

## THE GRASS FAMILY (POACEAE) IN COAHUILA, MEXICO: DIVERSITY AND DISTRIBUTION

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**Abstract:** We analyzed the species richness of the grass family (Poaceae) in the state of Coahuila, Mexico, evaluating data from herbarium specimens. The evaluation was made by dividing the state into a grid of 20' × 20' squares (latitude × longitude), the objective was to identify areas of high species diversity. The herbaria revision documented 319 species of grasses, distributed in eight subfamilies, 19 tribes, and 97 genera. The genera with the highest number of species are *Muhlenbergia* (32 species), *Bouteloua* (21), and *Eragrostis* (18). Seven species are endemic to Northeastern Mexico (*Bromus densus*, *Bouteloua eriostachya*, *B. johnstonii*, *Calamagrostis coahuilensis*, *Festuca coahuilana*, *F. valdesii*, and *Poa wendtii*) and, 58 species, plus one subspecies and one variety are rare. Because arid areas cover a larger portion of the state, the subfamily Chloridoideae is dominant with 125 species. The subfamily Panicoideae has a record of 87 species and is mainly present in humid regions, while the Pooideae is abundant in the mountain regions of southeast and northwest, and includes 86 species. We evaluated the species richness for each grid square and propose some of these as important areas to carry out future conservation projects.

**Keywords:** conservation, endemism, grasses, species richness.

**Resumen:** Se analiza la riqueza de la familia de las gramíneas (Poaceae) en el estado de Coahuila, México, para lo cual se evalúan datos de los ejemplares de herbario recolectados, identificados y georreferenciados, provenientes de dicha región. Utilizando una división de la región en cuadros de 20' × 20' (latitud × longitud), el objetivo fue identificar los sitios de alta diversidad para la familia. La región tiene documentadas, con ejemplares de herbario, 319 especies de Poaceae distribuidas en ocho subfamilias, 19 tribus y 97 géneros. Los géneros que tienen mayor número de especies son *Muhlenbergia* (32 especies), *Bouteloua* (21) y *Eragrostis* (18). Siete especies son endémicas del estado: *Bouteloua eriostachya*, *B. johnstonii*, *Bromus densus*, *Calamagrostis coahuilensis*, *Festuca coahuilana*, *F. valdesii* y *Poa wendtii*. Se consideran como gramíneas raras a 58 especies, una variedad y una subespecie. Debido a que en el estado las zonas áridas ocupan una mayor superficie, domina la subfamilia Chloridoideae, la cual posee 125 especies. Los miembros de la subfamilia Panicoideae se presentan en las zonas húmedas con 87 especies, mientras que las Pooideae son abundantes en las zonas montañosas del sureste y noroeste del estado, donde se presentan 86 especies. Se evalúa la riqueza por cuadro y se proponen algunos como importantes para llevar a cabo futuras estrategias de conservación con base en los patrones de riqueza encontrados.

**Palabras clave:** conservación, endemismo, gramíneas, riqueza de especies.

Studies on biodiversity at different scales (continent, country, national parks, or natural protected areas) constitute the basis for conservation and for establishing plans for proper management of natural resources (Smith and Wolfson, 2004; Klopper *et al.*, 2007; Finot *et al.*, 2009). Mexico is an important center of biodiversity clustering and endemism (hotspot), compared with other political entities of the World (Mittermeier, 1988; Villaseñor, 2003; Villaseñor and Ortiz, 2012). Floristic inventories are revealing regions with high plant diversity; however, many states of Mexico have not

documented their plant richness and it is difficult to estimate the true richness they harbor; some states have degraded so much their landscape that it is difficult to determine the biodiversity because a high rate of the species are attributed to anthropogenic disturbance (Villaseñor and Ortiz, 2012).

Chorological studies of Mexican Poaceae (Valdés and Cabral, 1993) identified regions of high species diversity for the subfamilies Chloridoideae, Pooideae, and Panicoideae. They indicate centers of endemism and mention 272 endemic species, mostly belonging to the subfamily Chloridoi-

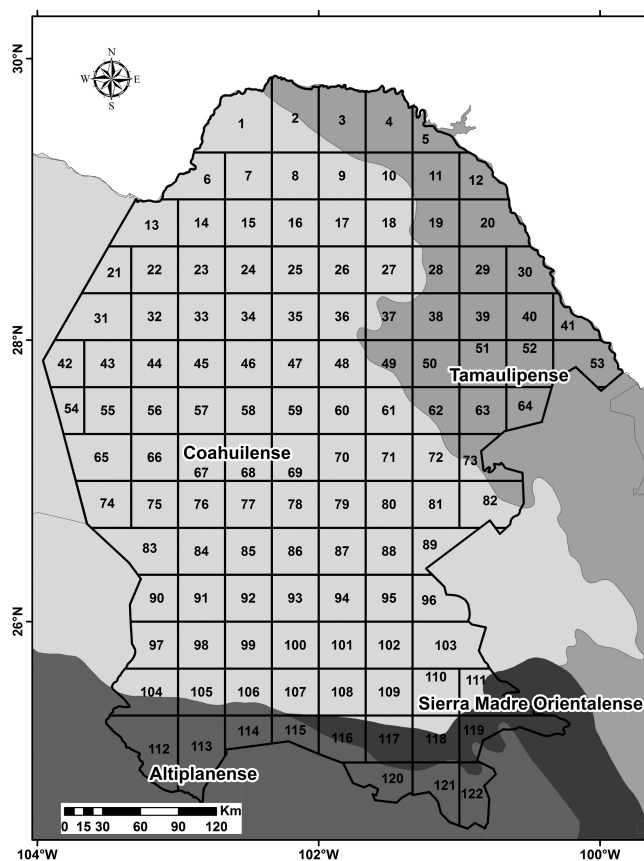


Figure 1. The morphotectonic provinces occurring in Coahuila.

deae (73 species). For Mexico, Valdés and Dávila (1995), and Dávila *et al.* (2006) list 204 genera, 1,182 species, and 207 subspecific categories; 1,119 are native, 278 are endemic to Mexico, and 159 are introduced, several of them known only under cultivation.

