Temporary freshwater wetlands floristics in central Mexico highlands

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Abstract

Background: Mexico has a high diversity of aquatic and subaquatic plants that occur between 1,000 and 2,500 m of elevation, although a larger proportion of aquatic plants is concentrated at lower altitudes. Temporary wetlands harbor close to 73 % of the aquatic species in Mexico. These systems are under a strong anthropogenic pressure and suffer constant degradation.

Questions: i) How many species grow in highland temporary wetlands? ii) Are they floristically similar? iii) Is there a latitudinal pattern of species richness?

Studied groups: Charophyta, Pteridophyta, Angiosperms.

Study site and years of study: Central Mexico (39 wetlands) from 2015 to 2016.

Methods: We collected in 39 temporary wetlands for two years. We made a presence/absence list of species per locality, and calculated floristic similarities and correlations between wetlands. We include data characterizing life form, plant use, and conservation status.

Results: We found 126 species belonging to 80 genera and 38 families. The richest families were Cyperaceae, Asteraceae, and Poaceae. As to genera, *Eleocharis*, *Cyperus*, and *Juncus* had more species. Species with the widest distributions were *Persicaria mexicana*, *Marsilea mollis*, *Luziola fluitans*, *Heteranthera peduncularis*, and *Nymphoides fallax*. We found five different life forms – all herbaceous, including 27 threatened species, 24 species with economic use, 48 endemic species, and 19 cosmopolitan species. In addition, we found 20 species recorded for the first time in some states included in our study, and two species of *Eleocharis* that might represent undescribed species. The richest wetland harbors 40 species, the poorest has only five. Wetlands were comparable to each other in species composition, and species richness increases towards the south.

Conclusions: Temporary wetlands harbor a high floristic diversity and are similar to each other. Lower latitudes host higher numbers of species.

Key words: Aquatic plants, floristic similarity, new species records.

Resumen

Antecedentes: En altitudes entre 1,000 y 2,500 m ocurre una gran diversidad de plantas acuáticas en México, a pesar de que la mayor diversidad está concentrada en bajas altitudes. Los humedales temporales albergan el 73 % de las especies acuáticas mexicanas. Este ecosistema singular sufre presión de degradación y es de gran interés para la conservación.

Preguntas: i) ¿Cuántas especies se encuentran en los humedales temporales de altitud? ii) ¿La flora de los humedales temporales es similar? iii) ¿Existe un gradiente latitudinal de riqueza de especies?

Grupos en estudio: Charophyta, Pteridophyta y Angiospermas.

Sitio de estudio y año del estudio: Centro de México (39 humedales) en 2015 y 2016.

Métodos: Colectamos en 39 sitios durante dos años. Los datos que se incluyeron fueron: forma de vida, hábito, distribución, uso y riesgo de extinción. Posteriormente, se elaboró un listado de presencia/ausencia de especies por sitio y se calculó la similitud florística por medio del índice de Jaccard y la correlación entre los humedales por medio de Friendly.

Resultados: Se encontraron 126 especies, 80 géneros y 38 familias. Las familias más ricas fueron Cyperaceae, Asteraceae, y Poaceae. Los géneros más ricos fueron *Eleocharis*, *Cyperus* y *Juncus*. Las especies con mayor distribución fueron *Persicaria mexicana*, *Marsilea mollis*, *Luziola fluitans*, *Heteranthera peduncularis* y *Nymphoides fallax*. Se observaron cinco formas de vida, todas de hábito herbáceo, 27 especies están amenazadas, 24 tienen uso económico, 48 son endémicas a MegaMéxico, y son 19 cosmopolitas. Encontramos 20 nuevos registros para algunos estados mexicanos y dos son probablemente nuevas especies de *Eleocharis*. El humedal más rico presentó 40 especies, el más pobre cinco. Los humedales presentaron similitud entre sí y mayor riqueza a bajas latitudes.

Conclusiones: Los humedales temporales son ecosistemas biodiversos que presentan similitud entre sí. En latitudes más bajas se observa mayor número de especies.

Palabras clave: Nuevos registros de especies, plantas acuáticas, similitud florística.

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Wetlands are among the most threatened ecosystems of the world (Zedler & Kercher 2005, Cui *et al.* 2012). Estimates over the last decades put wetland loss as high as 60 % worldwide (Davidson 2013), and 62 % for Mexico (Landgrave & Moreno-Casasola 2012). Mexico is a megadiverse country (Declaración de Cancún 2002) and a biodiversity conservation hotspot (Myers *et al.* 2000) that harbors 21,841 flowering plant species (Villaseñor & Ortiz 2014). According to the National Wetland Inventory (Dumac 2017), almost 6 % (128,000 km) of the Mexican territory is occupied by wetlands. There are 139 Ramsar sites in Mexico, which makes it the neotropical country with the highest increase in internationally protected wetlands in recent decades (Mauerhofer *et al.* 2015). Mexico has 1,283 aquatic and subaquatic angiosperms, of which 157 are endemic to the country (Villaseñor & Ortiz 2014). As to strictly aquatic plants, there are 240 species (Mora-Olivo *et al.* 2013). According to Lot *et al.* (1993) Mexico has 747 of vascular aquatic plants. Aquatic plants may belong to the groups Charophyta, Briophyta, Pteridophyta, Gymnosperms and Angiosperms (Lot 2012), and are a major component of aquatic ecosystems (Dar *et al.* 2014).

Temporary wetlands span over approximately 0.81 million km² of the Earth's surface (Pekel *et al.* 2016). They undergo severe changes in water saturation levels, and at times can dry completely (Martínez & García 2001). Temporary wetlands are dynamic and can change in shape and size (Frohn *et al.* 2009). They function as a connection among different ecosystems, either terrestrial or aquatic (Aavik *et al.* 2013, Ishiyama *et al.* 2014, Uden *et al.* 2014), provide ecosystem services (Marton *et al.* 2015), and substantially contribute in maintaining biodiversity (Balian *et al.* 2008). Temporary wetlands harbor almost 73 % of the aquatic plants and 31 % of the strictly aquatic plants in Mexico (Mora-Olivo *et al.* 2013). In particular, temporary wetlands in central Mexico are highly diverse ecosystems (Rico-Romero 2015). The largest number of aquatic plants is concentrated at lower altitudes (Rzedowski 1978), but at least 147 of the Mexican strictly aquatic plants populate wetlands located above 1,000 m a.s.l. (Mora-Olivo *et al.* 2013). Scientific studies of temporary wetlands are scarce, which contributes to habitat loss. In such a context, floristic inventories of temporary wetlands contribute to the knowledge and conservation of a rapidly disappearing ecosystem (Calhoun *et al.* 2016). The objectives of our paper are to determine the floristic composition and analyze the level of similarity among temporary highland wetlands in central Mexico.

