



## *Isoetes tamaulipana* (Isoetaceae), a new species from Mexico

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### Abstract

*Isoetes tamaulipana*, an aquatic plant that grows in small pools formed in outcrops of granitic rocks, and currently known only from the municipality of San Carlos in the state of Tamaulipas México, is described and illustrated. The new species is compared with taxa that are growing in similar environments conditions or have recently been described from the New World. *Isoetes tamaulipana* differs from these other taxa (e.g. *I. lithophila*, *I. orcuttii*, *I. texana*, etc.) in having megaspores with smooth perispore and microspores with echinate perispore.

### Resumen

Se describe e ilustra *Isoetes tamaulipana*, planta acuática que crece en pequeñas pozas formadas en afloramientos de rocas graníticas, y actualmente conocida sólo del municipio de San Carlos, en el estado de Tamaulipas México. La nueva especie se compara con los taxones que están creciendo en ambientes similares o que han sido descritas recientemente en el Nuevo Mundo. *Isoetes tamaulipana* difiere de estos otros taxones (ej. *I. lithophila*, *I. orcuttii*, *I. texana*, etc.) en tener megasporas con perisporio liso y microsporas con perisporio equinado.

**Key words:** Granitic outcrops, heterosporic plant, hydrophyte, Lycophytes, Tamaulipas

### Introduction

The genus *Isoetes* Linnaeus (1753: 1100) has a worldwide distribution (Hickey *et al.* 2003). About 200 species are recognized (Hickey 1995, Mickel & Smith 2004), although some estimates go up to 350 (Hickey *et al.* 2003). Six species have been reported from Mexico (Mickel & Smith 2004): *Isoetes howellii* Engelmann (1882: 385), *I. mexicana* Underwood (1888: 93), *I. montezumae* Eaton (1897: 25) *I. orcuttii* Eaton (1900: 13), *I. pallida* Hickey (1988: 35) and *I. pringlei* Underwood (1888: 94). Half of them (i.e., *I. mexicana*, *I. pallida* and *I. pringlei*) are endemic to the country (Mickel & Smith 2004). Specimens from the Yucatan peninsula previously identified as *Isoetes cubana* Engelmann ex Baker (1880: 110) belong to *I. pallida*, so actually this species is not present in Mexico (Mickel & Smith 2004).

Plants of *Isoetes* are frequently confused with species of Poaceae, Cyperaceae and Juncaceae in vegetative stages due to superficial resemblance (Underwood 1888; Valdez-Avila *et al.* 2009; Taylor *et al.* 1993, 2012, 2013). *Isoetes* occupies a broad range of habitats from fully aquatic to fully terrestrial but many taxa apparently need only small populations for survival, like *I. lithophila* Pfeiffer (1922: 135) and *I. piedmontana* (Pfeiffer 1937: 411) Reed (1965: 392), which occur only in temporary granitic pools (Heafner & Bray, 2005, Brunton & Britton, 2006, Taylor *et al.* 2012). Specialized habitat requirements restrict many *Isoetes* species to isolated places, hence many are still poorly known and new species may still be found in relatively well studied areas, such as *Isoetes texana* Singhurst, Rushing & Holmes (in Singhurst *et al.* 2011: 1).

Field explorations in the state of Tamaulipas were carried out in order to inventory the aquatic plant diversity in 2012–2014. A population of aquatic plants was encountered growing in seasonal pools granitic outcrop, in an isolated area of ca. 8–10 sqm at “Cerro El Diente”, located west of San Carlos. A detailed study of these plants was carried out together with an exhaustive literature review that allowed us to recognize these plants as a new species, *Isoetes tamaulipana*, increasing the total diversity of *Isoetes* in Mexico to seven species.

