

Chihuahuan Desert Flora of La Calera, Municipio de Agua Prieta, Sonora, Mexico

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Abstract—A total of 555 plant collections were made on 20 trips in 2002-2008 to La Calera area in the Sierra Anibácachi, Municipio de Agua Prieta, 11.3 km south of the Arizona border (31°13'59"N 109°37'53"W, elevation range from 1220 m to 1539 m) in northeastern Sonora. Chihuahuan desertscrub on limestone substrates is dominated by creosotebush (*Larrea divaricata*), Chihuahuan whitethorn (*Acacia neovernicosa*), mariola (*Parthenium incanum*), and tarbush (*Flourensia cernua*). Riparian vegetation along a rocky bedrock/gravel wash includes desert willow (*Chilopsis linearis*), netleaf hackberry (*Celtis reticulata*), desert hackberry (*C. pallida*), woolly buckthorn (*Sideroxylon lanuginosum*), soaptree yucca (*Yucca elata*), Arizona walnut (*Juglans major*), and Coahuila juniper (*Juniperus coahuilensis*). The flora is diverse with 350 taxa in 60 families and 222 genera in 25 km² (2.5 km² extensively inventoried). Only 5.1% of the taxa are non-native. The most numerous plants are in the Poaceae (57 taxa), Asteraceae (53), Fabaceae (26), Malvaceae (22), and Euphorbiaceae (21) in the genera *Euphorbia* (11), *Abutilon* and *Bouteloua* (7 each), *Eragrostis* and *Muhlenbergia* (6 each), and *Dalea*, *Ipomoea*, and *Sphaeralcea* (5 each). Twenty-six taxa are probably the first records for Sonora. Another 21 taxa are noteworthy state records (rare or significant range extensions).

Introduction

The Chihuahuan Desert is the largest of the three creosotebush-dominated warm deserts in North America (Shreve, 1942). It primarily occurs from New Mexico and Texas southeast through Chihuahua and Coahuila to San Luis Potosí (Lowe, 1964; Rzedowski, 1978; Brown, 1982). Most (90%) is in Mexico on the Mexican Plateau bounded to the east by the Sierra Madre Oriental and to the west by the Sierra Madre Occidental. Most of this area is above 1000 m elevation and regular incursions of frigid Arctic air from the north have shaped the evolution of the flora. More than 80% of Chihuahuan desertscrub is found on limestone and the gray gravel of this substratum give the characteristic view of the landscape (Lowe, 1964; Brown, 1982). Throughout the area, there is a mosaic of Chihuahuan desertscrub on limestone bedrock and desert grassland in fine-soiled valley bottoms. In the Santa Catalina Mountains of Arizona, Shreve (1922) and Whittaker and Niering (1968) concluded that vegetation is more xeric and open and that both vegetation and species reach higher elevations on limestone. We have noticed that this effect is most prevalent in drier Chihuahuan Desert areas, but hardly noticeable in foothills thornscrub on limestone in east-central Sonora southward.

The Chihuahuan Desert reaches its westernmost extent in southeastern Arizona and northeastern Sonora. In this paper, we study the flora in Chihuahuan desertscrub on Rancho La Calera in Sierra Anibácachi, southwest of Agua Prieta, Sonora.

Study Area

Rancho La Calera, is an isolated hill northeast of Sierra Anibácachi, ca. 10 km (by air) southwest of Agua Prieta, 11.3 km (by air) south of the United States/Mexico border 31°13'59"N 109°37'53"W (fig. 1). The vegetation on limestone substrates at 1220-1539 m elevation is Chihuahuan desertscrub. The flora is representative of an area of 25 km², with only 2.5 km² sampled intensively. The Sierra Anibácachi is formed by Lower Cretaceous limestone in the Bisbee Group, a southern extension of thick and well-exposed marine sediments in the Mule Mountains (McKee and others 2005).

The climate of the area is arid, with biseasonal rainfall, hot summers, and cold winters. Weather stations are located in Agua Prieta and Naco, Sonora. The mean annual rainfall is 353.5 mm in the Municipio of Agua Prieta, with 40-47% during the summer monsoon season in July-September. The mean annual temperature is 17.3 °C, with a summer maximum of 43 °C in June 1994 and July 1989; a winter minimum of -14 °C and wind chill of -24 °C was registered in February 2011. Low winter temperatures limit biological activities. Another climatic factor is prevailing winds from the south for more than 60% of the year, with a strength of 5.40 to 8.49 meters/second recorded in the international airport in Douglas, Arizona (Reza, 2011; CONAGUA, 2010; Universidad Autónoma de Tamaulipas, 2003).