The state of Coahuila, located in northeastern Mexico includes wide arid and semi-arid regions, as well as several mountain and subtropical ones, harboring a rich grasses flora. The state is divided into two important eco-regions or diversification centers for species of arid zones, the Chihuahuan desert and the Tamaulipan desert, the figure 1 shows the morphotectonic provinces occurring in Coahuila. This study emerges from the necessity to update the checklist of the grasses in the state and determine localities that have high species richness. The main objective of this study was to determine patterns of species richness and estimate areas of high species diversity for the grasses of Coahuila.

**Materials and methods**

We generated a database for the known grass species in Coahuila. The data base contains 3,250 records collected along the state’s political territory (Valdés, 1977; Valdés and Dávila, 1998). Specimens reviewed are registered in several herbaria, both in Mexico and foreign places (ANSM,

ARIZ, CIIDIR-DURANGO, COCA, CHAPA, ENCB, GH, MEXU, MICH, MO, NMCR, TAES, TEX, UAT, US, and WIS). Their study allowed us to verify their occurrences in the state. Also we reviewed the literature recently published on grass systematics, which includes nomenclatural changes for some genera and species distributed in the state of Coahuila (Bell *et al.*, 2012; Peterson *et al.*, 2012; Snow *et al.*, 2013; Peterson *et al.*, 2014; Saarela *et al.*, 2014).

The information from collecting locations was employed to georeference specimens and then, to spatially validate latitude and longitude coordinates using the geographical information system software ArcMap 10 (ESRI, 2010).

We carried out a pattern diversity analysis dividing Coahuila into a grid squares network. The size of the grid squares or cells defined, followed recommendations of the International Union for Nature Conservation (IUCN, 2001) for estimating Areas of Occupancy (AOO). This agency suggests that in order to determine the AOO of a species, grid square size should be 10% of the distance between the two more distant gathering locations known for the species. In our analysis, AOO for each species was estimated by using a GIS extension for ArcView (Moat, 2007). The AOO median

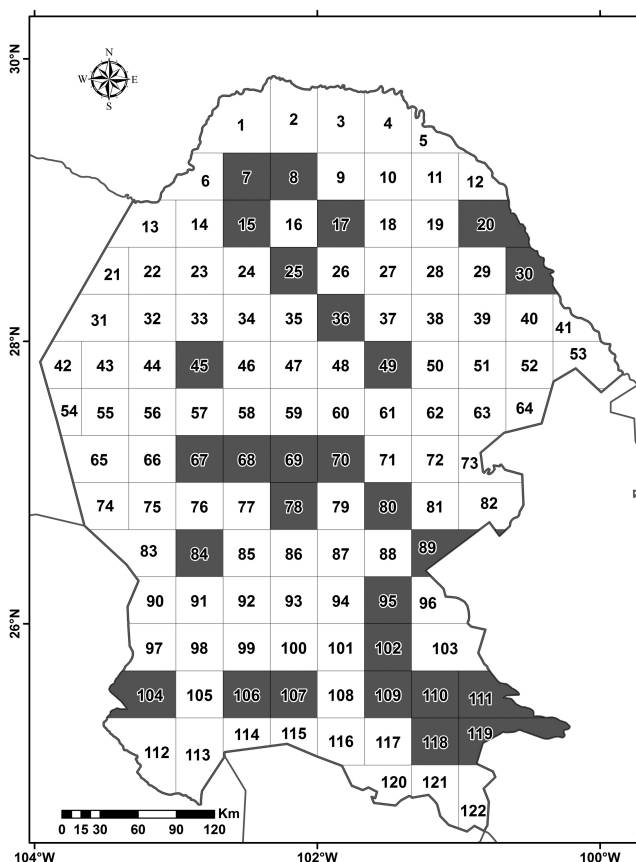


Figure 2. State of Coahuila divided in 122 grid squares 20’ (latitude and longitude size). Shaded grid squares are considered irreplaceable for conservation purposes since they contain exclusive species.

values of all estimates was obtained and used to determine cell size and this was applied to all species (Suárez-Mota and Villaseñor, 2011). The median obtained for cell size was 34.5 km per side, which is close to 20 arc minutes latitude and longitude. An edge effect resulted in cells of lesser size; therefore, those with a surface less than 50% of a full cell size were fused with a neighbor cell. In this way, the state of Coahuila was divided into 122 grid squares (Figure 2). This grid square system allowed us to determine the species richness for each cell by intersecting with the GIS the collecting locations from all the state's political surface.

*Species accumulation curve.* The species accumulation curves, because they consider rarity or abundance, are important emerging tools for estimating floristic richness from a place or region (Koellner *et al.*, 2004). To evaluate how exhaustive the Poaceae inventory was in the herbaria studied, we obtained a species accumulation curve by using EstimateS version 8.2.0 software (Colwell and Coddington, 1994; Colwell, 2009). As a measure of the collecting effort, we considered the 20 arc minute cell size and we calculated the estimated richness using a parametric coefficient based on Clench's function (Jiménez-Valverde and Hortal, 2003) using Statistica version 10 software (StatSoft Inc., 2011). This function is now widely used to estimate the accumulation curves of the expected floristic richness. Soberón and Llorente (1993) explain with details Clench's function and discuss its usefulness and limitations in biological inventories.

*Priority sites for conservation of Poaceae of Coahuila.* Once we obtained the species geographical distribution by cell, we identified those with high species richness. Among them, those with exclusive species; i.e. species recorded only in this grid square. Such cells were considered as irreplaceable sites, if we want to carry out efficient conservation strategies of known species.

Species richness by cells helped us carry out a complementary heuristic analysis (Villaseñor *et al.*, 2003) by ranking the cells in which the state was divided. Thus, we were

able to identify priority sites for conservation. In this work, endemism was not considered, only total species richness. Therefore, the complementary method (Villaseñor *et al.*, 2003) was modified to not account ties in the number of endemic species (step 3 of algorithm), going directly to step 4 ("in case of a tie, the cell closest to one already selected will be selected"). If ties persisted, the cell with higher species richness was selected.

