reported to be self-compatible but also often outcross.

Other islands (subsp. *cardiophylla*): Ángel de la Guarda, San Lorenzo, San Esteban, Tortuga, San Marcos.

1887, *Palmer 403* (UC). Locally abundant on a ledge on a high sea cliff, clumps dense, 3 ft high, 18 Apr 1921, *Johnston 3147* (CAS). Canyon on N side, [100 m, in field notes], occasional, 21 Mar 1962, *Moran 8820* (SD). 21 Mar 1962, *Wiggins 17186* (CAS).

## POACEAE—Grass Family

*Aristida adscensionis* Linnaeus. *Zacate tres barbas*; six-weeks three-awn.

Nonseasonal annuals, the roots often weakly developed. Spikelets needle-like, three-awned, or awns sometimes reduced or aborted when the plant is stressed by drought.

Seasonally widespread and common above about 100 m.

General distribution: Worldwide and common across the Sonoran Desert.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, Dátil, San Esteban, San Pedro Nolasco, Tortuga, San Marcos, Coronados, Carmen, Monserrat, Santa Catalina, San José, San Francisco, Espíritu Santo, Cerralvo.

Common, 25 Jan 1963, *Felger 6364*. Above ruins of the guano workers' village, 150 m, common between cardons, especially where the ground is not covered by *Vaseyanthus*, 11 Apr 2007, *Felger 07-15*.

*Digitaria californica* (Bentham) Henrard var. *californica* [*Trichachne californica* (Bentham) Chase] *Zacate punta blanca*; California cottontop.

Tufted perennials with a hard, knotty base; winter or dry-season dormant. Stems to over 0.5 m tall. Panicles white to purplish because of silvery or purple-tinged silky hairs on the spikelets, giving a cottony appearance. Spikelets 3–3.7 mm long (excluding the hairs).

A rather small, localized population occurs at the summit of the island, where scattered plants and small aggregations mostly grow sheltered at the bases of cardons. Listed for San Pedro Mártir by Moran (1983) but not by Rebman et al. (2002); we have not located specimens other than our 2007 collection.

General distribution: Southwestern United States, Mexico, the Caribbean, and South America. An additional variety occurs in South America and the Caribbean. We witnessed a non-botanist mistaking vegetative, nonflowering plants of this species for buffelgrass (*Cenchrus ciliaris*), a situation that needs to be taken into account in monitoring for potential invasives.

Other islands: Tiburón, Cholludo, Dátil, San Esteban, San Pedro Nolasco, San Marcos, Cerralvo.

High-elevation plateau, to the NW of highest point of island, 275 m, seen only at this locality, 28.38072° N, 112.30832° W, 6 Dec 2007, *Wilder 07-604*.

***Muhlenbergia microsperma*** (de Candolle) Trinius. *Liendrilla*; littleseed muhly.

Nonseasonal ephemerals, usually best developed during winter and spring, the roots usually weakly developed. Leaves soft and delicate. Panicles terminal, filmy, open, and loosely flowered, the spikelets (lemmas) tapering to a threadlike awn. Lower leaf axils bear cleistogamous spikelets.

Abundant throughout the vegetated part of the island, especially middle to peak elevations, often forming 100% ground cover between the cardons. Palmer reported it as “common among rocks, the only grass” (Watson 1889:80). Johnston also noted that it was the only grass and “very abundant” (1924:986). It is curious that they did not see *Aristida adscensionis*, the only other common grass. That species, however, tends to fall apart (disarticulate) and decompose earlier than *M. microsperma* and might thus be overlooked.

General distribution: Southwestern United States to South America.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, Cholludo, San Esteban, San Pedro Nolasco, Tortuga, San Marcos, Carmen, Danzante, Monserrat, Santa Catalina, Santa Cruz, San José, Espíritu Santo, Cerralvo.

1887, *Palmer 416* (UC, image). Abundant on all parts of island, the only grass, 18 Apr 1921, *Johnston 4398* (CAS, image; old, dry grass, with numerous loose, awned spikelets). Summit, 300 m, occasional, 21 Mar 1962, *Moran 8807* (SD, not seen, in SD data base). Common among rocks at higher elevations, 25 Jan 1963, *Felger 6362*. Above ruins of the guano workers’ village, ca. 150 m, abundant from above ca. ¼ way up island, forming 100% coverage in some places between cardons, especially where the ground is not covered by *Vaseyanthus*, 11 Apr 2007, *Felger 07-14*. S-facing slope of summit, dense cardón forest, 270 m, 7 Dec 2007, *Wilder 07-606*.