Materials and methods

The 39 studied temporary wetlands range in elevation from 1,900 to 2,700 m a.s.l. in the states of Aguascalientes (localities 1-12), Guanajuato (13-18), Jalisco (19-22), Michoacán (23), Querétaro (24-32), San Luis Potosí (33, 34), and Zacatecas (35-39, Figure 1, Appendix 1, Figure 2). Wetlands were located using bibliographical references, by field trips, and through the support of local researchers. The areas lie between the latitudes of 20° and 24° North, and longitudes 100° and 103° West (Appendix 1), in the Mexican Transvolcanic Belt and the Mexican Plateau. Weather is semiarid temperate, and temperate subhumid, with the following Koeppen classifications: 'BS1kw', 'C(wo)', and 'C(w1)'. Mean annual temperature ranges from 12 °C to 18 °C. Mean annual precipitation is 600 to 800 mm with the highest precipitations in June or July. Natural vegetation surrounding the wetlands is composed of oak forests and grasslands with agricultural activities present (INEGI 2017, CONABIO 2017). Water parameters were as follows (averages): pH 5.98, dissolved oxygen 4.87 mg/L, conductivity 126 µSTm, resistivity 0.027 mΩ, total dissolved solids 62 ppm, and salinity 0.06 PSU (Appendix 1).

Plant specimens were collected in the 39 wetlands from August 2015 to November 2016. Collection and herborization followed Lot (1986). Vouchers were deposited at Autonomous University of Queretaro Herbarium "Jerzy Rzedowski", QMEX with duplicates to be distributed in Mexico (CIIDIR, IBUG, MEXU, SLPM, and XAL) and Brazil (LUSC), acronyms according to Thiers (continuously updated). Family classification for ferns followed Smith *et al.* (2006), and Angiosperm Phylogeny Group IV (APG 2016) for angiosperms. Nomenclature followed the International Plant Name Index (IPNI 2017). We used the concept of Lot *et al.* (1986, 1993) to define life form (rooted emergent, rooted submersed, rooted floating, free floating, free submersed), and affinity as aquatic plant, which includes three categories (strictly aquatic,

Author Contributions

Tatiana Lobato de Magalhães conceived, designed, and performed the experiments, analyzed the data, and wrote the paper.

Mahinda Martínez conceived and designed the experiments, analyzed the data, reviewed drafts of the paper.

Figure 1. Map of studied temporary wetlands located in the highlands of Aguascalientes, Guanajuato, Jalisco, Michoacán, San Luis Potosí, Querétaro and Zacatecas States, central Mexico.

subaquatic, and tolerant). Strictly aquatic plants definition followed Mora-Olivo *et al.* (2013), subaquatic are according to Lot *et al.* (2013) for monocots and Lot *et al.* (2015).

We elaborated a presence/absence list per site, and calculated the floristic distance (Jaccard 1908, Krebs 1999) and the floristic correlation among wetlands (Friendly 2002). Graphs and maps were elaborated with ArcGIS® version 9.3 and R version 3.31 (R Development Core Team 2017), through *corrplot*, *vegan* packages (Wei y Simko 2017)

We included geographical and altitudinal distribution (Mora-Olivo *et al.* 2013, Lot *et al.* 2013, Lot *et al.* 2015, GBIF 2017, Tropicos 2017), conservation status: either national or international (SEMARNAT 2010, IUCN 2017), use: biofilters, medicinal (Medline 2017), and finally, weeds were defined as such if they are included in Villaseñor & Espinosa-García (1998). Records for the Mexican states were considered as new if the species was not included in Mickel & Smith (2004) for ferns, Lot *et al.* (2013) for monocotyledons, Flora del Bajío (Rzedowski & Rzedowski 2017) for several families, and Martínez *et al.* 2017 for Solanaceae.

Results

We found 126 species of 80 genera and 39 families (Appendix 2). Three were Charophyta, four Pteridophyta, and 119 Angiosperms. The richest family was Cyperaceae (27 species), followed by Asteraceae (17), Poaceae (16), Plantaginaceae (5), Fabaceae (5), and Juncaceae (4, Figure 3-A). The genera with the highest number of species were *Eleocharis* (16 species, Figure 4-A), *Cyperus* (8), and *Juncus* (4). The rest of the genera had three species or less. *Persicaria mexi-*

Figure 2. A) Site 15 in Guanajuato, October 2015. B) Site 15 starting to become dry in Guanajuato, December 2016. C) Site 7 in Aguascalientes, October 2016. D) Site 34 in San Luis Potosí, October 2016. E) Site 35 in Zacatecas, October 2015. F) Site 32 in Querétaro, October 2016. G) Site 29 surrounded by houses in Querétaro, October 2016. H) Site 26 it was covered with soil and asphalt during 2016 in Querétaro

Figure 3. A) Specie richest families; B) More frequent species; C) Number of species per locality; D) Dendrogram cluster by Jaccard; E) Floristic correlation between localities; F) Species distribution in higher and lower latitudes from 21° N.

cana had the widest distribution (32 localities, Figure 3-B, Figure 4-B), followed by *Marsilea mollis* (28 localities), *Luziola fluitans* (26 localities, Figure 4-C), *Heteranthera peduncularis* (25 localities, Figure 4-D), *Nymphoides fallax* (25 localities, Figure 4-E), *Eleocharis macrostachya* (24 localities), and *Paspalum distichum* (23 localities). Thirty-six species (28 %) were found in only one locality. Life forms were emergent (93 species), submersed (14 species), rooted floating (13 species), free floating (five species) and free submersed (one species). We found 49 strictly aquatic, 21 subaquatic, 38 tolerant, and 18 with no previous record as aquatic plant. All plants were herbaceous.

The richest wetland had 40 species (site 26 in Querétaro, Figure 3-C), followed by 37 (sites 16 in Guanajuato and 29 in Querétaro). However, one of the wetlands had only five species (site 36 in Zacatecas). The surveyed wetlands had a level of similarity among themselves (Figure 3-D). Wetlands with the highest correlations among them were those from Querétaro (sites 24, 25, 26, 27, 29, 30, 31, and 32, Figure 3-E), followed by those of Aguascalientes (sites 1, 2, 3, 4, 5, 6, 7, 8 and 9, Figure 3-E). Aguascalientes localities also showed a high correlation with Jalisco's Highlands (sites 19, 20, 21, and 22, Figure 3-E) and southern Zacatecas (site 36 and 37, Figure 3-E). In addition, Querétaro localities showed a correlation with Guanajuato (Figure 3-E). We observed the existence of a latitudinal gradient and found 47 species growing only at the lowest latitude wetlands (Figure 3-F). We only sampled 15 of the 39 wetlands at latitudes lower than 21°, but we found 103 of the 126 species (82 %) on these wetlands, 47 of which were exclusive. Wetlands higher than 21° latitude presented 79 species (63 %), and only 23 were exclusive. Forty-eight species are endemic to the MegaMéxico region: *Callitriche heterophylla*, *Eleocharis densa*, *E. ignota*, *E. reznicekii*, *E. tenarum*, *E. yecorensis*, *Eragrostis plumbea*, *Eriocaulon bilobatum*, *Galium proliferum*, *Glandularia teucrifolia*, *Helenium mexicanum*, *Heteranthera peduncularis*, *Heterosperma pinnatum*, *Isoetes mexicana*, *Jaegeria glabra*, *J. purpurascens*, *Karinia mexicana*, *Lobelia fenestralis*, *L. irasuensis* var. *fucata*, *Luziola fluitans*, *Marsilea mollis*, *Nierembergia angustifolia*, *Nymphaea gracilis*, *Nymphoides fallax*, *Plantago linearis*, *Polygala alba*, *P. subalata*, *Potamogeton diversifolius*, *Rorippa mexicana*, *Sagittaria demersa*, *Schkuhria schkuhrioides*, *Sisyrinchium convolutum*, *Sporobolus atrovirens*, *Stevia eupatoria*, *Tagetes lucida*, *T. pringlei*, *Trifolium wormskioldii*, *Tripogandra purpurascens*, *Utricularia per-versa*, and *Verbena carolina*. Nineteen species are cosmopolitan. Two species are introduced to Mexico: *Egeria densa*, and *Glyceria fluitans*.