## Results

To date, 319 species of Poaceae were recorded in Coahuila, all of them based on a herbarium specimen. The species are distributed in eight subfamilies, 19 tribes, and 97 genera (Table 1). Subfamily Chloridoideae, primarily distributed in arid zones, includes 125 species. Subfamily Panicoideae, usually found in more humid environments, includes 87 species, and Pooideae, found primarily in mountain temperate regions, includes 86 species. The other subfamilies include fewer species: Aristidoideae (12 spp.); Arundinoideae (2 spp.), Bambusoideae (2 spp.), Danthonioideae (2 spp.), and Ehrhartoideae (2 spp.). In Coahuila there are 253 native species and 65 naturalized or introduced species from Europe, Eurasia, Africa, and South America (Table 2). The genera with the most species are: *Muhlenbergia* (32), *Bouteloua* (21), *Eragrostis* (18), *Sporobolus* (13), *Aristida* (12), *Setaria* (11), and *Panicum* (11). In addition, 58 species are considered rare because their distribution is known only from one or just a few localities, and seven of these are endemic to the state: *Bouteloua eriostachya*, *B. johnstonii*, *Bromus densus*, *Calamagrostis coahuilensis*, *Festuca coahuilana*, *F. valdesii*, and *Poa wendtii*.

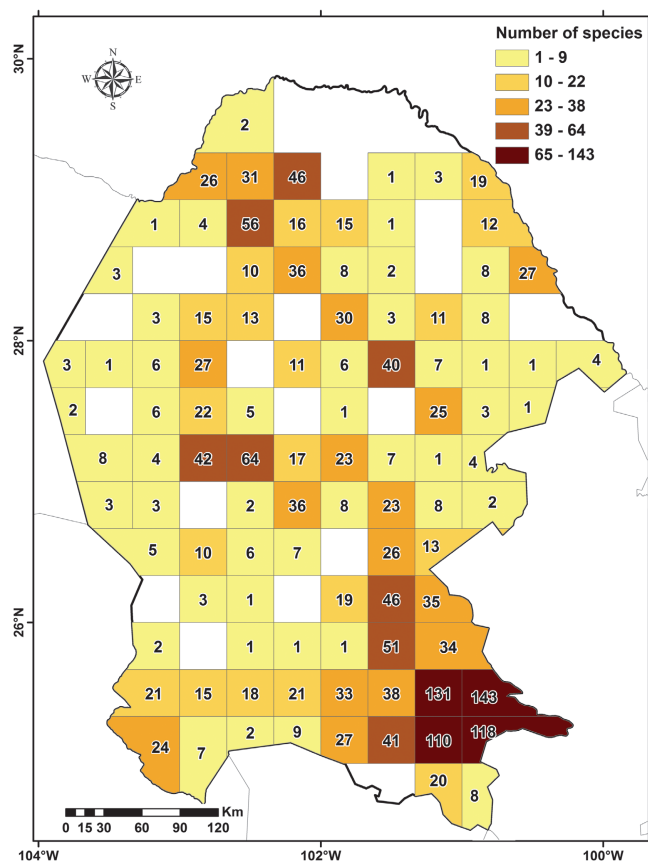
Poaceae richness does not distribute homogeneously in Coahuila. Figure 2 shows the state divided in 122 grid squares 20' × 20' latitude and longitude (about 1,133 km<sup>2</sup>), and grasses were only found in 99 (Figure 3). Our results indicate 81% of the area is inequitably sampled, because 51 of the grid squares scored from 1 to 9 species, whereas 19 scored between 10 to 22 species, 17 scored between 23 and 38 species and only 12 scored more than 39 species.

The species accumulation curve (Figure 4) shows the number of species collected as a function of sampling effort in the grid squares. The curve reveals a confident, although incomplete inventory. The estimated species richness when the asymptote is reached [ $y = 16.13236x(1 + 0.040668)^{-1}$ ] suggests the inventory will be completed with 396 species. Therefore, it still remains to add about 73 additional species to the state richness (80.5% completeness).

Most species (96) restrict their distribution to a single grid square; 58 additional species are known from two squares. In general, 75.7% of total richness is known from no more than five squares and only eight species (2.6%) are recorded from 15 or more squares. The widespread species are: *Aristida adscensionis*, *A. purpurea*, *Bouteloua curtipendula*,

**Table 1.** Number of grass subfamilies, tribes, genera, and species recorded in Coahuila.

Subfamily	Tribe	Genera	Species
Bambusoideae	2	2	2
Ehrhartoideae	1	1	2
Pooideae	7	36	86
Panicoideae	3	27	88
Danthonioideae	1	2	2
Arundinoideae	1	2	2
Aristidoideae	1	1	12
Chloridoideae	3	26	125
Total	19	97	319



**Figure 3.** Distribution of Poaceae species richness in the grid squares used to divide the state of Coahuila.

*Disakisperma dubium*, *Muhlenbergia tenuifolia*, *Panicum hallii*, *Setaria leucopila*, and *Tridentopsis mutica*.

The 96 grass species restricted to a single grid square represent Coahuila it is rare elements. These species are found in only 28 squares and are considered irreplaceable for conservation (Figure 2), because they must be considered, if we want to assure the long-term survival of these grasses. The 28 irreplaceable grid squares record 313 out of the 316 species. The three species not recorded are: *Aristida oligan-*

**Table 2.** Number of native, rare, endemic, and introduced grasses in Coahuila.

Subfamily	Native	Rare	Endemic	Introduced
Bambusoideae	--	--	-	2
Ehrhartoideae	1	--	-	1
Pooideae	65	15	5	21
Panicoideae	64	20	-	23
Danthonioideae	2	1	-	-
Arundinoideae	--	--	-	2
Aristidoideae	12	--	-	-
Chloridoideae	109	22	2	16
Total	253	58	7	65

**Table 3.** Grass species richness in 28 grid squares (Figure 1) or irreplaceable sites (with species exclusive to the grid) in Coahuila. Abbreviations of morphotectonic provinces are: ALTI = Altiplanense, COAH = Coahuilense, SMOR = Sierra Madre Orientalense, TAMA = Tamaulipense

Grid square	Total species	Exclusive species	Morphotectonic province
7	31	4	COAH
8	46	1	COAH
15	56	2	COAH
17	15	1	COAH
20	12	2	TAMA
25	36	2	COAH
30	27	3	TAMA
36	30	1	COAH
45	27	1	COAH
49	40	4	COAH
67	42	1	COAH
68	64	6	COAH
69	17	1	COAH
70	23	2	COAH
78	36	7	COAH
80	23	1	COAH
84	10	1	COAH
89	13	2	COAH
95	46	1	COAH
102	51	2	COAH
104	21	1	ALTI, COAH
106	18	1	ALTI, COAH
107	21	2	ALTI, COAH
109	38	2	COAH
110	131	17	COAH
111	143	14	COAH,SMOR
118	110	7	COAH,SMOR
119	118	7	SMOR

*tha*, *Paspalum urvillei*, and *Setariopsis auriculata*. Table 3 summarizes the number of species recorded in each of the 28 squares, and also includes their position according to the morphotectonic provinces in Coahuila (Figure 1) (Ferrusquía-Villafranca, 1990). The Coahuilense province records the larger number of grid squares (20); the Tamaulipense province includes two (grid squares 20 and 30), one in the Sierra Madre Orientalense province (grid 119) and five additional grids combine territories between two adjoining provinces, as are the Altiplanense and Coahuilense provinces (grids 104, 106, and 107) or Coahuilense and Sierra Madre Orientalense (grids 111 and 118).