#### SOLANACEAE—Nightshade Family

***Lycium brevipes*** Benth var. *brevipes* [*L. richii* A. Gray] *Salicieso*; desert wolfberry.

Densely branched shrubs often 1.5–2+ m tall, beset with glandular hairs. Leaves semisucculent, tardily drought deciduous. Corollas pale lavender with a white throat. Flowering branchlets, especially stem tips, often very crowded with flowers and fruits. Fruits fleshy berries, 1.5–2 mm long, edible, orange to red, the seeds many. Apparently reproductive at various times of the year except during extreme drought; recorded in flower December to April.

Scattered from middle to high elevations, most numerous at the higher elevations.

*Lycium brevipes* is the most abundant and widespread *Lycium* on the islands and along the coasts of the Gulf of California.

General distribution: Sinaloa to south-central Arizona, Baja California Sur to southern California, and gulf islands.

Other islands: Ángel de la Guarda, Tiburón, Cholludo, Dátil, Alcatraz, San Esteban, Tortuga, San Marcos, San Ildefonso, Carmen, Danzante, San José, Espíritu Santo, Cerralvo.

Frequent in a cordonado [cardón area?] at middle altitude along south side of island, shrub 4–5 ft high, 18 Apr 1921, *Johnston 3154* (CAS, image). Found only near top of island, not common, flowers, 25 Jan 1963, *Felger 6353*. Small canyon at base of SE-facing slope that leads to island summit, about one dozen shrubs seen here, mostly with few flowers, 11 Apr 2007, *Felger 07-16*. Summit of island, 290 m, locally common at a few places at higher elevations, 5 Dec 2007, *Felger 07-195*. High-elevation plateau, NW of highest point of island, 275 m, fairly common, 6 Dec 2007, *Wilder 07-601*.

***Nicotiana obtusifolia*** M. Martens & Galeotti [*N. trigonophylla* Dunal] *Tabaco del coyote*; coyote tobacco, desert tobacco.

Perennials and also flowers in the first season. Herbage sticky glandular-pubescent. Corollas cream-white, open all day. Flowers in winter and spring, the plants usually dying back severely during drought and often flowering again with summer rains. Seeds minute and numerous.

Widespread across the island at all elevations, including sea cliffs and crevices in guano-covered rock and gravelly soils near the shore.

General distribution: California deserts to Nevada and Texas and south to Nayarit.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, Cholludo, Dátil, Alcatraz, San Esteban, San Pedro Nolasco, Tortuga, San Ildefonso, Carmen, Santa Catalina.

1887, *Palmer 410* (UC). Common in rocky ground in all parts of island, 18 Apr 1921, *Johnston 3150* (UC, CAS). Summit, 300 m, occasional, 21 Mar 1962, *Moran 8811* (SD). 21 Mar 1962, *Wiggins 17190* (CAS). Scattered among rocks, with flowers and ripe seeds, 25 Jan 1963, *Felger 6365*. Hierba anual, 50 cm, flores amarillos pálidos, 4 May 1985, *Lott and Atkinson 2430* (CAS). N side of island, ca. 8 m elev., steep rock slopes and mini-valley/ arroyo white with bird guano, *Pachycereus pringlei*, *Sphaeralcea hainesii*, and *Vaseyanthus insularis* nearby, Blue-footed Boobies nesting nearby, *Nicotiana* scattered and locally abundant among rocks and on ruins of rock-wall platform of guano works, most common in areas devoid of *Vaseyanthus*, seen from ca. 4 to at least 20 m (by binoculars) above sea level, growing from rock crevices and rock rubble, nearly level to steep slopes, many of the plants are robust, to ca. 80 cm tall, others crowded and smaller, corollas open, early afternoon, 11 Apr 2007, *Felger 07-09*.

#### STEGNOSPERMATAACEAE—Stegnosperm Family

***Stegnosperma halimifolium*** Benth [S. *watsonii* D.J. Rogers] *Chapacolor*, *ojo de zanate*.

Shrubs with tardily and gradually deciduous foliage and semisucculent leaves. Moran found one on the island that was 4 m tall. Flowers whitish. Fruits reddish and fleshy, drying as capsules. Flowering and fruiting response nonseasonal. Seeds 3.5–3.8 mm long, shiny blackish, with a fleshy and bright red aril. (Description based on Midriff Island specimens.)

Known from San Pedro Mártir only by two records. In 1962 Moran found *Stegnosperma halimifolium* to be rare on the island, and it has not been recorded there since.