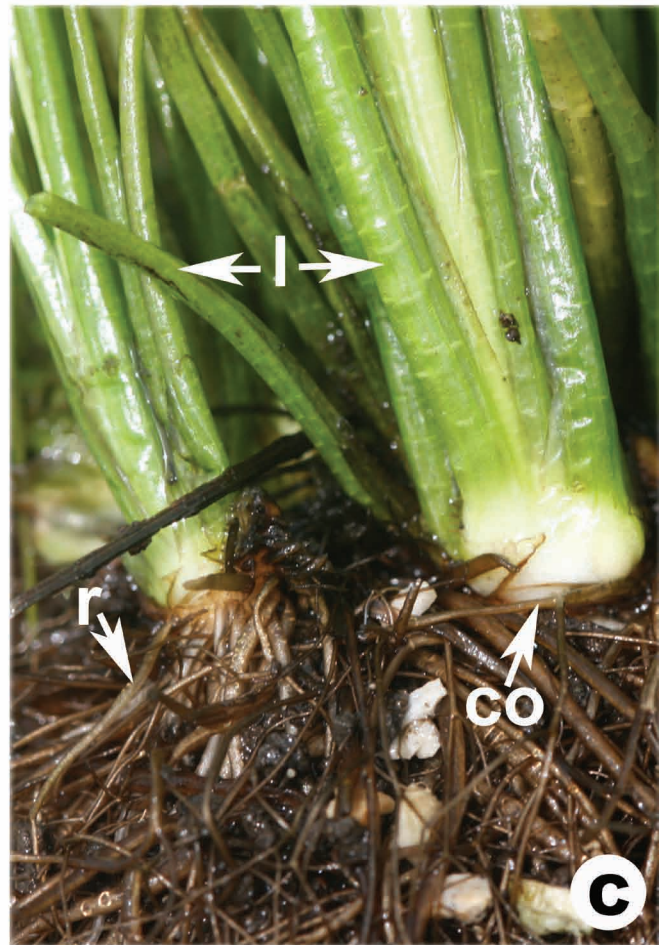


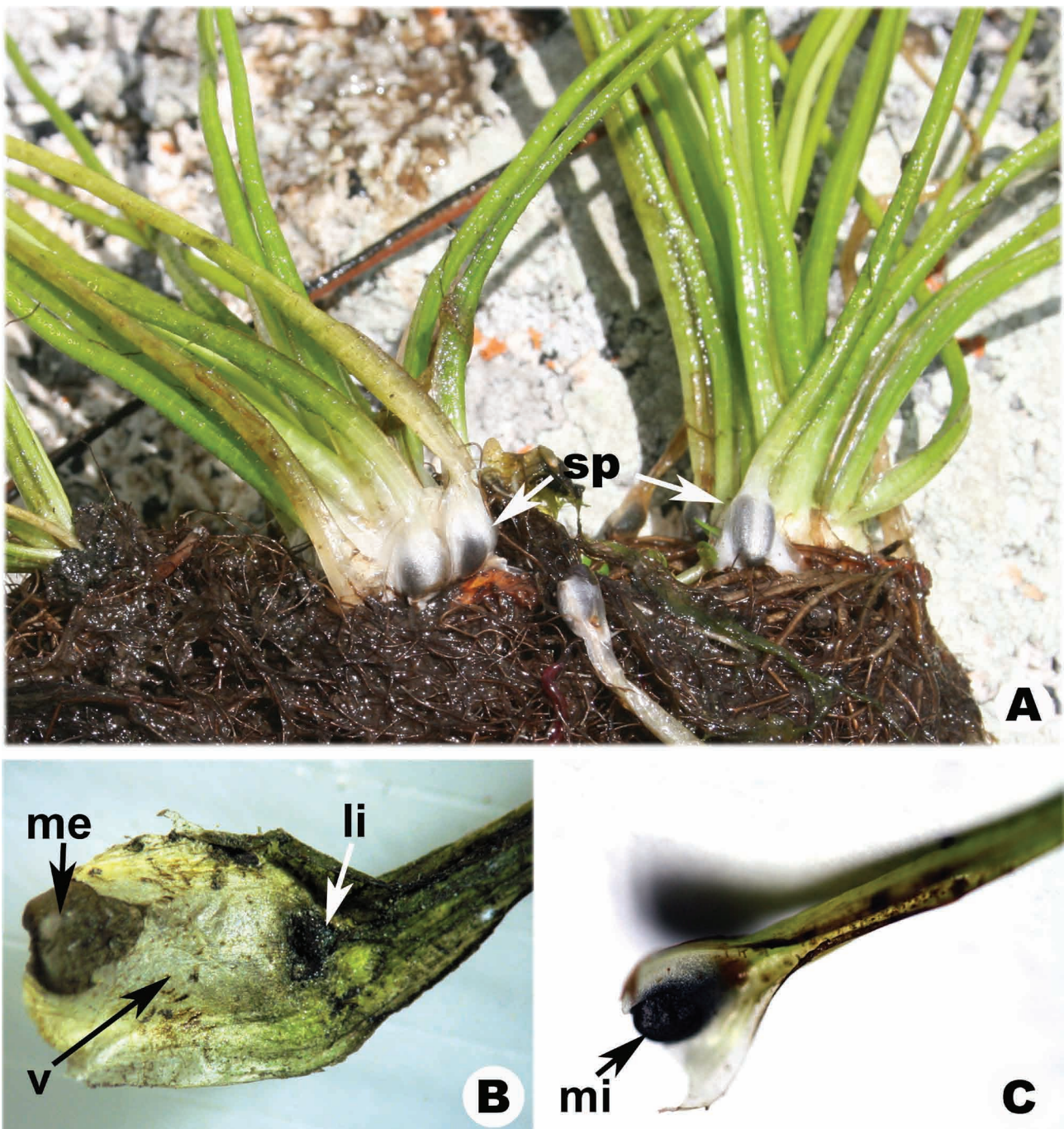
FIGURE 1. *Isoetes tamaulipana*. A. Habit. B. Plant. C. Basal region of the plant. co= corm, l= leaves, r= roots.