Table 4 summarizes the Poaceae richness recorded in the morphotectonic provinces occurring in Coahuila. The Coahuilense province has 281 species with 78 species known only from this province. The Sierra Madre Orientalense province contains 174 species with 17 unique species. The Tamaulipense province includes 90 species and ten of

**Table 4.** Morphotectonic provinces in Coahuila and grass species richness. Between parentheses is the number of irreplaceable grid squares restricted to the selected province or shared with its neighbor province.

Morphotectonic province	Species	Exclusive species	Irreplaceable grids
ALTI	56	2	3(3)
COAH	281	78	24(5)
SMOR	174	17	3(3)
TAMA	90	10	2

these are unique to the province. The Altiplanense province has 56 species and two unique species.

Since 28 grid squares identified are irreplaceable and contain 99% of the Poaceae richness, we carried out a complementary analysis of these 28 grid squares excluding the three unplaced species. Table 5 sorts the 28 grid squares containing most of the species in descending order; their distribution covers all the state's territory and their configuration could allow the establishment of corridors to facilitate species mobility among most of them. This strategy could guarantee the surviving of both, the species restricted to their territory as the other more widespread species. So the higher grids have diverse habitats worthy of preservation.

### Discussion

The 319 Poaceae species recorded in Coahuila represent 10.5% of the total floristic richness reported by Villarreal (2001) for all plants; additionally, these 319 species represent 26.9% of the Poaceae richness in Mexico, and 2.5% (seven spp.) represent the country endemics (Dávila *et al.*, 2006). Rzedowski (1975) considers that the high grass richness found in Mexico reflects the autochthonous origin of the flora, this pattern is also found in the state of Coahuila. The dominance of species in the Chloridoideae, mostly

found in arid and semi-arid environments, also corresponds with the dominant environment in the state (Valdés, 1977).

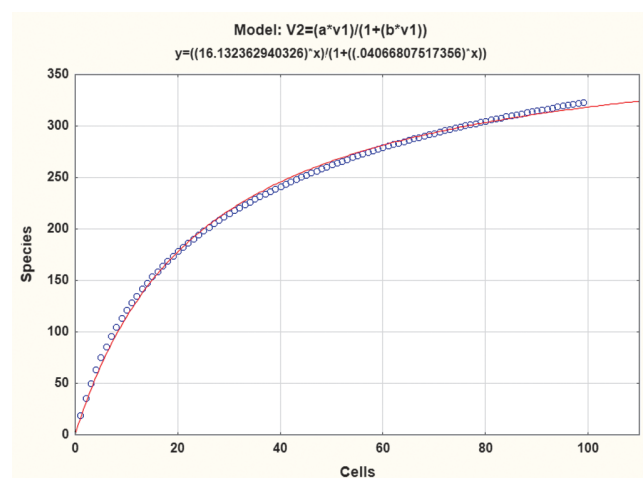
Areas with the highest species richness in Coahuila are also important collecting sites and have attracted notable botanical explorers such as Edward Palmer and Cyrus Pringle. The high rate of endemism is also related to this phenomenon, although other regions, such as Cuatro Ciénegas or the Sierra Maderas del Carmen, without strong historical records, are centers of endemism (Villarreal-Quintanilla and Encina-Domínguez, 2005).

The effort accumulation curve using Clench's function indicates a Poaceae richness of 81.5%, pointing to an increase of 73 species (Koellner *et al.*, 2004). Our results denote the need to increase the collecting effort in 23 grid squares (19% of state's surface) where no grasses have been recorded (Figure 3). Surely their exploration will extend the known distribution of many species and add new records.

The Coahuilense morphotectonic province contains the greatest number of irreplaceable sites (24 grid squares with exclusive species), although four of them are shared with

**Table 5.** Hierarchical arrangement of grid squares selected to establish a conservation strategy for the grasses in Coahuila.

Priority	Grid square	Complement	% species accumulated
1	111	170	45.7
2	110	117	62.6
3	119	93	70.3
4	118	81	74.1
5	49	70	77.6
6	7	60	80.8
7	68	51	83.7
8	25	43	86.3
9	78	36	88.5
10	15	32	89.8
11	30	28	91.0
12	109	25	92.0
13	70	22	93.0
14	67	20	93.6
15	95	18	94.2
16	102	16	94.9
17	36	14	95.5
18	107	12	96.2
19	89	10	96.8
20	20	8	97.4
21	8	7	97.8
22	45	6	98.1
23	80	5	98.4
24	106	4	98.7
25	69	3	99.0
26	17	2	99.4
27	104	1	99.7
28	84	0	100.0



**Figure 4.** Species accumulation curve for Poaceae in the state of Coahuila. The curve's asymptote is reached at 396 species.

two neighbor provinces (Altiplanense and Sierra Madre Orientalense) because this offers many diverse habitats. The Altiplanense province has three irreplaceable sites and it is found in the southern part of the state (112, 113, 114, 115, 116, 117, 120, 121, and 122). This province has higher grass richness further south in San Luis Potosí and Zacatecas, seen in the Asteraceae (Balleza and Villaseñor, 2011). In contrast, the Sierra Madre Orientalense province, which also finds its northernmost limit in the state (grid squares 111, 115, 116, 117, 118, 119, and 122) records three irreplaceable sites (grids 111, 118, and 119), sharing its foothills with the Coahuilense province.