We found 19 species that can occur in low and high elevations: *Diplachne fusca*, *Echinochloa crus-galli*, *Egeria densa*, *E. minima*, *E. montana*, *E. parishii*, *E. schaffneri*, *E. yecorensis*, *Heteranthera limosa*, *H. peduncularis*, *Juncus arcticus*, *Lemna minuta*, *Ludwigia octovalvis*, *L. pep-loides*, *Najas guadalupensis*, *Paspalum distichum*, *Potamogeton nodosus*, and *Schoenoplectus californicus*, and *Triglochin scilloides*; 24 species occur only above > 1,000 m a.s.l.: *Callitriche heterophylla*, *Echinochloa crus-pavonis*, *E. oplismenoides*, *Eleocharis aciculares*, *E. densa*, *E. ignota*, *E. macrostachya*, *Eriocaulon bilobatum*, *Glyceria fluitans*, *Isoetes Mexicana*, *Jaegeria glabra*, *Juncus dichotomus*, *J. ebracteatus*, *J. microcephalus*, *Karinia mexicana*, *Lemna gibba*, *L. obscura*, *Limosella aquatica*, *Luziola fluitans*, *Nymphoides fallax*, *Potamogeton diversifolius*, *Sagittaria demersa*, *Sisyrinchium convolutum*, and *Tripogandra purpurascens*. We did not find information on altitudinal distribution for the rest of the species collected in this study.

Twenty seven species were listed as threatened, 25 of which are on the international list (IUCN 2017) in the "least concern" category: *Azolla microphylla*, *Callitriche heterophylla*, *Cyperus esculentus*, *Diplachne fusca*, *Distichlis spicata*, *Echinochloa crus-galli*, *Elatine brachysperma*, *Eleocharis aciculares*, *E. atropurpurea*, *E. densa*, *E. macrostachya*, *Glyceria fluitans*, *Hippuris vulgaris*, *Lemna gibba*, *L. minuta*, *Limosella aquatica*, *Ludwigia octovalvis*, *Najas guadalupensis*, *Paspalum distichum*, *Poa annua*, *Polygonum punctatum*, *Potamogeton nodosus* (Figure 4-F), *Setaria parviflora*, *Trifolium amabile*, and *Triglochin scilloides*. Two species, *Nymphaea gracilis* (Figure 4-G), and *Trifolium wormskioldii*, are listed by SEMARNAT (2010) as threatened.

As to the actual or potential uses of the species, 21 have economic importance, 12 as medicinal, and eight as biofilter/ biofuel, and one with both purposes (*Azolla microphylla*, Appendix 2, Figure 4-H). Medicinal: *Azolla* spp. have antibacterial activity (Abraham *et al.* 2015), also *Cosmos bipinnatus* has the same medicinal property (Olajuyigbe & Ashafa 2014, Sohn *et al.* 2013). The oil of *Baccharis salicifolia* is a natural repellent (García *et al.* 2005). *Bidens aurea*

Figure 4. A) *Eleocharis densa* site 27, richest genus. B) *Persicaria mexicana* site 13, most frequent species. C) *Luziola fluitans* site 16, recurrent species. D) *Heteranthera peduncularis* site 8, recurrent species. E) *Nymphoides fallax* site 38, recurrent species. F) *Potamogeton nodosus* site 2, endangered. G) *Nymphaea gracilis* site 21, endangered. H) *Azolla microphylla* site 25, multiple economic use.

acts like omeprazole (De la Lastra *et al.* 1994). *Ludwigia octovalvis* is used against cancer (Chang *et al.* 2004). *Polygonum punctatum* has antibiotic, anti-inflammatory and anti-hyperalgesic properties (Alves *et al.* 2001). *Rumex crispus* has sun protection properties (Demirezer & Uzun 2016). *Schkuhria schkuhrioides* is antimicrobial (Delgado *et al.* 1998). *Stevia eupatoria* has anti-mutagenic and anti-oxidant properties (Cariño-Cortés *et al.* 2007). *Symphytotrichum subulatum* has anti-inflammatory properties (Lee *et al.* 2012). *Tagetes lucida* has medicinal properties as anti-depressive (Bonilla-Jaime *et al.* 2015) and *T. micrantha* has diverse medicinal properties (Linares & Bye 1987). Biofilter/ biofuel: *Azolla filiculoides* and *A. microphylla* are attractive species for the production of renewable biofuels (Miranda *et al.* 2016). *Egeria densa* can remove heavy metals from the environment (Tsuji *et al.* 2017), as can *Eleocharis acicularis*, *E. macrostachya*, and, *E. montana* (Ha *et al.* 2011, Olmos-Márquez *et al.* 2012). *Lemna gibba*, *L. obscura*, *L. minuta* are indicated for phytoremediation of contaminated water (Gallardo-Williams *et al.* 2002, Gür *et al.* 2016, Di-Baccio *et al.* 2017).

Forty four species were recorded as Mexican weeds: *Allium glandulosum*, *Baccharis salicifolia*, *Bahia absinthifolia*, *Bidens aurea*, *Cosmos bipinnatus*, *Cuphea wrightii*, *Cyperus esculentus*, *C. flavescens*, *C. virens*, *Dalea foliolosa*, *Echinochloa crus-galli*, *E. crus-pavonis*, *Egeria densa*, *Eleocharis acicularis*, *E. montana*, *Glandularia teucrifolia*, *Glyceria fluitans*, *Helenium mexicanum*, *Heteranthera limosa*, *Lemna gibba*, *L. minuta*, *L. obscura*, *Ludwigia octovalvis*, *L. peploides*, *Najas guadalupensis*, *Nothoscordum bivalve*, *Paspalum distichum*, *Plantago linearis*, *Poa annua*, *Polygonum punctatum*, *Potamogeton diversifolius*, *P. nodosus*, *Pycnus niger*, *Rorippa mexicana*, *Rumex crispus*, *Schkuhria schkuhrioides*, *Setaria parviflora*, *Sisyrinchium convolutum*, *Sporobolus indicus*, *Tagetes lucida*, *Tagetes micrantha*, *Trifolium amabile*, *Tripogandra purpurascens*, and *Verbena carolina*.

