ENDEMIC PLANTS OF THE CENTRAL GRASSLAND OF NORTH AMERICA: DISTRIBUTION, ECOLOGY, AND CONSERVATION STATUS

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ABSTRACT

This paper enumerates the endemic plants of the Central Grassland of North America. The Central Grassland encompasses the full extent of the tallgrass, mixed-grass, and shortgrass prairie ecological systems of North America plus floristically related plant communities that adjoin and/or interdigitate with the midcontinental grasslands including savanna-open woodland systems, shrub-steppe, and rock outcrop communities. There are 382 plant taxa endemic to the Central Grassland, 300 endemic species (eight of which have multiple subspecific taxa endemic to the region) and 72 endemic subspecies/varieties of more widely distributed species. Nine regional concentrations of endemic taxa were identified and are described as centers of endemism for the Central Grassland: Arkansas Valley Barrens, Edwards Plateau, Llano Estacado Escarpments, Llano Uplift, Mescalero-Monahans Dunes, Niobrara-Platte Tablelands, Raton Tablelands, Red Bed Plains, and Reverchon Rocklands. In addition to hosting localized endemics, these areas are typically enriched with more widely-distributed Central Grassland endemics as well as peripheral or disjunct occurrences of locally-rare taxa, making them regions of high floristic diversity for the Central Grassland. Most of the endemics (299 or 78%) are habitat specialists, associated with rock outcrop, sand, hydric, or riparian habitats. There is a strong correlation between geology and endemism in the Central Grassland, with 59% of the endemics (225 taxa) associated with rock outcrop habitat. Of the 382 Central Grassland endemics, 124 or 33% are of conservation concern (NatureServe ranking of G1/T1 to G3/T3). Of these at-risk taxa, 78 or 63% are primarily associated with one of the centers of endemism identified in the study. It is hoped these findings will be useful in focusing conservation action on the habitats, ecological associations, and regions of the Central Grassland that host the highest concentrations of unique and at-risk plant species and associated biological diversity.

Key Words: Central Grassland, conservation, endemism, floristic diversity, geobotany

RESUMEN

En este artículo se enumeran las plantas endémicas de la Pradera Central de Norteamérica. la Pradera Central abarca totalidad de los sistemas ecológicos de praderas de gramíneas altas, mezcladas, y bajas de Norteamérica junto con comunidades de plantas relacionadas florísticamente que se añaden y/o se entremezclan con las praderas continentales que incluyen sistemas de sabana-bosque abierto, arbusto-estepa, y comunidades de afloramientos rocosos. Hay 382 taxa endémicos de la Pradera Central, 300 especies endémicas (ocho de las cuales tienen múltiples taxa subspecíficos endémicos de la región) y 72 subespecies/variedades endémicas de especies de distribución más amplia. Se identificaron nueve concentraciones regionales de taxa endémicos y se describen como centros de endemismos de la Pradera Central: Arkansas Valley Barrens, Edwards Plateau, Llano Estacado Escarpments, Llano Uplift, Mescalero-Monahans Dunes, Niobrara-Platte Tablelands, Raton Tablelands, Red Bed Plains, y Reverchon Rocklands. Además de albergar endemismos localizados, estas áreas están típicamente enriquecidas con endemismos de la Pradera Central de distribución más amplia, así como ocurrencias periféricas o disyuntas de taxa localmente raros, que hacen de ellas regiones de alta diversidad florística para la Pradera Central. La mayoría de los endemismos (299 o 78%) están especializados en un hábitat, asociados con afloramientos rocosos, arena, agua, o hábitats riparios. Hay una correlación fuerte entre geología y endemismo en la Pradera Central, con 59% de los endemismos (225 taxa) asociados con afloramientos rocosos. De los 382 endemismos de la Pradera Central, 124 o 33% necesitan conservación (ranking de NatureServe de G1/T1 a G3/T3). De estos taxa en riesgo, 78 o 63% están asociados primariamente con uno de los centros de endemismo identificados en el estudio. Se espera que estos hallazgos sean útiles para establecer las acciones de conservación en los hábitats, asociaciones ecológicas, y regiones de la Pradera Central que alberga las mayores concentraciones de especies únicas y amenazadas y la diversidad biológica asociada.

INTRODUCTION

"The prairies have very few endemic plants."—*P.A. Rydberg* (1931)
"The relative shortage of endemics in the grassland vegetation is a significant fact."—*P.V. Wells* (1970)
"It is a striking fact that the Central Plains flora is not rich in unique taxa."—*D.I. Axelrod* (1985)

Knowledge of endemism in the flora of a region is an important element in understanding the biological

diversity and distinctiveness of the region and is helpful in prioritizing areas for conservation action. An endemic species or subspecific taxon is one whose geographic distribution is limited to some particular region. Depending on the geographic scale of the area under consideration, an endemic may have a relatively large area of distribution and may even be abundant within its range. Rare or narrow endemics are those having small ranges, high habitat specialization, low local abundance, or a combination of these attributes (Kruckeberg & Rabinowitz 1985). Generally, the narrower the distribution of a species, the greater the conservation concern.

Assessment of endemism requires a well-developed knowledge of a region's flora. Of the relatively few published enumerations of endemic plants for North America, most are limited to a particular state. Examples include Arkansas (Gentry et al. 2013), Colorado (Weber & Wittmann 1992), New Mexico (Spellenberg 1993; Sivinski & Knight 1996), Texas (Carr 2009), Utah (Shultz 1993), and Virginia (Weakley et al. 2012). California has the most extensive plant endemism literature of any state (Stebbins & Major 1965; Raven & Axelrod 1978; Smith & Sawyer 1988), including recent analyses of the biogeography of California endemic plants and the implications for conservation planning (Thorne et al. 2009; Kraft et al. 2010). Enumeration of endemic plants for regions that encompass more than one state or province are even fewer in number, but include the Atlantic and Gulf Coastal Plain (Sorrie &Weakley 2001; MacRoberts et al. 2002), the Interior Highlands (Zoller et al. 2005), the Four Corners region (Arizona, Colorado, New Mexico and Utah) of the southwest (Heil et al. 2013), and the California Floristic Province (Burge et al. 2016).

This paper enumerates the endemic plants of the grasslands and related plant communities of central North America. It is focused on the three major midcontinental grassland systems—tallgrass prairie, mixed-grass prairie and shortgrass prairie—which R. Anderson (2006) referred to collectively as the Central Grassland of North America. It roughly corresponds to the North American Prairies floristic province of Takhtajan (1986).

The study also includes floristically-related plant communities that adjoin and/or interdigitate with the midcontinental grasslands including savanna-open woodland systems, shrub-steppe, and rock outcrop communities. While not grassland or prairie vegetation per se, these associations possess a significant component of grasses, graminoids, and forbs characteristic of the regional grassland flora. This approach parallels that taken by Noss (2013) in his comprehensive survey of the grasslands of the southern United States in which he defined grassland as "any natural community or ecosystem in which the herbaceous layer is dominated by grasses, other graminoid (grass-like) plants such as sedges, and associated forbs (other herbaceous plants)." Such plant communities are here recognized collectively as "campestrian," a term used in biogeography to designate regions dominated by grassland vegetation (Cooper 1859; Mohr 1901; Turner 1959; Armstrong 1972). A synopsis of the NatureServe ecological systems encompassed by this study is presented in Table 1.

Previous Assessments of Endemism in the Central Grassland

Rydberg was the first to catalog the flora of the midcontinental grasslands, publishing *Flora of the Rocky Mountains and Adjacent Plains* in 1917 and *Flora of the Prairies and Plains of Central North America* in 1932. He also was first to comment on endemism in the flora, making the statement above in "A Short Phytogeography of the Prairies and Great Plains of Central North America." In this paper, Rydberg (1931) used "the prairies" to denote tallgrass prairie ("tall grass lands") and "the plains" to denote grasslands to the west ("short grass lands"). He provided no list or number of endemics or even examples of species he considered endemic, so it is unclear whether he was referring to all of the grasslands of central North America or only the tallgrass prairie of the east. He stated later in the paper that "about 25 species" are endemic to the "Staked Plains"—his term for the region of the western Great Plains south of the divide between the Arkansas and Platte rivers—but again provided no specific data.

The next published assessment of endemism in the flora of the region came nearly 40 years later in Wells' 1970 paper, "Historical Factors Controlling Vegetation Patterns and Floristic Distributions in the Central Plains Region of North America." Using Rydberg's (1932) *Flora of the Prairies and Plains of Central North America* for his analysis, Wells estimated that about five percent of the flora of the grassland vegetation of the Interior Plains was endemic. Rydberg's treatment included 3,988 species, which Wells distilled down to 954

Table 1. Synopsis of NatureServe ecological systems encompassed within study region.

Prairies
Central Mixedgrass Prairie
Central Tallgrass Prairie
North-Central Interior Sand and Gravel Tallgrass Prairie
Northern Great Plains Fescue-Mixed Grass Prairie
Northwestern Great Plains Mixedgrass Prairie
Southeastern Great Plains Tallgrass Prairie
Texas Blackland Tallgrass Prairie
Western Great Plains Foothill and Piedmont Grassland
Western Great Plains Sand Prairie
Western Great Plains Shortgrass Prairie
Western Great Plains Tallgrass Prairie

Savanna and Woodland
Cross Timbers Oak Forest and Woodland
Eastern Great Plains Tallgrass Aspen Parkland
Edwards Plateau Limestone Savanna and Woodland
North-Central Interior Oak Savanna
North-Central Oak Barrens
Northwestern Great Plains Aspen Forest and Parkland
Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna
Ozark Prairie and Woodland
Southern Rocky Mountain Juniper Woodland and Savanna
Southern Rocky Mountain Pinyon-Juniper Woodland
Southern Rocky Mountain Ponderosa Pine Savanna
Western Great Plains Dry Bur Oak Forest and Woodland

Shrubland
Edwards Plateau Limestone Shrubland
Llano Estacado Caprock Escarpment and Breaks Shrubland and Steppe
Northwestern Great Plains Shrubland
Western Great Plains Mesquite Scrub Woodland and Shrubland
Western Great Plains Sandhill Steppe

Barrens, Glades, and Outcrops
Central Interior Highlands Calcareous Glade and Barrens
Edwards Plateau Carbonate Glade and Barrens
Llano Uplift Acidic Forest, Woodland and Glade
Northwestern Great Plains Canyon
Southeastern Great Plains Cliff
Southwestern Great Plains Canyon
Western Great Plains Badlands
Western Great Plains Cliff and Outcrop

Herbaceous Wetland
Eastern Great Plains Wet Prairie, Meadow and Marsh
Edwards Plateau Playa
Edwards Plateau Riparian
Great Plains Prairie Pothole
North-Central Interior Freshwater Marsh
Western Great Plains Closed Depression Wetland and Playa
Western Great Plains Open Freshwater Depression Wetland
Western Great Plains Riparian
Western Great Plains Saline Depression Wetland

species that occurred naturally "in grassland vegetation on the plains." Five percent of this more restricted flora would translate into roughly 50 endemic species.

On a more limited scale, Bare and McGregor (1970) mapped and analyzed the distribution patterns of 479 vascular plants species native to Kansas and determined that only six species in the Kansas flora were endemic to the Great Plains. Five of these are recognized herein as endemic to the Central Grassland: *Aster fendleri* (= *Symphyotrichum fendleri*), *Juncus brachyphyllus*, *Oenothera fremontii* (= *O. macrocarpa* subsp. *fremontii*), *Phlox oklahomensis*, and *Scutellaria resinosa*.

The most recent assessment of endemism in the flora of the region appears in "Rise of the Grassland Biome, Central North America" by Axelrod (1985). Axelrod's analysis benefited from the detailed distribution maps published in *Atlas of the Flora of the Great Plains* (GPFA 1977), by which he determined that 68 taxa were endemic to "the central grassland region" and 322 "almost endemic, but with some sites in bordering areas." Axelrod limited his analysis to herbaceous and perennial taxa and excluded aquatic, near-aquatic, and riparian families such as Salicaceae and Potamogetonaceae.

In his overview of phytogeography for *Flora of North America* Volume 1, Thorne (1993) echoed Rydberg, Wells, and Axelrod in stating, "endemism is rather limited in the Prairies Province," noting "no endemic families, few if any endemic genera, and perhaps fewer than 50 endemic species."

Resources for a New Assessment

Publication of *Flora of the Great Plains* (GPFA 1986) was a crucial milestone in documenting the flora of the midcontinental grasslands and represented the culmination of decades of field and herbarium work by a team of researchers located at colleges and universities throughout the Great Plains. Even so, contributor Robert Kaul noted at the time of publication, "Basic floristic information is lacking for large parts of our area." Today, students of the flora of the region have many more resources at hand to aid their work, notably updated state floristic references for Colorado (Ackerfield 2015; Weber and Wittmann 2012), Missouri (Yatskievych 1999, 2006, 2013), Montana (Lesica 2012), Nebraska (Kaul et al. 2011), Texas (Diggs et al. 1999; Turner et al. 2003),

and Wyoming (Dorn 2001). Additionally, smaller scale floristic inventories and vegetation studies have been published for special areas within the Plains, including several of the U.S.D.A. Forest Service National Grassland units (Hazlett 1998, 2004; Hazlett et al. 2009; Kuhn et al. 2011). These resources, coupled with recent phylogenetic studies of groups with Plains taxa, many in preparation for the *Flora of North America* (FNAEC 1993–), provide data for a new assessment of endemism in the flora of the Central Grassland.

STUDY REGION

The core of the study region is the Central Grassland of North America as delineated by R. Anderson (2006) and encompasses the full extent of the tallgrass, mixed-grass, and shortgrass prairies of the midcontinent. This descriptive name is abbreviated hereafter as "Central Grassland" and endemics of the region as "CG endemics." Figure 1 shows the geographic extent of the study region.

The study region encompasses but is not limited to the Great Plains of North America. Fenneman's (1931) physiographic definition of the Great Plains is widely used in ecological and biogeographic studies but the boundaries of Fenneman's Great Plains physiographic province excludes most of the tallgrass prairie and much of the southern mixed-grass prairie. The study region is also more expansive than that considered in *Atlas of the Flora of the Great Plains* (GPFA 1977) and *Flora of the Great Plains* (GPFA 1986), which exclude significant reaches of the midcontinental grasslands that lie to the east, south and north (see Figure 1). The use of the term "Great Plains" or "Plains" is limited hereafter to the physiographic province as defined by Fenneman.

