

## IN PURSUIT OF MEXICAN *PINGUICULA*: A JOURNEY TO NORTHWESTERN OAXACA

MARTÍN MATA-ROSAS • Instituto de Ecología • A.C., Red Manejo Biotecnológico de Recursos  
• Carretera antigua a Coatepec 351 • El Haya • Xalapa • Ver. México 91073 • martin.mata@inecol.mx

JULIÁN HERNÁNDEZ-RENDÓN • Departamento de Botánica y Zoología • Centro Universitario de Ciencias Biológicas y Agropecuarias • Universidad de Guadalajara • Guadalajara • Mexico  
• juli19barca7s9k@hotmail.com

MARÍA MAGDALENA SALINAS-RODRÍGUEZ • Herbario Jerzy Rzedowski • Facultad de Ciencias Naturales  
• Universidad Autónoma de Querétaro • Querétaro • Mexico • manesalinas@outlook.com

After much planning and aligning our schedules, we finally defined the dates to visit populations of various *Pinguicula* species in northwestern Oaxaca, Mexico. It is essential to highlight that the state of Oaxaca has the greatest biodiversity in Mexico, as regard to vascular plants, it has 10,299 species, of which 4,071 are endemic to the state (Villaseñor 2016). It is also the state where it is possible to find most *Pinguicula* species (Table 1). Fifteen species have been reported, including the recently described *P. pygmaea* (Rivadavia *et al.* 2017). Also, some of these species are controversial and under taxonomic discussion, i.e., *P. rectifolia* and *P. medusina*, whereas others have not been seen since they were first collected (*P. greenwoodii* and *P. utricularioides*).

Our meeting spot was in the city of Puebla on 15 July 2019. From there, we departed in a pickup truck toward the first location of our journey along the Tehuacán-Oaxaca highway. After a couple of hours of travel, filled with enjoyable and fun conversation, we arrived at the location. We parked the vehicle in a safe place and prepared to climb the mountain in search of a population of *Pinguicula mirandae*. Despite having visited this site previously, Martín got confused and guided the group up a slope that he thought was the right way. The ascent was complicated because of the density of plants, many of which bear thorns or spines (*Haematoxylum brasiletto*, *Havardia acatlensis*, *Caesalpinia melanadenia*, *Leucaena lanceolata*, *Mimosa lacerata*, *M. polyantha*, *M. luisana*, *M. mollis*, *M. lactiflua*, *M. aculeaticarpa*, *M. benthamii*, *Hechtia* sp., and others). Complicating our climb was the steep, rugged terrain composed of lots of loose stones (lithic leptosol, Arriaga *et al.* 2000). Our goal was to reach a vertical wall cut in the mountain side above the highway and from there walk a few meters to find the population of *P. mirandae*. Although Martín realized that it was not the right way to the population that he had previously visited, we decided to continue in order to find out if there was also *P. mirandae* on the cliffs above. Martín was at the head of the group, followed a few meters behind by Mané and Julián. As enthusiastic botanists, they were amazed by the plants found along the way, such as *Tillandsia grandis*, *Sedum alantoides*, *S. compactum*, *Dasyllirion serratifolium*, *Agave petrophila*, *A. kerchovei*, *A. karwinskii*, *A. macrocantha*, and *Beaucarnea gracilis*.

The first pleasant surprise was to observe on our way a beautiful and quiet black-tailed rattlesnake (*Crotalus molossus*). We tried to make no sound, but in the time it took us to take the cameras out of the backpack and get closer to it, the rattlesnake felt our presence and began to slither away and hide in a hole under a large rock. Since we moved slowly and kept a reasonable and safe distance, it didn't feel threatened and allowed us to take some photos (Fig. 1). It never rang its rattle or tried to intimidate us with attack-defense movements, and after a brief photoshoot, we left it alone and continued on our way. When we reached the northeast-facing wall, we could observe *Pinguicula* plants on the inaccessible upper rock face about 7-10 meters from our position (Fig. 2), sadly though, we did not observe any at our level, and thus we decided to head back. The descent of the mountain took us about one hour, and we drank water to keep hydrated and then began our ascent to

Table 1. *Pinguicula* species naturally occurring in Oaxaca, Mexico.