Two species probably yet undescribed of the genus *Eleocharis* were found at site 7, Aguascalientes, and site 35, Zacatecas (S. González pers. comm.). New records of 20 species were found for the following Mexican states: Aguascalientes: *Eleocharis parishii*, *E. reznicekii*, *Eriocaulon bilobatum*, *Isoetes mexicana*, *Lemna obscura*, *Potamogeton nodosus*, and *Schoenoplectus californicus*. Guanajuato: *Eleocharis tenarum*, *E. yecorensis*, *Echinochloa oplismenosides*, *Eriocaulon bilobatum*, *Juncus ebracteatus*, and *Lemna minuta*. Michoacán: *Jaegeria purpurascens*. Querétaro: *Azolla microphylla*, *Eleocharis ignota*, and *Lemna obscura*. San Luis Potosí: *Lemna obscura*. Zacatecas: *Elatine brachysperma*, *Eriocaulon bilobatum*, *Heteranthera limosa*, *Isoetes mexicana*, *Juncus arcticus*, *Marsilea mollis*, and *Nierenbergia angustifolia*.

Discussion

In several wetland studies, Asteraceae, Cyperaceae and Poaceae arise as the most important families and emergent species stand out as the most abundant life form in wetlands. (Pott & Pott 2000, Rolon *et al.* 2010, Magalhães *et al.* 2016). Cyperaceae and Poaceae are among the richest aquatic monocotyledons plant families in Mexico (Lot *et al.* 2013). Aquatic Cyperaceae have morphological adaptations that enables them to survive drought spells (Rocha & Martins 2011). As to distributions, aquatic plants frequently are cosmopolitan, but a few only prosper in specific environments and are endemic (Rzedowski 1978). Cyperaceae and Poaceae also have a high endemism among Mexican aquatic plants (Lot *et al.* 2013). *Allium glandulosum*, *Azolla filiculoides*, *Eleocharis ignota*, *Hippuris vulgaris*, *Jaegeria glabra* and *Sagittaria demersa* are some of the 47 species registered only below 21° N. *S. demersa* is endemic to MegaMexico and is considered rare, or even threatened (Lot *et al.* 2002). The Cyperaceae *Eleocharis parishii*, *E. atropurpurea*, *E. coloradoensis*, *E. minima*, *E. reznicekii* and *Schoenoplectus californicus* are among the 47 species registered above 21° N latitude. Some of the 56 species are present at both north and south of latitude 21° N were *Callitriche deflexa*, *C. heterophylla*, *Eleocharis acicularis*, *E. densa*, *E. dombeyana*, *E. macrostachya*, *E. montana*, *E. schafenerri*, *E. tenarum*, *E. yecorensis*, *Eriocaulon bilobatum*, *Heteranthera limosa*, *H. peduncularis*, *Najas guadalupensis*, *Nymphoides fallax*, *Triglochin scilloides*, and *Utricularia perversa*. Species with restricted distribution to Mexico or Central America are *Eleocharis reznicekii*, *Eriocaulon bilobatum*, *Sisyrinchium convolutum* (Lot *et al.* 2013), *Utricularia perversa*, and *Nymphoides fallax* (GBIF 2017, Tropicos 2017). Altitudinal distribution presented species which strictly occur at higher

elevations, and others that are able to develop at both low and high elevations. Rzedowski (1978) and Mora-Olivo *et al.* (2013) suggest that there is a pattern of lower species diversity at higher elevation wetlands. However, there are two possible explanations for such a perception: 1) highland wetlands are under-detected and under-collected because many have a temporary water regime, and 2) at higher elevations terrain slopes hinder large water areas and many of the wetlands occupy small areas.

Differences in floristic composition found among sampled wetlands can also be explained by the surrounding vegetation cover and land use, as well as by physical and chemical water characteristics (Declerck *et al.* 2006, Lacoul & Fredman 2006, Ot'ahel'ová *et al.* 2007, Dar *et al.* 2014, Lu *et al.* 2014). Geographically isolated temporary wetlands can contribute to the landscape functions (Cohen *et al.* 2016). Localities 1 (Aguascalientes), 29 (Querétaro), 35 and 39 (Zacatecas) had higher conductivity, dissolved solids and salinity than the rest. Localities 1 and 29 are very close to a town, especially site 29 (Figure 2-G) which is delimited by houses. However, site 29 is among the richest localities, with 37 species. Wetlands 35 and 39 had higher salinity, and had a lower number of species (15 and 10, respectively). Both localities also had pH values above eight. Besides water contamination and nutrient deposition in the water, temporary wetlands are vulnerable to landscape conversion, drainage and obliteration. Site 26 (Querétaro) presented the highest number of species in 2015, however in 2016, it was covered with soil and asphalt, and was completely surrounded by houses (Figure 2-H). We found some aquatic species in 2016, as *Triglochin scilloides* and *Jaegeria purpurascens*, even when the site was already dry. Vegetation restoration of a 100 m belt surrounding a temporary wetland can significantly improve water quality (Bird & Day 2014). Submersed species as *Najas guadalupensis* and *Chara* spp. are important in maintaining ecological processes in wetlands exposed to high level of nutrients (Dierberg *et al.* 2002). Aquatic plants are also economically important as biofilters to remove excess of nutrients (Kostel 2016), as well as to control eutrophication (Fisher & Acreman 2004). *Lemna* spp. acts as a filter and inhibits submersed plants growth by blocking the light (Arroyave 2004, Rai 2008, Cuasquer *et al.* 2016).

A large proportion of the plants listed as weeds (Villaseñor & Espiosa-Garcia 1998), are also aquatic, either strict or subaquatic (Lot *et al.* 2013, Mora-Olivo *et al.* 2013, Lot *et al.* 2015), for example: *Baccharis salicifolia*, *Cyperus esculentus*, *C. flavescens*, *C. virens*, *Echinochloa crus-galli*, *E. crus-pavonis*, *Eleocharis aciculares*, *E. montana*, *Heteranthera limosa*, *Ludwigia octovalvis*, *L. peploides*, *Najas guadalupensis*, *Paspalum distichum*, *Plantago linearis*, *Poa annua*, *Polygonum punctatum*, *Potamogeton diversifolius*, *P. nodosus*, *Pycnus niger*, *Rorippa mexicana*, *Rumex crispus*, *Schkuhria schkuhrioides*, *Sisyrinchium convolutum*, *Sporobolus indicus*, and *Tripogandra purpurascens*. We could not consider them so, since they are in their typical habitat, the temporary wetlands. The concept of weed depends of the moment, place, and conditions where the plant is developing (Lorenzi 1991). In addition, 15 of the 44 species cited as weed are also cited as economically important, such as potentially medicinal (nine species): *Baccharis salicifolia*, *Bidens aurea*, *Cosmos bipinnatus*, *Ludwigia octovalvis*, *Polygonum punctatum*, *Rumex crispus*, *Schkuhria schkuhrioides*, *Tagetes lucida*, and *Tagetes micrantha*, or as biofilters (six species): *Egeria densa*, *Eleocharis aciculares*, *E. montana*, *Lemna gibba*, *L. minuta*, and *L. obscura*. On the other hand, we did not find previous record as aquatic plant for 17 species of Asteraceae (*Acmella repens*, *Aster moranensis*, *Bahia absinthifolia*, *Bidens aurea*, *Cosmos bipinnatus*, *Gnaphalium luteo-album*, *Heterosperma pinnatum*, *Tagetes lucida*, and *T. micrantha*), Fabaceae (*Dalea foliolosa*, *Macroptilium* sp., *Mimosa aculeaticarpa*, *Trifolium amabile*, and *T. wormskioldii*), Rubiaceae (*Galium* cf. *proliferum*), and Verbenaceae (*Glandularia teucrifolia*, *Verbena carolina*). We could consider the above species as weeds for the temporary wetlands where recorded.

