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Community structure and floristic composition of *Quercus fusiformis* and *Carya illinoinensis* forests of the Northeastern Coastal Plain, Coahuila, Mexico

Estructura y composición florística de los bosques de *Quercus fusiformis* y *Carya illinoinensis* de la planicie costera del noreste, Coahuila, México

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Abstract. In order to describe community structure and richness in oak and walnut forests occurring along the San Rodrigo, San Diego, Escondido and Arroyo de las Vacas rivers on the Northeastern Coastal Plain (NE Coahuila, Mexico), we established 30 1 000-m^2 circular plots, where we measured diameter at breast height (DBH) and tree heights. Tree regeneration and herb and shrub stratum were assessed in 5 2-m^2 quadrats per site. A total of 48 species distributed in 29 families were recorded. Families with the largest richness were Poaceae, Asteraceae, and Malvaceae. For the oak forest, tree stratum density and basal area values were 386 stems/ha and 24.36 m^2/ha, respectively, whereas for the walnut forest the corresponding values were 302 stems/ha and 21.26 m^2/ha. The species with the highest relative importance values were *Quercus fusiformis* (59.48%) and *Carya illinoinensis* (57.58%). Total tree richness was 14 species, the most common ones being *Celtis reticulata* and *Diospyros texana*, followed closely by *C. illinoinensis* and *Q. fusiformis*. Anthropogenic impact appears to result in a poor regeneration reflected as a low sapling density, as well as in the reduction and fragmentation of these communities; in turn, this process has led to intrusions of species typical of the xerophytic Tamaulipan Thorn Scrub. Further studies are needed on the regeneration of the dominant species of these forests in order to describe their dynamics and to promote their preservation.

Key words: basal area, forest regeneration, oak forest, species invasions, tree density, walnut forest.

Resumen. Con la finalidad de conocer la estructura y la composición florística de los bosques de encino y nogal situados a lo largo de los ríos San Rodrigo, San Diego, Escondido y Arroyo de las Vacas en la planicie costera nororiental (NE de Coahuila, México), se establecieron 30 parcelas circulares de 1 000 m^2 en las que se midió el DAP y la altura de las especies arbóreas; además, se evaluó la regeneración de las especies arbóreas y el estrato herbáceo y arbustivo en 5 cuadros de 2 m^2 por sitio. Se registraron 48 especies, integradas en 29 familias, siendo Poaceae, Asteraceae y Malvaceae las de mayor riqueza. La densidad y el área basal para el estrato arbóreo del bosque de encino fueron 386 ind/ha y 24.36 m^2/ha, mientras que los valores respectivos para el bosque de nogal fueron 302 ind/ha y 21.26 m^2/ha. Las especies con los mayores valores de importancia fueron *Quercus fusiformis* y *Carya illinoinensis*, con 59.48% y 57.58%, respectivamente. La riqueza arbórea fue de 14 especies; las más frecuentes fueron *Celtis reticulata* y *Diospyros texana*, seguidas de *C. illinoinensis* y *Q. fusiformis*. El impacto antropogénico ha ocasionado que la regeneración y el arbolado juvenil tengan densidades bajas, y ha reducido y fragmentado estas comunidades, lo que ha permitido la colonización de especies xerófitas del matorral tamaulipeco. Es necesario realizar estudios sobre la regeneración de las especies para conocer su dinámica y garantizar la conservación de estas comunidades.

Palabras clave: área basal, bosque de encino, bosque de nogal, densidad de los árboles, invasión de especies, regeneración del bosque.

Introduction

In the northern Mexican State of Coahuila, riparian semi-evergreen forests ('*bosques subperennifolios ribereños*' *sensu* Lot and Novelo, 1990) occur along riverbanks in the eastern watershed of the El Burro Range. Despite the lack of adequate cartography, these communities appear to have a very restricted and irregular distribution; they are dominated by *Carya illinoinensis* (Wang.) K.Koch (walnut or '*nogal*' in Spanish), a very common species in deciduous forests of southeastern USA (Correll and Johnston, 1970). In Mexico, trees of this species are common in forest communities

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located in the vicinity of rivers in northeastern Coahuila (Johnston, 1944; Villarreal-Quintanilla et al., 2006), whilst in Nuevo León they have been reported to form part of temperate deciduous forests (Alanís et al., 1996), or of gallery forests (Treviño et al., 2001). Further common genera in these forests are *Quercus*, *Morus*, *Platanus*, *Fraxinus*, *Juglans*, and *Prosopis* (Villarreal-Quintanilla and Valdés-Reyna, 1992-93; Villarreal-Quintanilla et al., 2006).

Similarly, the only region of Mexico where oak forests dominated by *Quercus fusiformis* Small occur is in northeastern Coahuila, where they cover less than 1% of the state's territory (Anonymous, 2001). These communities are also present on the Coastal Plain of Texas and on the Edwards Plateau, west of the Pecos River (Muller, 1951; Correll and Johnston, 1970; Fowler, 1988). Relict populations of this species are patchily distributed along intermittent creeks and ravines in Coahuila's eastern corner (Encina-Domínguez and Villarreal-Quintanilla, 2002), in central and northeastern Nuevo León (Valdés and Aguilar, 1983; Marroquín, 1985), as well as in the San Carlos Range, Tamaulipas (Briones, 1991). Rzedowski (1978) described low elevation (*ca*. 350 m) communities dominated by this species located to the southwest of Piedras Negras.

The estimated total area occupied by these forest communities in Coahuila is 44 629 ha (equivalent to 1.84% of the state's territory), of which 23 039 ha (0.95%) correspond to oak forest, and the remaining 21 590 ha (0.89%) to riparian vegetation (Anonymous, 2001). Among the most important environmental services provided by these forests are erosion prevention and the filtering of sediments, nutrients, and pollutants, which ultimately improves water quality (Patten, 1998), along with their role as habitat for wild fauna (Solís and Jenkins, 1998). Unfortunately and in spite of these benefits, these forests are continuously subjected to irrational human practices, ranging from conversion into pastures for cattle raising, timber extraction, mining of construction materials, and the building of reservoirs (Villarreal-Quintanilla et al., 2006). Motivated by this situation, the aim of this study was to provide information on the structure, floristics, and diversity of oak (*Q. fusiformis*) and walnut (*C. illinoinensis*) forests growing in the northeastern Gulf of Mexico coastal plain, NE Coahuila. The ultimate goal was to provide a sound synecological basis for future studies examining their dynamics and to contribute to their conservation.