Thus circumscribed, the study region takes in all or part of 17 states—Arkansas, Colorado, Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Wisconsin, and Wyoming—plus the Canadian provinces of Alberta, Manitoba, and Saskatchewan. Finer-scale, ecosystem-level boundaries are delineated below. A synopsis of NatureServe ecological systems encompassed by this study is presented in Table 1.

Northern Extent

The study region extends north of the United States to encompass the praire grasslands of Canada, including the Aspen Parkland. Shorthouse (2010) recognized eight ecoregions within Canada's Prairies Ecozone—Mixed Grassland, Cypress Upland, Moist Mixed Grassland, Fescue Grassland, Tall-Grass Prairie, and Aspen Parkland. Aspen Parkland occurs at the northern limits of the grassland biome in Manitoba, Saskatchewan, and Alberta and adjacent portions of Minnesota, North Dakota, and Montana. So named because of the parklike appearance of open grassland and scattered groves of quaking aspen (*Populus tremuloides* Michx.), this zone forms an interface between the grassland biome to the south and the boreal forest to the north (Archibold 1999; Shorthouse 2010). Looman and Best (1987) recognized eastern, central, and western sections of the Parklands in the Canadian Prairie Provinces, with the herbaceous component derived from tallgrass prairie in the eastern section and mixed-grass prairie in the central and western portions.

Western Extent

While the Rocky Mountain cordillera provides an easily recognizable western physiographic boundary for the Great Plains, many species typical of Plains grassland systems extend up onto the eastern slope of the mountains, either in piedmont or foothill grassland communities or as components of the herbaceous layer of conifer woodland/savanna (Moir 1969; Mueggler & Stewart 1980; Dick-Peddie 1993; Knight 1994). For the purposes of this study, the western boundary of the study region is set at the lower elevational limits of *Pinus ponderosa* Douglas × P. Laws. & C. Laws. woodland. This delineation incorporates into the study region conifer savanna/open woodland formations that occur in places along the eastern flank of the Rocky Mountains between *Pinus ponderosa* woodland and Plains grassland systems (Knight 1999; West 1999). In the Southern Rocky Mountains, from south-central Colorado into New Mexico, this zone is occupied by juniper (*Juniperus monosperma* (Engelm.) Sarg.) or juniper-piñon pine (*Juniperus monosperma-Pinus edulis* Engelm.) woodland/savanna systems that also extend eastward onto the Plains in association with tablelands and canyons. Northward along the Rocky Mountain front this zone is occupied by open stands of *Juniperus scopulorum* Sarg. and/or *Pinus flexilis* E. James, which also extend eastward onto the Plains along escarpments. As with *Pinus*

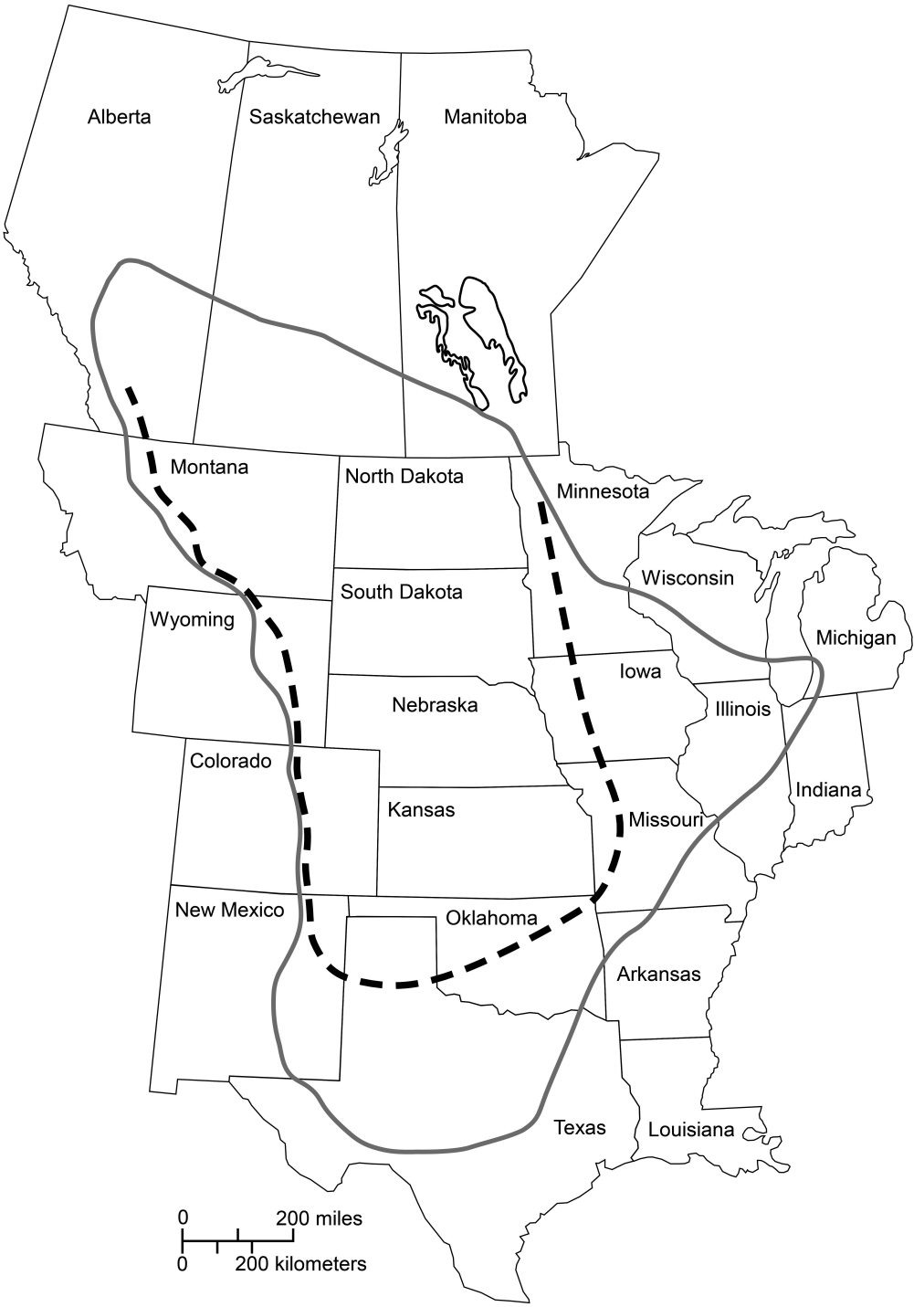

Fig. 1. The Central Grassland of North America. Adapted from R. Anderson (2006). Dashed line indicates the geographical area covered in *Flora of the Great Plains* (GPFA 1986).

ponderosa savannas, the herbaceous layer of these xeric conifer woodlands is composed of grassland species, although in the northwestern part of the study region in eastern Montana the species composition has stronger affinities with Intermountain sagebrush steppe than Great Plains grasslands (Lavin & Seibert 2011).

In many places along the Rocky Mountain front, geologic strata of the Plains have been sharply upturned by the rise of the mountains into series of erosional scarps, hogbacks, mesas, and other topographic features. This rocky habitat often supports sparsely-vegetated barrens communities dominated by low-growing forbs and sub-shrubs, including many narrowly-distributed edaphic endemics. These rock outcrop communities are included in the study region.

Significant gaps in the Rocky Mountain cordillera occur in central Wyoming and central New Mexico. In both regions there exists a transition zone where the flora of the semiarid Plains gives way to species and ecological systems characteristic of arid regions to the west. In Wyoming, the transition zone is centered on the Casper Arch, an elevated area that extends from the southern tip of the Bighorn Mountains (Middle Rocky Mountains) to the northern edge of the Laramie Range (Southern Rocky Mountains). This marks the eastern edge of the Wyoming Basin, which is strongly influenced by the flora of the Great Basin (Dorn 2001). In New Mexico, the transition zone occurs between the southern end of the Sangre de Cristo Range (Southern Rocky Mountains) and the northern edge of mountains of the Basin and Range Province. This region marks a zone of tension between the flora of the Central Grassland and the flora of the Colorado Plateau (Dick-Peddie 1993). For the purposes of this study, a taxon is included in the analysis if the main part of its range lies to the east of these transition zones.

Eastern Extent

The study region encompasses the full eastern extent of the historically-known distribution of the tallgrass prairie in North America, sometimes referred to as True Prairie (Clements 1920; Rydberg 1931; Weaver 1954; Diamond & Smeins 1988) to distinguish it from mixed-grass and shortgrass prairie of the central and western Plains. Prior to almost complete conversion to agricultural production, tallgrass prairie occurred across the upper Midwest (Illinois, Iowa, Minnesota, and Wisconsin) and through the "Prairie Peninsula" (Transeau 1935) as far east as Indiana and Ohio, often in mosaic with oak woodland and savanna (Curtis 1959; Nuzzo 1986; Anderson & Bowles 1999; Will-Wolf & Stearns 1999; Cochrane & Iltis 2000; Nelson 2005).

The study region also includes the tallgrass prairies and related campestrian communities of the Ozark Highlands, which occur primarily on the Springfield Plateau of southwestern Missouri and northwestern Arkansas. Maps depicting the distribution of tallgrass prairie in North America do not usually include the Ozarks (e.g., Kuchler 1985; Lauenroth et al. 1999; Sims & Risser 2000) but the system of upland prairie, savanna, open woodland, and rock outcrop communities that historically (Bielmann & Brenner 1951; Schroeder 1982; Hanberry et al. 2014) and currently (Nelson 2005) form a continuum across the region shares a suite of grasses and other herbaceous species common to the tallgrass prairies and even mixed-grass prairies of the Central Grassland (Lawless et al. 2006). In addition, a number of species associated with rocky prairies and campestrian communities in the Ozarks also occur in association with carbonate rock outcrop habitat in Flint Hills of Kansas and Oklahoma, the Arbuckle Uplift in Oklahoma, the Blackland Prairie and Grand Prairie regions of north-central Texas, and along the eastern edge of the Edwards Plateau of central Texas. Examples include *Argyrochosma dealbata*, *Erythronium mesochoreum*, *Oenothera macrocarpa* subsp. *macrocarpa*, and *Zeltnera texensis*.

Many species characteristic of the once-extensive tallgrass prairie range beyond the study region where they occur in localized herbaceous communities within an otherwise forested landscape. On the upper Gulf Coastal Plain in Arkansas and Louisiana, these communities are remnant or naturally-isolated small-patch blackland prairies, clay prairies, saline prairies, and glades (Foti et al. 2003; MacRoberts et al. 2002, 2003, 2009, 2011; Reid et al. 2010; Foti & Witsell 2013). Farther east in Kentucky, Tennessee, Mississippi, Alabama, Georgia, and Florida, a number of species with tallgrass prairie affinities have disjunct occurrences in association with calcareous glades, barrens, and riverscour habitat (Bridges & Orzell 1986; Allison & Stevens 2001; Pringle & Witsell 2005; Lawless et al. 2006; Johnson et al. 2013; Noss 2013). Examples include *Echinacea*

pallida (Nutt.) Nutt., *Muhlenbergia cuspidata* (Torr. ex Hook.) Rydb., *Polytaenia nuttallii* DC., *Silene regia* Sims, *Silphium laciniatum* L., and *Spiranthes magnicamporum* Sheviak. Species such as these that are characteristic components of tallgrass prairie but range considerably beyond the study region are excluded from the analysis.

The grasslands and related campestian communities of the southeastern United States have recently received attention for their biological richness and critical need for conservation efforts (Noss 2013). These communities often support locally rare species, both disjunct populations of species with tallgrass prairie affinities and narrowly distributed endemics. Many of these southeastern endemics are of genera, subgeneric sections/series, or phylogenetic lineages well represented in the Central Grassland including *Astragalus bibullatus* Barneby & E.L. Bridges, *Dalea cahaba* J.R. Allison, *Pediomelum piedmontanum* J.R. Allison, M.W. Morris, & A.N. Egan, and *Physaria globosa* (Desv.) O'Kane & Al-Shehbaz. While the floristic affinities of these communities indicate past connections with the Central Grassland, the associated endemics are generally highly localized in the southeastern United States and are excluded from the present analysis.

Southern Extent

The southern reach of the study region extends considerably beyond that treated in the *Atlas of the Flora of the Great Plains* (GPFA 1977) and *Flora of the Great Plains* (GPFA 1986) to allow for consideration of the full extent of ecological systems (i.e., tallgrass, mixed-grass, and shortgrass prairie) that range from the central Plains (Kansas and Oklahoma) south into Texas. As delineated by Griffith et al. (2004) in Ecoregions of Texas, the study region includes the Texas Blackland Prairies, Cross Timbers (including the Grand Prairie and Limestone Cut Plain), Central Great Plains, Southwestern Tablelands, High Plains, and Edwards Plateau (including the Llano Uplift).

The study region excludes the Post Oak Savanna and Coastal Prairies of the Texas Coastal Plain. Recent studies have shown the Western Gulf Coastal Plain to be a distinctive floristic region and center of endemism within the larger Coastal Plain Floristic Province of North America (Estill & Cruzan 2001; Sorrie & Weakley 2001; MacRoberts et al. 2002; Noss et al. 2015). Although the Texas Blackland Prairies ecoregion is also located on the Coastal Plain, it is included in the study region because it shares many species with tallgrass prairie formations to the north (Diamond & Smeins 1985, 1988) and a number of species associated with the Edwards Plateau and Grand Prairie regions to the west have outlying occurrences in the Blackland Prairies region on outcroppings of the calcareous Austin Chalk.

On the southwest, the study region encompasses the full extent of the Llano Estacado, a vast tableland and remnant of the ancient High Plains surface that stretches from the Canadian River south to the valley of the Pecos River. Only the northern one-third of the Llano Estacado (the Texas Panhandle and adjacent part of New Mexico) was included in the region treated in the *Flora of the Great Plains* (1986) (see Fig. 1). Several unique habitats and ecological systems are associated with the Llano Estacado, notably escarpment breaks, canyonlands, playa wetlands, and dune fields (Rowell 1967; Bolen et al. 1989; Muhs & Holliday 2001; Smith 2003; Flores 2010).

MATERIALS AND METHODS

The distribution data needed to identify endemic plants in the flora of the Central Grassland were drawn from a wide variety of sources including regional, state, and local floras, floristic atlases, published descriptions of new species, recent phylogenetic literature, monographs, conservation assessments of rare species, state natural heritage program databases, examination of herbarium specimens, and the author's 30 years of field experience in the study region. Ecological community affiliations of these taxa were drawn from the same sources.