In spite of recent compilation studies for Mexican aquatic plants (such as Lot *et al.* 2013, Lot *et al.* 2015), several states (especially Aguascalientes and Zacatecas) need a higher collecting effort. We found seven new records and probably one undescribed species for each state.

Given that temporary wetlands present a high anthropic degradation, but still have a high biodiversity (Pollock *et al.* 1998, Balian *et al.* 2008, Murray-Hudson *et al.* 2012), with economically species (Pott & Pott 2000, Magalhães *et al.* 2016), they should be a conservation priority. Hence, studies of landscape influence on species occurrence are a new challenge to create

strategies for conservation of temporary freshwater wetlands. Knowledge and awareness of the distribution, biodiversity, and economic potential of botanical species in temporary wetlands is the first step to establish conservation policies (Calhoun *et al.* 2016), as they are a very peculiar and highly threatened environment of central Mexico.

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Literature cited

- Aavik T, Holderegger R, Edwards PJ, Billeter R. 2013. Patterns of contemporary gene flow suggest low functional connectivity of grasslands in a fragmented agriculture landscape. *Journal of Applied Ecology* **50**: 395-403. DOI: 10.1111/1365-2664.12053
- Abraham G, Yadav RK, Kaushik GK. 2015. Antimicrobial activity and identification of potential antimicrobial compounds from aquatic pteridophyte, *Azolla microphylla* Kaulf. *Indian Journal of Experimental Biology* **53**: 232-235.
- Alves TMDA, Ribeiro FL, Kloos H, Zani CL. 2001. Polygodial, the fungitoxic component from the Brazilian medicinal plant *Polygonum punctatum*. *Memórias do Instituto Oswaldo Cruz* **96**: 831-833. DOI: 10.1590/S0074-02762001000600016
- APG, Angiosperm Phylogeny Group. 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* **118**: 1-20. DOI: 10.1046/j.1095-8339.2003.t01-1-00158.x
- Arroyave MP. 2004. La lenteja de agua (*Lemna minor* L.): una planta acuática promisoría. *Revista Escuela de Ingeniería de Antioquia* **1**: 33-38.
- Balian EV, Segers H, Martens K, Lévêque C. 2008. The freshwater animal diversity assessment: an overview of the results. *Hydrobiologia* **595**: 627-637. DOI: 10.1007/s10750-007-9246-3
- Bird MS, Day JA. 2014. Wetlands in changed landscape: the influence of habitat transformation on the physico-chemistry of temporary depression wetlands. *PLOS ONE* **9**. DOI: 10.1371/journal.pone.0088935
- Bonilla-Jaime H, Guadarrama-Cruz G, Alarcón-Aguilar FJ, Limón-Morales O, Vazquez-Palacios G. 2015. Antidepressant-like activity of *Tagetes lucida* Cav. is mediated by 5-HT1A and 5-HT2A receptors. *Journal of Natural Medicines* **69**: 463-470. DOI: 10.1007/s11418-015-0909-5
- Calhoun AJ, Mushet DM, Bell KP, Boix D, Fitzsimons JA, Isselin-Nondedeu F. 2016. Temporary wetlands: challenges and solutions to conserving a 'disappearing' ecosystem. *Biological Conservation* **211**: 3-11. DOI: 10.1016/j.biocon.2016.11.024
- Cariño-Cortés R, Hernández-Ceruelos A, Torres-Valencia JM, González-Avila M, Arriaga-Alba M, Madrigal-Bujaidar E. 2007. Antimutagenicity of *Stevia pilosa* and *Stevia eupatoria* evaluated with the Ames test. *Toxicology in vitro* **21**: 691-697. DOI: 10.1016/j.tiv.2006.12.001
- Chang CI, Kuo CC, Chang JY, Kuo YH. 2004. Three new oleanane-type triterpenes from *Ludwigia octovalvis* with cytotoxic activity against two human cancer cell lines. *Journal of Natural Products* **67**: 91-93. DOI: 10.1021/np030267m
- Cohen MJ, Creed IF, Alexander L, Basu NB, Calhoun AJ, Craft C, D'Amico E, DeKeyser E, Fowler L, Golden HE, Jawitz JW, Kalla P, Kirkman LK, Lane CR, Lang M, Leibowitz SG, Lewis DB, Marton J, MacLaughlin DL, Mushet DM, Raanan-Kiperwas H, Rains MC, Smith L, Walls SC. 2016. Do geographically isolated wetlands influence landscape functions? *Proceedings of the National Academy of Sciences* **113**: 1978-1986. DOI: 10.1073/pnas.1512650113
- CONABIO, [Comisión Nacional para el Conocimiento y Uso de la Biodiversidad]. 2017. *Geoportal*. <<http://www.conabio.gob.mx/informacion/gis/>> (accessed May 15, 2017).
- Cuasquer E, Salvatierra D, Jimenez E, Boira H. 2016. La vegetación del humedal "Abrás de Mantequilla". Composición florística. Bases para su restauración. *Ciencia y Tecnología* **9**: 17-30.
- Cui B, Zhang Z, Lei X. 2012. Implementation of diversified ecological networks to strengthen wetland conservation. *Clean – Soil, Air, Water* **40**: 1015-1026. DOI: 10.1002/clen.201200026