## Taxonomy

*Isoetes tamaulipana* Mora-Olivo, A. Mend. & Mart.-Aval., *sp. nov.* (Figs. 1–3)

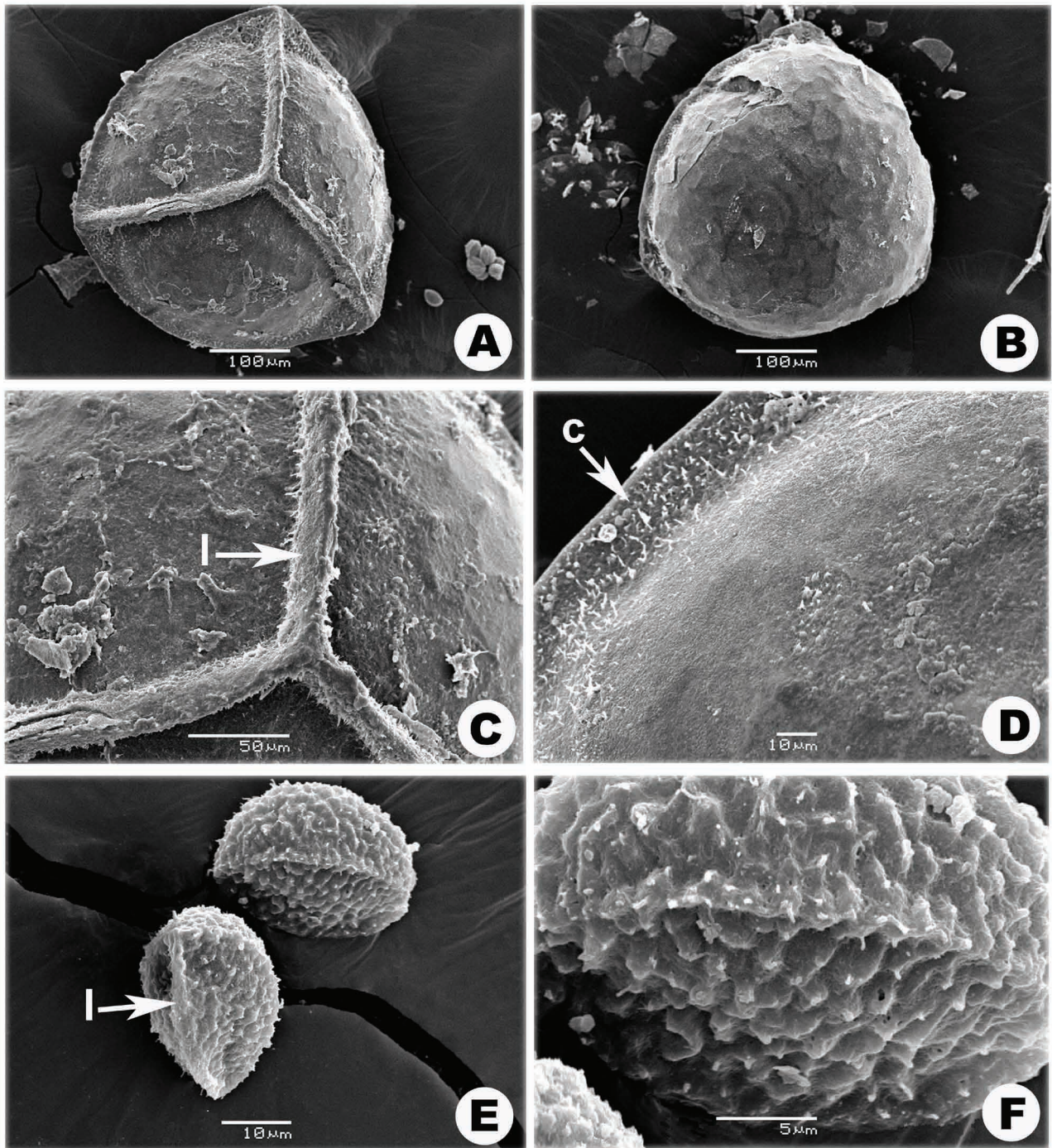
*Isoetes tamaulipana* is most similar to *I. mexicana* in length, width and color of leaves, but differs in having rootstocks 3 to 4 lobed (vs. 2 lobed in *I. mexicana*) and a velum covering 3/4 of the sporangium (vs. covering 1/3 of the sporangium). It further differs from this and other species in having light brown or greyish megaspores with a smooth to rugulate perispore and thin laesural walls, laesurae and proximal face of the equatorial ridge bearing tiny spines, and microspores being grey and echinate (vs. megaspores white to pale grey, smooth to weakly tuberculate, microspores grey and tuberculate-verrucose in *I. mexicana* and other similar species).