General distribution: Generally coastal on gulf islands and both sides of the Gulf of California, sometimes ranging inland.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, Cholludo, Dátil, San Esteban, Tortuga, San Marcos, Coronados (observation), Carmen, Danzante, Monserrat (observation), Santa Catalina, Santa Cruz (observation), San Diego, San José, Espíritu Santo, Cerralvo.

Center [of island], Oct 1887, *Palmer 400* (GH, image). 300 m, shrub 4 m tall, only two seen, 21 Mar 1962, *Moran 8816* (SD).

#### ZYGOPHYLLACEAE—Caltrop Family

***Viscainoa geniculata*** (Kellogg) Greene var. *geniculata*.

Shrubs, often less than 1 m tall, but also often 2 (occasionally to 3) m tall at the highest elevations. Leaves simple, tardily drought deciduous, larger leaves 3–5.5 cm long; herbage with soft hairs. Reproductive at various seasons. Flowers 2 cm wide, cream-white. Fruits velvety green capsules, the dry capsules often semipersistent. Seeds ovoid, black, 5 mm long, generally exposed and adhering to the capsules with a thin, sticky, orange aril.

Widely scattered on the island, mostly at higher elevations, often in the shelter of large cardons. Johnston (1924:1054) wrote, “One of the most characteristic and widely distributed shrubs in the gulf area” and noted the islands from which *Viscainoa geniculata* is absent, including San Pedro Mártir. Neither he nor Palmer collected or reported this species on the island in 1887 or 1921. Moran saw only one on

his hike to the top of the island in 1962, and the next year Felger also found it at the top, noting it was rare. In 2007 it was common at the top of the island and scattered at lower elevations.

General distribution: Sonora from the mainland coast opposite Tiburón to Guaymas, both states of Baja California, and islands in the gulf. Another variety in northwest Baja California Sur has trifoliate leaves.

Other islands: Ángel de la Guarda, San Lorenzo, Tiburón, Cholludo, Dátil, Alcatraz, San Esteban, Tortuga, San Ildefonso, Coronados (observation), San Diego, San José, Espíritu Santo.

Near summit, 300 m, only one seen, shrub 3 m tall, 21 Mar 1962, *Moran 8812* (SD). Seen only near top of island, rare, shrub ca. 3 m tall, 25 Jan 1963, *Felger 6355* [undoubtedly the same individual as *Moran 8812*]. 125 m elev, 17 Mar 1971, *Hastings 71-58*. Arbusto 0.5 m, 4 May 1985, *Lott and Atkinson 2429* (CAS). Above ruins of guano workers' village, ca. 150 m elev., shrub to ca. 1.5 m tall, several scattered shrubs, mostly partially shaded or sheltered by large cardons, 11 Apr 2007, *Felger 07-12*. Summit of island, common shrub 2–2.5 m tall, corollas white, 5 Dec 2007, *Felger 07-196*.

## DOUBTFUL AND EXCLUDED SPECIES

### Asteraceae

*Bahiopsis chenopodina* (Greene) E.E. Schilling & Panero [*Viguiera chenopodina* Greene. *V. deltoidea* A. Gray var. *chenopodina* (Greene) S.F. Blake]

Shrubs with slender, brittle stems. Flower heads with bright yellow ray and disk florets.

General distribution: Widespread through Baja California Sur, on many gulf islands, and along the Sonora coast from Guaymas north at least to Tastiota. To the north it is replaced by *B. parishii* (Greene) E.E. Schilling & Panero and to the south and on other gulf islands by *B. triangularis* (M. E. Jones) E.E. Schilling & Panero.

We have not found *Bahiopsis* on San Pedro Mártir and have not located a specimen or reference to a specimen from the island. It was listed for the island by Gentry (1949), Felger and Lowe (1976) on the basis of Gentry's report, and Rebman et al. 2002. It was not reported for the island by Watson (1889) or Johnston (1924). We believe the listing for the island is an error.

### Cactaceae

*Stenocereus thurberi* (Engelmann) Buxbaum [*Lemaireocereus thurberi* (Engelmann) Britton & Rose] *Pitaya dulce*; organ pipe.

Gentry (1949:110) listed this species for San Pedro Mártir. Johnston (1924:1118) noted that on this island *Pachycereus pringlei* may have "the branches starting from the ground and making the plant appear like monstrous specimens of *Lemaireocereus* [*sic*] *thurberi*." We did not find *Stenocereus thurberi* on the island but saw several plants above the village site that from a distance looked like organ pipes but were in fact stunted, dead, and withered cardons. We believe that Gentry's report is an error.

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