Materials and methods

The study area is located along the San Rodrigo, San Diego, Escondido, and Arroyo de las Vacas rivers in northern Coahuila, and it includes portions of Acuña, Jiménez, Piedras Negras, and Zaragoza counties (Fig. 1). This region is part of the Great North American Plains physiographic province (Anonymous, 1983), known in Mexico as the Gulf Coast Plain morphotectonic province (Ferrusquía-Villafranca, 1993). More precisely, it corresponds to the northern portion of the Northeastern Coastal Plain (Rzedowski, 1978), which includes the northern and eastern sectors of Nuevo León State, the whole territory of Tamaulipas State, northeastern Coahuila, and adjacent portions of Texas (González-Medrano, 1985). In Coahuila, the area included within this physiographic province is 25 665 km^2; its northern limit is the Rio Bravo (known as Rio Grande in the USA) and to the west it abuts with the Sierra Madre Oriental; the region is characterized by wide-open plains, occasionally broken by scattered gently rolling hills with elevations ranging from 250 to 500 m asl. This zone is part of the RH-24 "Bravo-Conchos" hydrologic region, within the Rio Bravo-Piedras Negras Basin, which encompasses intermittent streams and a few isolated rivers that flow mostly from the El Burro Range (Anonymous, 1983). The climate is of the $BS_0h'(x')$ type, i.e., dry, warm to semi-warm, with mean annual temperature > 22ºC and wide thermal fluctuations (Anonymous, 2001); mean total annual precipitation fluctuates from 350 to 500 mm and is evenly distributed throughout the year. The oldest rocks found in the parental bedrock are associations of lutites-sandstones and limestone-lutites of Upper Cretaceous age. The clayey, alluvial soils are alkaline and they include a limestone layer in the subsoil; their color is brown or gray and they have low organic matter contents. The most extensive soil units are Calcic xerosols, Haplic xerosols and Calcaric regosols of medium texture; on the hills medium-textured Lithosols prevail that may be associated to varying degrees with calcaric regosols (Anonymous, 2001).

From a floristic viewpoint, this region is considered part of the Northeastern Coastal Plain Province, which in Mexico covers almost the entire territory of Tamaulipas, the northeastern third of Nuevo León, and the northeastern sector of Coahuila (Rzedowski, 1978). Despite its northern location in the country, the region has strong links with southern floras, although it also hosts a considerable number of species with restricted distributions (Rzedowski, 1965). The Tamaulipan Thorn Scrub is the prevailing vegetation in NE Coahuila (Muller, 1945); however, in areas with higher moisture availability and deeper soils other plant communities occur, such as mesquite forests, riparian vegetation, and oak forests (Rzedowski, 1978; Villarreal-Quintanilla and Valdés-Reyna, 1992-93).

We estimated community-level variables by sampling the vegetation at 30 sites: 9 of them were on the Arroyo de las Vacas river, 16 were along the San Diego river, 3 on the San Rodrigo, and 2 on the Escondido river (Fig. 1). At each site we established a circular plot with an area of 1 000 m^2, within which individuals of tree species were tallied and their normal diameter (or diameter at breast height, DBH) were measured; individual tree heights were also recorded. For assessing dominant trees species regeneration (individuals ≤ 1.30 m tall) and characteristics of the herb and shrub stratum, we established 5 2-m^2 plots, 1 at the center and 4 near the border of each circular plot, in the corresponding cardinal direction (Olvera-Vargas et al., 1996; Figueroa-Rangel and Olvera-Vargas, 2000). Taxonomic identities of the collected plant specimens were determined and the vouchers deposited at the ANSM herbarium (Universidad Autónoma Agraria Antonio Narro). Vegetation types were defined following Muller (1945) and Villarreal-Quintanilla and Valdés-Reyna (1992-93), and the structure of their tree stratum was analyzed by calculating the basal area and density of those species representing the adult tree community (DBH ≥ 5 cm). Density, frequency, and absolute dominance values were calculated by species; by adding the relative values of these variables we obtained a Relative Importance Value (RIV) for each species (Mueller-Dombois and Ellenberg, 1974); the abundance-dominance of species in the herb and shrub strata was assessed qualitatively (see Appendix 1). Site classification was performed by applying Ward's method or Minimum Variance method, which is a hierarchical, polythetic, agglomerative clustering technique (Manly, 1986; Digby and Kempton, 1987), using NTSYSpc ver. 2.0 (Rohlf, 1998) to a species/sites matrix containing density values of 13 tree species; between-cluster distance was computed as an increment in squared Morisita's index (Krebs, 1999) towards cluster centroid after fusion of 2 clusters (van Tongeren 1995). Floristic similarity between the 2 communities was assessed by calculating Jaccard's index (Magurran, 1988):

$$Cj = j/(a + b - j)$$

where a and b represent species richness in each of the 2 examined sets, and j is the number of shared species.

The criteria established in the Regulatory Appendix I (Method for Assessing the Extinction Risk of Wild Species) of the Mexican Official Norm NOM-059-SEMARNAT-2001 (Semarnat, 2002) were applied in order to locate 4 species (*Quercus fusiformis*, *Carya illinoinensis*, *Ulmus crassifolia*, and *Platanus occidentalis*) in the proper risk category; the selection of these species was based on their highly restricted distribution in Mexico. This procedure is based on the sum of the values given to 4 criteria that allow assigning each species to a risk category. These criteria are: (a) size of the taxon's range in Mexico, (b) habitat condition with respect to the natural development of the taxon, (c) intrinsic biological vulnerability of the taxon, and (d) impacts of human activities on the taxon. The maximum sum value for the 4 criteria is 14 points (4, 3, 3, and 4, respectively). A species is considered in risk of extinction ('*peligro de extinción*'; P) with sum values between 12 and 14 points, and threatened ('*amenazada*'; A) when they are between 10 and 11.

Results

Floristics. A total of 48 species belonging to 29 families were recorded, among which Poaceae, Asteraceae (5 species each), and Malvaceae (4) were prominent. Species distribution by growth form categories was characterized by the dominance of herbs (20 species; 41.66%) and trees (15 species; 31.25%), whereas shrubs (6 species, 12.5%) and climbers (7 species; 14.58%) were more poorly represented. Dominant species (and consequently the strongest contributors to physiognomy) in the tree stratum were *Carya illinoinensis* and *Quercus fusiformis*; in the subcanopy *Celtis reticulata* and *Diospyros texana* were dominant, but *Bumelia lanuginosa*, *Acacia farnesiana*, *Salix nigra*, and *Prosopis glandulosa* were also noteworthy. The most abundant herbs were *Ruellia nudiflora*, *Sanvitalia ocymoides*, *Viguiera dentata*, *Allowissadula holosericea*, and *Malvastrum coromandelianum*. The complete checklist of the flora is presented in Appendix 1.

Site classification. The cluster analysis clearly separated 2 groups of sites (Fig. 2). Group 1 corresponds to oak forest and comprises 19 sites with a mean between-site similarity of 43%; this community encompasses 11 tree species, among which the most common ones were *Quercus fusiformis*, *Celtis reticulata*, and *Diospyros texana*. For this forest we distinguished 3 variants: stands dominated by *Q. fusiformis* (14 sites), others characterized by a co-dominance of *Q. fusiformis* and *C. reticulata* (4), and 1 dominated by species of xeric affinities like *Prosopis glandulosa*. Group 2 embodies the remaining 11 sites, for which a mean between-site similarity was 23%; they correspond to the walnut forest, which as a whole hosts a tree richness of 10 species, the most frequent ones being *Carya illinoinensis*, *Q. fusiformis*, and *C. reticulata*. For this community we were also able to distinguish 2 variants, 1 in which dominance corresponds to *C. illinoinensis* (9 sites), and the other dominated by *Ulmus crassifolia* (2 sites only). Eight species were shared between the 2 forest types, which produced a Jaccards's similarity index of 0.61 between them.