Species	Habitat	Distribution in Mexico
<i>P. conzattii</i> Zamudio & van Marm	Montane cloud forest	Oaxaca
<i>P. crenatiloba</i> A.DC.	Tropical Savannah climate	Chiapas, Estado de México, Guerrero, Jalisco, Michoacán, Morelos, Nayarit, Oaxaca, Sinaloa, Sonora
<i>P. gigantea</i> Luhrs	Tropical rain forest	Oaxaca
<i>P. greenwoodii</i> Cheek	Tropical Savannah	Oaxaca
<i>P. hemiepiphytica</i> Zamudio & Rzed.	Montane cloud forest	Oaxaca
<i>P. heterophylla</i> Benth.	Mainly Oak-Pine forest	Guerrero, Morelos, Oaxaca
<i>P. laeana</i> Speta & F.Fuchs	Montane cloud forest and Oak-Pine forest	Oaxaca
<i>P. lilacina</i> Schltdl. & Cham.	Oaks woods, Pine-Oaks woods or cloud forest at elevations from 700-2400 m	Chiapas, Guerrero, Jalisco, Nayarit, Nuevo León, Oaxaca, Puebla, Querétaro, San Luis Potosí, Sinaloa, Tamaulipas, Veracruz
<i>P. medusina</i> Zamudio & Studnicka	Xeric shrubland, semi-arid ecosystem with gypsum soils	Oaxaca
<i>P. mirandae</i> Zamudio & A.Salinas	Tropical deciduous forest and thorny xerophytic scrub	Oaxaca
<i>P. moranensis</i> Kunth	Several ecosystems, with elevations ranging from 770-3200 m	Chiapas, Guanajuato, Guerrero, Hidalgo, México, Michoacán, Morelos, Nuevo León, Oaxaca, Puebla, Querétaro, San Luis Potosí, Tamaulipas, Veracruz
<i>P. orchidioides</i> DC.	Deciduous oak-pine forest	Guerrero, Oaxaca
<i>P. pygmaea</i> Rivadavia, E.L.Read & A.Fleischm.	Xeric shrubland, semi-arid ecosystem with gypsum soils	Oaxaca
<i>P. rectifolia</i> Speta & F.Fuchs	Tropical deciduous forest	Oaxaca
<i>P. utricularioides</i> Zamudio & Rzed.	Montane cloud forest	Oaxaca



Figure 1: A beautiful black-tailed rattlesnake (*Crotalus molossus*) guarding the habitat of *Pinguicula mirandae*.

the next wall. Again, after struggling with diverse thorny thickets and loose stones, we reached the base of the vertical wall and almost immediately observed the first plants of *P. mirandae*. We continued along the base of the wall until we reached a small precipice with a northwest orientation. There, between the cracks of the rocks, we could observe a considerable number of plants, and in some cases, there were rows of a dozen individuals (Fig. 3). We conjectured that this peculiar distribution of individuals is because in these places, the seeds can accumulate and find the right conditions of moisture, temperature, and soil to germinate and grow.

On the date of our visit (summertime in Mexico and at the beginning of the rainy season), most of the plants already formed their summer rosettes, and unfortunately, we could not find any flowers or capsules. An exceptional phenomenon present in this population was that under the same conditions of soil and light, plants with green and reddish tones grew intermingled (Fig. 3). Also, we observed plants of *P. mirandae* on the vertical wall in asso-



Figure 2: Plants of *Pinguicula mirandae* below an *Agave macrocartha* at the upper of the wall and out of our reach.





Figure 3: Different sizes of *P. mirandae* plants in summer rosettes with green and reddish tones.

ciation with *Tillandsia grandis*, *Selaginella lepidophylla*, *Agave petrophila*, and *Hechtia* sp. The number of plants of *P. mirandae* at this site was relatively low since we could only observe them in an area of 10 square meters. We climbed a few more meters on one side of the wall, but the density of the plants decreased until we no longer could find them.