Definition of Endemic

Following the criteria used in other phytogeographic studies (Sorrie & Weakley 2001; MacRoberts et al. 2002), a taxon is considered endemic to the study region if at least 90% of its geographic distribution is limited to the Central Grassland as here delineated. This allows for inclusion of taxa with distributions centered in the Central Grassland but extending to some extent beyond, either as a slight overlapping of its contiguous range

or as relatively few isolated, disjunct occurrences. Examples of such taxa include *Penstemon haydenii*, all but limited to the Nebraska Sandhills except for highly disjunct populations in sand habitat in the Wyoming Basin, *Castilleja genevievana*, endemic to the southwestern Edwards Plateau of Texas except for one closely adjacent occurrence in Coahuila, Mexico, and *Solidago gattingeri*, limited to rocky prairies and glades in the Ozark Plateaus of Missouri and Arkansas except for disjunct occurrences in the cedar glade region of central Tennessee.

Only taxa associated with campestrian plant communities were included in the analysis of endemism in the study region. As defined herein, "campestrian" encompasses grasslands as well as savanna-open woodland systems, shrub-steppe, and rock outcrop communities that possess a significant component of grasses, graminoids, and forbs characteristic of the regional grassland flora. This definition excludes taxa which may be geographically restricted to the study region but are ecologically associated with closed-canopy forests.

Taxonomic Considerations

The list of Central Grassland endemics presented in Appendix 1 includes a relatively small number of taxa which have been synonymized by some authorities or are of otherwise uncertain taxonomic status. These are included because they appear to be associated with a distinct region or habitat within the Central Grassland and further study may prove them worthy of recognition. Examples include *Echinocereus coccineus* subsp. *roemeri* of granite habitat in the Llano Uplift region of Texas and *Thelypodium wrightii* var. *oklahomensis* of the Mesa de Maya region of Colorado and Oklahoma. Authorities for scientific names are given in the text only for taxa not listed in Appendix 1.

Conservation Status

A taxon is here considered a plant of conservation concern if it has been given a NatureServe global conservation status ranking of G1/T1, G2/T2, or G3/T3. G-rankings pertain to species, T-rankings to subspecific taxa. Table 2 presents the NatureServe global conservation status rankings used in this study.

RESULTS AND DISCUSSION

This paper identifies 382 plant taxa that are endemic to the Central Grassland of North America as defined herein. There are 300 endemic species, eight of which have multiple subspecific taxa (totaling 10 taxa) endemic to the region (e.g., *Oenothera macrocarpa* and *Physaria ovalifolia*), and 72 endemic subspecies/varieties of more widely distributed species. Appendix 1 presents an annotated list of these taxa. Families and genera with the largest number of endemic taxa in the Central Grassland are show in Table 3 and Table 4, respectively.

DISTRIBUTION OF ENDEMIC PLANTS IN THE CENTRAL GRASSLAND

Analysis of the geographic distribution patterns of CG endemics reveals regional concentrations of endemic taxa. These nine areas are here recognized as centers of endemism for the Central Grassland. Figure 2 shows the location of these areas within the study region and Table 5 summarizes the number of CG endemics with distributions limited to or primarily centered in each center of endemism. These taxa may range to some extent into adjacent regions but are mostly localized in a particular area of endemism and associated with distinctive habitat characteristic of the area.

The flora of these centers of endemism typically includes additional taxa that are endemic to the Central Grassland but range more widely. These are not included in Table 5 but are noted in the discussion of each center of endemism that follows. The ecological character and associated taxa of each center of endemism are presented below. Plants of conservation concern are noted by their NatureServe global conservation status ranking (see Table 2).

Arkansas Valley Barrens.—Rocky habitat along the middle Arkansas River valley in south-central Colorado between Pueblo (Pueblo County) and Cañon City (Fremont County) has long been recognized for supporting a distinctive flora with a number of rare and endemic species (Kelso et al. 1996; Colorado Native Plant Society 1997; D. Anderson 2006; Neid & Handwerk 2007; Neely et al. 2011; Weber & Wittmann 2012). This habitat has been termed the Niobrara Chalk Barrens because the regional endemics are strongly

Table 2. NatureServe global conservation status rankings used in this study.

G1 Critically imperiled: At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2 Imperiled: At high risk of extinction due to very restricted range, very few populations (often 20 or fewer populations), steep declines, or other factors.
G3 Vulnerable: At moderate risk of extinction or extirpation due to a restricted range, relatively few populations (often 80 or fewer populations), recent and widespread declines, or other factors.
GH Possibly extinct: Missing; known from only historical occurrences but still some hope of rediscovery.

Table 3. Families with the largest number of endemic taxa in the Central Grassland.

Asteraceae	79 taxa in 40 genera
Fabaceae	56 taxa in 16 genera
Brassicaceae	20 taxa in 8 genera
Onagraceae	16 taxa in 1 genus
Polygonaceae	13 taxa in 2 genera
Plantaginaceae	12 taxa in 2 genera
Polemoniaceae	11 taxa in 2 genera

Table 4. Genera with the largest number of endemic taxa in the Central Grassland.

Astragalus (Fabaceae)	18
Oenothera (Onagraceae)	16
Physaria (Brassicaceae)	13
Eriogonum (Polygonaceae)	12
Pediomelum (Fabaceae)	11
Penstemon (Plantaginaceae)	11
Phlox (Polemoniaceae)	10
Dalea (Fabaceae)	9
Yucca (Agavaceae)	7
Asclepias (Asclepiadaceae)	6
Callirhoe (Malvaceae)	6

associated with the Niobrara Formation, a Cretaceous sedimentary bedrock complex forming shale, limestone, and chalk outcrops (Scott & Cobban 1964). The most botanically important barrens occur on the Middle Chalk and Upper Chalk units of the Smoky Hill Member of the Niobrara Formation (Kelso et al. 2003).

The distributions of five taxa are limited to or primarily centered in the Arkansas Valley Barrens (Table 6). *Mentzelia chrysantha* and *Oonopsis puebloensis* are strictly limited to the Pueblo-Cañon City area. The distributions of *Mirabilis rotundifolia*, *Parthenium tetraneuris*, and *Penstemon versicolor* are concentrated in this area but also include outlying occurrences in the Raton Tablelands to the southeast where they are associated with similar calcareous rock formations (Neid et al. 2007). All of these species are of conservation concern. Three CG endemics with distributions centered on the Raton Tablelands—*Oenothera harringtonii* (G3), *Penstemon auriberbis*, and *Physaria calcicola* (G2)—also have occurrences in the Arkansas Valley Barrens. All of these species occur in sparsely vegetated (10–20% cover) rock outcrop communities dominated by low-growing perennial herbs in mosaic with sparse shrubland and piñon-juniper (*Pinus edulis – Juniperus monosperma*) woodland (Kelso et al. 1996; Neid & Handwerk 2007; Neely et al. 2011).

These rock outcrop communities also host a number southwestern species that are at the northern limits of their distributions in the Pueblo-Cañon City area including *Artemisia bigelovii* A. Gray, *Dalea jamesii* (Torr.) Torr. & A. Gray, *Eriogonum lachnogynum* Torr., *Frankenia jamesii* Torr. ex A. Gray, *Physaria fendleri* (A. Gray) O'Kane & Al-Shehbaz, and *Townsendia fendleri* A. Gray (G3). The distribution of *Frankenia jamesii* in the Plains is essentially bi-centric between the Arkansas Valley Barrens and the Raton Tablelands (Decker 2007; Snow 1990). This shrub occurs on calcareous rock outcrops in both regions and is the dominant species of an

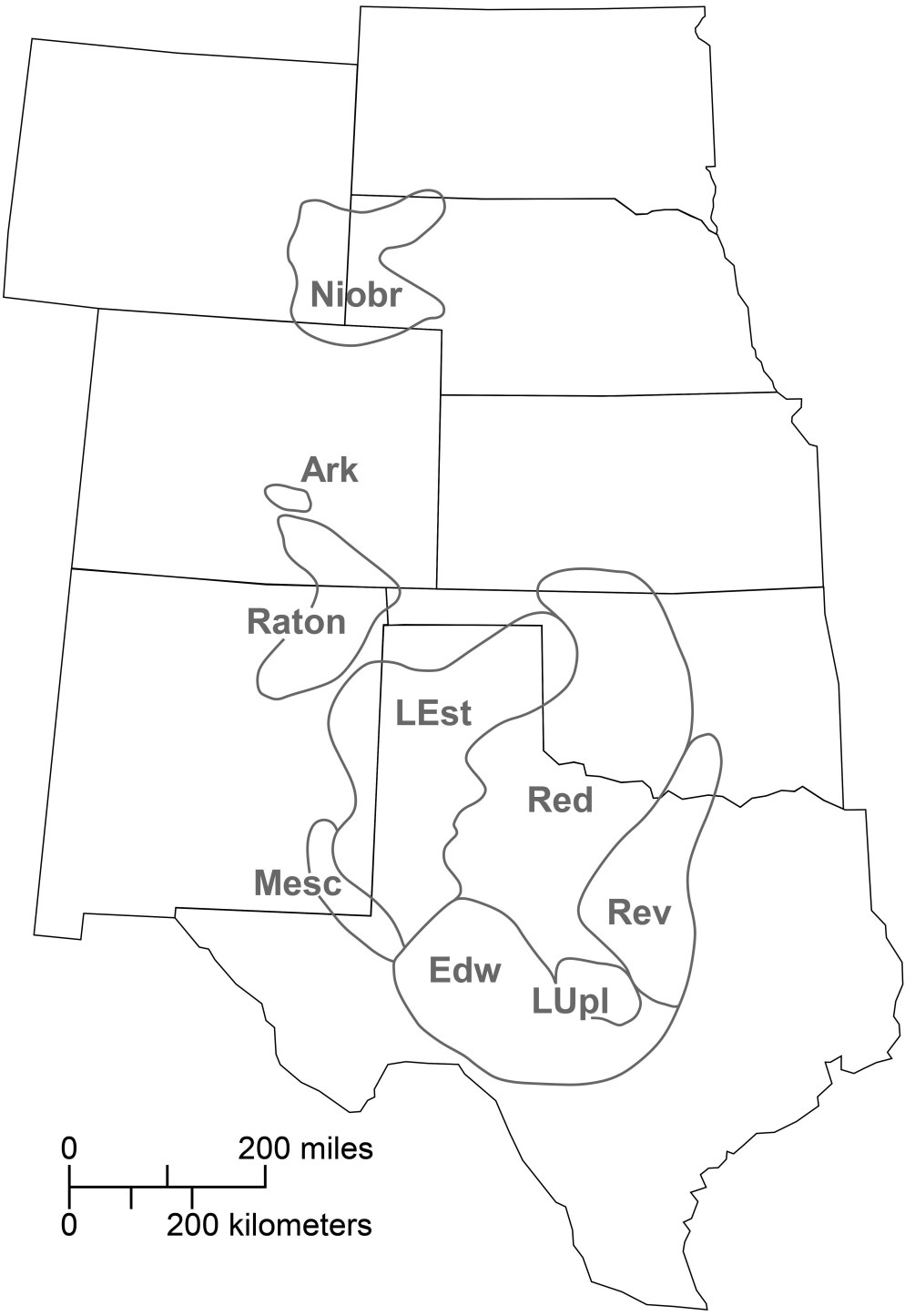

Fig. 2. Centers of plant endemism in the Central Grassland. **Ark**= Arkansas Valley Barrens; **Edw** = Edwards Plateau; **LEst** = Llano Estacado Escarpments; **LUpl** = Llano Uplift; **Mesc** = Mescalero-Monahans Dunes; **Niobr** = Niobrara-Platte Tablelands; **Raton** = Raton Tablelands; **Red** = Red Bed Plains; **Rev** = Reverchon Rocklands.

Table 5. Centers of endemism in the Central Grassland.

Center of endemism	States of occurrence	Number of localized CG endemics
Arkansas Valley Barrens	CO	5
Edwards Plateau	TX	59
Llano Estacado Escarpments	NM, OK, TX	7
Llano Uplift	TX	11
Mescalero-Monahans Dunes	NM, TX	7
Niobrara-Platte Tablelands	CO, NE, WY	10
Raton Tablelands	CO, NM, OK	15
Red Bed Plains	KS, OK, TX	8
Reverchon Rocklands	OK, TX	11

Table 6. Regional endemics of the Arkansas Valley Barrens.

Mentzelia chrysantha G2
Mirabilis rotundifolia G2
Oonopsis puebloensis G2
Parthenium tetraneuris G3
Penstemon versicolor G3

unusual and geographically limited shrubland with which several taxa of rare and endemic plants are associated (Neid et al. 2007; Shaw et al. 1989a). Populations of *Asclepias uncialis* Greene (G3) occur within the Arkansas Valley Barrens region in association with shortgrass prairie (Decker 2006).

Edwards Plateau.—The Edwards Plateau is a vast tableland bounded on its southern and southeastern margins by the Balcones Canyonlands, a highly dissected landscape of steep canyons, narrow divides, and high-gradient streams. The Balcones Escarpment provides a sharp demarcation between the Edwards Plateau and the Gulf Coastal Plain. The central and western portion of the plateau is a broad, gently rolling plain that grades gradually from east to west into the Grand Prairie, Rolling Plains, and High Plains regions to the north. Limestones of the Edwards Formation (Cretaceous) dominate the central and western portions of the plateau. In the Balcones Canyonlands, erosion has in many places removed rocks of the Edwards Formation and exposed older Cretaceous strata, primarily the Glen Rose Formation.

Rocky habitat is a characteristic feature of the Edwards Plateau landscape. The nearly horizontal limestone strata of the Edwards Formation are relatively massive and resistant to erosion and exposures occur in the landscape as ground-level expanses of fractured bedrock and as ledges, bluffs, or rimrock above watercourses. The Glen Rose Formation is composed of alternating bands of hard limestone and soft marl and the different weathering and erosion rates of these rock types results in "stair step" topography of relatively flat-topped hills and upland divides with moderate to steeply sloping hillsides (Riskind & Diamond 1988).

Such rocky habitat plays a significant role in structuring vegetation on the Edwards Plateau. In canyons along the Balcones Escarpment, a gradation of microhabitats occurs from rimrock and cliff face to canyon bottom. Springs and seeps develop in these canyons at the contact between strata of the Edwards Formation and the lower (older) Glen Rose Formation, creating mesic conditions that support closed-canopy deciduous forest (Riskind & Diamond 1988). In contrast, xeric conditions prevail on upland sites where hard-bedding limestone strata have been exposed and soils are very shallow and rocky. Such habitat supports small patch communities of herbaceous vegetation within the surrounding matrix of juniper-oak woodland and savanna (Terletzky & Van Auken 1996; Van Auken 2000).