Oak forest structure. This community thrives along the San Diego and Escondido rivers, as well as in areas south of Ciudad Acuña, at elevations ranging between 270 and 320 m. *Quercus fusiformis* (white oak) was the dominant species (RIV of 59.48%; density of 231 stems/ha); the trees of this species form a closed canopy 13 to 25 m tall. In this forest a second tree stratum was distinguished with trees measuring between 6 and 9 m tall, in which palo blanco (*Celtis reticulata*) dominates (RIV of 11.14%); further common species were *Diospyros texana, Carya illinoinensis*, and *Bumelia lanuginosa* (RIVs of 4-10%). Although *Ulmus crassifolia* was scarce (3.68 stems/ha), the size of their individuals is noteworthy (mean DBH of 29 cm), which led this species to attain a RIV of 1.68% (Table 1). In sites where canopy was open the occurrence of *Prosopis glandulosa* (mesquite) and *Acacia farnesiana* (huizache) trees was observed (RIV of 4.64% and 1.16%, respectively), along with shrubs such as *Opuntia lindheimeri*, *Leucophyllum frutescens*, and *Celtis pallida* with heights between 1 and 2 m. In the herb stratum, whose height ranges from 10 to 35 cm, *Allowissadula holosericea*, *Croton fruticulosus*, *Pavonia lasiopetala*, and *Siphonoglossa pilosella* were dominant. *Smilax bona-nox* and *Vitis cinerea* were frequent climbers.

In this forest we recorded a total density of 386 stems/ha in the tree stratum, with tree heights ranging between 6 and 25 m, and mean DBH as large as 44.17 cm, which accounts for its total basal area of 24.36 m^2/ha. A large fraction (21.90 m^2/ha; 89%) of this value was contributed exclusively by *Quercus fusiformis*, whereas all associated trees combined (10 species) accumulated a basal area < 2 m^2/ha (Table 1). We did not record any juveniles, so that sprouting was the only regeneration form observed.

The community-level diameter frequency distribution in this forest showed an inverted J shape (Fig. 3). Two thirds of all trees (255 stems, 66%) had DBH values between 5 and 15 cm; this fraction was accounted for mainly by *Diospyros texana*, *Celtis reticulata*, and *Carya illinoinensis*. The former species had its highest density (40 stems/ha) in the 5 cm centered diameter class, whilst the latter 2 were more abundant in the class centered on the 10 cm mark (16 and 6 stems/ha, respectively). The large DBH categories were dominated by *Quercus fusiformis*, whose diameter frequency distribution had a sigmoid shape, with its highest density (41 stems/ha) in the class centered on 15 cm (Fig. 3).

Walnut forest structure. The *Carya illinoinensis* community thrives on the banks of the San Diego, San Rodrigo and Arroyo de las Vacas rivers, at elevations ranging from 250 to 300 m. This species was physiognomically and structurally dominant (RIV of 57.58%; density of 230 stems/ha), followed by white oak (*Quercus fusiformis*) with 13 stems/ha and a RIV of 13.39%. Together, these 2 species make up the upper stratum, which is 12 to 18 m tall (Table 2). In the lower tree stratum (6 to 8 m tall) *Celtis reticulata*, *Platanus occidentalis*, and *Morus celtidifolia* were common (RIV of 4-9%); *M. celtidifolia* and *P. occidentalis* were only recorded along the San Rodrigo river, both with low densities (16 and 8 stems/ha, respectively). *Ulmus crassifolia* occurred exclusively in those open-canopy *C. illinoinensis* communities located near Ciudad Acuña, with a low density (5 stems/ha) but a rather robust growth, illustrated by a mean diameter of 47.25 cm (allowing this species to reach a RIV of 4.06%). *Bumelia lanuginosa*, *B. celastrina*, and *Diospyros texana* were uncommon, only recorded in habitats with less water availability. In areas with low forest cover, seedlings and juveniles of *Acacia farnesiana* and *Prosopis glandulosa* were frequent, together with xerophytic shrubs like *Opuntia lindheimeri* and *Celtis pallida*. Climbers like *Vitis cinerea*, *Smilax bona-nox*, and *Toxicodendron radicans* were common. Plant height in the herb stratum ranged between 5 and 60 cm; in this stratum the most abundant species were *Viguiera dentata, Sanvitalia ocymoides*, *Carex schiedeana*, and *Abutilon incanum*.

Total density in the tree stratum of this community was 302 stems/ha. Tree height ranged between 6 and 18 m, and maximum DBH mean was 64.96 cm. Total basal area was 21.27 m^2/ha, of which over 89% (18.92 m^2/ha) was accounted for by *Carya illinoinensis* and *Quercus fusiformis* (63% and 26%, respectively). Basal area values of the remaining 8 species were < 1 m^2/ha (Table 2). Seedlings and juveniles of *C. illinoinensis* were scarce and apparently restricted to the most humid sites.

As was the case for the oak forest, diameter frequency distributions of the various species of this forest also exhibited inverted J shapes (Fig. 4). More than one half of all trees (178 individuals; 58%) had DBH values between 5 and 15 cm. The largest density in these categories was contributed by *Carya illinoinensis*, whose population diameter distribution matched that observed for the whole community. The large DBH categories exclusively contained *C. illinoinensis* and *Quercus fusiformis* individuals; in fact, for the latter species we recorded the largest diameter (150 cm) in the entire sampling. The most important species in the lower tree stratum were *Platanus occidentalis* and *Celtis reticulata,* whose highest densities fell in those categories centered on the 15 and 5 cm marks, respectively (Fig. 4).