The 28 irreplaceable grid squares include a surface of about 31,724 km<sup>2</sup>, representing a little more than 21% of the state's surface (Figure 2). Undoubtedly this area is too large to be considered in conservation strategies. However, its identification will allow the planning and further action, such as forming conservation refuges. These highly unique areas will be then inventoried for other plants and animals. In this way, we can contribute to the scientific knowledge and begin to initiate a list of possible areas to protect in the future.

The southeastern edge of the state where the Sierra Madre Orientalense morphotectonic province exists has the largest floristic richness. The three irreplaceable grid squares in this region have high richness values (Table 4). There are many diverse habitats in this region and it is located within the confluence of two provinces, these squares increase the biogeographical complexity and the environmental heterogeneity, which favor the occurrence of a large number of species. This region was identified as a biogeographic node for the Asteraceae (González-Zamora *et al.*, 2007), where the nodes represent regions with biotic elements from different sources; i.e., from different geological origins and climatic regimes. All these factors combine to promote a high biodiversity and increased endemism (hotspots). This area is important because it contains a diverse assemblage of grasses and should be considered for conservations measures. Additional studies on the diversity and distribution of introduced and invasive species (Valdés, 2008) are needed to understand the impact of agricultural and forest practices. Our results emphasize the need for ongoing collecting activities in Coahuila, particularly of grasses and other organisms, especially in the already protected natural areas.

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**Appendix 1.** List of species of Poaceae recorded in the state of Coahuila. (\*) indicates endemic to the states, (°) exotic or introduced species, and (†) rare species. The list includes subspecific taxa although they were not used in the analysis.

<i>Achnatherum editorum</i> (E.Fourn.) Valdés-Reyna & Barkworth	* <i>Bothriochloa hirtifolia</i> (J.Presl) Henrard
<i>Achnatherum eminens</i> (Cav.) Barkworth	* <i>Bothriochloa ischaemum</i> (L.) Keng var. <i>songarica</i> (Rupr. ex Fisch. & Meyen) Celerier & J.R.Harlam
<i>Achnatherum hirticulme</i> (S.L.Hatch, Valdés-Reyna & Morden) Valdés-Reyna & Barkworth	<i>Bothriochloa laguroides</i> (DC.) Herter subsp. <i>torreyana</i> (Steud.) Allred & Gould
<i>Achnatherum lobatum</i> (Swallen) Barkworth	<i>Bothriochloa saccharoides</i> (Sw.) Rydb. subsp. <i>reevesii</i> (Gould) Allred & Gould
<i>Achnatherum multinode</i> (Scribn. ex Beal) Valdés-Reyna & Barkworth	* <i>Bothriochloa springfieldii</i> (Gould) L.R.Parodi
<i>Achnatherum robustum</i> (Vasey) Barkworth	<i>Bouteloua aristidooides</i> (Kunth) Griseb.
<i>Agrostis hyemalis</i> (Walter) Britton, Sterns & Poggenb.	<i>Bouteloua barbata</i> Lag.
* <i>Allolepis texana</i> (Vasey) Soderstrom & Decker	<i>Bouteloua chasei</i> Swallen
<i>Amelichloa clandestina</i> (Hack.) Arriaga & Barkworth	<i>Bouteloua chondrosioides</i> (Kunth) Benth.ex Watson
<i>Andropogon gerardii</i> Vitman	<i>Bouteloua curtispindula</i> (Michx.)Torr. var. <i>caespitosa</i> Gould & Kapadia
<i>Andropogon glomeratus</i> (Walter) Britton, Sterns & Poggenb.	<i>Bouteloua curtispindula</i> (Michx.)Torr. var. <i>curtispindula</i>
<i>Aristida adscensionis</i> L.	* <i>Bouteloua curtispindula</i> (Michx.) Torr. var. <i>tenuis</i> Gould & Kapadia
<i>Aristida arizonica</i> Vasey	<i>Bouteloua dactyloides</i> (Nutt.) Columbus
<i>Aristida curvifolia</i> E.Fourn.	* <i>Bouteloua erecta</i> (Vasey & Hack.) Columbus
<i>Aristida divaricata</i> Humb. & Bonpl. ex Willd.	<i>Bouteloua eriopoda</i> (Torr.) Torr.
<i>Aristida eludens</i> Allred & Valdés-Reyna	* <i>Bouteloua eriostachya</i> (Swallen) J.Reeder
<i>Aristida gypsophyla</i> Beetle fo. <i>gypsophyla</i>	<i>Bouteloua gracilis</i> (Willd. ex Kunth) Lag. ex Steud.
<i>Aristida gypsophyla</i> Beetle fo. <i>gypsophyloides</i> Allred & Valdés-Reyna	<i>Bouteloua hirsuta</i> Lag.
<i>Aristida havardii</i> Vasey	* <i>Bouteloua johnstonii</i> Swallen
<i>Aristida oligantha</i> Michx.	<i>Bouteloua karwinskii</i> (E.Fourn.) Griffiths
<i>Aristida pansa</i> Wooton & Standl. fo. <i>contracta</i> Allred & Valdés-Reyna	* <i>Bouteloua parryi</i> (E.Fourn.) Griffiths
<i>Aristida pansa</i> Wooton & Standl. fo. <i>dissita</i> (I. M. Johnston) Allred & Valdés-Reyna	<i>Bouteloua radicata</i> (E.Fourn.) Griffiths
<i>Aristida pansa</i> Wooton & Standl. fo. <i>pansa</i>	<i>Bouteloua ramosa</i> Scribn. ex Vasey
<i>Aristida purpurea</i> Nutt. fo. <i>brownii</i> (Warnock) Allred & Valdés-Reyna	<i>Bouteloua repens</i> (Kunth) Scribn. & Merr.
<i>Aristida purpurea</i> Nutt. var. <i>fendleriana</i> (Steud.) Vasey	<i>Bouteloua simplex</i> Lag.
<i>Aristida purpurea</i> Nutt. var. <i>longiseta</i> (Steud.) Vasey	<i>Bouteloua trifida</i> S.Watson
<i>Aristida purpurea</i> Nutt. var. <i>nealleyi</i> (Vasey) Allred	<i>Bouteloua uniflora</i> Vasey var. <i>coahuilensis</i> Gould & Kapadia
<i>Aristida purpurea</i> Nutt. var. <i>perplexa</i> Allred & Valdés-Reyna	<i>Bouteloua uniflora</i> Vasey var. <i>uniflora</i>
<i>Aristida purpurea</i> Nutt. var. <i>purpurea</i>	* <i>Bouteloua warnockii</i> Gould & Kapadia
<i>Aristida purpurea</i> Nutt. var. <i>wrightii</i> (Nash) Allred	<i>Brachypodium mexicanum</i> (Roem & Schult.) Link. var. <i>inermis</i> Beetle
<i>Aristida schiedeana</i> Trin. & Rupr. var. <i>orcuttiana</i> (Vasey) Allred & Valdés-Reyna	<i>Brachypodium mexicanum</i> (Roem & Schult.) Link. var. <i>mexicanum</i>
<i>Aristida schiedeana</i> Trin. & Rupr. var. <i>schiedeana</i>	* <i>Brachypodium pringlei</i> Scribn. ex Beal
<i>Aristida ternipes</i> Cav. var. <i>gentilis</i> (Henrard) Allred	<i>Bromus anomalus</i> Rupr. ex E. Fourn.
<i>Aristida ternipes</i> Cav. var. <i>ternipes</i>	<i>Bromus carinatus</i> Hook. & Arn.
* <i>Arundo donax</i> L.	* <i>Bromus catharticus</i> Vahl.
* <i>Avena fatua</i> L.	* <i>Bromus densus</i> Swallen
* <i>Avena sativa</i> (L.) Huskn.	<i>Bromus frondosus</i> (Shear) Wooton & Standl.
* <i>Bambusa vulgaris</i> Schrad. ex J.C.Wendl.	* <i>Bromus inermis</i> Leyss.
* <i>Blepharidachne bigelovii</i> (S.Watson) Hack.	<i>Bromus lanatipes</i> (Shear) Rydb.
<i>Bothriochloa alta</i> (Hitchc.) Henr.	<i>Bromus richardsonii</i> Link
<i>Bothriochloa barbinodis</i> (Lag.) Herter var. <i>barbinodis</i>	* <i>Bromus tectorum</i> L.
<i>Bothriochloa barbinodis</i> (Lag.) Herter var. <i>perforata</i> (Trin. ex Fourn.) Gould	* <i>Calamagrostis coahuilensis</i> P.M.Peterson, Soreng & Valdés-Reyna