**Type**.—MEXICO. Tamaulipas: Municipio de San Carlos, aproximadamente 20 km W de San Carlos, ladera W del cerro El Diente, vegetación acuática en depresión de afloramiento rocoso de granito, rodeado por bosque de pino, 24°31'20.64" N, 98°57'48.61" W, 1071 m, 11 July 2012–17 March 2014, A. Mora-Olivo 13834 (holotype UAT, isotypes IEB, MEXU, UAMIZ).



**FIGURE 2.** Sporophylls of *Isoetes tamaulipana*. **A.** Sporophylls. **B.** Sporophyll with megasporangium. **C.** Sporophyll with microsporangium. li= ligulae, me= megasporangium, mi= microsporangium, sp= sporophylls, v= velum.

Perennials; aquatic plants rooted in substrate with emergent leaves; rootstock semi-globose, 3–4 lobed, 10–25 mm wide, 6–10 mm tall, without scales, leaves 15–30 per plant, erect and compactly arranged, 15–25 cm long, 3.5–6.0 mm wide at the base, 1.5–2.0 mm wide at the half the length, sub-terete in transversal section, basal part with hyaline alae, tapering to the apex, flexible, green when fresh or yellowish when dried; sporangia with translucent walls, globose or elliptical to obovate in the adaxial face, velum covering 75% of the macrosporangium, and 40% of the microsporangium, ligulae triangular and membranaceous; megasporangia white when fresh or pale brown when dried; microsporangia dark colored when fresh or greyish when dried. Megaspores tetrahedral, trilete, 380–400  $\mu\text{m}$  in diameter, light brown to greyish, proximal and distal face smooth or slightly wavy; length of the lasural arms 0.22–0.26  $\mu\text{m}$ , laesural arms 18–25  $\mu\text{m}$  wide, 15–20  $\mu\text{m}$  tall, with tiny spines besides the laesurae and proximal to the equatorial ridge; equatorial ridge 18–20  $\mu\text{m}$  wide. Microspores bilateral, cristate to echinate, greyish in mass, 27–30  $\mu\text{m}$  long, 17–20  $\mu\text{m}$  wide.



**FIGURE 3.** Scanning electron micrographs of *Isoetes tamaulipana*, A–B. Megaspore proximal and distal view. C. Close up of trilete laesura with tiny spines. D. Close up of cingulum with tiny spines. E. Microspores with proximal and distal views. F. Microspore ornamentation. c= cingulum, l= laesure.