Within the different species of Mexican *Pinguicula*, it is common to encounter small populations limited to a specific area, and such populations are threatened because any alteration of the habitat or poaching could lead to their demise. By that time, it was late in the afternoon, so we returned to the pickup truck and decided to travel to the city of Tehuacán to spend the night and eat a necessary dinner, which was particularly well received because after a long day of *Pinguicula* searching, we were starving!

The next day we departed early toward the next site of the field trip, an area along Highway 15 (Huajuapán de León-San Miguel Tlacotepec), where there is a wall in the west side of the road that is used to advertise, with a big graffiti, music events (the famous Mexican band dancing). There it is pos-

sible to find a population of *P. moranensis* or perhaps *P. rectifolia*, because both species are quite similar. In fact, for some botanists the latter species is synonymous with the former (Lampard *et al.* 2016; Hernández & Zamudio 2017). We observed the plants distributed in the basal part of the wall, near the ground, but most of them were in the upper part of the wall, precisely below the vegetation comprised of *Manfreda verhoekiae*, *Quercus magnoliifolia*, *Q. castanea*, *Q. glaucoides*, *Brahea dulcis*, *Psidium guajava*, and *Conzattia multiflora* (Fig. 4a). During a previous visit to the site a few years earlier, it was possible to observe more plants across the wall, but inevitably the negative impact of constant graffiti has limited their growth to its lower and upper portions (Fig. 4b). The plants had already formed their carnivorous summer leaves and possessed many flowers with a great diversity in size, shape, and color tones (Fig. 4 c-e); also, there were a lot of capsules and seeds (Fig. 4d). It is frequent to find populations of butterworts, mainly of *P. moranensis*, on the adjacent walls of roads and highways, and they thrive pretty well in spite of the disturbances caused by traffic and the continuous maintenance, which consists mainly of cutting the grasses along its edges. Contrary to what one might expect, this species seems to be favored by these altered conditions and sometimes forms huge populations.

We followed our route and after a few kilometers arrived at “El Boquerón”, an impressive canyon carved out by a tributary of the Salado River and framed along its sides by beautiful, pristine tropical deciduous forest. This area is a flora and fauna protection area, and it has a beautiful path with wonderful panoramic views (Fig. 5a). After a few minutes of walking along the trail and enjoying the view, we observed on the vertical walls (limestone), shaded areas that presented water drainages having accumulations of calcium carbonate concretions (caliche). In this peculiar niche,