Appendix 1. Continuation.

- Chascolytrum subaristatum* (Lam.) Desv  
 \**Cenchrus ciliaris* L.  
*Cenchrus echinatus* L.  
 †*Cenchrus myosuroides* Kunth  
*Cenchrus setaceus* (Forssk.) Morrone  
*Cenchrus spinifex* Cav.  
*Cenchrus villosus* (Spreng.) Spreng.  
*Chloris andropogonoides* E.Fourn.  
*Chloris ciliata* Sw.  
*Chloris cucullata* Bisch.  
 \**Chloris gayana* Kunth  
*Chloris submutica* Kunth  
*Chloris virgata* Sw.  
 \**Coix lacrima-jobi* L.  
*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn.  
 †*Cottea pappophoroides* Kunth  
 \**Cymbopogon citratus* (DC.) Stapf  
 \**Cynodon dactylon* (L.) Pers.  
 \**Dactylis glomerata* L.  
 \**Dactyloctenium aegyptium* (L.) Willd.  
 †*Danthonia spicata* (L.) P.Beauv. ex Roem. & Schult.  
*Dasyochloa pulchella* (Kunth) Willd.ex Rydb.  
*Deschampsia caespitosa* (L.) P.Beauv.  
*Dichantherium acuminatum* (Sw.) Gould & C.A.Clark var.  
*acuminatum*  
*Dichantherium acuminatum* (Sw.) Gould & C.A.Clark var.  
*lindheimeri* (Nash) Gould & C.A.Clark  
*Dichantherium acuminatum* (Sw.) Gould & C.A.Clark var.  
*longiligulatum* (Nash) Gould & C.A.Clark  
*Dichantherium oligoanthes* (Schult.) Gould var.  
*scribnerianum* (Nash) Fernld  
*Dichantherium pedicellatum* (Vasey) Gould  
 \**Dichanthium annulatum* (Forssk.) Stapf  
 \**Dichanthium aristatum* (Poir.) C.E. Hubb.  
*Digitaria californica* (Benth.) Henrard  
*Digitaria ciliaris* (Retz.) Koeler  
 †*Digitaria hitchcockii* (Chase) Stuck.  
*Digitaria insularis* (L.) Fedde  
 \**Digitaria ischaemum* (Schreb.) Muhl.  
*Digitaria pubiflora* (Vasey) Wipff  
 \**Digitaria sanguinalis* (L.) Scop.  
*Diplachne fusca* (L.) P. Beauv. ex Roem. & Schult. subsp.  
*fascicularis* (Lam.) P.M.Peterson & N.Snow  
*Dinebra panicea* (Retz.) Ohwi subsp. *mucronata* (Michx.)  
 P.M.Peterson & N.Snow  
*Disakisperma dubium* (Kunth) P.M.Peterson & N.Snow  
*Distichlis littoralis* (Engelm.) H.L.Bell & Columbus  
*Distichlis spicata* (L.) Greene  
 \**Echinochloa colona* (L.) Link  
 \**Echinochloa crus-gallii* (L.) P.Beauv.  
 †*Echinochloa crus-pavonis* (Kunth) Schult.  
*Echinochloa muricata* (P.Beauv.) Fernard  
 \**Eleusine indica* (L.) Gaertn.  
 \**Eleusine multiflora* Hochst. ex A.Rich.  
*Elymus arizonicus* (Scribn. & J.G.Sm.) Gould  
*Elymus canadensis* L.  
*Elymus elymoides* (Raf.) Swezey  
 \**Elymus repens* (L.) Gould  
*Elymus trachycaulus* (Link) Gould ex Shinners  
*Enneapogon desvauxii* P.Beauv.  
 \**Eragrostis barrelieri* Daveau  
 \**Eragrostis cilianensis* (All.) Vignolo ex Janch.  
 \**Eragrostis ciliaris* (L.) R.Br.  
 †*Eragrostis curtipedicellata* Buckley  
 \**Eragrostis curvula* (Schrad.) Nees  
*Eragrostis erosa* Scribn. ex Beal  
*Eragrostis hypnoides* (Lam.) B.S.P.  
*Eragrostis intermedia* Hitchc.  
 \**Eragrostis lehmanniana* Nees  
*Eragrostis lugens* Nees  
*Eragrostis mexicana* (Hornem.) Link  
*Eragrostis palmeri* S.Watson  
*Eragrostis pectinacea* (Michx.) Nees var. *miserrima* (Fourn.)  
 Reeder  
*Eragrostis pectinacea* (Michx.) Nees var. *pectinacea*  
 \**Eragrostis pilosa* (L.) P.Beauv.  
*Eragrostis reptans* (Michx.) Nees  
*Eragrostis spectabilis* (Pursh) Steud.  
 \**Eragrostis superba* Peyr.  
*Eriochloa acuminata* (J. Presl) Kunth var. *acuminata*  
*Eriochloa acuminata* (J. Presl) Kunth var. *minor* (Vasey)  
 R.B.Shaw  
 †*Eriochloa punctata* (L.) Desv. ex Hamilt.  
 †*Eriochloa sericea* (Scheele) Munro ex Vasey  
*Erioneuron avenaceum* (Kunth) Tateoka  
*Erioneuron nealleyi* (Vasey) Tateoka  
*Erioneuron pilosum* (Buckley) Nash  
*Festuca arizonica* Vasey  
 \**Festuca coahuilana* Gonz.-Led. & S.D.Koch  
 †*Festuca ligulata* Swallen  
 †*Festuca pinetorum* Swallen  
*Festuca rubra* L.  
*Festuca thurberi* Vasey  
 \**Festuca valdesii* Gonz.-Led. & S.D.Koch  
*Glyceria striata* (Lam.) Hitchc.  
 \**Hemarthria altissima* (Poir.) Stapf. & C.E.Hubb.  
*Hesperostipa neomexicana* (Thurb.) Barkworth  
*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.  
*Hilaria belangeri* (Steud.) Nash  
*Hilaria swallenii* Cory  
*Hopia obtusa* (Kunth) Zuloaga & Morrone  
*Hordeum jubatum* L.