**TABLE 1.** Comparison of the salient characteristics between *Isoetes taumalipana* and some species of United States and Mexico. Taken from: <sup>a</sup>Taylor *et al.* 1993, <sup>b</sup>Brunton & Britton 2006, <sup>c</sup>Mickel & Smith 2004, <sup>d</sup>Heafner & Bray 2005, <sup>e</sup>Singhurst *et al.* 2011.

| Characteristics/<br>taxa                     | <i>I. lithophilica</i> <sup>a</sup>                              | <i>I. melanopoda</i> <sup>b</sup>                                 | <i>I. mexicana</i> <sup>c</sup>                           | <i>I. orcutti</i> <sup>e</sup>   | <i>I. piedmontana</i> <sup>d</sup>   | <i>I. texana</i> <sup>c</sup>                        | <i>Isoetes taumalipana</i>   |
|--|--|---|---|--|--|--|--|
| Length and color of leaves                   | 10–12(20) cm, bright green, pale at base, straw-colored when dry | 16–40 cm, bright green, pale to bright black at base              | 12–25 cm, green when fresh, yellowish opaque when dry.    | 3–8 cm, bright green, pale at base, often surrounded by black scales of ca. 5 mm | 2.5–17.5 cm, subulate, green, yellowish when dry                           | 24–62 cm, green to yellowish                         | 15–25 cm, green when fresh to green yellowish when dry   |
| Width of leaves in the middle                | 0.5–0.9 mm   | 0.7–1.10 mm   | 0.5–0.9 mm  | 0.5–0.9 mm   | 0.2–1.75 mm  | data deficient                                       | 0.8–1.10 mm wide   |
| Width of leaves at the base; base coloration | 1.8–2.7 mm wide, stramineous                                     | 6–20 mm wide, black   | 4–10 mm wide, light brown to stramineous                  | 3.2–4 mm wide, greyish   | 4–6 mm wide, hyaline wings above the sporangium, pale to black shiny bases | data deficient                                       | 3.5–5 mm wide, greyish to dark brown   |
| Shape and size of rootstock                  | Globose, 2 lobed   | Globose, 2 (3) lobed  | Globose, 1–2 lobed  | Globose, 2–3 lobed   | Globose, 2 lobed   | Globose, 2 lobed, 3–9 mm wide                        | Semiglobose, 3–4 lobed, 10–15 mm wide  |
| Velum coverage and sporangium pigmentation   | Completely covering the sporangium, wall unpigmented             | Covering 3/4 of the sporangium, wall dark brown to black          | Covering 1/3 of the sporangium, wall unpigmented          | Completely covering the sporangium, wall unpigmented                             | Covering 1/3 of the sporangium, wall pigmented                             | Completely covering the sporangium, wall unpigmented | Covering 3/4 of the sporangium, wall unpigmented   |
| Shape, size and color of megaspores          | trilete, 290–360 µm in diameter, light grey to grey-brown        | trilete, 250–450 µm in diameter, white                            | trilete, 275–375 µm in diameter, white to light grey      | trilete, 200–380 µm in diameter, white, grey to atropurpureous                   | trilete, 250–650 µm in diameter, white wet or dry                          | trilete, 350–405 µm in diameter, white               | trilete, 350–410 µm in diameter, brown to greyish  |
| Ornamentation of megaspores                  | low ridges obscurely rugulate                                    | rugulate darkly with low ridges, rarely tuberculate or reticulate | smooth to tubercles, occasionally forming folds tubercles | smooth, tuberculate or lightly verrucate   | tuberculate-rugulate, with ridges crosslinked or rugulate                  | smooth to obscurely rugulate.                        | Proximal and distal surface smooth to slightly rugulate, with tiny spines besides the laesura and in the proximal part of the cingulum |

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TABLE 1. (Continued)