Proposal for the protection of tree species. By applying the criteria of the Regulatory Appendix I of the Mexican Norm NOM-059-SEMARNAT-2001, we propose that *Quercus fusiformis*, *Carya illinoinensis* and *Ulmus crassifolia* be classified as 'In danger of local extinction',

Table 1. Structural attributes of the tree stratum in the oak (*Quercus fusiformis*) forest in the Northeastern Coastal Plain, Coahuila, Mexico. RIV = Relative Importance Value

Species	*Mean DBH (cm)*	*Density (ind/ha)*	*Relative density (%)*	*Basal area (m^2/ha)*	*Relative dominance (%)*	*Relative frequency (%)*	*RIV*
Quercus fusiformis	44.17	231.05	59.73	21.91	89.93	28.79	59.48
Celtis reticulata	16.43	42.11	10.88	0.70	2.86	19.70	11.15
Diospyros texana	7.86	58.42	15.10	0.31	1.26	12.12	9.49
Carya illinoinensis	23.09	19.47	5.03	0.88	3.61	12.12	6.92
Prosopis glandulosa	12.96	15.79	4.08	0.18	0.75	9.09	4.64
Bumelia lanuginosa	9.13	12.63	3.27	0.09	0.37	6.06	3.23
Ulmus crassifolia	29.79	3.68	0.95	0.26	1.08	3.03	1.69
Acacia farnesiana	11.25	1.58	0.41	0.01	0.06	3.03	1.17
Condalia hookeri	12.00	1.05	0.27	0.01	0.05	3.03	1.12
Morus celtidifolia	15.00	0.53	0.14	0.009	0.04	1.52	0.56
Bumelia celastrina	6.00	0.53	0.14	0.001	0.006	1.52	0.55
Total		386.84	100.00	24.36	100.00	100.00	100.00

Table 2. Structural attributes of the tree stratum in the walnut (*Carya illinoinensis*) forest in the Northeastern Coastal Plain, Coahuila, Mexico. RIV = Relative Importance Value

Species	*Mean DBH (cm)*	*Density (ind/ha)*	*Relative density (%)*	*Basal area (m^2/ha)*	*Relative dominance (%)*	*Relative frequency (%)*	*RIV*
Carya illinoinensis	36.13	230.75	76.24	13.40	63.02	32.26	57.58
Quercus fusiformis	64.96	13.58	4.49	5.53	25.99	9.68	13.39
Celtis reticulata	27.45	11.28	3.73	0.51	2.40	19.36	8.57
Platanus occidentalis	16.97	16.44	5.43	0.55	2.57	6.45	4.79
Morus celtidifolia	16.29	8.12	2.68	0.20	0.96	9.68	4.48
Ulmus crassifolia	47.13	5.87	1.94	0.92	4.33	6.45	4.06
Bumelia lanuginosa	7.41	11.65	3.85	0.09	0.42	6.45	3.51
Salix nigra	30.00	1.53	0.51	0.06	0.28	3.23	1.26
Bumelia celastrina	8.00	1.47	0.49	0.004	0.02	3.23	1.18
Diospyros texana	8.00	1.99	0.66	0.004	0.02	3.23	1.18
Total		302.67	100.00	21.27	100.00	100.00	100.00

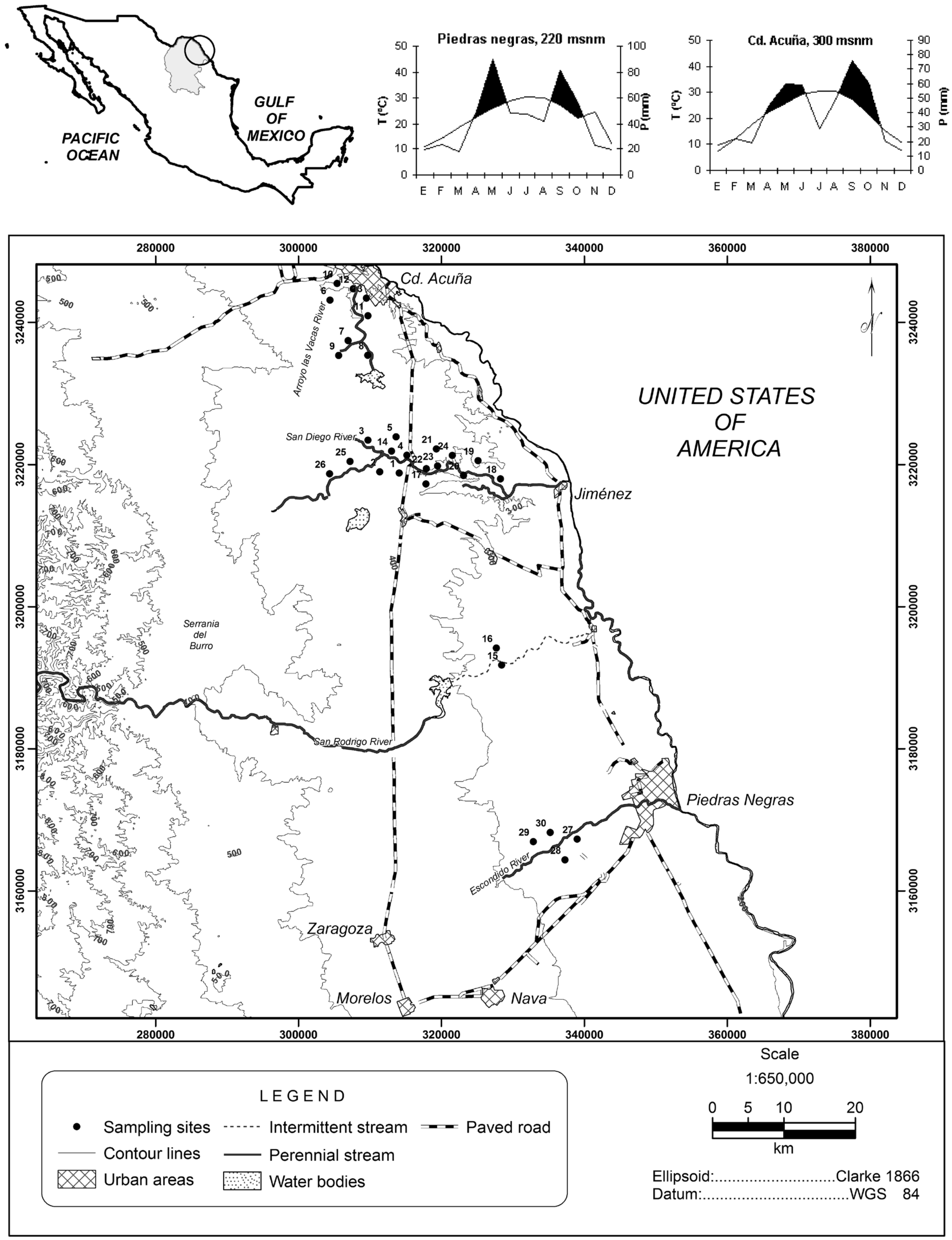

Figure 1. Location of the study area and the sampling sites in the Northeastern Coastal Plain, Mexico (UTM 14N).