## Appendix 1. Continuation.

- \**Hordeum murinum* (Kunth) Zuloaga & Morrone  
 \**Hordeum vulgare* L.  
*Jarava ichu* Ruiz & Pav.  
 †*Kalinia obtusiflora* (E.Fourn.) H.L. Bell & Columbus  
*Koeleria macrantha* (Ledeb.) Schult.  
*Leersia hexandra* Sw.  
 †*Leersia monandra* Sw.  
*Leptochloa crinita* (Lag.) P.M.Peterson & N.Snow  
*Leptochloa pluriflora* (E.Fourn.) P.M.Peterson & N.Snow  
*Leymus condensatus* (J.Presl) Á. Löve  
 †*Limnodea arkansana* (Nutt.) L.H.Dewey  
 †*Lolium multiflorum* Lam.  
 †*Lolium perenne* L. var. *aristatum* Schard.  
 †*Melica montezumae* Piper  
 †*Melica nitens* (Scribn.) Nutt. ex Piper  
 †*Melica porteri* Scribn.  
 \**Melinis repens* (Willd.) Zizka  
*Metcalfia mexicana* (Scribn.) Conert  
 †*Microchloa kunthii* Desv.  
*Muhlenbergia alopecuroides* (Griseb.) P.M.Peterson & Columbus  
*Muhlenbergia arenacea* (Buckley) Hitchc.  
*Muhlenbergia arenicola* Buckley  
 †*Muhlenbergia asperifolia* (Nees & Meyen ex Trin.) Parodi  
 †*Muhlenbergia depauperata* Scribn.  
*Muhlenbergia dubia* E.Fourn.  
*Muhlenbergia emersleyi* Vasey  
*Muhlenbergia glauca* (Nees) B.D.Jacks.  
*Muhlenbergia gypsophila* Reeder & C.Reeder  
*Muhlenbergia lindheimeri* Hitchc.  
 †*Muhlenbergia macroura* (Kunth) Hitchc.  
*Muhlenbergia microsperma* (DC.) Kunth  
 †*Muhlenbergia montana* (Nutt.) Hitchc.  
*Muhlenbergia phleoides* (Kunth) Columbus  
*Muhlenbergia polycaulis* Scribn.  
*Muhlenbergia porteri* Scribn. ex Beal  
*Muhlenbergia pubigluma* Swallen  
*Muhlenbergia quadridentata* (Kunth) Trin.  
 †*Muhlenbergia racemosa* (Michx.) Britton Sterns & Poggenb.  
*Muhlenbergia ramulosa* (Kunth) Swallen  
*Muhlenbergia repens* (J.Presl) Hitchc.  
*Muhlenbergia rigens* (Benth.) Hitchc.  
*Muhlenbergia rigida* (Kunth) Kunth  
 †*Muhlenbergia robusta* (E.Fourn.) Hitchc.  
*Muhlenbergia setifolia* Vasey  
*Muhlenbergia spiciformis* Trin.  
*Muhlenbergia tenuifolia* (Kunth) Kunth  
 †*Muhlenbergia torreyi* (Kunth) Hitchc. ex Bush  
*Muhlenbergia tricholepis* (Torr.) Columbus  
*Muhlenbergia utilis* (Torr.) Hitchc.  
*Muhlenbergia villiflora* Hitchc. var. *villosa* (Swallen) Morden  
 †*Muhlenbergia wrightii* Vasey ex J.M.Coult.  
*Nassella leucotricha* (Trin. & Rupr.) R.W.Pohl  
*Nassella mucronata* (Kunth) P.W. ohl  
*Nassella tenuissima* (Trin.) Barkworth  
*Oplismenus hirtellus* (L.) P.Beauv. subsp. *hirtellus*  
*Oplismenus hirtellus* (L.) P.Beauv. subsp. *setarius* (Lam.)  
 Mez ex. Ekman  
*Panicum alatum* Zuloaga & Morrone  
 \**Panicum antidotale* Retz.  
 †*Panicum capillare* L.  
 \**Panicum coloratum* L.  
 †*Panicum decolorans* Kunth  
 †*Panicum hallii* Vasey var. *filipes* (Scribn.) F.R.Waller  
*Panicum hallii* Vasey var. *hallii*  
 †*Panicum hirticaule* Presl.  
 †*Panicum lepidulum* Hitchc. & Chase  
 †*Panicum parcum* Hitchc. & Chase  
 †*Panicum rigidulum* Bosc. ex Nees.  
 †*Panicum virgatum* L.  
*Pappophorum bicolor* E. Fourn.  
 \**Pappophorum pappiferum* (Lam.) Kuntze  
*Pappophorum vaginatum* Buckley  
*Pascopyrum smithii* (Rydb.) Barkworth & D.R.Dewey  
 †*Paspalum crinitum* Chase  
 \**Paspalum denticulatum* Trin.  
 †*Paspalum dilatatum* Poir.  
*Paspalum distichum* L.  
*Paspalum pubiflorum* Rupr. ex E.Fourn.  
*Paspalum setaceum* Michx. var. *ciliatifolium* (Michx.) Vasey  
 \**Paspalum urvillei* Steud.  
*Peyritschia deyeuxioides* (Kunth) Finot  
 \**Phalaris canariensis* L.  
*Phalaris caroliniana* Walt.  
 \**Phalaris minor* Retz.  
 †*Phleum alpinum* L.  
 \**Phragmites australis* (Cav.) Trin. ex Steud.  
 \**Phyllostachys aurea* Carrière ex Rivière & C.Rivière  
 †*Piptochaetium angustifolium* (Hitchc.) Valencia & Costas  
*Piptochaetium fimbriatum* (Kunth) Hitchc.  
*Piptochaetium pringlei* (Beal) Parodi  
 †*Piptochaetium virescens* (Kunth) Parodi  
*Pleuraphis mutica* Buckley  
 \**Poa annua* L.  
*Poa bigelovii* Vasey & Scribn.  
 \**Poa compressa* L.  
*Poa fendleriana* (Steud.) Vasey  
 †*Poa occidentalis* (Vasey) Vasey  
*Poa palmeri* Soreng & P.M.Peterson  
 \**Poa pratensis* L. subsp. *agassiezensis* (B.Boivin & D.Löve)  
 Roy L.Taylor & MacBryde  
 †*Poa ruprechtii* Peyr.