The Edwards Plateau is recognized as a distinct vegetational area and floristic province with one of the highest levels of vascular plant endemism of any region in North America (Correll & Johnston 1970; Poole et al. 2007). While the Edwards Plateau is included in geologic and physiographic delineations of the Great

Plains (Fenneman 1931; Hunt 1974), the floristic linkages with the Central Grassland are complicated. A high percentage of strict Edwards Plateau endemics occur in forested, relatively mesic habitat in the Balcones Canyonlands along the southern and southeastern margins of the plateau (Amos & Rowell 1988; Poole et al. 2007; Carr 2009), and analysis of phytogeographic relationships indicate strong connections with the flora of southeastern North America and the Madrean region of northern Mexico (Saghatelyan 2015). Yet most of the central and western portions of the Edwards Plateau, as well as upland divides in the Canyonlands region, historically supported a mosaic of grassland with juniper and/or oak woodland or open woodland and savanna with the herbaceous layer composed of species characteristic of adjacent or interdigitating Plains grassland formations, grading from shortgrass prairie on the west to mixed-grass prairie on the east (Fowler & Dunlap 1986).

Survey of floristic, ecological, and rare plant literature for this study identified 82 taxa with distributions limited to or primarily centered on the Edwards Plateau. Of these, 21 are associated with mesophytic forest in the Balcones Canyonlands where the tree canopy is generally closed and the herbaceous layer lacks grassland species. These canyon species, including *Carex edwardsiana* E.L. Bridges & Orzell, *Clematis texensis* Buckley, *Galactia watsoniana* W.C. Holmes & Singhurst, *Lithospermum helleri* (Small) J. Cohen, *Prenanthes carrii* Singhurst, O'Kennon, & W.C. Holmes, and *Salvia pentstemonoides* Kunth & Bouché, are excluded from the present analysis. Also excluded are *Donrichardsia macroneuron* (Grout) H.A. Crum & L.E. Anderson, an aquatic moss, and *Zizania texana* Hitchc., an aquatic grass, both endemic to spring-fed streams at the edge of the Edwards Plateau.

Exclusion of these forest and aquatic species leaves 59 taxa that are regional endemics of Edwards Plateau campestrian plant communities (Table 7). An additional 32 CG endemics also occur in campestrian plant communities on the Edwards Plateau but range more widely, most often into the Grand Prairie region of north-central Texas (see discussion of Reverchon Rocklands that follows).

Quite a few Edwards Plateau endemics have limited distributions and are of conservation concern, including almost all of those associated mesophytic forests in the Balcones Canyonlands. Another concentration of rare species occurs in xeric rock outcrop habitat in the semi-arid southwestern Edwards Plateau, including *Dalea sabinalis* (possibly extinct), *Eriogonum nealleyi* (G2), *Forsellesia texensis* (G1) *Perityle warnockii* (G1), and *Pomaria brachycarpa* (G2).

Llano Estacado Escarpments.—The Llano Estacado is the portion of the High Plains south of the Canadian River in northwestern Texas and eastern New Mexico. This phenomenally flat tableland is an alluvial plain composed of deposits carried eastward by ancient streams flowing from the Rocky Mountains. The surface geology of the region is shaped by underlying deposits of the Ogallala Group (Pliocene), known colloquially as "caprock" due to the tendency of its constituent sand and gravel deposits to be cemented by calcium carbonate into erosion-resistant ledges or "mortar beds" (Reeves 1972).

Much of the plateau is bounded by dramatic escarpments—the Caprock Escarpment on the east, the Mescalero Ridge on the west, and the Canadian Breaks on the north (Flores 2010). Along the length of these escarpments, erosion by headward-cutting streams has resulted in a zone of rugged, broken terrain that includes cliffs, breaks, badlands, mesas, and canyons. Where streams have carved most deeply into the surface of the plateau, as in the spectacular Palo Duro Canyon near Amarillo, Texas, older rocks of Jurassic, Triassic, and Permian systems are exposed below the Ogallala caprock, some of which have formations containing dolomite and gypsum (Hood & Underwood 2001; Nesom & O'Kennon 2008; Spearing 1991).

This center of endemism roughly corresponds to the Llano Estacado Caprock Escarpments and Breaks Shrubland and Steppe ecological system of NatureServe but encompasses escarpment habitat along the entire extent of the Llano Estacado, not just the eastern Caprock. The matrix vegetation of this rugged habitat is sparse shrubland and juniper woodland in mosaic with grassland (Rowell 1967).

The distributions of seven taxa are limited to or primarily centered in the Llano Estacado Escarpments region (Table 8). Most of these occur along the eastern Caprock Escarpment and all are associated with rock outcrop habitat. A number of other CG endemics also occur in this habitat in the region, including *Astragalus*

Table 7. Regional endemics of Edwards Plateau campestrian plant communities.

Agalinis edwardsiana	*Muhlenbergia involuta*
Amorpha roemerana G3	*Nolina lindheimeriana*
Argemone aurantiaca	*Paronychia lindheimeri*
Argythamnia aphoroides G2	*Parthenocissus heptaphylla*
Argythamnia simulans	*Pectis angustifolia* var. *fastigiata*
Astragalus crassicarpus var. *berlanderii* T3	*Pediomelum latestipulatum* var. *appressum*
Astragalus mollissimus var. *coryi* T3	*Penstemon guadalupensis* G3
Berberis swaseyi G3	*Penstemon helleri*
Brickellia cylindracea	*Penstemon triflorus* G3
Brickellia dentata G3	*Perityle lindheimeri* var. *halimifolia* T3
Brickellia eupatorioides var. *gracillima* T3	*Perityle lindheimeri* var. *lindheimeri* T3
Cardamine carrii	*Perityle warnockii* G1
Castilleja genevievana G3	*Phlox villosissima* subsp. *villosissima*
Castilleja lindheimeri T3	*Physaria sessilis*
Chamaesyce angusta	*Pomaria brachycarpa* G2
Chamaesaracha edwardsiana	*Prunus minutiflora*
Chaetopappa bellidifolia	*Ruellia metziae*
Condalia hookeri var. *edwardsiana* T1	*Sclerocactus brevihamatus* subsp. *tobuschii* T3
Crataegus turnerorum G3	*Selenia jonesii* G3
Dalea sabinalis GH	*Seymeria texana* G3
Daucosma laciniatum	*Streptanthus petiolaris*
Echinocereus milleri G1	*Tinantia anomala*
Elymus texensis G1	*Triodanus coloradensis*
Eriogonum nealleyi G2	*Valerianella stenocarpa* G3
Eucnide bartonioides var. *edwardsiana*	*Verbesina lindheimeri*
Forsellesia texensis G1	*Vernonia guadalupensis*
Galactia texana	*Vitis monticola*
Hesperaloe parviflora G3	*Yucca reverchonii* G3
Ipomoea costellata var. *edwardsiana* T2	*Yucca rupicola*
Lythrum ovalifolium G3	

Table 8. Regional endemics of the Llano Estacado Escarpments.

Eriogonum alatum var. *glabriusculum*
Eriogonum correllii G2
Forsellesia planiterium
Hedyotis nigricans var. *papillacea* T3
Oenothera macrocarpa subsp. *incana* T3
Solidago altiplanites
Townsendia texensis

puniceus var. *puniceus* (T3), *Dalea tenuifolia*, *Oenothera coryi* (G3), *Pediomelum linearifolium*, *Physaria ovalifolia* subsp. *ovalifolia*, *Scutellaria resinosa*, and *Symphyotrichum fendleri*.

Llano Uplift.—The Llano Uplift of central Texas, also known as the Central Texas Uplift and Central Mineral Region, is a region of exposed Precambrian granitic bedrock mostly surrounded by the Cretaceous limestone formations of the Edwards Plateau and Grand Prairie. Fenneman (1931) included it in the Great Plains physiographic province and it is often treated as a unique subregion or vegetational area of the Edwards Plateau (Correll & Johnston 1970; Griffith et al. 2004; Poole et al. 2007). It is here treated separately from the Edwards Plateau since the regional endemics of the Llano Uplift are strictly associated with granite and do not occur on the limestone formations in the surrounding regions.

The matrix vegetation of the Llano Uplift is oak woodland and savanna in mosaic with grassland but granite exposures are sparsely vegetated and nearly devoid of woody species (Whitehouse 1933; Walters & Wyatt 1982; Singhurst et al. 2007; Taylor & O'Kennon 2016). The 11 regional endemics of the Llano Uplift (Table 9) are all associated with granite outcrops or granitic soils. All are strictly limited to the Llano Uplift

Table 9. Regional endemics of the Llano Uplift.

Brazoria enquistii G2
Campanula reverchonii G2
Croptilon hookerianum var. *graniticum*
Echinocereus coccineus subsp. *roemeri*
Eriogonum tenellum var. *ramosissimum* T3
Indigofera miniata var. *texana*
Isoetes lithophila G2
Monarda stanfieldii G3
Packera texensis G2
Tradescantia pedicellata G2
Valerianella texana G2

texcept *Packera texensis* which has a few outlying populations to the north. While not entirely limited to Llano Uplift, the distribution of CG endemic *Phlox drummundii* var. *mcallisteri* is centered on the region but also extends into adjacent areas where sandstone bedrock has weathered into coarse arenaceous soils similar in texture to granitic sands (Locklear 2011).

The lithology and inherent weathering patterns of granite bedrock present a variety of unique microhabitats to which the regional endemics of the Llano Uplift are adapted (Whitehouse 1933; Smith 1981; Walters & Wyatt 1982; Trock & O'Kennon 2003; M. Turner 2003; Poole et al. 2007; Carr 2009). *Isoetes lithophila* is restricted to shallow ephemeral pools formed atop barren bedrock. *Eriogonum tenellum* var. *ramosissimum* and *Tradescantia pedicellata* occur in bedrock fractures. *Campanula reverchonii*, *Croptilon hookerianum* var. *graniticum*, *Packera texensis*, and *Valerianella texana* occur in shallow accumulations of gravel over bedrock. *Brazoria enquistii* and *Monarda stanfieldii* are associated sandbar deposits along streams. *Brazoria enquistii*, *Campanula reverchonii*, *Croptilon hookerianum* var. *graniticum*, and *Valerianella texana* are annuals.

The Llano Uplift shares floristic connections with the Arbuckle Uplift and Wichita Mountains of Oklahoma, two regions where granitic bedrock also is exposed. Among these are remarkably disjunct occurrences of granite specialists of the Piedmont region of the southeastern United States: *Isoetes piedmontana* (N.E. Pfeiffer) C.F. Reed has been discovered in the Llano Uplift and *Cyperus granitophilus* McVaugh (G3) in the Llano Uplift, Arbuckle Mountains, and Wichita Mountains (O'Kennon & Taylor 2015; Taylor & O'Kennon 2016). These granitic areas also host disjunct and/or peripheral occurrences of xeric-adapted fern species associated with igneous rock outcrop habitat in the southwestern United States and Mexico, including *Astrolepis integerrima* (Hook.) Benham & Windham, *Cheilanthes horridula* Maxon, *Cheilanthes lindheimeri* Hook., *Cheilanthes wootonii* Maxon, *Notholaena standleyi* Maxon, and *Pellaea wrightiana* Hook. (Smith 2010; Diggs & Lipscomb 2014).

Mescalero-Monahans Dunes.—The Mescalero-Monahans Dunes are the southernmost dune fields of the Great Plains (Muhs & Holliday 1995). This extensive belt of sand dunes is located on the east side of the Pecos River valley adjacent to the western escarpment of the southern High Plains (the Llano Estacado), the portion in New Mexico called the Mescalero dunes and the portion in Texas the Monahans dunes (Holliday 2001; Muhs & Holliday 2001). Sometimes included in floristic and ecological treatments of the arid Trans-Pecos region of Texas, these dune fields are included in the study region because the matrix vegetation is sand shinnery, a type of shrub-steppe dominated by Havard shin oak (*Quercus havardii*) that is unique to the Great Plains, ranging from the Mescalero-Monahans Dunes region north through the Llano Estacado into Oklahoma (Peterson & Boyd 1998; Dhillion & Mills 1999).

The distributions of seven taxa are limited to or primarily centered in the Mescalero-Monahans Dunes region (Table 10). All but one are associated with deep, dry, loose sand, the exception being *Cyperus onerosus* which occurs in moist to wet sand in depressions among active or partially stabilized dunes (Poole et al. 2007). Two of these species, *Panicum havardii* and *Proboscidea sabulosa*, range just across the international border into the Samalayuca Dunes of northeastern Chihuahua, Mexico (Carr 2009). Ten additional CG endemics occur in

Table 10. Regional endemics of the Mescalero-Monahans Dunes.

Cyperus onerosus G2
Ephedra coryi G3
Eurytaenia hinckleyi G3
Helianthus neglectus G2
Mentzelia strictissima
Panicum havardii
Proboscidea sabulosa G3

the regional flora, all associated with sand habitat: *Chamaesyce carunculata* (G3), *Chenopodium cycloides* (G3), *Dalea lanata*, *Dimorphocarpa candicans*, *Mimosa rupertiana*, *Oenothera cinerea* subsp. *cinerea*, *Oenothera engelmannii*, *Polansia jamesii*, *Penstemon buckleyi*, and *Yucca campestris*. The recently-described CG endemic *Evolvulus arenarius* (Harms 2014) also has occurrences in the Mescalero-Monanhans Dunes region and may be a species of conservation concern.

Along with this concentration of endemic plants, the biodiverse Mescalero-Monahans Dunes region hosts the endemic dune sagebrush lizard (*Sceloporus arenicolus*) plus endemic whipscorpions, scorpions, and nine endemic insect species (Longing et al. 2014).

Niobrara-Platte Tablelands.—The Niobrara-Platte Tablelands is a center of endemism located at the northern end of the High Plains section of the Great Plains physiographic province. The region extends from the Niobrara River south to the South Platte River and encompasses western Nebraska, southeastern Wyoming, and extreme northeastern Colorado.