The Sierra Anibácachi is in the Río Agua Prieta drainage basin, which is a tributary of the greater Río Yaqui. It begins as White Water Draw in Arizona before crossing the border into Sonora in Agua Prieta. The watershed area in Arizona is 2,650 km². From the border south to its junction with Río Fronteras, the Río Agua Prieta basin has an area of 1,444 km². Downstream this drainage coalesces into the Río Bavispe upstream of Lázaro Cárdenas (La Angostura) reservoir (CONAGUA 2010).

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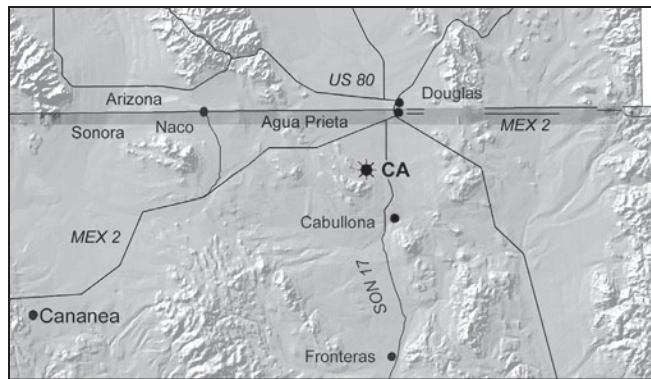


Figure 1—Map of the Rancho Calera (CA) area.

Methods

Plant Collections

Between September 2002 and May 2008, we made 20 trips to the study area, both during the summer rainy season in August-October, and the dry spring in March-June. We surveyed a broad range of habitats, including rocky slopes, peaks, cliffs, alluvial bajadas, arroyos, and cattle tanks. Most of our efforts were concentrated on the slopes and arroyo close to the La Calera ranch headquarters, and the quarry (calera) owned by Grupo México. Whenever possible we recorded plant common names from local cowboys.

We collected 590 specimens under the SEMARNAT permit to J. Jesús Sánchez-E., Curator of the Universidad de Sonora Herbarium (USON). Specimens were deposited into herbaria at the University of Arizona (ARIZ), USON, Arizona State University (ASU), and the Universidad Nacional Autónoma de México (MEXU). Although there were some previous collections from the Municipio of Agua Prieta, the Calera area had not been collected before. Specimens were identified in the University of Arizona herbarium or by specialists in other herbaria using duplicates or images. Nomenclature mostly follows the list in Van Devender and others (2010), which is available and updated in the Madrean Archipelago Biodiversity Assessment (MABA)/Southwest Environmental Information Network (SEINet) online database (Madrean.org). Plant collections, observations, and photographs are available in this database. A complete list of the La Calera flora will be available as a Research Species list in the database.

Results

Vegetation

The vegetation in the La Calera study area is Chihuahuan desertscrub, which occurs on limestone bedrock, limestone-derived alluvial bajadas, and the lower fine-soiled flats. The limestone bedrock on a northeast slope is dominated by *Fouquieria splendens*, in association with the shrubs *Acacia neovernicosa*, *Calliandra eriophylla*, *Senna wislizenii*, and *Vauquelinia californica*. Additional shrubs include *A. millefolia*, *Aloysia wrightii*, *Brickellia baccharidea*, *Dalea formosa*, *Eysenhardtia orthocarpa*, *Fraxinus gooddingii*, *Mimosa biuncifera*, *Mortonia scabrella*, and *Tecoma stans*. On upper parts of ridges, *Quercus pungens* and *Bernardia myricifolia* are locally dominant. Succulents on bedrock slopes, including *Agave palmeri*, *Dasyliroton wheeleri*, *Opuntia phaeacantha*, and *Yucca baccata*, are important

in the community, as are the perennial herbs *Anemone tuberosa*, *Astrolepis cochisensis*, *Physaria fendleri*, *P. purpurea*, and *Salvia parryi*. Perennial bunch grasses, notably *Aristida purpurea* var. *nealleyi*, *Bouteloua curtispindula*, *Muhlenbergia arizonica*, and *Panicum hallii*, are common.