## Appendix 1. Continuation.

- Poa strictiramea* Hitchc.  
 \**Poa wendtii* Soreng & P.M.Peterson  
*Polypogon elongatus* Kunth  
 \**Polypogon monspeliensis* (L.) Desf.  
 \**Polypogon viridis* (Gouan) Breistr.  
 \**Schedonorus arundinaceus* (Schreb.) Dumort.  
*Schizachyrium cirratum* (Hack.)Wooton & Standl.  
*Schizachyrium sanguineum* (Retz.) Alston  
*Schizachyrium scoparium* (Michx.) Nash  
*Scleropogon brevifolius* Phil.  
 \**Secale cereale* L.  
 \**Setaria adhaerens* (Forssk.) Chiov.  
*Setaria grisebachii* E.Fourn.  
*Setaria leucopila* (Scribn. & Merr.) K.Schum.  
*Setaria macrostachya* Kunth  
 \**Setaria magna* Griseb.  
 \**Setaria parviflora* (Poir.) Kerguélen  
*Setaria pumila* (Poir.) Roem. & Schult.  
*Setaria reverchonii* (Vasey) Pilg. var. *ramiseta* (Scribn.)  
 W.E.Fox  
*Setaria reverchonii* (Vasey) Pilg. var. *reverchonii*  
*Setaria scheelei* (Steud.) Hitchc.  
 \**Setaria verticillata* (L.) P. Beauv.  
 \**Setaria villosissima* (Scribn. & Merr.) K.Schum.  
 \**Setariopsis auriculata* (E.Fourn.) Scribn.  
 \**Sorghastrum brunneum* Swallen  
*Sorghastrum nutans* (L.) Nash  
 \**Sorghum bicolor* (L.) Moench.  
 \**Sorghum halepense* (L.) Pers.  
 \**Spartina spartinae* (Trin.) Merr.ex Hitchc.  
*Sphenopholis obtusata* (Michx.)Scribn.  
*Sporobolus airoides* (Torr.)Torr. subsp. *airoides*  
*Sporobolus airoides* (Torr.)Torr. subsp. *regis* (I.M. Johnston)  
 Wipff & S.D.Jones  
*Sporobolus atrovirens* (Kunth) Kunth  
 \**Sporobolus coahuilensis* Valdés-Reyna  
 \**Sporobolus compositus* (Poir.) Merr.  
*Sporobolus contractus* Hitchc.  
*Sporobolus cryptandrus* (Torr.) A.Gray  
*Sporobolus flexuosus* (Thurb. ex Vasey) Rydb.  
*Sporobolus giganteus* Nash  
 \**Sporobolus indicus* (L.) R.Br.  
*Sporobolus nealleyi* Vasey  
*Sporobolus pyramidatus* (Lam.) Hitchc.  
*Sporobolus spiciformis* Swallen  
*Sporobolus wrightii* Munro.  
 \**Stenotaphrum secundatum* (Walter) Kuntze  
 \**Tragus berteronianus* Schult.  
*Tridens albescens* (Vasey) Woot & Standl.  
 \**Tridens flavus* (L.) Hitchc.  
*Tridens texanus* (S.Watson) Nash  
 \**Tridentopsis eragrostoides* (Vasey & Scribn.) P.M.Peterson  
*Tridentopsis mutica* (Torr.) P.M.Peterson  
*Tripsacum dactyloides* (L.) L.  
 \**Trisetum filifolium* Scribn. ex Beal  
 \**Trisetum palmeri* Hitchc.  
*Trisetum spicatum* (L.) K. Ritch.  
 \**Trisetum viride* (Kunth) Kunth  
 \**Triticosecale* Wittm.  
 \**Triticum aestivum* L.  
 \**Urochloa arizonica* (Scribn. & Merr.) Morrone & Zuloaga  
*Urochloa fusca* (Sw.) B.F.Hansen & Wunderlin  
*Urochloa meziana* (Hitchc.) Morrone & Zuloaga  
*Urochloa ophryodes* (Chase) Morrone & Zuloaga  
 \**Urochloa plantaginea* (Link) R.D.Webster  
*Urochloa texana* (Buckley) R.D.Webster  
*Zea mays* L.  
 \**Zoysia matrella* (L.) Merr. var. *pacifica* Goudswaard  
*Zuloagaea bulbosa* (Kunth) Bess