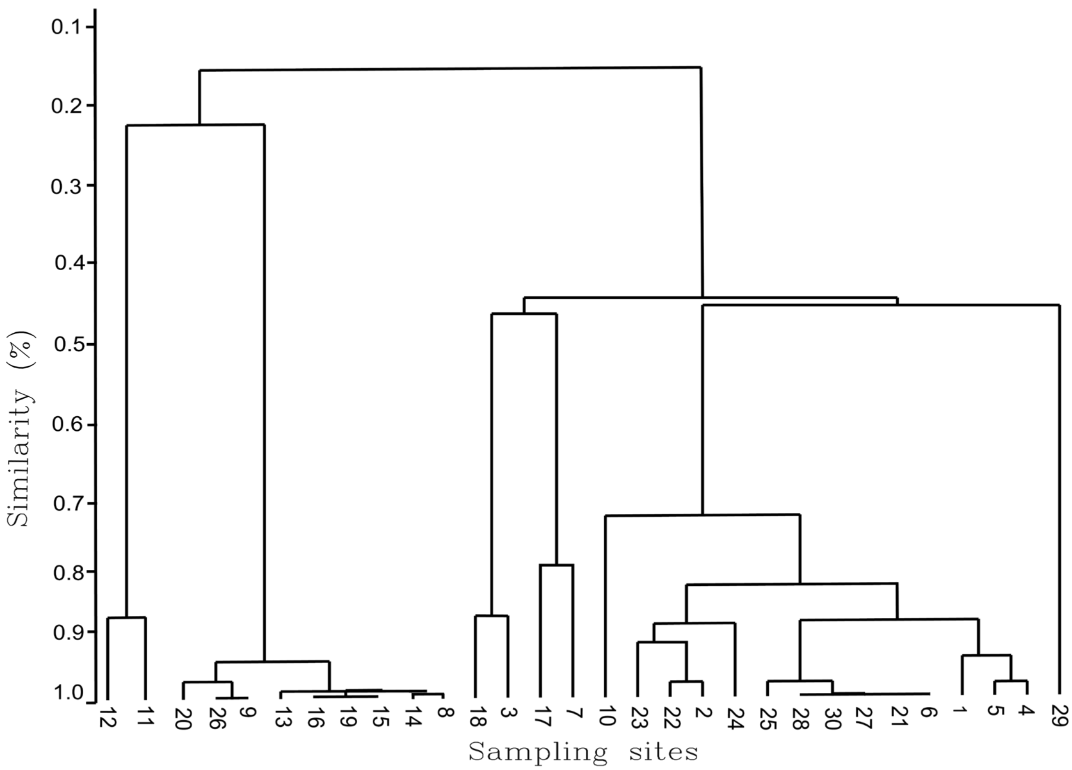

Figure 2. Site classification based on Ward's (Minimum Variance) method for the *Quercus fusiformis* and *Carya illinoinensis* forests.

whereas *Platanus occidentalis* corresponds better to the 'Threatened' category'. These standings were based on the criterion of the restricted ranges of these species to Mexico and to Coahuila State.

Discussion

Forests dominated by *Quercus* and *Carya* species of northeastern Mexico are essentially restricted to humid ravines of mountainous regions, in temperate areas with elevations ranging from 900 to 2 600 m, and shallow soils (Briones, 1991; Muller-Using, 1994; Eckelmann, 1995; Encina-Domínguez, 2003). The *Quercus fusiformis* and *Carya illinoinensis* forests typical of the Coastal Plain of Coahuila greatly contrast with them due to their occurrence at much lower elevations (250-350 m), their strong preference for humid locations near streams, and their occurrence in temperate and semiarid habitats with deeper soils. Moreover, these forests may represent relict communities (Rzedowski, 1978), and indeed they can be viewed as an outstanding plant community, as it is the only one in the country that is composed of species with clear temperate climate affinities that occurs within a semiarid environment. In southeastern USA *Carya illinoinensis* dominated forests are common (Bonner and Maisenhelder, 1974; Peterson, 1990; Fowler, 2005), but the southernmost limit of this community's range is found in our study region; further south this tree species only occurs as an isolated component of riparian vegetation and oak forests of central Coahuila (Villarreal-Quintanilla et al., 2006), south central Nuevo León (Muller-Using, 1994; Treviño et al., 2001), and central Mexico (Pérez-Calix, 2001).

Floristic composition and phytogeographical affinities. Total species richness recorded in the oak and walnut forests of Coahuila is lower than that reported by Villarreal-Quintanilla et al. (2006) for the Sabinas and San Rodrigo rivers (243 taxa), and the same was true for tree species richness (22 species versus 15 recorded by us). In spite of these differences, both studies coincide in pointing out the prevalence of the Asteraceae and Poaceae families. Tree richness in forests of the Eastern Sierra Madre fluctuates between 3 and 6 species (Briones, 1991; Muller-Using, 1994; Encina-Domínguez, 2003), which is less than our records for the *Quercus fusiformis* (11 species) and the walnut (10 species) forests, and less than figures reported