Strata of the Arikaree Group (Late Oligocene to Early Miocene) underly the northern portion of the region, from the Niobrara River south to the North Platte River (Diffendal 1991; Swinehart et al. 1985). The component rocks are primarily fine-grained sandstones and sandy siltstones. The ancient tableland formed by these deposits has been entrenched by the Niobrara and North Platte and their tributaries into dissected uplands, forming escarpments, bluffs, buttes, and other rough, broken terrain. In this region, the Arikaree caps escarpments like the Pine Ridge and Wildcat Hills of Nebraska and the Hat Creek Breaks of Wyoming along with dramatic erosional outliers like Scotts Bluff and Chimney Rock in Nebraska.

Younger rocks of the Ogallala Group (Miocene to earliest Pliocene) replace those of the Arikaree in the southern part of the region, which encompasses the Ogallala-capped interfluve between the valleys of the North Platte and South Platte rivers known as the Cheyenne Tableland (McMillan et al. 2002; Maher et al. 2003). The Cheyenne Tableland extends westward to the foot of the Laramie Range of the Rocky Mountains and eastward to the confluence of the North and South Platte rivers. Significant areas of exposed rock and broken topography occur along the northern and southern escarpments of the tableland. The southern escarpment marks the boundary between the High Plains and the lower-elevation Colorado Piedmont and forms an irregular line of Ogallala-capped cliffs and erosional outliers in the Pawnee Buttes region of northeastern Colorado.

Mixed-grass prairie is the matrix vegetation of the Niobrara-Platte Tablelands (Rolfsmeier & Steinauer 2010). The regional endemics mostly occur in sparsely-vegetated rock outcrop communities on ridgecrests and escarpments where bedrock is at or near the surface. Soils are very shallow sandy loams or silty loams and the sites are often subjected to strong, prolonged winds. These herbaceous communities are dominated by perennial forbs, most of which have a low, compact growth habit, with grasses contributing little to the vegetation cover (Hardy 1991; Hazlett 1998; Heidel & Handley 2004; Decker 2007; Rolfsmeier & Steinauer 2010; Locklear 2014).

The distributions of 10 taxa are limited to or primarily centered in the Niobrara-Platte Tablelands (Table 11). Of these, only *Eriogonum nebraskense* and *Eriogonum pauciflorum* var. *gnaphaloides* are restricted to the region. Most have distributions that are centered in the Niobrara-Platte Tablelands with scattered occurrences to the north, south, or west where they occur in similar rock outcrop habitat. Other CG endemics occurring in

Table 11. Regional endemics of the Niobrara-Platte Tablelands.

Astragalus hyalinus
Astragalus sericoleucus
Cuscuta plattensis G1
Eriogonum nebraskense
Eriogonum pauciflorum var. *gnaphaloides*
Musineon tenuifolium
Oenothera coloradensis G2
Oreocarya cana
Paronychia depressa
Parthenium alpinum G3

the region are *Astragalus kentrophyta* var. *kentrophyta*, *Pediomelum linearifolium*, *Phlox andicola*, and *Physaria arenosa* var. *arenosa*.

Two of the regional endemics of the Niobrara-Platte Tablealands are not associated with rock outcrop habitat. *Oenothera coloradensis* (formerly *Gaura neomexicana* subsp. *coloradensis*) is a biennial or short-lived perennial associated with subirrigated alluvial soils on the level or slightly sloping floodplains and drainage bottoms of smaller plains streams (Fertig 2000). *Cuscuta plattensis* is a twining parasitic herb reported to attach to *Ambrosia*, *Grindelia*, *Helianthus*, *Psoralea*, and *Solidago* (Nelson 1899; Handley & Fertig 2002). This critically imperiled species is documented from a very small number of collections from southeastern Wyoming within the Niobrara-Platte Tablelands and may also occur in Nebraska and Washington (Costea et al. 2006). While not entirely limited to the Central Grassland, *Dalea cylindriceps* Barneby (G3) has scattered occurrences in the Niobrara-Platte Tablelands in sandy loam soils derived from sandstone outcrops.

A number of species that are more common to the west have peripheral or disjunct occurrences in Niobrara-Platte Tablelands rock outcrop communities including *Astragalus shortianus* Nutt. and *Scutellaria brittonii* Porter of the Rocky Mountains and *Linanthus cespitosus* (Nutt.). J.M. Porter & L.A. Johnson, *Oxytropis multiceps* Nutt., and *Phlox muscoides* Nutt. of the Wyoming Basin. Another group of Wyoming Basin species occur where fine-textured siltstones and claystones of the older White River Group are exposed in deeply dissected terrain below Arikaree or Ogallala caprock. These include *Eriogonum brevicaule* Nutt., *Lomatium nuttallii* (A. Gray) J.F. Macbr. (G3), *Phacelia hastata* Douglas ex Lehm., and *Stephanomeria runcinata* Nutt.

Raton Tablelands.—The Raton Tablelands is a center of endemism associated with the physiographic region delineated by Fenneman (1931) as the Raton section of the Great Plains. The Raton section is an uplifted area located in southeastern Colorado, northeastern New Mexico, and the adjacent portion of the Oklahoma panhandle drained by the Arkansas River on the north and the Canadian River on the south.

The Raton section has a complex geological history that includes volcanic activity and has the greatest diversity of exposed rock formations of any part of the study area. Topographic features include high mesas, extensive dissected plateaus, deep canyons, and extinct volcanoes (Lee 1902, 1903, 1912; Fenneman 1931; Flores 2010). Among the most prominent of these landforms is the Mesa de Maya, a lava-capped plateau extending about 70 km along the Colorado-New Mexico border to its terminus in Oklahoma (where it is known as the Black Mesa). Other significant geologic features are the canyons of the Purgatoire River in Colorado and the Canadian River in New Mexico, the latter being the biggest and deepest canyon in the Great Plains.

The surface geology of the Raton section is strongly influenced by Cretaceous marine strata. Sandstone of the Dakota Formation is prevalent throughout most of the region, but the endemics are primarily associated with younger carbonate Cretaceous strata, notably Niobrara Formation chalk, Greenhorn Limestone, and various shale formations. Older rocks of Jurassic, Triassic, and Permian systems are exposed within the canyons of the Purgatoire, Dry Cimarron, and Canadian rivers where these streams have cut down below the Dakota Sandstone.

This geologically complex region supports a rich flora and a diversity of plant communities. The flora and rare plants of the region has been the subject of numerous studies (Rogers 1953, 1954; Shaw et al. 1989a, 1989b;

Naumann 1991; Clark 1996; Ladyman 2005; Neid et al. 2007; Schiebout et al. 2008; Buthod & Hoagland 2015) including floristic inventories of national grasslands in the region—Comanche National Grassland in Colorado (Hazlett 2004; Kuhn et al. 2011) and Kiowa/Rita Blanca National Grassland in New Mexico (Hazlett et al. 2009). The vegetation of the region is a complex mosaic of grassland, shrubland, and conifer woodland. Shaw et al. (1989a) recognized 26 distinct plant communities from the U.S. Army Piñon Canyon Maneuver Site in southeastern Colorado, including those associated with the slopes of canyons and with outcroppings of limestone and shale.

The distributions of 15 taxa are limited to or primarily centered in the Raton Tablelands (Table 12). All of these are associated with rock outcrop habitat, although the nature of the habitat varies. *Astragalus wittmannii*, *Frasera coloradensis*, and *Packera spellenbergii* are primarily associated with ground-level exposures of Greenhorn Limestone. *Eurybia horrida*, *Nolina greenei*, *Thelypodium wrightii* subsp. *oklahomensis*, *Solidago capulinensis*, and *Yucca neomexicana* are associated with the rocky slopes of canyons, mesas, and volcanic cinder cones. *Eriogonum aliquantum*, *Oenothera harringtonii*, and *Oonopsis monocephala* occur in association with low shale hills and the saline clay flats and alluvial fans that develop downslop from eroding shale exposures.

Mirabilis rotundifolia (G2), *Parthenium tetraneuris* (G3), and *Penstemon versicolor* (G3) are CG endemics of conservation concern that occur primarily in the Arkansas Valley Barrens of south-central Colorado but also have occurrences in the Raton Tablelands (Neid et al. 2007). A number of more widely distributed CG endemics have occurrences in rock outcrop habitat in the Raton Tablelands, including *Argythamnia humilis* var. *leiosperma*, *Forsellesia planitierum*, *Grindellia inornata* (G2), *Oonopsis engelmannii* (G3), and *Oonopsis foliosa* (G3). While not endemic to the Central Grassland, *Asclepias uncialis* (G3) historically ranged through much of the shortgrass prairie of the western Great Plains and is now limited to scattered occurrences, the largest and most viable of which occur in the Raton Tablelands (Decker 2006; Neid et al. 2007).

In his analysis of the distribution of mammals in Colorado, Armstrong (1972) recognized a Raton Faunal District which he described as "the most distinctive" region of mammal diversity in the plains of eastern Colorado. This zoogeographic area strongly corresponds to the Colorado portion of the Raton Tablelands described herein, further marking the region as a biodiversity hotspot for the Great Plains.

Red Bed Plains.—The Red Bed Plains stretch from north-central and northwestern Texas through central and western Oklahoma into south-central Kansas. Within this region, brick-red shales, siltstones, and sandstones of Permian age have been exposed by erosion. The eastern part of Red Bed Plains is characterized by gently rolling hills and broad plains, but more broken topography prevails to the west where formations containing beds of gypsum and dolomite are exposed. Escarpments, mesas, buttes, and badlands are typical of areas where gypsum and dolomite cap more easily erodible shale and sandstone formations, notably the Red Hills of Kansas (Buchanan 1984) and the Cimarron Gypsum Hills, Mangum Gypsum Hills, and Weatherford Gypsum Hills of Oklahoma (Curtis et al. 2008).

Mixed-grass prairie is the matrix vegetation of most of the Red Bed Plains (Hoagland 2000; Lauver et al. 1999). The distinctive aspects of the flora, including the regional endemics, typically occur in sparsely vegetated communities associated with gypsum-bearing rock formations (Buckallew & Caddell 2003; Hoagland & Buthod 2005; Barber 2008; Nesom & O'Kennon 2008; Caddell & Rice 2012). Gypsum is a mineral rock formed by calcium sulfate dehydrate ($CaSO_4$ $2H_2O$). The mineral gypsum has a pronounced effect on plant growth (Kruckeberg 2002; Escudero et al. 2014) and, generally, the higher the gypsum content of the substrate and soil the more sparse the vegetation and less diverse the flora, although the flora often includes specialized gypsum endemics.

The distributions of eight taxa are limited to or primarily centered in the Red Bed Plains (Table 13). None of the regional endemics are obligate gypsophiles. *Oenothera macrocarpa* subsp. *oklahomensis* is strongly associated with gypsum but also occurs on other substrates. A number of more wide ranging CG endemics are frequently associated with gypsum and dolomite substrates in the region, including *Astragalus lindheimeri*, *Castilleja citrina*, *Cymopterus macrorhizus*, and *Phlox oklahomensis* (G3). The flora of the Red Bed Plains region also is enriched by species characteristic of gypsum habitats in the northern Chihuahuan Desert, including

Table 12. Regional endemics of the Raton Tablelands.

Astragalus puniceus var. *puniceus* T3
Astragalus wittmannii G3
Eriogonum aliquantum G3
Eurybia horrida G2
Frasera coloradensis G3
Grindelia fastigiata var. *revoluta*
Nolina greenei G2
Oenothera harringtonii G3
Oonopsis monocephala G2
Packera spellenbergii G2
Penstemon auriberbis
Physaria calcicola G2
Solidago capulinensis G1
Thelypodium wrightii subsp. *oklahomensis*
Yucca neomexicana

Table 13. Regional endemics of the Red Bed Plains.

Aphanostephus pilosus
Callirhoe scabriuscula G2
Chamaesaracha darcyi
Oenothera coryi G3
Oenothera macrocarpa subsp. *oklahomensis* T3
Oenothera triangulata G3
Phlox drummondii subsp. *johnstonii* T3
Solidago mollis var. *angustata* T3

Haploesthes greggii A. Gray, *Nama stevensii* C.L. Hitchc., *Oenothera hartwegii* Benth. subsp. *filifolia* (Eastw.) W.L. Wagner & Hoch, *Phacelia integrifolia* Torr., *Psilostrophe villosa* Rydb. ex Britton, and the recently described *Oenothera gayleana* B.L. Turner & M.J. Moore (Turner & Moore 2014). *Eriogonum correllii* (G2) and *Solidago altiplantites*, two species primarily associated with the Llano Estacado Escarpments region, also have occurrences in the Red Bed Plains.

Two highly-localized regional endemics of the Red Bed Plains are associated with sandy habitat. *Callirhoe scabriuscula* occurs on deep, shifting sands of ancient and contemporary terraces of the Colorado River in Coke, Mitchell, and Runnels counties in west-central Texas (Dorr 1990; Poole et al. 2009). It is listed as an endangered species by the USFWS. *Phlox drummondii* subsp. *johnstonii* occurs in similar habitat in the watersheds of the Salt Fork and Double Mountain Fork of the Brazos River in Fisher, Kent, and Stonewall counties in the southern Texas Panhandle (Locklear 2011).

While not strictly limited to the Red Bed Plains, most known occurrences of *Aschisma kansanum* are in the Red Hills region of south-central Kansas. This fascinating moss, one of the rarest in North America, is associated with Pleistocene gravel deposits where it grows at the base of relatively clear quartz pebbles that are partially imbedded in sandy soil, the translucent pebbles appear to provide protective cover and a thin film of moisture in the dry, open habitat while also letting in enough light for plant growth (Cridland 1959; Smith 1966).

Reverchon Rocklands.—The Grand Prairie of north-central Texas (sensu Diggs et al. 1999) is a vegetational region composed of the Fort Worth Prairie to the north of the Brazos River and the Lampasas Cut Plain (Limestone Cut Plain) to the south, and is contained within the Cross Timbers ecoregion of Texas (Griffith et al. 2004). Physiographically, the Grand Prairie roughly corresponds to the Comanche Plateau, a region related geologically to the Edwards Plateau to the south but from which the limestones of the Edwards Formation have in large part been eroded away, exposing older Cretaceous formations in a dissected landscape of scarps, cuestas, and mesa-like divides (Hill 1901; Fenneman 1931; Stephens & Holmes 1989). The most significant of these

strata from the standpoint of vegetation structure and endemism are the Walnut Formation and Glen Rose Formation. These are composed of interbedded erosion-resistant limestones and less consolidated strata variously termed marl, clay, or shale. The contrasting lithification of these strata create a diversity of habitats including limestone barrens, glades, and seeps that supports small patch communities of herbaceous vegetation within the surrounding matrix of juniper-oak woodland/savanna and grassland.