| Characteristics/<br>taxa       | <i>Isoetes lithophiloid</i> <sup>a</sup> | <i>I. melanopoda</i> <sup>b</sup>  | <i>I. mexicana</i> <sup>c</sup>  | <i>I. orcuttii</i> <sup>e</sup>          | <i>I. piedmontana</i> <sup>d</sup>                 | <i>I. texana</i> <sup>d</sup>       | <i>Isoetes tamaulipana</i>                 |
|--------------------------------|--|--|--|--|--|-------------------------------------|--|
| Equatorial ridge of megaspores | data deficient                           | data deficient   | data deficient   | smooth                                   | small and papillate                                | smooth                              | with tiny spines in the proximal surface   |
| Size and color of microspores  | 30–33 µm, brown                          | 20–30 µm, grey   | 25–35 µm, light grey   | 20–35 µm, slightly grey to brown         | 27–47 µm, brown to castaneous when mature          | 25–30 µm, white                     | 26–29 µm long, 17–20 µm wide, greyish      |
| Ornamentation of microspores   | tuberculate to echinate                  | echinate   | minutely glandulose to echinate, tuberculate or tuberculate- verrucose                               | echinate to tuberculate                  | echinate   | tuberculate                         | cristate to echinate                       |
| Habit (life form) and habitat  | aquatic, pools in rocky granite outcrop  | emergent aquatic, inundated, ditches and shallow pools rocky outcrops of sandstone | aquatic to sub-terrestrial, flooded areas, in oak-pine forests                                       | aquatic, pools outcrop in some wet areas | aquatic, in pools in granite outcrop               | emergent aquatic, in flooded areas  | aquatic, in pools of granite outcrop       |
| Vegetation and elevation       | aquatic, in mountains, 300–553 m         | aquatic, in oak forest, 95–326 m   | aquatic, surrounded by pine-oak forest, 1750–2500 m  | aquatic, 300–1500 m                      | aquatic or underwater, 518–621 m                   | emergent aquatic, sea level to 15 m | aquatic, surrounded by pine forest, 1071 m |
| Distribution                   | USA: Texas                               | USA: New Jersey, North Carolina, South Carolina, Utah and Virginia, etc.           | Mexico: Chihuahua, Durango, Hidalgo, Guanajuato Jalisco, Michoacan, Morelos, Queretaro and Zacatecas | USA: California, Mexico: Baja California | USA: east Alabama, Carolina, Georgia and Virginia, | USA: Texas                          | Mexico: Tamaulipas                         |

**Distribution and ecology:**—*Isoetes tamaulipana* is currently known only from the pools located at “Cerro El Diente” located west of San Carlos, in the northern part of the state of Tamaulipas, Mexico. Plants are emergent in small pools formed in granitic rocks (Fig. 1A), with roots 5–15 cm deep in the substrate, and are associated with submerged plants such as *Elatine* Linnaeus (1753: 367) (Elatinaceae).

**Etymology:**—Epithet refers to the Mexican state where the species was discovered.

**Discussion:**—*Isoetes tamaulipana* is the first record for the family Isoetaceae in the state of Tamaulipas and is the only known species from northeastern Mexico (Mora-Olivo & Villaseñor 2007).

It is important to point out that plants of *Isoetes* are always associated with moist environments and only a few species grow in seasonal ponds in basaltic or granitic outcrops. The flora that develops in this type of substrate has been widely studied in the United States of America (Singhurst *et al.* 2011) and several species of *Isoetes* are associated with these habitats such as *I. melanospora* Engelm (1878: 1), *I. tegetiformans* Rury (1978: 108), and *I. piedmontana* (Pfeiffer 1939: 411) Reed (1965: 392) (Heafner & Bray, 2005, Brunton & Britton 2006, Singhurst *et al.* 2011). However, *I. orcuttii* Eaton (1900: 13) from Baja California is the only species known in Mexico previously known from this kind of habitat.

Table 1 provides a comparative analysis of the features of known species of *Isoetes* that grow in habitats similar to that of *I. tamaulipana*, or that have been described recently and share some characteristics with *I. tamaulipana*. However, the new species is easily distinguished by its light brown or greyish megaspores with a smooth or slightly wavy exospore, thin laesure, laesure and proximal face of the cingulum with tiny spines (perispore), and microspores that are grey and echinate.

Because of its restricted distribution and its specialized aquatic habitat, *Isoetes tamaulipana* might be considered an endangered or vulnerable species. Future plans to implement a Natural Protected Area at the Cerro El Diente in Sierra de San Carlos, Tamaulipas could help to conserve and protect this and other species in the area.