- Dar NA, Pandit AK, Ganai BA. 2014. Factors affecting the distribution patterns of aquatic macrophyte. *Limnological Review* **14**: 75-81. DOI: 10.2478/limre-2014-0008
- Davidson NC. 2014. How much wetlands has the world lost? Long-term and recent trends in global wetlands area. *Marine and Freshwater* **65**: 936-941. DOI:10.1071/MF14173
- De la Lastra CA, Martin MJ, La-Casa C, Motilva V. 1994. Antiulcerogenicity of the flavonoid fraction from *Bidens aurea*: comparison with ranitidine and omeprazole. *Journal of Ethnopharmacology* **42**: 161-168. DOI: 10.1016/0378-8741(94)90081-7
- Declaración de Cancún. 2002. *Declaración de Cancún de Países Megadiversos Afines*. <<http://www.inecc.gob.mx/descargas/ai/con199328.pdf>> (accessed May 15, 2017).
- Declerck S, De Bie T, Ercken D, Hampel H, Schrijvers S. 2006. Ecological characteristics of small farmland ponds: Associations with landuse practices at multiple spatial scales. *Biological Conservation* **131**: 523-532. DOI:10.1016/j.biocon.2006.02.024
- Delgado G, Tejeda V, Salas A, Chávez MI, Guzmán S, Bolaños A, Aguilar ML, Navarro V, Villarreal ML. 1998. New Melampolides from *Schkuhria schkuhrioides*. *Journal of Natural Products* **61**: 1082-1085. DOI: 10.1021/np970548s
- Demirezer LO, Uzun M. 2016. Determination of sun protection factor (SPF) of *Rumex crispus* and main anthraquinones. *Planta Medica* **82**: S01. DOI: 10.1055/s-0036-1596459
- Di-Baccio D, Pietrini F, Bertolotto P, Pérez S, Barcelò D, Zacchini M, Donati E. 2017. Response of *Lemna gibba* L. to high and environmentally relevant concentrations of ibuprofen: Removal, metabolism and morpho-physiological traits for biomonitoring of emerging contaminants. *Science of the Total Environment* **584**: 363-373. DOI: 10.1016/j.scitotenv.2016.12.191
- Dierberg FE, DeBusk TA, Jackson MJ, Chimeney MJ, Pietro K. 2002. Submerged aquatic vegetation-based treatment wetlands for removing phosphorous from agricultura runoff: response to hydraulic and nutrient loading. *Water Research* **36**: 1409-1422. DOI: 10.1016/S0043-1354(01)00354-2
- Dumac, Ducks Unlimited de México, A.C. 2017. *Inventario y Clasificación de Humedales en México, Parte I*. <<http://www.dumac.org/dumac/habitat/esp/publicaciones03.htm>> (accessed May 15, 2017).
- Fisher J, Acreman MC. 2004. Wetland nutrient removal: a review of the evidence. *Hydrology and Earth System Sciences* **8**: 673-685. DOI: 10.5194/hess-8-673-2004
- Friendly M. 2002. Corrgrams: Exploratory displays for correlation matrices. *The American Statistician* **56**: 316-324. DOI: 10.1198/000313002533
- Frohn RC, Reif M, Lane C, Autrey B. 2009. Satellite remote sensing of isolated wetlands using object-oriented. *Wetlands* **29**: 931-941. DOI: 10.1672/08-194.1
- Gallardo-Williams MT, Whalen VA, Benson RF, Martin DF. 2002. Accumulation and retention of lead by cattail (*Typha domingensis*), hydrilla (*Hydrilla verticillata*), and duckweed (*Lemna obscura*). *Journal of Environmental Science and Health, Part A*. **37**: 1399-1408. DOI: 10.1081/ESE-120013265
- García M, Donadel OJ, Ardanaz CE, Tonn CE, Sosa ME. 2005. Toxic and repellent effects of *Baccharis salicifolia* essential oil on *Tribolium castaneum*. *Pest Management Science* **61**: 612-618. DOI: 10.1002/ps.1028
- GBIF, Global Biodiversity Information Facility. 2017. Free and open source access to biodiversity database. <www.gbif.org> (accessed May 15, 2017).
- Gür N, Türker OC, Böcük H. 2016. Toxicity assessment of boron (B) by *Lemna minor* L. and *Lemna gibba* L. and their possible use as model plants for ecological risk assessment aquatic ecosystems boron pollution. *Chemosphere* **157**: 1-9. DOI: 10.1016/j.chemosphere.2016.04.138
- Ha NTH, Sakakibara M, Sano S. 2011. Accumulation of Indium and other heavy metals by *Eleocharis acicularis*: an option for phytoremediation and phytomining. *Bioresource Technology* **102**: 2228-2234. DOI: 10.1016/j.biortech.2010.10.014
- IPNI, International Plant Name Index. 2017. <<http://www.ipni.org/>> (accessed May 15, 2017).
- INEGI, Instituto Nacional de Estadística y Geografía. 2017. *Atlas Nacional Interactivo de México*. <<http://www.inegi.org.mx/>> (accessed May 15, 2017).
- Ishiyama N, Akasaka T, Nakamura F. 2014. Mobility-dependent response of aquatic animal species richness to a wetland network in an agricultural landscape. *Aquatic Sciences* **76**: 437-449. DOI: 10.1007/s00027-014-0345-8
- IUCN, International Union for Conservation of Nature. 2017. *Red List of threatened species*. 2015. <<http://www.iucnredlist.org/>> (accessed May 15, 2017).
- Jaccard P. 1908. Nouvelles recherches sur la distribution florale. *Bulletin Société Sciences Naturelles*, **44**: 223-270. DOI: 10.5169/seals-268384
- Kostel J. 2016. The wetlands initiative. Q: The wetlands initiative is helping farmers install wetlands to naturally reduce nutrient runoff. How exactly do wetlands remove nutrients? <<http://www.wetlands-initiative.org/nutrient-removal/>> (accessed May 15, 2017).
- Krebs CJ. 1999. *Ecological Methodology*. Menlo Park, California: Benjamin Cummings.
- Lacoul P, Fredman B. 2006. Environmental influences on aquatic plants in freshwater ecosystems. *Environmental Reviews* **14**: 89-136. DOI: 10.1139/a06-001