On the alluvial slopes, the dominants are *Acacia neovernicosa*, *Larrea divaricata*, and *Parthenium incanum*, with *Krameria erecta* and *Tiquilia canescens*. These plants are also common in flatter areas along with *Flourensia cernua* and *Prosopis velutina*. On benches above the arroyo, we found *Anisacanthus thurberi*, *Condalia warnockii*, *Forestiera angustifolia*, *F. phyllireoides*, *Koeberlinia spinosa*, and *Ziziphus obtusifolia*. Along a gravelly/rocky wash incised through the alluvium to the limestone bedrock, *Baccharis salicifolia*, *Gutierrezia microcephala*, and *Hymenoclea monogyra*, are common in riparian vegetation. In the wash, *B. sarothroides*, *Celtis reticulata*, *C. pallida*, *Chilopsis linearis*, *Sideroxylon lanuginosum*, and *Yucca elata* are occasional, and *Juglans major* and *Juniperus coahuilensis* are rare.

Flora Composition

We documented 350 taxa in 60 families and 222 genera in Chihuahuan desertscrub at La Calera. The families with more species are Poaceae (57 taxa, 16.3%), Asteraceae (53 taxa, 15.1%), Fabaceae (26 taxa, 7.4%), Malvaceae (22 taxa, 6.3%), Euphorbiaceae (21 taxa, 6.0%), Solanaceae (15 taxa, 4.3%), and Cactaceae (12 taxa, 3.4%). The genera with the most species are *Euphorbia* (11 taxa), *Abutilon* and *Bouteloua* (7 taxa each), *Eragrostis* and *Muhlenbergia* (6 taxa each), *Dalea*, *Ipomoea*, and *Sphaeralcea* (5 taxa each), *Acacia*, *Boerhavia*, *Brickellia*, *Lepidium*, *Opuntia*, and *Sporobolus* (4 taxa each). Only 18 species are non-native (5.1%), including *Cynodon dactylon*, *Eragrostis lehmanniana*, *Pennisetum ciliare*, *Sorghum halepense*, and *Tamarix chinensis*. Although those species sometimes are invasive in other areas, they do not represent an ecological threat at La Calera. The life forms of La Calera are herbs (70.0%, including grasses), woody plants (24.9%), and succulents (5.1%). The dicot herbs (188 taxa) are perennial (97 taxa) and annual (91 taxa). The grasses and sedges (57 taxa) are perennial (38 taxa) and annual (19 taxa).

Noteworthy Records—About 26 species in the La Calera area are probably the first records for Sonora, with no previous records in the MABA/SEINet database. These include *Abutilon coahuilae*, *Acurtia nana*, *Amaranthus blitoides*, *Asclepias macrotis*, *Bothriochloa laguroides* var. *laguroides*, *Chamaesaracha sordida*, *Cryptantha albida*, *Cylindropuntia leptocaulis* X *O. spinosior*, *Cyphomeris gypsophiloides*, *Dyssodia papposa*, *Fumaria parviflora*, *Gaillardia pulchella*, *Heliotropium greggii*, *H. pringlei*, *Hybanthus verticillatus*, *Ibervillea tenuisecta*, *Nolina texana*, *Opuntia macrocentra* (most other Sonoran records are misidentified *O. gosseliniana*), *Physaria fendleri*, *Physalis lagascae*, *Quercus pungens*, *Ruellia parryi*, *Simsia lagascaeformis*, *Sphaeralcea polychroma*, *Stipa eminens*, and *Vicia ludoviciana*. Most of these records represent southern extensions from the United States.

An additional 28 taxa are considered rare in Sonora: *Abutilon parvulum*, *A. wrightii*, *Asclepias nyctaginifolia*, *Bernardia myricifolia*, *Clerodendron coulteri*, *Conoclinium dissectum*, *Cryptantha pusilla*, *Erioneuron avenaceum*, *Euphorbia exstipulata*, *E. stictospora*, *Polygala scoparioides*, and *Vauquelinia californica* ssp. *pauciflora*. Other species are rarely collected in Sonora: *Dalea formosa*, *Flourensia cernua*, *Mortonia scabrella*, *Phyllanthus polygonoides*, and *Thamnosma texana*. The annual *Streptanthus carinatus* had canary yellow sepals in limestone cliffs and white sepals in sand in the arroyo. The yellow form was formerly *S. arizonicus* S. Watson var. *luteus* Kear-

ney & Peebles. It was synonymized into *S. carinatus* ssp. *arizonicus* by Kruckeberg and others (1982), but warrants reevaluation. Again most of these species are southern range extensions, but *Abutilon abutiloides*, *Physalis lagascea*, and *Ipomoea aristolochiifolia* (Austin, 2006) are northern extensions of tropical species not recorded in the United States.