The distinctiveness of the flora and vegetation of the Grand Prairie has long been recognized (Hill 1901; Dyksterhuis 1946; Diamond & Smeins 1985) and recent studies of plants associated with calcareous rock outcrop habitat in the Grand Prairie have shown the region to be a center of floristic diversity with several unique and locally-restricted plant communities (Nesom & O'Kennon 2001; Swadek & Burgess 2012; Taylor & O'Kennon 2013, 2014). A number of taxa associated with barrens and glades in the Grand Prairie region also occur in calcareous rock outcrop habitat in the Arbuckle Uplift of south-central Oklahoma (Hoagland & Johnson 2001; Nesom & O'Kennon 2001), warranting inclusion of the Arbuckles into this center of endemism.

Since the region is more expansive than just the Grand Prairie of Texas, and to avoid confusion with the Grand Prairie of Arkansas, this center of endemism is here named the Reverchon Rocklands in honor of Julien Reverchon (1837–1905), French-American immigrant to Dallas and the first botanist to collect extensively in north-central Texas (Diggs et al. 1999). Reverchon collected the types of several species that are endemic to or strongly associated with the region, notably *Dalea reverchonii*, *Muhlenbergia reverchonii*, and *Pediomelum reverchonii*.

As here delineated, the Reverchon Rocklands also encompasses the East and West Cross Timbers of north-central Texas, which border the Grand Prairie on both sides. These are the southernmost belts of the larger Cross Timbers vegetational region that stretches from north-central Texas through central Oklahoma into southeastern Kansas and is characterized by a mosaic of forest, woodland, prairie, and glade communities on soils derived from sandstone formations (Diggs et al. 1999; Hoagland et al. 1999).

The distributions of 11 taxa are limited to or primarily centered in the Reverchon Rocklands (Table 14). *Silphium albiflorum* and *Yucca pallida* have the largest distributions of the regional endemics, occurring throughout the Grand Prairie region and overlapping to some extent onto the Edwards Plateau. The rarest taxa of the region are *Yucca necopina* and *Dalea reverchonii*, both endemic to north-central Texas (Poole et al. 2007; Taylor & O'Kennon 2013), and *Echinacea paradoxa* var. *neglecta*, which is endemic to the Arbuckle Uplift. *Liatris aestivalis* and *Pediomelum reverchonii* have occurrences in both the Grand Prairie and the Arbuckles.

While almost all of the regional endemics are associated with limestone, *Yucca necopina* and *Mirabilis gigantea* occur in deep, coarse-textured soils weathered from sandstone formations in the Cross Timbers area, often in association with sandy stream terraces.

The flora of the Reverchon Rocklands includes other CG endemics and locally-rare species. A number are strongly associated with rock outcrop communities in the Reverchon Rocklands but range more widely, including *Amphiachyris amoena*, *Bouteloua pectinata*, *Callirhoe pedata*, *Dysodiopsis tagetoides*, *Hedeoma reverchonii*, *Marshallia caespitosa* var. *signata*, *Matelia biflora*, *Muhlenbergia reverchonii*, and *Paronychia virginica* var. *scoparia*. Also significant are CG endemics with distributions that are essentially shared between the Grand Prairie and Edwards Plateau, including *Centaurium beyrichii*, *Juncus texanus*, *Pediomelum hypogaeum* var. *scaposum*, *Salvia engelmannii*, and *Vernonia lindheimeri*. *Ipomoea shumardiana* (G2), *Matelea edwardsensis* (G3), and *Pediomelum cyphocalyx* (G3) are rare CG endemics with occurrences in the Reverchon Rocklands. The flora also includes remarkable disjunct occurrences of several species associated with limestone cedar glades in the southeastern United States: *Gratiola quartermaniae* D. Estes (G3), *Isoetes butleri* Engelm., and *Phemeranthus calcaricus* (Ware) Kiger (G3) (Swadek 2012; Swadek & Burgess 2012; Taylor et al. 2012; Taylor & O'Kennon 2014).

Four additional regions of the Central Grassland have notable concentrations of CG endemics, some of conservation concern.

Missouri Plateau Badlands.—In the unglaciated portion of the Missouri Plateau, interstream uplands

Table 14. Regional endemics of the Reverchon Rocklands.

Dalea hallii G3
Dalea reverchonii G2
Echinacea paradoxa var. *neglecta* T1
Liatris aestivalis
Mirabilis gigantea
Pediomelum reverchonii G3
Phlox villosissima subsp. *latisepala*
Senecio quaylei G1
Silphium albiflorum
Yucca necopina G1
Yucca pallida G3

underlain by fine-grained sedimentary rock formations (primarily siltstones and claystones) have in places been dissected into badlands. Badland terrain consists of complex networks of barren gullies and ridges, the slopes often steep and with sharp edges. Weathered outcroppings of these substrates and the fine-textured soils derived from them present a root-inhibiting combination of high rates of erosion, high shrink-swell capacity, low organic matter, low infiltration rate, low fertility and high alkalinity, with selenium sometimes present. As a result, badlands are very sparsely vegetated. Yet a suite CG endemics are strongly associated with Missouri Plateau badland habitat, notably *Astragalus barrii* (G3), *Atriplex suckleyi*, *Eriogonum pauciflorum* var. *pauciflorum*, *Eriogonum visheri* (G3), *Oonopsis multicaulis*, *Physaria arenosa* var. *argillosa* (T3), and *Physaria brassicoides* (Beatty et al. 2003; Ladyman 2006a, 2006c; Rolfsmeier & Steinauer 2010; Charboneau et al. 2013). The most extensive areas of badland topography in the Plains are the White River Badlands of western South Dakota and the Little Missouri Badlands of western North Dakota, with significant areas also occurring in northwestern Nebraska, northeastern Wyoming, and eastern Montana.

Smoky Hills.—The Smoky Hills region of north-central Kansas and adjacent south-central Nebraska lies within the Plains Border section of the Great Plains (Fenneman 1931) where the original level surface of the High Plains has been dissected by eastward-flowing, headward-cutting streams, exposing older rock formations beneath. The rolling hills of the region are formed in relatively flat-lying strata (gently dipping to the west) of Cretaceous sedimentary rocks (Buchanan 1984), notably Dakota Sandstone, Greenhorn Limestone (Hattin 1975), and Niobrara Formation limestone and chalk (Hattin 1982), geologic units that are exposed more narrowly along the eastern flank of the Rocky Mountains as upturned scarps and hogbacks. The characteristic vegetation of the region is southern mixed-grass prairie (Lauver et al. 1999).

Three CG endemics of conservation concern are strictly limited to rock outcrop habitat in the Smoky Hills: *Oenothera macrocarpa* subsp. *fremontii* (T3) occurs throughout much of the region in association with limestone and chalk outcroppings; *Eriogonum helichyrsoides* (G2) and *Eriogonum jamesii* var. *simplex* (T2) are limited to the western part of the Smoky Hills where they occur in association with badlands formed in chalk of the Smoky Hill Member of the Niobrara Formation. Other more widely distributed CG endemics occurring in the region include *Physaria ovalifolia* var. *ovalifolia*, *Scutellaria resinosa*, and *Symphyotrichum fendleri*.

The Great Plains distribution of *Clematis fremontii* S. Watson is essentially limited to the Smoky Hills. This distinctive species is fairly common in limestone uplands of the Smoky Hills, occurring in 15 counties in Kansas and three in Nebraska, but is absent from the nearby Flint Hills of eastern Kansas where Permian limestones outcrop extensively. Farther to the east, scattered occurrences of *C. fremontii* are found on dolomite glades in the Ozark Highlands of Missouri (Yatskievych 2013) and Arkansas (Graves 2016). Even more highly disjunct populations of *C. fremontii* have recently been discovered in rock outcrop habitat in southeastern Tennessee and northwestern Georgia (Horn & Shaw 2007).

Southwestern Ozarks.—A number of taxa of conservation concern are associated with rocky tallgrass prairie and related campestrian plant communities in the southwestern portion of the Ozark Highlands. Four of these, *Callirhoe bushii* (G3), *Delphinium treleasei* (G3), *Echinacea paradoxa* var. *paradoxa* (T2), and *Physaris*

filiformis (G3) are strongly associated with the Springfield Plateau in southwestern Missouri and northwestern Arkansas but also have occurrences beyond, mostly in the adjacent White River Hills region of the Ozarks. Mississipian-age limestone formations dominate the surface geology of the Springfield Plateau while dolomite of Ordovician age underlies the White River Hills (Foti & Bukenhofer 1998; Nelson 2005). Topography varies from level to gently rolling hills on the western and central Springfield Plateau (referred to as the Springfield Plain in Missouri) to more dissected and strongly sloping terrain on the eastern edge and in the White River Hills.

Historically, tallgrass prairie was the matrix vegetation across the rolling uplands of the Springfield Plateau (Schroeder 1982; Nelson 2005; Foti & Witsel 2013) but was more limited in extent toward the dissected eastern portion, occurring in mosaic with savanna and open woodland complexes or as discrete landscape units on uplands bounded by timbered stream valleys (Schroeder 1982). In the more densely forested portions of the Ozark Highlands, this vegetation is presently limited to glades—small patch herbaceous communities associated with rock outcrop habitat (Nelson & Ladd 1980; Yatskievych 1999; Baskin & Baskin 2000; Ware 2002; Nelson 2005). The intergrading complex of prairies, savannas, and open woodlands on the Springfield Plateau is recognized by NatureServe as the Ozark Prairie and Woodland ecological system. In addition to the four regional endemics named above, the flora of these rocky campestrian communities is enriched by occurrences of other CG endemics of Ozarkian affinity including *Astragalus crassicarpus* var. *trichocalyx*, *Callirhoe digitata*, *Lithospermum subsetosum*, *Nemastylis nuttallii*, *Rudbecka missouriensis, Scutellaria bushii* (G3), *Solidago gattingeri* (G3), and *Valerianella ozarkana* (G3).

Texas Blackland Prairies.—The blackland prairies of Texas are floristically distinct grassland formations within the continuum of North American tallgrass prairie, combining elements of Midwestern tallgrass prairie (True Prairie) and the Gulf Coastal Prairies of Texas and Louisiana (Diamond & Smeins 1988; Diggs et al. 1999). The calcareous clay soils that support blackland prairie are derived from underlying shales, marls, and limestone bedrock. A number of CG endemics associated with limestone rock outcrop communities on the Grand Prairie and/or Edwards Plateau have outlying occurrences in the Texas Blackland Prairies ecoregion on surfacing exposures of the calcareous Austin Chalk (Cretaceous), including *Callirhoe pedata*, *Marshallia caespitosa* var. *signata*, *Physaria densiflora*, and *Salvia engelmannii* (Diggs et al. 1999). *Astragalus reflexus* (G3) and *Liatris glandulosa* (G3) are CG endemics of conservation concern that appear to be mostly restricted to outcroppings of Austin Chalk in the Texas Blackland Prairies ecoregion. The rarest plant of the ecoregion is *Hymenoxys perpygmaea* (G1), a recently-described species (Mink et al. 2012) associated with the regionally-restricted and critically imperiled (G1) *Sporobolus silveanus* Swallen – *Carex meadii* Dewey herbaceous grassland community (Diamond & Smeins 1985, 1988, 1993). Areas of deeper soils in the Texas Blackland Prairies ecoregion have been almost entirely lost to agricultural production with the result that this grassland exists today in only a few preserves, small remnants, and native hay meadows.

ECOLOGY OF ENDEMIC PLANTS OF THE CENTRAL GRASSLAND

Of the 382 CG endemics, 299 or 78% are habitat specialists, associated with rock outcrop, sand, hydric, or riparian habitats (Table 15). These habitats typically occur as discrete, localized areas and support unique plant communities within the regionally dominant matrix vegetation of grassland, shrubland, or woodland (Kelso et al. 2001). Such "habitat islands" with their distinctive and specialized floras have been termed insular ecosystems and are often important to regional biodiversity (Cartwright & Wolfe 2016).

Rock Outcrop Habitat.—Fifty-nine percent of CG endemics (225 taxa) are primarily associated with rock outcrop habitat (indicated by the abbreviation R in Appendix 1). Rock outcrop habitat is the prevailing ecological association of regional endemics in all but one of the nine centers of endemism recognized above, the exception being the Mescalero-Monahans Dunes. The descriptive term "rock outcrop" is here used broadly to signify rocky, shallow-soil habitat that supports plant associations that are distinct from the surrounding matrix vegetation on zonal soils and encompasses a range of habitat from massive exposures of bedrock to areas of rocky/gravelly soils. The topographic position of this habitat is upland and includes interstream divides, escarpments, buttes, mesas, canyon slopes, etc. where bedrock is exposed.

Table 15. Habitat affinities of Central Grassland endemics.

Habitat	Number of taxa
Rock outcrop	225
Sand	53
Hydric	14
Riparian	7
	299 Total habitat specialists

The majority of CG rock outcrop endemics are associated with limestone or other carbonate substrates. Limestone formations dominate the surface geology of the Edwards Plateau and Reverchon Rocklands, two major centers of endemism for the Central Grassland, as well as the Springfield Plateau of the southwestern Ozark Highlands. Elsewhere in the Central Grassland, more geographically-limited exposures of limestone also support CG endemics, notably outcroppings of the Greenhorn Limestone in the Raton Tablelands and Smoky Hills. A number of narrowly-distributed endemics of conservation concern are associated with chalky limestone strata of the Niobrara Formation in the Arkansas Valley Barrens region and the Smoky Hills.

The most geographically-restricted CG endemics are those associated with granite. Within the study region, granite exposures occur in the Llano Uplift of Texas, the Arbuckle Mountains and Wichita Mountains of Oklahoma, the Hartville Uplift in Wyoming, the Black Hills in South Dakota and Wyoming, and certain isolated mountain ranges on the plains of eastern Montana (Diffendal 2017). Granite specialists are typically associated with unique microhabitats that result from the lithology and inherent weathering patterns of granite bedrock and are often of conservation concern due to their limited distribution and narrow ecological association (Shure 1999). Eleven taxa are limited to granite substrates in the Llano Uplift, nine of which are of conservation concern. Two additional CG endemics, *Phlox pilosa* subsp. *longipilosa* (T2) and *Echinocereus reichenbachii* subsp. *baileyi* (T3) are associated with granite substrates in the Wichita Mountains.