- Landgrave R, Moreno-Casasola P. 2012. Evaluación cuantitativa de la pérdida de humedales en México. *Investigación Ambiental* **4**: 19-35.
- Lee K, Shen CC, Lin CF, Li SY, Huang YL. 2012. A Phenolic Derivative and Two Diacetylenes from *Symphytotrichum subulatum*. *Planta Medica* **78**: 1780-1783. DOI: 10.1055/s-0032-1315372
- Linares E, Bye RA. 1987. A study of four medicinal plant complexes of Mexico and adjacent United States. *Journal of Ethnopharmacology* **19**: 153-183. DOI: 10.1016/0378-8741(87)90039-0
- Lorenzi H. 1991. *Plantas daninhas do Brasil: Terrestres, Aquáticas, Parasitas, Tóxicas e Medicinais*. Nova Odessa: Editora Plantarum.
- Lot A. 1986. Acuáticas Vasculares. In: Lot A, Chiang F. *Manual de Herbario*. México: Consejo Nacional de la Flora de México, 87-92.
- Lot A. 2012. Las monocotiledóneas acuáticas y subacuáticas de México. *Acta Botanica Mexicana* **100**: 135-148.
- Lot A, Novelo A, Ramírez-García P. 1986. *Listados florísticos de México V: Angiospermas acuáticas mexicanas 1*. México: Universidad Nacional Autónoma de México. 60 pp.
- Lot A, Novelo A, Ramírez-García P. 1993. Diversity of mexican aquatic vascular plant flora. In: Ramamoorthy TP, Bye R, Lot A, Fa J. *Biological Diversity of Mexico: origins and distribution*. New York: Oxford University.
- Lot A, Ramos F, Ramírez-García P. 2002. *Sagittaria demersa* (Alismataceae) en la Sierra Tarahumara, México. *Anales del Instituto de Biología - Serie Botánica* **73**: 95-97.
- Lot A, Lemos RM, Chiang F. 2013. *Plantas Acuáticas Mexicanas: una contribución a la Flora de México*. Vol I. México: Universidad Nacional Autónoma de México.
- Lot A, Olvera M, Flores C, Díaz A. 2015. *Guía ilustrada de Campo Plantas Indicadoras de Humedales*. México: Universidad Nacional Autónoma de México.
- Lu Y, Xu XL, Zhang DY, Zhu XN, Feng F, Zhou QJ, Xie P. 2014. Correlations between aquatic plant diversity and water environmental in the typical sites of Hangzhou section of the Beijing-Hangzhou Grand Canal. *Huan Jing Ke Xue* **35**: 1708-1717.
- Magalhães TL, Bortoluzzi RLC, Mantovani A. 2016. Plant distribution in freshwater wetlands of the Brazilian subtropical highland grasslands. *Brazilian Journal of Botany* **39**: 239-249. DOI: 10.1007/s40415-015-0226-y
- Martínez M, García A. 2001. Flora y vegetación acuática de localidades selectas del estado de Querétaro. *Acta Botanica Mexicana* **54**: 1-23. DOI: 10.21829/abm54.2001.864
- Martínez M, Vargas O, Rodríguez A, Chiang F, Ocegueda S. 2017. Solanaceae family in Mexico. *Botanical Sciences* **95**: 131-145. DOI: 10.17129/botsoci.658
- Marton JM, Creed IF, Lewis DB, Lane CR, Basu NB, Cohen MJ, Craft CB. 2015. Geographically isolated wetlands are important biogeochemical reactors on the landscape. *BioScience* **65**: 408-418. DOI: 10.1093/biosci/biv009
- Mauerhofer V, Kim RE, Stevens C. 2015. When implementation works: A comparison of Ramsar Convention implementation in different continents. *Environmental Science and Policy* **51**: 95-105. DOI: 10.1016/j.envsci.2015.03.016
- Medline. 2017 <<https://www.nlm.nih.gov/bsd/pmresources.html>> (accessed May 15, 2017).
- Mickel JT, Smith AR. 2004. The Pteridophytes of Mexico. In: *Memoirs of the New York Botanical Garden*, **88**. New York.
- Miranda AF, Biswas B, Ramkumar N, Singh R, Kumar J, James A, Roddick F, Lal B, Subudhi S, Bhaskar T, Mouradov A. 2016. Aquatic plant *Azolla* as the universal feedstock for biofuel production. *Biotechnology for Biofuels* **9**: 1-17. DOI 10.1186/s13068-016-0628-5.
- Mora-Olivo A, Villaseñor JL, Martínez M. 2013. Las plantas vasculares acuáticas estrictas y su conservación en México. *Acta Botanica Mexicana* **103**: 27-63. DOI: 10.21829/abm103.2013.50
- Murray-Hudson M, Lane CR, North S, Brown MT. 2012. Macrophyte Species Distribution, Indices of Biotic Integrity and Sampling Intensity in Isolated Florida Marshes. *Wetlands* **32**: 449-460. DOI: 10.1007/s13157-012-0278-8
- Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GA, Kent J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**: 853-858. DOI: 10.1038/35002501
- Olajuyigbe O, Ashafa A. 2014. Chemical Composition and Antibacterial Activity of Essential Oil of *Cosmos bipinnatus* Cav. *Leaves from South Africa*. *Iranian Journal of Pharmaceutical Research* **13**: 1417-1423.
- Olmos-Márquez MA, Alarcón-Herrera MT, Martín-Domínguez IR. 2012. Performance of *Eleocharis macrostachya* and its importance for arsenic retention in constructed wetlands. *Environmental Science and Pollution Research* **19**: 763-771. DOI: 10.1007/s11356-011-0598-x
- Ot'ahel'ová H, Valachovič M, Hrivnák R. 2007. The impact of environmental factors on the distribution pattern of aquatic plants along the Danube River corridor (Slovakia). *Limnological Ecology and Management of Inland Waters* **37**: 290-302. DOI: 10.1016/j.limno.2007.07.003

- Pekel JF, Cottam A, Gorelick N, Belward AS. 2016. High-resolution mapping of global surface water and its long-term changes. *Nature* **450**: 418-422. DOI: 10.1038/nature20584
- Pollock MM, Naiman RJ, Hanley TA. 1998. Plant species richness in riparian wetlands: a test of biodiversity theory. *Ecology* **79**: 94-105. DOI: 10.1890/0012-9658(1998) 079[0094:PSRIRW]2.0.CO;2
- Pott VJ, Pott A. 2000. *Plantas Acuáticas do Pantanal*. Brasília: Embrapa.
- R Development Core Team, 2017. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <<http://www.R-project.org>> (accessed January 28, 2017).
- Rai PK. 2008. Heavy metal pollution in aquatic ecosystems and its phytoremediation using wetlands plants: an ecosustainable approach. *International Journal of Phytoremediation* **10**: 133-160. DOI: 10.1080/15226510801913918
- Rico-Romero SER. 2015. *Relación entre las algas y plantas acuáticas en cuerpos de agua de Querétaro y Guanajuato*. BSc Thesis, Universidad Autónoma de Querétaro.
- Rocha DC, Martins D. 2011. Adaptações morfoanatômicas de Cyperaceae ao ambiente aquático. *Planta Daninha* **29**: 7-15. DOI: 10.1590/S0100-83582011000100002
- Rolon AS, Homem HF, Maltchik L. 2010. Aquatic macrophytes in natural and managed wetlands of Rio Grande do Sul State, Southern Brazil. *Acta Limnológica Brasileira* **22**: 133-146. DOI: 10.4322/actalb.02202003
- Rzedowski J. 1978. *Vegetación de México*. Ciudad de México: Limusa.
- Rzedowski JR, Rzedowski GC (Eds.). 2017. *Flora del Bajío y Regiones Adyacentes*. <<http://www1.inecol.edu.mx/publicaciones/FLOBA.htm>> (accessed May 15, 2017).
- SEMARNAT [Secretaría del Medio Ambiente y Recursos Naturales]. 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, 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*. 2da Sección, 30 de diciembre de 2010.
- Smith AR, Pryer KM, Schuettpelz E, Korall P, Schineider H, Wolf PG. 2006. A classification for extant ferns. *Taxon* **55**: 705-731. DOI: 10.2307/25065646
- Sohn SH, Yun BS, Kim SY, Choi WS, Jeon HS, Yoo JS, Kim SK. 2013. Anti-inflammatory activity of the active components from the roots of *Cosmos bipinnatus* in lipopolysaccharide-stimulated RAW 264.7 macrophages. *Natural Product Research* **27**: 1037-1040. DOI: 10.1080/14786419.2012.686906
- Thiers, B. [continuously updated]. Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. <<http://sweetgum.nybg.org/science/ih/>> (accessed May 15, 2017).
- Tropicos. 2017. <<http://www.tropicos.org/>> (accessed May 15, 2017).
- Tsuji K, Asayama T, Shiraki N, Inoue S, Okuda E, Hayashi C, Nishida K, Hasegawa H, Harada E. 2017. Mn accumulation in a submerged plant *Egeria densa* (Hydrocharitaceae) is mediated by epiphytic bacteria. *Plant, Cell & Environment* **40**: 1163-1173. DOI: 10.1111/pce.12910
- Uden DR, Hellman ML, Angeler DG, Allen CR. 2014. The role of reserves and anthropogenic habitats for functional connectivity and resilience of ephemeral wetlands. *Ecological Applications* **24**: 1569-1582. DOI: 10.1890/13-1755.1
- Villaseñor JL, Espinosa-García FJ. 1998. Catálogo de malezas de México. Ciudad de México: Universidad Nacional Autónoma de México.
- Villaseñor JL, Ortiz E. 2014. Biodiversidad de las plantas con flores (División Magnoliophyta) en México. *Revista Mexicana de Biodiversidad* **85**: 134-142. DOI: 10.7550/rmb.31987
- Wei T, Simko V. 2017. R package “corrplot”: Visualization of a Correlation Matrix (Version 0.84). <<https://github.com/taiyun/corrplot>> (accessed May 15, 2017)
- Zedler JB, Kercher S. 2005. Wetland resources: status, trends, ecosystems services, and restorability. *Annual Review of Environmental Resources* **30**: 39-74. DOI: 10.1146/annurev.energy.30.050504.144248