Discussion

After 7 years of plant collections, the flora of the La Calera area is well represented. This is a limestone flora rich in plant species and the first Chihuahuan desertscrub flora studied in Sonora. The only North American desert characterized by trees is the subtropical Sonoran Desert, and not the more temperate Great Basin, Mohave and Chihuahuan Deserts. Only 1.7% of the La Calera flora are trees. Of these, *Celtis reticulata*, *Chilopsis linearis*, *Juglans major*, and *Juniperus coahuilensis* are riparian along the wash. *Prosopis glandulosa* and *P. velutina* are trees in other areas, but shrubs in La Calera. *Vauquelinia californica* is a tall shrub that is locally dominant on steep slopes. This species is endemic to central Arizona and adjacent Sonora, and does not occur in the main Chihuahuan Desert in New Mexico, Texas, Chihuahua, or Coahuila. The subspecies *pauciflora* is found on limestone in southeastern most Arizona and few places in Sonora. *Quercus pungens* is typically a shrub on limestone, but becomes a tree of 5-6 m height in western Texas.

Of the 85 species of native annuals, 62 (72.9%) are summer annuals, 20 (23.5%) spring annuals, and three active in either season. The abundance of summer annuals (72.9%) is interesting because to the west in the Sonoran Desert, and more so in the Mohave Desert, winter annuals are dominant.

The flora of the San Pedro Riparian National Conservation Area (SPRNCA) in Cochise County, Arizona, supports a flora of 625 taxa (56% greater than La Calera) in an area of 19,291 ha (8 times larger than La Calera; Makings, 2006). The flora of the Huachuca Mountains in Cochise County supports a flora of 917 taxa (61% greater than La Calera) in an area of 31,600 ha (12 times larger than La Calera; Bowers and McLaughlin, 1996). According to Bowers and McLaughlin (1996), species diversity is best correlated with elevational range and habitat diversity, since both temperature and precipitation vary with elevation. The La Calera flora is interesting because habitat diversity and elevational range are minimal but the flora is diverse. Wentworth (1982) documented the distributions of plant species on limestone bedrock and calcareous soils at 1400 to 1900 m elevations in the Mule Mountain. Of 232 species in these habitats, 147 are shared with La Calera. The 85 species not in La Calera were in the mesic limestone habitat in oak woodland zone, which is 400 m above the La Calera study area; i.e., *Bouvardia ternifolia*, *Cercocarpus montanus*, *Garrya wrightii*, *Quercus arizonica*, *Pinus discolor*, etc. It is especially interesting that La Calera had 203 taxa not recorded in the Mule Mountains, only 39 km west-northwest of La Calera.

The distributions of the plants in the La Calera flora are predominantly southwestern United States and northwestern Mexican, with biotic affinities to the Great Plains grasslands and the Chihuahuan Desert, which form a mosaic in most areas. *Fouquieria splendens*, *Larrea divaricata*, *Tecoma stans*, *Opuntia phaeacantha*, and *Yucca elata* are widespread. *Bernardia myricifolia*, *Acacia neovernicosa*, *Flourensia cernua*, *Mortonia scabrella*, *Nolina texana*, *Panicum hallii*, *Parthenium incanum*, *Quercus pungens*, *Salvia parryi*, *Senna wislizeni*, and *Tiquilia canescens* are Chihuahuan species mostly found on limestone or calcareous soils. *Opuntia chlorotica* primarily occurs in Arizona and adjacent southern California, southwestern New

Mexico, and northern Sonora, but not in the Chihuahuan Desert to the east.

Three species in La Calera are considered “in risk” or “candidate” species according to the Official Mexican Regulation NOM-059-ECOL-2002 (D.O.F. 2002), which establishes the degree of protection for species: *Amoreuxia palmatifida* and *Peniocereus greggii* var. *greggii* are listed as Pr [special protection] and *Juglans major* is listed as A [threatened]. None of the plants from La Calera is listed either in Arizona or the United States.