Aside from granite specialists, substrate fidelity is not pronounced among CG rock outcrop endemics. Within its limited range in southeastern Colorado, *Frasera coloradensis* occurs in association with a variety of Cretaceous strata including Greenhorn Limestone, Graneros Shale, and Dakota Sandstone (Naumann 1981). *Phlox oklahomensis* occurs in association with sandstone, shale, gypsum, and dolomite of the Ogallala, Rush Springs, and Marlow formations in the Gypsum Hills of Kansas and Oklahoma and limestone of the Permian-age Chase and Council Grove groups in the southern Flint Hills of Kansas (Springer and Tyrl 2003). The narrowly-distributed *Mentzelia chyrsantha* (D. Anderson 2006) and *Physaria bellii* (Colorado Natural Heritage Program 1997) of Colorado are strongly associated with Niobrara Formation chalk but also occur on other strata where these are exposed in proximity.

This general broad tolerance of different rock types or lack of fidelity to a specific geologic substrate has also been observed among rock outcrop endemics in the eastern United States (Baskin & Baskin 1988) and suggests that chemical properties of the parent material are not a significant factor in the association of CG endemics with rock outcrop habitat. This conclusion is supported by the work of Kelso et al. (2003) in which they investigated factors influencing plant endemism associated with the Smoky Hill Chalk Member of the Niobrara Formation in the Arkansas Valley Barrens of Colorado and determined that structural components of the barrens (e.g., dry, unstable slopes and extremely shallow, mineralized soils) were more influential than the chemistry of the bedrock and that the endemics were functionally adapted to survive in habitat that is stressful enough to exclude more competitive vegetation.

As geobotanist Arthur Kruckeberg (1986) observed, "Though a region's climate sets the limits for a biota, geology enriches local discontinuity and habitat diversity." The common perception of the Central Grassland as a region of subdued landscape diversity and broad environmental gradients is generally true in the eastern portion of the region, particularly where the landscape is mantled by deposits of loess and glacial till. But exposures of surfacing bedrock in the central and western portions of the Central Grassland (Fenneman 1931;

Diffendal 2017) significantly increase local landscape heterogeneity and support more structurally complex vegetation and higher overall plant diversity than the surrounding matrix vegetation (Kelso et al. 2001). University of Kansas biogeographer P.V. Wells (1970) was correct in noting that "contrary to popular opinion, the plains are by no means lacking in edaphic diversity," but went on to conclude, "Nevertheless, the considerable potential for the evolution of narrow endemics has not been realized in the existing flora of the Central Plains region." An additional four decades of field work has yielded a much more complete knowledge of the flora of the region and has allowed the present analysis which reveals a strong correlation between geology and endemism in the Central Grassland.

Sand Habitat.—Fifty-three CG endemics are primarily associated with sand habitat (indicated by the abbreviation s in Appendix 1). Eolian sand sheets and sand dunes are common landforms in the central and western Plains (Muhs & Holliday 1995). At present, these dune fields are mostly stabilized by vegetation. Some Plains dune fields are expansive, notably the Nebraska Sandhills at approximately 50,000 sq. km. Extensive dune fields also occur along the South Platte River in Colorado and in the Pecos River valley adjacent to the western escarpment of the Southern High Plains in New Mexico and Texas. Smaller, more isolated dune fields and belts occur in the Plains where loose sand has been blown into dunes from alluvial deposits along streams that have traversed areas of sandstone bedrock. This type of habitat is particularly common below the eastern escarpment of the southern High Plains in Oklahoma and Texas (Muhs & Holliday 1995, 2001; Curtis et al. 2008) where eastward-flowing streams have downcut into sandstone rocks of the Ogallala caprock and older (deeper) formations of the Jurassic, Triassic, and Permian systems. Where these areas of sand occur as a discrete belts or "islands" within the surrounding landscape of non-sandy or less sandy soil types, they enrich the local flora with arenaceous species (Ramaley 1939; Kelso et al. 2007; Nesom & O'Kennon 2008).

Some CG sand endemics have relatively large areas of distribution in the western Plains, including *Astragalus ceramicus* var. *filiformis*, *Dalea arenicola*, *Eriogonum annuum*, *Ipomoea leptophylla*, *Mentzelia nuda*, *Phlox andicola*, and *Polanisia jamesii*. Others, notably *Callirhoe scabriuscula* and *Phlox drummondii* subsp. *johnstonii* of Texas, are much more limited in distribution and are of conservation concern. Most CG sand endemics are species of the southern High Plains and are associated with shrub-steppe communities, either sandsage prairie dominated by *Artemisia filifolia* Torr. or shinnery dominated by *Quercus havardii*. Examples of these include *Aphanostephus pilosus*, *Chamaesyce carunculata*, *Chenopodium cycloides*, *Euphorbia strictior*, *Oenothera cinerea* subsp. *cinerea*, *Oenothera engelmannii*, and *Penstemon buckleyi*. The greatest concentration of CG sand endemics occurs in the Mescalero-Monahans Dunes of New Mexico and Texas, the southernmost dune fields of the Great Plains where seven regional endemics occur.

Although the Nebraska Sandhills is the largest dune field in the Western Hemisphere, no vascular plants are strictly limited to this region. The critically imperiled *Penstemon haydenii* was long thought to occur only in the Nebraska Sandhills until an outlying population center was discovered in 1996 in the Ferris Dune Field of central Wyoming (Heidel 2012).

The sandy habitat that hosts localized endemics in the western Plains is primarily dervived from the activity of wind (eolian processes). But in the Cross Timbers region of north-central Texas and south-central Oklahoma, CG endemics *Ipomoea shumardiana*, *Mirabilis gigantea*, *Monarda punctata* var. *intermedia*, and *Yucca necopina* are associated with deep, coarse-textured soils weathered from sandstone strata by colluvial and/or alluvial processes.

The association of distinct floristic assemblages, often including endemic taxa, with geographically isolated areas of sandy habitat is well documented. Examples in the United States include the Fall-line Sandhills of the Carolinas and Georgia (Sorrie & Weakley 2001), the Lake Wales Ridge of peninsular Florida (Menges 1999), and the Carrizo Sands of east-central Texas (Diggs et al. 2006). In a study of endemism in the flora of the West Gulf Coastal Plain of Texas, 53% of the 96 endemics were associated with xeric sandylands (MacRoberts et al. 2002).

Hydric and Riparian Habitats.—Fourteen CG endemics are primarily associated with hydric habitat (indicated by the abbreviation h in Appendix 1). Wetlands and hydric habitats of various kinds occur through-

out the study region, and provide discrete landscape patches that enhance heterogeneity and species diversity. The majority of vascular plants associated with hydric features in the Central Grassland are relatively widespread, obligate or facultative wetland generalists, with endemics being relatively uncommon in this habitat type.

One of the most unique landscape features of the study region are the freshwater playa wetlands of the southern and central Great Plains. Playas are shallow, closed basin, precipitation-filled recharge wetlands. The greatest number and highest concentration of playas occur in the southern High Plains on the Llano Estacado of northwestern Texas and eastern New Mexico where they are the most significant topographic feature of the region and provide islands of biodiversity in one of the most intensively agriculturalized areas of North America (Bolen et al. 1989; Hoagland & Collins 1997; Smith 2003). Nearly 350 species of vascular plants have been identified in association with playas in the Southern High Plains (Rowell 1971; Haukos & Smith 1997). Several of these are relatively wide-ranging CG endemics, including *Ambrosia grayi*, *Oenothera canescens*, and *Suckleya suckleyana*. *Polygonum texense* is endemic to Texas where it occurs in seasonally moist habitat on the southern High Plains and the adjacent northwestern Edwards Plateau.

Less well-known concentrations of playas occur in the central Great Plains, primarily in western Kansas and eastern Colorado (Cariveau & Johnson 2007; Evans 2010). These playas differ from those on the Llano Estacado in generally being smaller and shallower and experiencing shorter periods of inundation, and with vegetation dominated by graminoids tolerant of wet periods (e.g., *Elymus smithii* (Rydb.) Gould and *Buchloe dactyloides* (Nutt.) Engelm.) as opposed to wetland species. These playas are also more likely to occur in the context of relatively intact grassland communities than those of the intensively farmed Llano Estacado. *Ambrosia linearis* is endemic to east-central Colorado and is closely associated with playa habitat, occurring at the outer edge of the zone of inundation (Locklear 1989, 1990). The highly restricted distribution of *A. linearis* is remarkable in a genus known for widespread weeds.

Closed basin wetlands similar to High Plains playas occur on the western edge of the Edwards Plateau and have been designated the Edwards Plateau Playa ecological system by NatureServe. These shallow wetlands are internally draining depressions of karstic origin on level plateau surfaces, forming from solution of underlying limestone formations. *Selenia jonesii*, an annual, is endemic to this habitat.

A number of CG endemics are associated with groundwater seeps in the Reverchon Rocklands. The surface geology of this region is dominated by interbedded limestone and marl formations and seeps occur on hillslopes where groundwater flowing through fractured limestone encounters an impervious rock layer and flows laterally. Such sites experience alternating vernal saturation and summer desiccation and support herbaceous vegetation of which several Plains endemics are characteristic species (Swadek & Burgess 2012). *Muhlenbergia reverchonii* is typically a component of these communities and is often the dominant species present, hence the colloquial name "Muhly seep" for this vegetation (Dyksterhuis 1946; Llado & Slattery 2015). Other CG endemics characteristic of this habitat include *Bouteloua pectinata*, *Eleocharis occulta*, *Juncus texanus*, and *Rhyncohospora nivea*. Groundwater seep habitat occurs in the context of xeric rock outcrop habitat (glades and barrens) that supports additional CG endemics. This unique vegetation also occurs in limestone areas of the Arbuckle Uplift of Oklahoma (Hoagland & Johnson 2001), which is included as part of the Reverchon Rocklands.

Oenothera coloradensis (formerly *Gaura neomexicana* subsp. *coloradensis*) is a noteworthy CG endemic associated with hydric habitat. This short-lived perennial is associated with subirrigated alluvial soils on the level or slightly sloping floodplains and drainage bottoms of smaller plains streams (Fertig 2000). The largest populations of this imperiled taxon occur in southeastern Wyoming, with its historical range extending into adjacent parts of Colorado and Nebraska.

Seven CG endemics are primarily associated with riparian habitat (indicated by the abbreviation RIP in Appendix 1), particularly gravel and cobble bars along high-gradient streams as they emerge from canyons cut into the Balcones Escarpment. These often intermittent streams typically occupy only a small part of the streambed except during periods of flooding. Scouring by periodic flash floods keep this riparian corridor

habitat relatively open and free of woody vegetation. Examples of endemics associated with Edwards Plateau riverscour habitat include *Brickellia dentata*, *Crataegus turnerorum*, *Lythrum ovalifolium*, and *Phlox villosissima* subsp. *villosissima*.

CONSERVATION STATUS OF ENDEMIC PLANTS OF THE CENTRAL GRASSLAND

Of the 382 CG endemics, 124 or 33% are of conservation concern, having been given NatureServe global conservation status rankings of critically imperiled (G1/T1; 14 taxa), imperiled (G2/T2; 32 taxa), vulnerable (G3/T3: 77 taxa), or possibly extinct (GH; 1 species). Eight of these are also listed by the U.S. Fish and Wildlife Service as threatened or endangered.

Appendix 2 presents the entire list of CG endemics of conservation concern. Three additional CG endemics may be of conservation concern but are recently-described and not yet assigned conservation status rankings: *Cardamine carrii* (Turner 2012a) and *Eucnide bartonioides* var. *edwardsiana* (Turner 2012b) of the Edwards Plateau and *Evolvulus arenarius* (Harms 2014) of the southern High Plains.

Central Grassland endemics of conservation concern are not distributed uniformly across the study region. Of the 124 at-risk taxa in the Central Grassland, 78 or 63% are primarily associated with one of the centers of endemism identified in this study (Table 16). States with highest number of at-risk CG endemics are Texas (75), Colorado (22), Oklahoma (22), New Mexico (21), and Kansas (19) (Table 17).

Table 16. Distribution of Central Grassland endemics of conservation concern by center of endemism.

	Total	G1/T1	G2/T2	G3/T3	GH
Edwards Plateau	30	5	4	20	1
Raton Tablelands	11	1	5	5	
Llano Uplift	8	0	6	2	
Reverchon Rocklands	7	3	1	3	
Red Bed Plains	6	0	1	5	
Arkansas Valley Barrens	5	0	3	2	
Mescalero-Monahans Dunes	5	0	2	3	
Llano Estacado Escarpments	3	0	1	2	
Niobrara-Platte Tablelands	3	1	1	1	

Table 17. Distribution of Central Grassland endemics of conservation concern by state/province.

	Total	G1/T1	G2/T2	G3/T3	GH
Texas	75	8	16	50	1
Colorado	22	1	10	11	
Oklahoma	22	1	4	17	
New Mexico	21	1	6	14	
Kansas	19	2	4	13	
Nebraska	10	3	1	6	
Missouri	8	0	2	6	
Arkansas	7	0	1	6	
Wyoming	7	2	1	4	
South Dakota	6	0	0	6	
Iowa	4	0	1	3	
Illinois	3	0	1	2	
Minnesota	3	0	0	3	
Montana	3	0	0	3	
Wisconsin	3	0	1	2	
Indiana	2	0	1	1	
North Dakota	2	0	0	2	
Manitoba	1	0	0	1	
Michigan	1	0	0	1	
Ohio	1	0	0	1	

The centers of endemism identified for the Central Grassland could constitute or contain sites worthy of recognition as an "Important Plant Area" in that they contain assemblages of globally rare (G1-G3) taxa as well as disjunct and peripheral occurrences of plants that may be locally rare and of conservation concern at the state level (S1-S2). The identification of Important Plant Areas is used as a conservation planning tool in a number of state rare plant conservation strategies in the United States.

CONCLUSION

Temperate grasslands are among the most modified ecosystems on Earth due to productive soils and relative ease of conversion to cropland (Henwood 2010). Globally, temperate grasslands have been identified as one of the two terrestrial biomes in which biodiversity and ecosystem services are at greatest risk because of extensive habitat conversion and limited habitat protection (Hoekstra et al. 2005). In the Central Grassland of North America, 21.5 million hectares (53 million acres) of grassland, an area the size of Kansas, was converted to cropland between 2009 and 2015, with the region losing more habitat in 2014 than the Brazilian Amazon lost to deforestation (Gage et al. 2016; World Wildlife Fund 2016). Among the many consequences of this habitat loss is the continental-scale population decline of grassland birds, one of the prominent wildlife conservation crises of the 21st century (Brennan & Kuvlesky 2005).