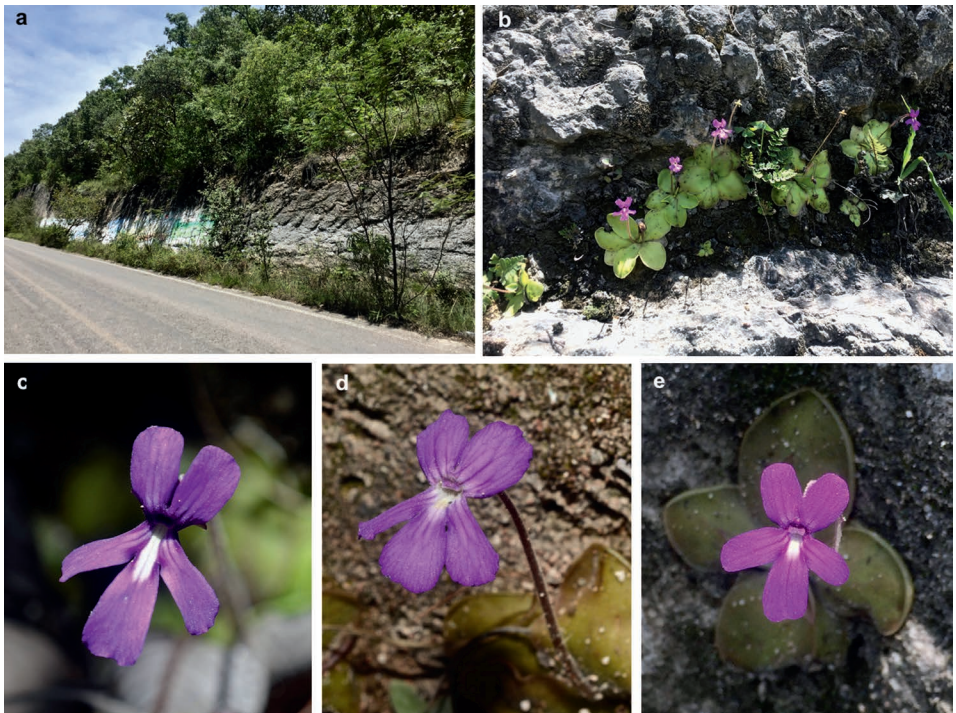


Figure 4: a) Population of *P. moranensis* or *P. rectifolia* thriving on a wall next to the highway b). The plants grow only on the base or upper part of the wall, c, d, e). There is great variation in the size, shape, and color of the flowers.





Figure 5: a) Panoramic view of flora and fauna protection area El Boquerón. b-e) The colonies of *P. rectifolia* were amazing and the plants had a great diversity of shapes and colors.

plants of *P. rectifolia* thrive. At first, these spots had only a few individuals, but some meters ahead the number of plants increased considerably (Fig. 5b). Most of them had large summer leaves and were in full bloom (Fig. 5 b-e). It was astonishing to appreciate the spectacular and synchronous pink to magenta bloom, and we even saw occasional individuals with white flowers (Fig. 5d). Most of the Mexican butterworts grow in association with other species, but in this locality, the presence of other species was low, and only a few grasses were visible with the higher clumps of *Pinguicula* and an occasional maidenhair fern (*Adiantum* sp.).

Adjacent to the path, there is an irrigation channel approximately three meters wide running next to the mountain wall. The plants are located at a height of 3 to 5 meters, making it difficult to

reach them, which is very convenient so that they are not easily collected or accidentally damaged by visitors. At the time, we visited this population, it was the beginning of the rainy season, so the level of water in the channel was low. This allowed Mané to skillfully transverse the channel and observe the plants close up (Fig. 6). It was also possible to collect some individuals for herbarium specimens to be deposited in the herbaria IBUG of the Universidad de Guadalajara and XAL of the Instituto de Ecología, A.C.

*Pinguicula rectifolia* thrives in this area, taking advantage of its yearlong warm weather and permanently wet walls, presumably the result of microclimatic conditions. The individuals of this population do not form winter rosettes, something unusual if, as was mentioned before, this species is to be considered synonymous with the widespread *P. moranensis*. Julián noticed another peculiar characteristic: the presence of non-glandular trichomes along the midrib of the lower (abaxial) surface of the leaf. This feature has not been reported for *P. moranensis*, and we believe that an in-depth genetic study is necessary to discriminate between both species and resolve their taxonomic status.

We continued our trip along the same Highway 15 (Huajuapán de León-San Miguel Tlacotepec) until our next stop, a population of *Pinguicula heterophylla*, known by collectors and enthusiasts of this group as Tonalá. In this place, we missed the fresh weather of El Boquerón, because the temperature was above 30°C, and the xerophilous scrub provided little shade. The landscape was dominated by shrubs of different species of Leguminosae and trees of the magnificent *Fouquieria ochoteranae*. The first spot we visited was a small canyon, in which we found a few plants of *P. heterophylla* on a small gypsum wall behind the shrubs (Fig. 7a). To our delight, some plants had flowers, the color of the plants was pale green, and they were about 7 cm tall. We moved to an open area of low hills covered by gypsum and with smooth, bright white slopes that hurt our eyes due



Figure 6: Mané Salinas observing *P. rectifolia* plants. Note that the water level was at least one meter below its highest level.





Figure 7: a) Plants of *P. heterophylla* growing in a small canyon were pale green in color and showed a transition between the winter rosette and the carnivorous summer leaves. b) The second location was an open area of low hills covered by gypsum where the plants were bigger and had more flowers and fruits.

to the intense reflection of sunlight (Fig. 7b and 8a). Here we observed a greater number of plants wholly exposed to the sun. They were either alone or associated with *Selaginella lepidophylla* and a few xerophytic ferns. The convenience of the date of our field trip permitted us to observe the transition between the winter rosette and the carnivorous summer leaves, as well as buds, flowers, and capsules. At the locality, there were both plants with a green hue and many plants with a beautiful intense red color (Fig. 8b-c).