We conclude that the La Calera is a very interesting area with a rich, regionally unique flora in the westernmost Chihuahuan Desert. With records of about 40 species new to or rare in Sonora in the northwestern borderlands of the country, the flora is very important for Mexico. The Grupo México quarry operation has severely disturbed slopes on the La Calera ridge just northeast of the study area. Protection of a representative area of this habitat and vegetation is warranted. .

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References

- Austin, Daniel F. 2006. Noteworthy distributions and additions in Southwestern Convolvulaceae. *Canotia*, 2: 79-106
- Bowers, Janice E.; and McLaughlin, Steven P. 1996. Flora of the Huachuca Mountains, a botanically rich and historically significant sky island in Cochise County, Arizona. *Journal of the Arizona-Nevada Academy of Science*, 29: 66-107.
- Brown, David E. 1982. Chihuahuan Desertscrub. In Brown, David E. ed. *Biotic Communities of the American Southwest – United States and Mexico. Desert Plants. Special Issue. 4 (1-4): 169-179.*
- CONAGUA. 2010. Determinación de la disponibilidad de agua en el acuífero 2629, río Agua Prieta, estado de Sonora. 30 p.
- D.O.F. 2002. NOM-059-ECOL-2001. Protección ambiental - especies nativas de México de flora y fauna silvestres - Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio - Lista de especies en riesgo. *Diario Oficial de la Federación*, 6 March 2002.
- Kearney, Thomas H.; and Peebles, Robert H. 1964. *Arizona Flora*. Berkeley: University of California Press. 1085 p.
- Kruckeberg, A.R.; Rodman, J.E.; and Worthington, Richard D. 1982. Natural hybridization between *Streptanthus arizonicus* and *S. carinatus* (Cruciferae). *Systematic Botany*, 7: 291-299.
- Lowe, Charles H. 1964. *Arizona's Natural Environment. Landscapes and Habitats*. Tucson: The University of Arizona Press. 136 p.
- Makings, Elizabeth. 2006. Flora of the San Pedro Riparian National Conservation Area. *Deserts Plants. Special Issue. 22. 104 p.*
- McKee, J.W.; McKee, M.B.; and Anderson, T.H. 2005. Mesozoic basin formation, mass-gravity sedimentation, and inversion in northeastern Sonora and southeastern Arizona. In Anderson, T.H.; Nourse, J.A.; McKee, J.W.; and Steiner, M.B. eds. *The Mohave-Sonora Megasear Hypothesis: Development, Assessment, and Alternatives*. The Geological Society of America. Special Paper 393. 481-508.
- Reza, Francisco; and López, Gerardo. Sonora se congela: -16 °C. *El Imparcial*. *Diario Independiente de Sonora: Hermosillo, México. Febrero 4, 2011. p. A1, col. 1.*
- Rzedowski, Jerzy. 1978. *Vegetación de México*. México: Editorial Limusa. 432 p.

- Shreve, Forrest. 1922. Conditions indirectly affecting vertical distribution on desert mountains. *Journal of Ecology*, 3: 269-274
- Shreve, Forrest. 1942. The desert vegetation of North America. *Botanical Review*, 8: 195-246
- Universidad Autónoma de Tamaulipas. 2003. Manifestación de impacto ambiental modalidad particular. Comisión Federal de Electricidad. Proyecto ciclo combinado Agua Prieta II. 151 p.
- Van Devender, Thomas R.; Felger, Richard F.; Fishbein, Mark; Molina-Freaner, Francisco; Sánchez-Escalante, J. Jesús; and Reina-Guerrero, Ana L. 2010. Biodiversidad de las plantas vasculares. Pp. 229-262 in Molina-Freaner, Francisco; and Van Devender, Thomas R. eds., *Diversidad Biológica de Sonora*, Universidad Nacional Autónoma de México, Hermosillo. <http://www.skyislandalliance.org/Sonoran%20vascular%20plants-VanDevender%20et%20al.2010.pdf>
- Wentworth, Thomas R. 1982. Vegetation and flora of the Mule Mountains, Cochise County, Arizona. *Journal of the Arizona-Nevada Academy of Science*, 17: 29-44.
- Whittaker, Robert H.; and Niering, William A. 1968. Vegetation of the Santa Catalina Mountains, Arizona. IV. Limestone and acid soils. *Journal of Ecology*, 56: 523-544.