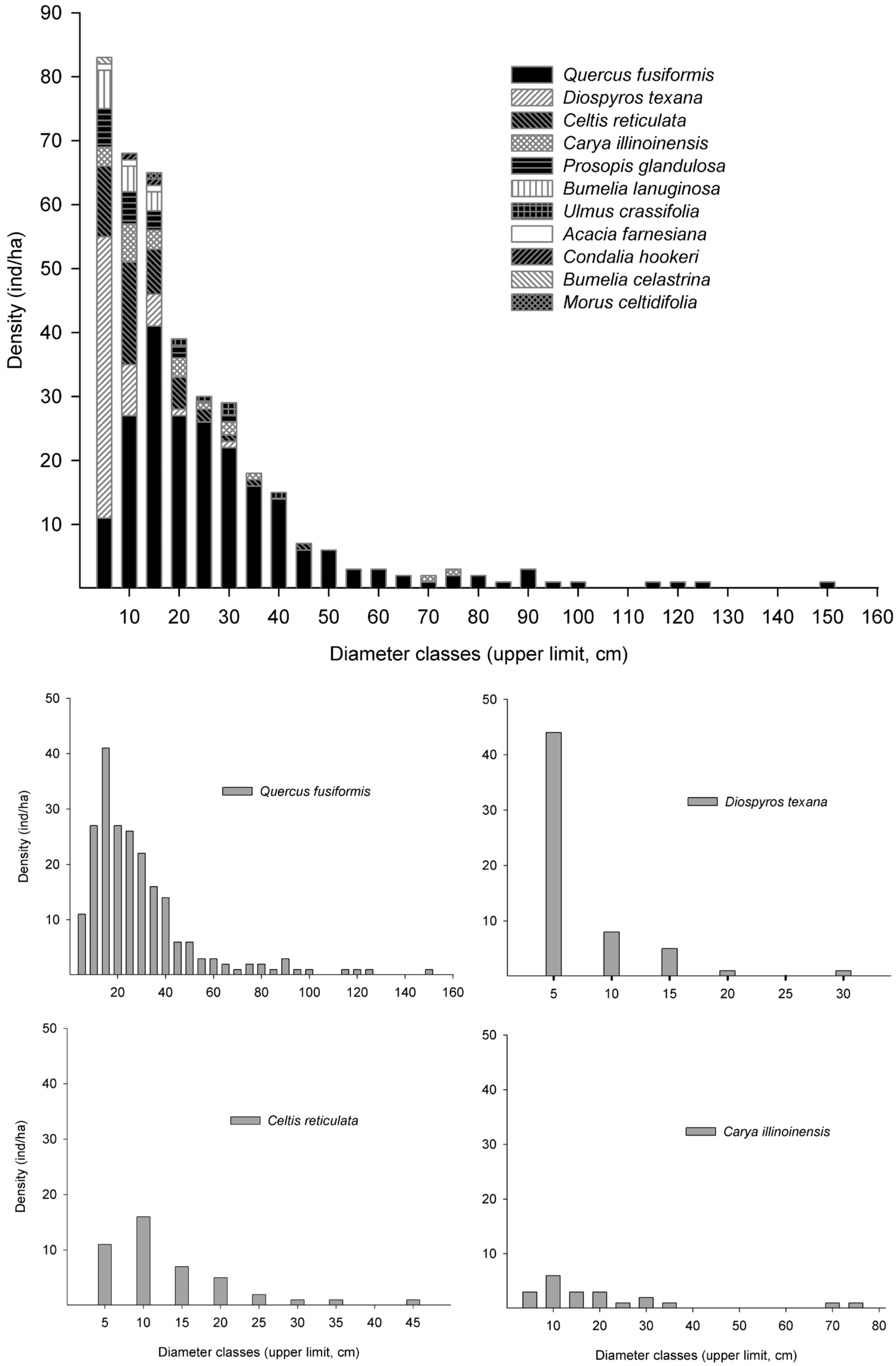

Figure 3. Diameter structure of the *Quercus fusiformis* forest and dominant species.

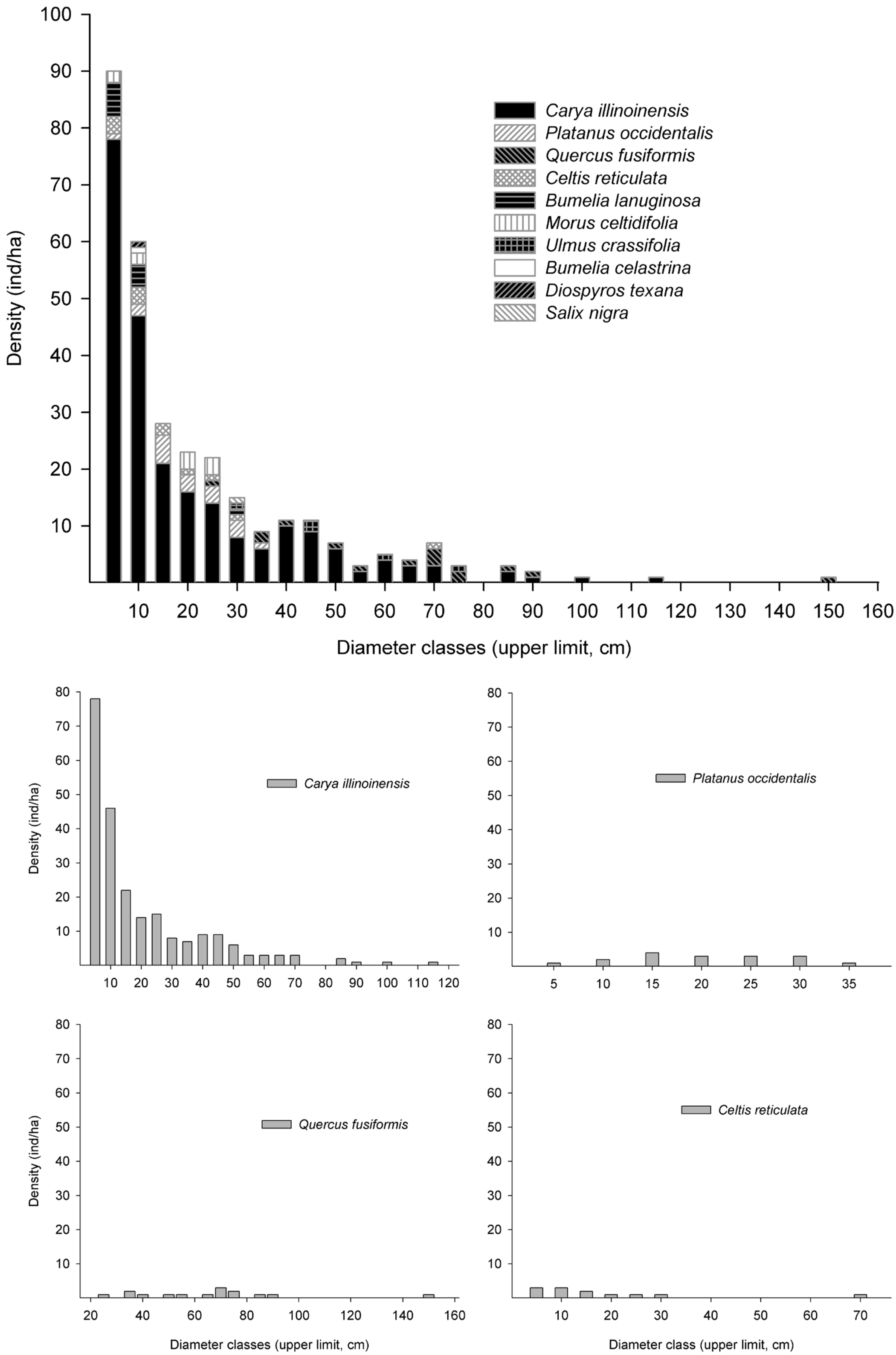

Figure 4. Diameter structure of the *Carya illinoinensis* forest and dominant species.

for gallery forests of the Ramos and Cabezones rivers in Nuevo León, where Treviño et al. (2001) tallied 16 and 21 species, respectively.

In the forests studied by us, the tree stratum is dominated by genera of Nearctic affinity (Rzedowski et al., 2001), and only at sites with a more open canopy is there presence of Neotropical trees, such as members of *Acacia* and *Prosopis*. Conversely, in the herb and shrub strata Neotropical elements often dominate (Rzedowski, 1965). The fact that Asteraceae and Poaceae are the most speciose families in the herb stratum of the oak forest agrees with observations from other Mexican oak forests (Rzedowski, 1978); however, as in broadleaved forests of central Texas, malvaceous species dominate such strata (Fowler, 2005).

The high similarity between sites representing the oak and walnut forests demonstrates their large share of common species, probably due to similar ecological requirements among their floristic sets (Johnston, 1944; Villarreal-Quintanilla et al., 2006). Also, it leads to the conclusion that these 2 forests represent a single community with 2 variants, differentiated by the respective strong dominance of *Carya illinoinensis* and *Quercus fusiformis*, whilst the variation in their composition and the discontinuity in their distribution is largely an outcome of the anthropogenic activity in the region.