*Pinguicula heterophylla* occurs naturally in at least three states of Mexico (Morelos, Guerrero, and Oaxaca). It usually grows in oak and pine-oak forests, with some populations in tropical deciduous forest. Its elevation ranges from 850 to 3060 m, and soils are derived from igneous and limestone rocks. The peculiar and exceptional thing about the Tonalá population is that it inhabits a semi-arid ecosystem with gypsum soils, a unique habitat for the species (Fig. 8a). Also, this area is the type locality of *P. pygmaea*, a recently described annual butterwort. We were aware that it would be challenging to encounter plants of this species this early in the rainy season; nevertheless, we were on the lookout to see if by chance, we found any individuals, but sadly, we were unlucky. Heading back to the pickup truck and under the sparse shade of a bush, Julián skillfully pressed some individuals of *P. heterophylla* for herbarium specimens.

Almost every time we visit populations of Mexican *Pinguicula*, we notice that some of them are endangered. At this locality, we observed the construction of maybe houses or warehouses 500 meters from the population. This habitat alteration represents a severe threat to these *Pinguicula*, as well as other species' viability.

The last stop of our field trip was at the only known population of *P. medusina*; some authors consider this species as a synonym of *P. heterophylla* (e.g., Lampard *et al.* 2016). This taxon inhabits a small gypsum hill, where we could quickly locate them in the first few meters of the northeast-facing slope (Fig. 9a). Although the site is next to "Laguna Encantada", a recreational area with a lagoon, a basketball court, and BBQ areas, the actual area where this species grows does not seem to be so disturbed, except for small areas that were recently burned (Fig. 9d).