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## References

- Baker, J.G. (1880) A synopsis of the species of *Isoetes*. *Journal of Botany* 18: 65–110.
- Brunton, D.F. & Britton, D.M. (2006) *Isoetes melanopoda* spp. *silvatica* (subsp. nov.), a new quillwort (Isoëtaceae) from eastern North America. *Castanea* 71 (1): 15–30.  
<http://dx.doi.org/10.2179/05-5.1>
- Eaton, A.A. (1897) A new quillwort from Mexico. *Fern Bulletin* 5: 25.
- Eaton, A.A. (1900) The genus *Isoetes* in New England. *Fernwort Papers* 2: 1–16.
- Engelmann, G. (1878) The species of *Isoetes* of the Indian Territory. *Botanical Gazette* 3: 1.  
<http://dx.doi.org/10.1086/325109>
- Engelmann, G. (1882) The genus *Isoetes* in North America. *Transactions of the Academy Science of St. Louis* 4: 358–390.
- Heafner, K. & Bray, R.D. (2005) Taxonomic reassessment of North American granite outcrop *Isoetes* species with emphasis on vegetative morphology and *I. piedmontana* (Pfeiffer) Reed sensu lato. *Castanea* 70 (3): 204–221.
- Hickey, R.J. (1988) *Isoetes pallida*, a new species from Mexico. *American Fern Journal* 78: 35–36.  
<http://dx.doi.org/10.2307/1547599>
- Hickey, R.J. (1995) Isoëtaceae. In: Davidse, G., Sousa, M. & Knapp, S. (Eds.) *Flora Mesoamericana vol. 1 Psilotaceae a Salviniaceae*. Universidad Nacional Autónoma de México, Missouri Botanical Garden & The Natural History Museum (London), México, D. F., pp. 42–43.
- Hickey, R.J., Macluf, C.C. & Taylor, W.C. (2003) A Re-evaluation of *Isoetes savatieri* Franchet in Argentina and Chile. *American Fern Journal* 93: 126–136.
- Linnaeus, C. (1753) *Species plantarum*. L. Salvius, Stockholm, 1200 pp.

- Mickel, J.T. & Smith, A.R. (2004) The pteridophytes of Mexico. *Memoirs of the New York Botanical Garden* 88: 1–1054.
- Mora-Olivo, A. & Villaseñor, J.L. (2007) Diversidad y distribución de la flora vascular acuática de Tamaulipas, México. *Journal of the Botanical Research Institute of Texas* 1 (1): 511–527.
- Pfeiffer, N.E. (1922) Monograph of the Isoëtaceae. *Annals of the Missouri Botanical Garden* 9: 79–232.  
<http://dx.doi.org/10.2307/2990000>
- Pfeiffer, N.E. (1937) A new *Isoetes* from Virginia. *Claytonia* 3 (3):29–30.
- Pfeiffer, N.E. (1939) A new variety of *Isoetes virginica*. *Bulletin of the Torrey Botanical Club* 66 (6): 411–413.  
<http://dx.doi.org/10.2307/2481040>
- Reed, C.F. (1965) *Isoetes* in southeastern United States. *Phytologia* 12: 369–400.  
<http://dx.doi.org/10.5962/bhl.part.10348>
- Rury, P.M. (1978) A new and unique, mat-forming merlin's grass (Isoetes) from Georgia. *American Fern Journal* 68: 99–108.  
<http://dx.doi.org/10.2307/1546480>
- Singhurst, J.R., Rushing, A.E., Hanks, C.K. & Holmes, W.C. (2011) *Isoetes texana* (Isoëtaceae): A new species from the Texas Coastal Bend. *Phytoneuron* 22: 1–6.
- Taylor, K.N., O'Kennon, R.J. & Rehman, T.F. (2012) Expanded distribution of *Isoetes butleri* (Isoëtaceae) in Texas. *Journal of the Botanical Research Institute of Texas* 6 (2): 753–757.
- Taylor, W.C., Luebke, N.T., Britton, D.M., Hickey R.J. & Brunton, D.F. (1993) Isoëtaceae Reichenbach. Quillwort Family. In: Flora of North America Editorial Committee (Eds.) *Flora of North America north of Mexico. Volume 2*. Oxford University Press, New York, New York, 496 pp.
- Taylor, W.C., Luebke, N.T., Britton, D.M., Hickey, R.J. & Brunton, D.F. (2013) Pteridophytes and Gymnosperms. 4. Isoëtaceae. In: Barkley, T.M. *Flora of North America*. Available from: [http://www.efloras.org/florataxon.aspx?flora\\_id=1&taxon\\_id=116581](http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=116581) (accessed 27 May 2013)
- Underwood, L.M. (1888) The distribution of *Isoetes*. *Botanical Gazette* 13 (4): 89–94.  
<http://dx.doi.org/10.1086/326251>
- Valdez-Avila, R., Mendoza-Ruiz, A. & Pérez-García, B. (2009) Nota científica. *Isoetes*, ¿una planta rara? *Contactos* 73: 57–62.
- Velázquez-Montes, E. (2014) The family Isoëtaceae in Guerrero, Mexico: A new record. *Botanical Sciences* 92 (2): 183–188.  
<http://dx.doi.org/10.17129/botsci.59>