Ecological factors affecting vegetation. The segregation of sampling sites in 2 variants of a single oak-walnut forest is not only due to subtle differences in floristic composition and to the higher densities of some species in either variant, but it is also related to overall ecological differences between them. The variant recognized by us as walnut forest is preferentially found on river banks, at higher altitudes and more northern latitudes, and its range includes a clear temperature gradient, whereas the geographical range of oak forest stretches more to the south where temperatures are higher; this latter forest can develop near or far away from rivers, as long as there is a shallow water table (Rzedowski, 1978), and it often forms isolated clusters, locally known as *motas*, scattered across the Tamaulipan thorn scrub. Zavala (2001) reported similar ecological properties for other *Quercus* species and emphasized that oaks are drought-tolerant, whilst they cannot withstand flooding and excess soil moisture. Forest composition and distribution are largely determined by temperature and humidity; the distributions of *Carya illinoinensis*, *Morus celtidifolia*, *Platanus occidentalis*, and *Ulmus crassifolia*, all of them typical walnut forest species, are limited to the most humid sites within the area. Conversely, the remaining species appear to be more tolerant to variable temperate and water conditions, as they were recorded in most sampling sites.

Forest structure and regeneration. Oak forests of northeastern Mexico are usually dominated by 2 or 3 tree species reaching heights of 8 to 10 m, with diameters of 19 to 22 cm and densities between 220 and 240 stems/ha (Briones, 1991; Muller-Using, 1994; Baca, 2000; Torres, 2000; Encina-Domínguez, 2003). These forests differ from the communities studied by us because of the clear single-species dominance in the latter, whose individuals generally grow to larger sizes (DBH and mean height of 44.17 cm and 15 m, respectively), despite similar values of mean density. The likely cause for the larger sizes of trees (and forests) in the Coastal Plain of Coahuila is a higher productivity derived from a higher nutrient and moisture availability compared to environmental conditions in mountainous regions; this possibility would also strengthen the argument for the suggested mature and relict condition of these forests.

Basal areas estimated by us were slightly higher in the oak than in the walnut forest. This finding may be related to a combination of a higher stem density with larger stem diameters of *Quercus fusiformis* in this forest, relative to the same variables measured for *Carya illinoinensis* in the walnut forest variant.

The diameter class distributions of both communities had inverted J shapes, which in principle could be interpreted as a sign of good forest regeneration (Kormondy, 1985). Nonetheless, only the densities of 2 out of the 5 most important species peaked in the 5 cm DBH class, namely *Carya illinoinensis* and *Diospyros texana*, whereas the remaining ones were poorly represented in that category, suggesting an insufficient or poor regeneration (Bongers et al., 1988; Godínez-Ibarra and López-Mata, 2002; Ajbilou et al., 2003; Ayerde-Lozada and López-Mata, 2006). In many oak populations facing difficulties to regeneration from seeds, a situation resulting not only from human intervention but also from a combination of many factors such as herbivory, exotic grass invasions, and summer drought (MacDougall et al. 2010), sprouting becomes the only regeneration alternative (Zavala and García, 1997; Johnson et al., 2002). However, sprouting does not necessarily guarantee a healthy regeneration, as shown by significant grazing on sprouts by goats and white-tail deer in *Quercus fusiformis* central Texas populations (Fowler 2005).

Anthropogenic disturbance. Anthropogenic impact is a further factor capable of exerting a considerable influence on community structure and composition. Human influence on the studied forests is manifold: grazing of cattle, sheep, and horses; selective logging of oaks and other species; land used change to establish agricultural areas; diversion of rivers; construction of reservoirs and the mining of river banks (Arriaga et al., 2000; Anonymous, 2001). Its action has resulted in the fragmentation and reduction of the range of these oak-walnut forests and the promotion of significant modifications in their structure and species composition, similar to changes reported for temperate and riparian forests of western USA (Norton, 1996; Dwire and Kauffman, 2003). In Coahuila, human activities include the cutting of young trees (mostly of *Quercus fusiformis* and *Celtis reticulata*) for fence construction and charcoal production, and overgrazing (unpub. obs.); interestingly, these were also recognized by Ajbilou et al. (2003) as the main reasons for the poor regeneration of *Quercus* forests in Marocco. Overall, *Q. fusiformis* and *Carya illinoinensis* seedlings are scarce and concentrate under the canopies of seeding trees, a pattern also shown by *Quercus rugosa* along a disturbance gradient that includes varying levels of canopy openness (Bonfil and Soberón, 1999). Our data suggest a higher impact on the regeneration of oak than of walnut forest; moreover, there seems to be an intrinsic reason for the overgrazing of this forest variant, since recently flushed oak leaves are more palatable than those of walnut (Andersson, 1991) and therefore grazed more intensely. In oak forests of Nuevo León (Mexico), cattle grazing concentrated on 67% of *Quercus cupreata* and *Q*. *prinopsis* resprouted stems, whereas *Carya myristicaeformis* seedlings were the least affected by cattle (Eckelmann, 1995). Moreover, in the Coahuilan forests *C. illinoinensis* displays a better seed reproduction than oaks (pers. obs.).

Human-induced changes in canopy structure are related to diversity losses and species invasions (Hobbs and Huenneke, 1992). In our study area, sites with low canopy cover appear to be gradually colonized by species from the neighboring thorn scrub, with *Prosopis glandulosa* and *Acacia farnesiana* acting as disturbance indicator species (Sttubbendieck et al., 1992). *Prosopis glandulosa* was recorded by us in almost one fifth of all oak forest sites, where past tree extraction was evident. Such changes warrant the suspicion that regional xerophytic communities are increasingly replacing these forests. An analogous deteriorating process was observed in the mountains of Chiapas, southern Mexico, where human-disturbed oak forests are being gradually replaced by pine-dominated stands (González-Espinosa et al., 1995a, b). In southeastern USA, reservoir construction and mining in open-air quarries have triggered the transformation of riparian forests into scrub vegetation (Busch and Smith, 1995; Everitt, 1998; Shafroth et al., 2002).

The negative effects of human activities are not exclusively seen in the upper canopy, as our results provide evidence of species richness reductions in the lower tree stratum: sites showing stronger human impact consistently had fewer species in this stratum, and in extreme cases mature oaks and walnut trees were the only plants occurring at the site. Human-caused floristic richness reductions have also been documented for cloud forests of Chiapas (Ramírez-Marcial et al., 2001). If current management practices were to continue, these communities are highly likely to disappear in the long run.

Implications for oak and walnut forests protection. The region where we conducted this study hosts a relatively large biodiversity; consequently, it was included in the Priority Terrestrial Regions for Conservation Nos. 73 and 74 defined by the Mexican Government, named Sierra El Burro-Rio San Rodrigo, and Cinco Manantiales, respectively (Arriaga et al., 2000). Worldwide, the area devoted to temperate forest protection is notably scant (Norton, 1996). Protection of these Coahuilan forests started in June 18, 1940, with the publication of the official ordinance that created the Los Novillos National Park (Gómez-Pompa et al., 1995), a 42-ha nature protection area located along the Arroyo de las Vacas river, 65 km southeast of Ciudad Acuña (Anonymous, 1993). Obviously, this small area cannot guarantee the conservation of these forests, considering the minute representation of their total area (0.09%), the regeneration problems faced by most species, and the numerous factors threatening their permanence. Therefore, the protection of oak and walnut forests of the Northeastern Coastal Plain must be decidedly promoted, as in the entire territory of Mexico this is the only region where they occur and, even there, they only cover 1.84% of Coahuila State (Anonymous, 2001). Further criteria supporting the need to conserve these forests are their insular condition within a semiarid ecosystem dominated by the Tamaulipan Thorn Scrub (Villarreal-Quintanilla and Valdés-Reyna, 1992-93), and the consideration of at least one of the variants (i.e., the *Quercus fusiformis* forest) as a relict of formerly more extensive forests (Rzedowski, 1978). Ultimately, conservation of these uncommon and particular Coahuilan forests will rely on an adequate management through rational forest exploitation, as well as on an active research program aimed at understanding the dynamics of their dominant species.