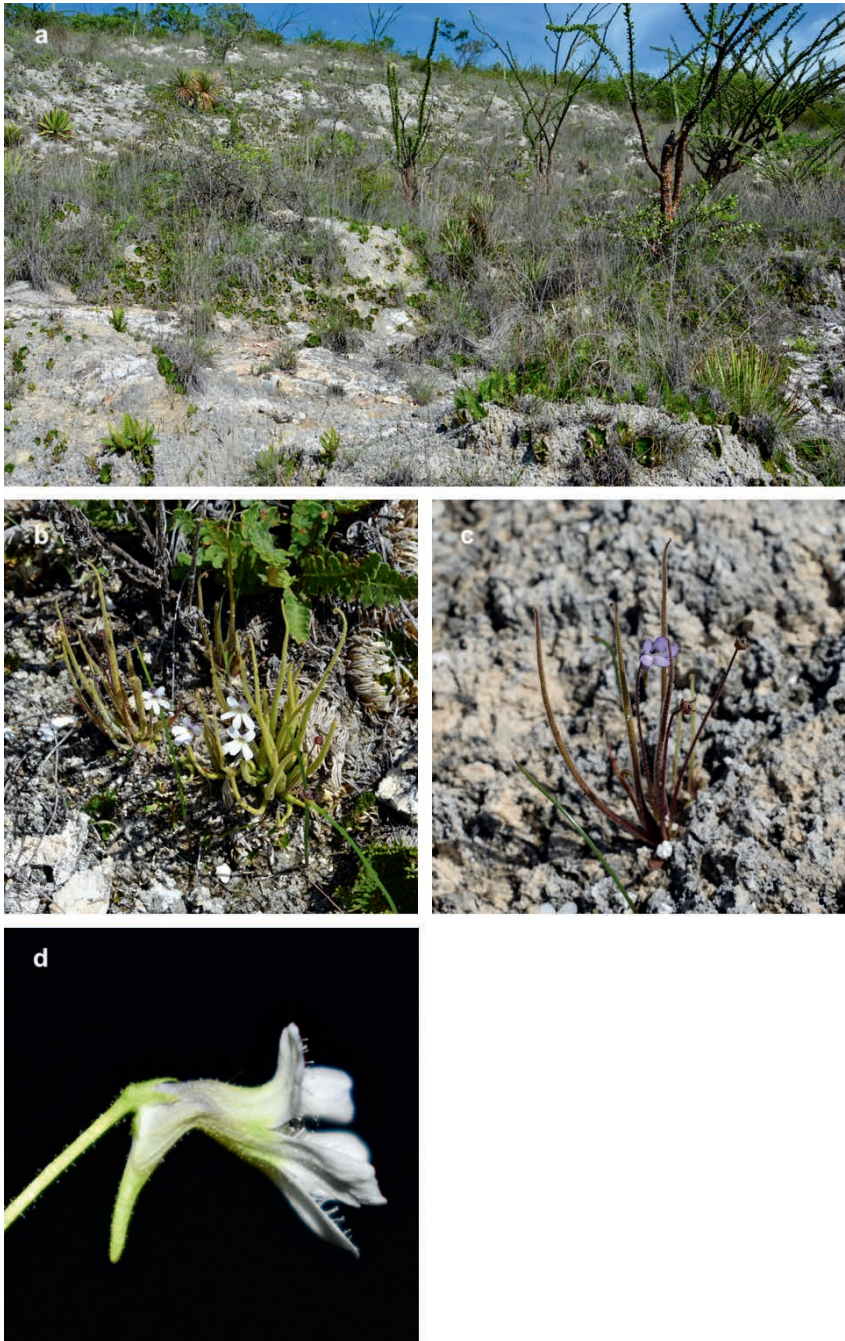


Figure 8: a) The singular habitat of *P. heterophylla* in Santo Domingo Tonalá, Oaxaca, low hills covered by gypsum. b, c) It is possible to observe plants with different pigmentation of leaves and flowers. d) Lateral view of *P. heterophylla* flower, where it is possible to observe that the spur forms an obtuse-straight angle in relation to the tube.





Figure 9: a) A gypsum northeast-facing slope, habitat of *P. medusina*. b) Lateral view of *P. medusina* flower. c) On the date of our field trip, it was possible to observe flowers and fruits. d) A small area of *P. medusina* habitat that was recently burned.



*Pinguicula medusina* is associated with *Selaginella* species and sometimes grows under the shade of the fan palm *Brahea dulcis*. Most of the plants of *P. medusina* were in the transition between winter rosette and summer leaves; many small individuals started to develop their summer leaves, but there were also adult individuals with flowers and developing fruits (Fig. 9c).

The particularity of this population lies in its unique asexual propagation that occurs at the apex of its leaves, where there are bulbils that later develop into new plants. This characteristic has not been reported in any other Mexican species of *Pinguicula*, except for the observations made by Oliver Gluch in a population of *P. heterophylla* in Oaxaca. At first sight, we noticed that *P. medusina* and *P. heterophylla* from Tonalá are quite similar, but we observed some differences, mainly in the flowers. According to the description of Zamudio & Studnicka (2000) and Zamudio (2006), *P. heterophylla* does not have a geniculate tube of the flower. However, we noticed that the Tonalá specimens have the tube of the flowers geniculate in the central part and that the spur forms an obtuse-straight angle in relation to the tube (Fig. 8d); in contrast, *P. medusina* has flowers with a non-geniculate tube, and the spur forms a sub-angle (Fig. 9b).

Thus, the question arises: could this population represent a variant of *P. heterophylla*? Again, we believe that is necessary to conduct more in-depth studies based on morphological and molecular criteria for the discrimination of these two species.

Finally, it occurred to us to end this field trip by looking for a population of *Pinguicula conzattii*; however, it was getting late and the approximate time to reach that population was 3 hours. So, we gave up and took the road back to Huajuapán de León, where we would spend the night. On the way back, the talk revolved around everything we had observed and what a delightful trip it was. While we were already traveling at night and in the darkness of the winding mountain roads, we took a curve and began to perceive a growing light. To our joy, we were rewarded with a spectacular and beautiful full moon that illuminated the remainder of the route. What better way to finish our field trip!

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