Appendix 1. Temporary wetlands localization of the studied areas and water parameters. * Average of four measurements with Hanna equipment model HI 9829 ** the wetland was dry.

Site	Municipality	State	Latitude	Longitude	Altitude	pH*	ppmDO*	µSTm*	mΩ*	ppmT*	PSU*
1	Asientos	Aguascalientes	22.1769	-102.0252	2,009	6.7	5.90	681.5	0.0015	343.75	0.3375
2	Asientos	Aguascalientes	22.1847	-102.0214	2,004	6.4	7.17	112.5	0.0089	57.50	0.0525
3	Asientos	Aguascalientes	22.1986	-102.064	2,058	6.1	5.75	86.3	0.0143	44.00	0.0400
4	Asientos	Aguascalientes	22.1974	-102.0725	2,078	6.0	5.62	65.0	0.0152	34.00	0.0300
5	Calvillo	Aguascalientes	21.8885	-102.8437	2,342	6.0	4.54	55.0	0.0165	31.00	0.0300
6	Calvillo	Aguascalientes	21.8915	-102.8448	2,345	5.0	4.69	24.5	0.0502	15.00	0.0150
7	Calvillo	Aguascalientes	21.884	-102.8464	2,382	6.0	2.84	73.5	0.0131	39.00	0.0375
8	San José de Gracia	Aguascalientes	22.1681	-102.4166	2,031	5.3	3.71	200.5	0.0050	103.25	0.0975
9	San José de Gracia	Aguascalientes	22.1588	-102.4848	2,047	5.4	5.02	24.0	0.0380	13.75	0.0125
10	San José de Gracia	Aguascalientes	22.1688	-102.5834	2,580	4.8	4.75	6.0	0.0161	3.75	0.0050
11	San José de Gracia	Aguascalientes	22.1905	-102.6102	2,613	4.8	4.31	6.5	0.1260	7.00	0.0050
12	San José de Gracia	Aguascalientes	22.1627	-102.6511	2,646	4.9	6.15	2.0	0.1250	1.00	0.0000
13	Jerécuaro	Guanajuato	20.2542	-100.5477	2,123	5.0	2.67	141.5	0.0065	80.00	0.0800
14	San Felipe	Guanajuato	21.3232	-101.6058	2,669	5.0	4.37	78.5	0.0147	41.00	0.0400
15	San Miguel de Allende	Guanajuato	20.8064	-101.0356	2,303	6.0	2.80	48.8	0.0207	24.50	0.0200
16	San Miguel de Allende	Guanajuato	20.8089	-101.0339	2,307	6.3	7.84	30.5	0.0332	15.25	0.0100
17	San Miguel de Allende	Guanajuato	20.8033	-101.0308	2,276	6.8	5.91	36.0	0.0278	18.00	0.0200
18	Santa Cruz de Juventino Rosas	Guanajuato	20.7492	-101.0244	2,189	6.8	5.88	73.5	0.0136	36.75	0.0300
19	Lagos de Moreno	Jalisco	21.3813	-102.1381	1,992	5.0	5.50	120.8	0.0080	62.25	0.0600
20	Lagos de Moreno	Jalisco	21.334	-102.0883	1,964	5.0	3.39	171.8	0.0060	89.00	0.0850
21	Lagos de Moreno	Jalisco	21.3307	-102.0851	1,975	5.0	3.70	42.8	0.0210	25.75	0.0225
22	Lagos de Moreno	Jalisco	21.3756	-102.1353	2,021	5.0	6.56	8.3	0.1450	5.75	0.0075
23	Epitacio Huerta	Michoacán	20.1405	-100.2947	2,508	5.0	5.58	146.8	0.0069	74.75	0.0725
24	Amealco de Bonfil	Querétaro	20.2903	-100.185	2,314	6.7	1.87	85.8	0.0118	43.00	0.0375
25	Amealco de Bonfil	Querétaro	20.2122	-100.1186	2,577	6.4	1.85	152.0	0.0066	77.75	0.0725
26	Amealco de Bonfil	Querétaro	20.1717	-100.0733	2,614	**	**	**	**	**	**
27	Amealco de Bonfil	Querétaro	20.3181	-100.1442	2,245	7.2	4.83	181.8	0.0070	91.75	0.0875
28	Amealco de Bonfil	Querétaro	20.312	-100.2063	2,359	5.0	1.82	111.3	0.0091	60.00	0.0575
29	Huimilpan	Querétaro	20.3922	-100.2692	2,318	7.2	2.89	501.8	0.0020	249.75	0.2425
30	Pedro Escobedo	Querétaro	20.3994	-100.2686	2,324	7.3	4.83	127.0	0.0079	63.50	0.0600
31	Pedro Escobedo	Querétaro	20.4164	-100.2661	2,266	6.8	3.47	40.8	0.0243	20.50	0.0200
32	San Juan del Río	Querétaro	20.3283	-100.1328	2,222	7.0	5.71	82.5	0.0135	42.00	0.0375
33	Mexquitic de Carmona	San Luis Potosí	22.2293	-101.2941	2,045	5.0	5.62	39.5	0.0279	22.00	0.0200
34	Villa de Arriaga	San Luis Potosí	21.9556	-101.1876	2,147	5.0	6.56	8.3	0.0700	5.75	0.0075
35	Cañitas de Felipe Pescador	Zacatecas	23.5742	-102.7525	2,032	8.0	4.75	513.0	0.0029	181.50	0.1800
36	Pinos	Zacatecas	22.4481	-101.4958	2,141	9.4	6.88	190.3	0.0053	95.25	0.0900
37	Teúl de González Ortega	Zacatecas	21.4524	-103.4746	1,961	5.0	6.47	6.5	0.1172	4.50	0.0250
38	Tlaltenango de Sánchez Román	Zacatecas	21.7018	-103.1778	2,563	5.0	5.41	121.0	0.0082	68.50	0.0750
39	Villa de Cos	Zacatecas	23.1225	-102.4367	2,008	8.2	7.51	402.0	0.0026	199.50	0.1850

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