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Appendix 1. Floristic checklist of the oak (*Quercus fusiformis*) and walnut (*Carya illinoinensis*) forests of the Northeastern Coastal Plain, Coahuila, Mexico.
Abbreviations of collector names: C = Miguel Agustín Carranza Pérez, E = Juan A. Encina Domínguez, R = Andrés Rodríguez Gámez, V = José A. Villarreal Quintanilla. The vouchers were deposited in the ANSM herbarium, Universidad Autónoma Agraria Antonio Narro, Saltillo (Coahuila), Mexico.

Family / Species	Specimen collection numbers	Life form	Abundance -dominance
ACANTHACEAE			
Ruellia nudiflora (Engelm. et A.Gray) Urb. var. *nudiflora*	---------	Herb	Abundant
Ruellia occidentalis (A.Gray) Tarph et F.A.Barkley	E 1862	Herb	Scarce
Siphonoglossa pilosella (Nees) Torr.	--------	Herb	Frequent
ANACARDIACEAE			
Toxicodendron radicans (L.) Kuntze subsp. *eximium* (Greene) Gillis	E 1069, C 2571, V 6000	Vine	Frequent
ASTERACEAE			
Baccharis salicifolia (Ruiz et Pav.) Pers.	E 1074, C 2569	Shrub	Scarce
Calyptocarpus vialis Less	E 1845, C 3372, R 1245	Herb	Abundant
Sanvitalia ocymoides DC	--------	Herb	Frequent
Viguiera dentata (Cav.) Spreng. var. *dentata*	E 1886, C 3433, R 1277	Herb	Abundant
Xanthium strumarium L.	--------	Herb	Scarce
CACTACEAE			
Opuntia lindheimeri Engelm.	--------	Shrub	Scarce
CYPERACEAE			
Carex schiedeana Kunze	--------	Herb	Scarce
EBENACEAE			

Appendix 1. Continues

Family / Species	Specimen collection numbers	Life form	Abundance -dominance
Diospyros texana Scheele	E 1857, C 2481	Tree	Frequent
EUPHORBIACEAE			
Bernardia myricaefolia (Scheele) Benth et Hook.	---------	Shrub	Scarce
Croton fruticulosus Engelm. ex Torr.	E 1054, C 2482	Herb	Abundant
FABACEAE			
Acacia farnesiana (L.) Willd.	C 2541, R 960	Tree	Scarce
Prosopis glandulosa Torr. var. *glandulosa*	C 2543	Tree	Scarce
FAGACEAE			
Quercus fusiformis Small	E 1030, C 2483 R 954, V 8971	Tree	Abundant
JUGLANDACEAE			
Carya illinoinensis (Wangenh.) K.Koch	E 1029, C 2510, V 6076	Tree	Abundant
Juglans microcarpa Berland. var. *microcarpa*	E 1068, C 2511, R 1064, V 5994	Tree	Rare
MALVACEAE			
Abutilon incanum (Link) Sweet	---------	Herb	Rare
Allowissadula holosericea (Scheele) D.M.Bates	E 1052	Herb	Abundant
Malvastrum coromandelianum (L.) Garcke	R 1247	Herb	Frequent
Pavonia lasiopetala Scheele	E 1860	Herb	Abundant
MENISPERMACEAE			
Cocculus carolinus (L.) DC.	E 1843	Vine	Rare
MORACEAE			
Morus celtidifolia Kunth	E 1067, C 3473	Tree	Scarce
OLEACEAE			
Fraxinus berlandieriana DC.	C 2567, V 8947	Tree	Rare
PASSIFLORACEAE			
Passiflora foetida L. var. *gossypiifolia* (Desv. ex Ham.) Mast.	E 1060, C 3727, R 1261, V 8964	Vine	Scarce
PLATANACEAE			
Platanus occidentalis L. var. *palmeri* (Kuntze)Nixon et J. Poole ex Geerinck	E 1065, C 2460, R 1052, V 6002	Tree	Rare
POACEAE			
Aristida purpurea Nutt.	E 1089	Herb	Frequent
Chloris subdolichostachya C.Muell.	E 1851, C 3090	Herb	Rare
Dichanthium annulatum (Forssk.) Stapf	E 1854, C 2525	Herb	Rare

Appendix 1. Continues

Family / Species	Specimen collection numbers	Life form	Abundance -dominance
Setaria parviflora (Poir.) Kerguélen	E 1888, C 2447	Herb	Scarce
Tridens texanus (S. Watson) Nash	C 3353	Herb	Frequent
RANUNCULACEAE			
Clematis drummondii Torr. et A.Gray	---------	Vine	Scarce
RHAMNACEAE			
Condalia hookeri M.C.Johnst.	E 1072	Tree	Scarce
SALICACEAE			
Salix nigra Marshall	---------	Tree	Rare
SAPINDACEAE			
Serjania incisa Torr.	E 1842	Vine	Rare
SAPOTACEAE			
Bumelia celastrina Kunth	--------	Tree	Rare
Bumelia lanuginosa (Michx.) Pers. var. *texana* (Buckley) Cronquist	---------	Tree	Scarce
SCROPHULARIACEAE			
Leucophyllum frutescens (Berland.) I.M.Johnst.	E 1076, C 2547	Shrub	Scarce
SIMAROUBACEAE			
Castela erecta Turpin subsp. *texana* (Torr. et A.Gray) Cronquist	E 1087	Shrub	Scarce
SMILACACEAE			
Smilax bona-nox L.	E 1070, C 3784, R 1258, V 6075	Vine	Frequent
STERCULIACEAE			
Melochia pyramidata L.	E 1891, C 2590, R 1263	Herb	Scarce
ULMACEAE			
Celtis pallida Torr.	C 2267, R 963	Shrub	Frequent
Celtis reticulata Torr.	E 1084, C 3473	Tree	Frequent
Ulmus crassifolia Nutt.	E 1031	Tree	Rare
VERBENACEAE			
Phyla nodiflora (L.) Greene var. *nodiflora*	E 1039, C 2508, V 8900	Herb	Scarce
VITACEAE			
Vitis cinerea (Engelm.) Engelm. ex Millardet	E 1032, C 2529, R 1270, V 6069	Vine	Scarce