The Central Grassland of North America encompasses all or part of 17 states and three Canadian provinces. Developing strategies and priorities for the conservation and protection of biological diversity for such a vast region is challenging. It is hoped that the findings of this study will be useful in focusing conservation action on the habitats, ecological associations, and regions of the Central Grassland that host the highest concentrations of unique and at-risk plant species and associated biological diversity.

APPENDIX 1

Annotated list of plants endemic to the Central Grassland of North America

The following compilation enumerates all plant taxa endemic to the Central Grassland as defined herein. Families are arranged alphabetically within major groups. Taxa are listed alphabetically within their respective families by genus, species, and subspecific epithet. Each entry is annotated with the following information where pertinent.

Distribution: States and provinces in which a taxon occurs are listed for CG endemics that are (1) localized within a center of endemism or (2) of limited distribution within the Central Grassland (three states or less). No states/provinces of occurrence are provided for CG endemics that are more widely distributed unless ranked as a plant of conservation concern. Standard abbreviations are used for states/provinces; **MX** = Mexico; **adj** = ranges into adjacent region; **disj** = disjunct occurrences. Taxa that are regional endemics of a center of endemism are noted using the following abbreviations:

Ark	Arkansas Valley Barrens	**Niobr**	Niobrara-Platte Tablelands
Edw	Edwards Plateau	**Raton**	Raton Tablelands
LEst	Llano Estacado Escarpments	**Red**	Red Bed Plains
LUpl	Llano Uplift	**Rev**	Reverchon Rocklands
Mesc	Mescalero-Monahans Dunes		

Habitat: If a taxon is specialized to a particular type of habitat identified in the study, that habitat is indicated using the abbreviations below. No habitat type is indicated if the taxon is not a specialist of one of these habitats.

H	Hydric	**RIP**	Riparian
R	Rock outcrop	**S**	Sand

Conservation status: Taxa of conservation concern are indicated by their NatureServe global conservation status ranking. G-rankings pertain to species, T-rankings to subspecific taxa. See Table 2 for more detailed descriptions of these rankings. Taxa listed by the U.S. Fish and Wildlife Service as threatened or endangered are also indicated.

G1/T1 Citically imperiled
G2/T2 Imperiled
G3/T3 Vulnerable
GH Possibly extinct
US-LT U.S. Fish and Wildlife Service Listed Threatened
US-LE U.S. Fish and Wildlife Service Listed Endangered

Other notes: Brief notes pertaining to taxonomic issues are provided where appropriate. Important references pertaining to ecology or conservation assessement are also noted.

BRYOPHYTES

Pottiaceae
Aschisma kansanum A.L. Andrews KS R G1
Molendoa ogalalensis (G.L. Smith) R.H. Zander [*Ozobryum ogalalense* G.L. Smith] KS, NE, disj MX R G1?
Pterygoneurum subsessile (Brid.) Jur. var. *kieneri* Habeeb NE G4?TNR | known from single collection (Chase County, NE) but recognized in FNA (vol. 27, 2007)

PTERIDOPHYTES

Isoetaceae
Isoetes lithophila Pfeiffer TX (**LUpl**) R G2

Pteridaceae
Argyrochosma dealbata (Pursh) Windham R

GYMNOSPERMS

Ephedraceae
Ephedra coryi E.L. Reed NM, TX (**Mesc**) S G3

ANGIOSPERMS: MONOCOTS

Agavaceae
Camassia angusta (Engelm. & A. Gray) Blank.
Hesperaloe parviflora J.M. Coult. TX (**Edw**), adj MX R G3
Yucca campestris McKelvey NM, TX (**Mesc**) S
Yucca glauca Nutt.
Yucca necopina Shinners TX (**Rev**) S G1
Yucca neomexicana Wooton & Standl. CO, NM, OK (**Raton**) R
Yucca pallida McKelvey TX (**Rev**) R G3
Yucca reverchonii Trel. TX (**Edw**) R G3
Yucca rupicola Scheele TX (**Edw**) R

Alliaceae
Allium canadense L. var. *fraseri* Ownbey R
Allium canadense L. var. *hyacinthoides* (Bush) Ownbey & Aase OK, TX R
Allium canadense L. var. *lavendulare* (Bates) Ownbey & Aase R
Allium perdulce S.V. Fraser var. *perdulce* S
Allium stellatum Fras.ex Ker. Gawl.

Commelinaceae
Tinantia anomala (Torr.) C.B. Clarke TX (**Edw**) R
Tradescantia bracteata Small
Tradescantia edwardsiana Tharp TX R
Tradescantia pedicellata Celariar TX (**LUpl**) R G2
Tradescantia gigantea Rose TX, disj LA R
Tradescantia tharpii E.S. Anderson & Woodson R

Cyperaceae
Carex missouriensis P. Rothr. & Reznicek
Carex perdentata S.D. Jones OK, TX R
Carex shinnersii P. Rothr. & Reznicek AR, KS, OK, TX H G3
Cyperus onerosus M.C. Johnst. TX (**Mesc**) H G2
Cyperus setigerus Torr. & Hook. H
Eleocharis occulta S.G. Sm. OK, TX H
Rhynchospora nivea Boeckeler OK, TX H

Iridaceae
Nemastylis nuttallii Pickering ex R.C. Foster AR, MO, OK R
Sisyrinchium campestre E.P. Bicknell

Juncaceae
Juncus brachyphyllus Wiegand H
Juncus texanus (Engelm.) Coville OK, TX H

Liliaceae
Erythronium mesochoreum Knerr

Melanthiaceae
Zigadenus nuttallii (A. Gray) S. Watson R

Nolinaceae
Nolina greenei S. Watson ex Trel. CO, NM, OK (**Raton**) R G2
Nolina lindheimeriana (Scheele) S. Watson TX (**Edw**) R

Orchidaceae
Platanthera praeclara Sheviak & M.L. Bowles MB; IA, KS, MN, MO, ND, NE, OK, SD G3/US-LT

Poaceae
Bouteloua pectinata Feath. OK, TX R
Elymus texensis J.J.N. Campb. TX (**Edw**) R G1
Muhlenbergia ammophila P.M. Peterson [*Redfieldia flexuosa* (Thurb.) Vasey] S
Muhlenbergia involuta Swallen TX (**Edw**) R | possibly of hybrid origin involving *M. lindheimerii* Hitchc. × *M. reverchonii* Vasey & Scribn. (= *M.* × *involuta*)
Muhlenbergia reverchonii Vasey & Scribn. OK, TX H
Panicum havardii Vasey NM, TX (**Mesc**), adj MX S

Themidaceae
Androstephium coeruleum (Scheele) Greene KS, OK, TX

ANGIOSPERMS: DICOTS

Acanthaceae
Ruellia drummondiana A. Gray TX R
Ruellia metziae Tharp TX (**Edw**) R

Amaranthaceae
Atriplex suckleyi (Torr.) Rydb. R
Chenopodium cycloides A. Nelson CO, KS, NE, NM, TX S G3 | Ladyman 2006b
Chenopodium pallescens Standl. R
Suckleya suckleyana (Torr.) Rydb. H

Apiaceae

Cymopterus macrorhizus Buckley OK, TX R
Cymopterus montanus Torr. & A. Gray R
Daucosma laciniatum A. Gray TX (**Edw**) R
Eryngium diffusum Torr. OK, TX S
Eryngium leavenworthii Torr. & A. Gray R
Eurytaenia hinckleyi Mathias & Constance NM, TX (**Mesc**) S G3
Lomatium foeniculaceum (Nutt.) J.M. Coult. & Rose subsp. *daucifolium* (Torr. & A. Gray) W.L. Theobald R
Musineon tenuifolium (Nutt. ex Torr. & A. Gray) J.M. Coult. & Rose CO, NE, SD, WY (**Niobr**) R

Apocynaceae

Amsonia ciliata Walter var. *texana* (A. Gray) J.M. Coult. OK, TX R

Asclepiadaceae

Asclepias arenaria Torr. S
Asclepias lanuginosa Nutt.
Asclepias meadii Torr. ex A. Gray IA, IL, IN, KS, MO, WI G2/US-LT
Asclepias pumila (A. Gray) Vail
Asclepias stenophylla A. Gray
Asclepias sullivantii Engelm. ex A. Gray
Matelea edwardsensis Correll TX G3
Matelea biflora (Raf.) Woodson OK, TX R

Asteraceae

Ambrosia grayi (A. Nelson) Shinners H
Ambrosia linearis (Rydb.) W.W. Payne CO H G3 | Locklear 1989, 1990
Amphiachyris amoena (Shinners) Solbrig TX R
Aphanostephus pilosus Buckley OK, TX (**Red**) S
Brickellia cylindracea A. Gray & Engelm. TX (**Edw**) R
Brickellia dentata (DC.) Sch. Bip. TX (**Edw**) RIP G3
Brickellia eupatorioides (L.) Shinners var. *gracillima* (A. Gray) B.L. Turner TX (**Edw**) RIP G5T3
Brickellia eupatorioides (L.) Shinners var. *texana* (Shinners) Shinners R
Chaetopappa bellidifolia (A. Gray & Engelm.) Shinners TX (**Edw**) R
Coreopsis palmata Nutt.
Coreopsis wrightii (A. Gray) H.M. Parker OK, TX R
Croptilon hookerianum (Torr. & A. Gray) House var. *graniticum* (E.B. Sm.) E.B. Sm. TX (**LUpl**) R
Croptilon hookerianum (Torr. & A. Gray) House var. *validum* (Rydb.) E.B. Sm. KS, OK, TX, disj AR
Dieteria canescens Nutt. var. *nebraskana* (B.L. Turner) D.R. Morgan & R.L. Hartm. NE, SD S G5T3?
Diaperia prolifera (Nutt. ex DC.) Nutt. var. *prolifera*
Dysodiopsis tagetoides (Torr. & A. Gray) Rydb. OK, TX R
Echinacea angustifolia DC.
Echinacea atrorubens (Nutt.) Nutt. KS, OK, TX G3 R
Echinacea paradoxa (Norton) Britton var. *neglecta* McGregor OK (**Rev**) R G2T1
Echinacea paradoxa (Norton) Britton var. *paradoxa* AR, MO R G2T2
Erigeron bellidiastrum Nutt. var. *robustus* Cronquist S
Eurybia horrida (Wooton & Standl.) G.L. Nesom CO, NM (**Raton**) R G2?
Grindelia adenodonta (Steyerm.) G.L. Nesom TX R
Grindelia fastigiata Greene var. *revoluta* (Steyerm.) Adr. Bartoli & Tortosa [*G. revoluata* Steyerm., *G. hirsutula* Hook. & Arn. var. *revoluta* (Steyerm.) Ackerf.] CO (**Raton**) R
Grindelia inornata Greene CO, NM R G2? | Bartoli & Tortosa 2012 place under *G. fastigiata* Greene var. *fastigiata*
Grindelia lanceolata Nutt. var. *texana* (Scheele) Shinners OK, TX, adj MX R
Grindelia nuda Alph. Wood var. *nuda* R
Helianthus neglectus Heiser NM, TX (**Mesc**) S G2Q | possibly geographically restricted ecologically distinct subspecies of the more widespread *H. petiolaris* Nutt. (Raduski et al. 2010)
Helianthus salicifolius A. Dietr. R
Heterotheca canescens (DC.) Shinners
Heterotheca stenophylla (A. Gray) Shinners [including var. *angustifolia* (Rydb.) Semple]
Heterotheca villosa (Pursh) Shinners var. *ballardii* (Rydb.) Semple
Hymenopappus flavescens A. Gray var. *flavescens* S
Hymenopappus tenuifolius Pursh
Hymenoxys perpygmaea W.C. Holmes, Singhorst & Mink TX G1 | Mink et al. 2012
Iva corbinii B.L. Turner TX | apparently restricted to floodplain of Colorado River in Travis County, TX (Turner 2009); probably of conservation concern
Liatris aestivalis G.L. Nesom & O'Kennon OK, TX (**Rev**) R
Liatris glandulosa G.L. Nesom & O'Kennon TX R G3
Liatris lancifolia (Greene) Kittel S
Liatris punctata (Hook.) var. *mucronata* (DC.) B.L. Turner
Liatris squarrosa (L.) Michx. var. *glabrata* (Rydb.) Geiser
Marshallia caespitosa Nutt. ex DC. var. *signata* Beadle & F.E. Boynton OK, TX, disj. AR, LA, MO R
Nothocalais cuspidata (Pursh) Greene
Oonopsis engelmannii (A. Gray) Greene CO, KS R G3
Oonopsis foliosa (A. Gray) Greene CO R G3
Oonopsis monocephala A. Nelson [*O. foliosa* var. *monocephala* (A. Nelson) Kartesz & Gandhi] CO (**Raton**) R G4T2 | Schulz & Shaw 1992
Oonopsis multicaulis (Nutt.) Greene R
Oonopsis puebloensis G. Brown & Evans CO (**Ark**) R G2
Packera spellenbergii (T.M. Barkley) C. Jeffrey NM (**Raton**) R G2
Packera texensis O'Kennon & Trock TX (**LUpl**) R G2
Parthenium alpinum (Nutt.) Torr. & A. Gray CO, WY (**Niobr**), disj NM R G3 | Heidel & Handley 2004
Parthenium tetraneuris Barneby CO (**Ark**) R G3
Pectis angustifolia Torr. var. *fastigiata* (A. Gray) D.J. Keil. TX (**Edw**) R
Perityle lindheimeri (A. Gray) Shinners var. *halimifolia* (A. Gray) A.M. Powell TX (**Edw**) R G4T3Q
Perityle lindheimeri (A. Gray) Shinners var. *lindheimeri* TX (**Edw**) R G4T3
Perityle warnockii A.M. Powell TX (**Edw**) R G1
Pyrrhopappus grandiflorus (Nutt.) Nutt. KS, OK, TX R
Rayjacksonia annua (Rydb.) R.L. Hartm. & M.A. Lane S
Rudbeckia missouriensis Engelm. ex C.L. Boynt. & Beadle R
Senecio quaylei T.M. Barkley TX (**Rev**) G1Q | known only from type localtion in Parker County; Turner et al. (2003) place under *S. ampullaceus* Hook.
Shinnersoseris rostrata (A. Gray) Tomb S
Silphium albiflorum A. Gray TX (**Rev**) R
Silphium integrifolium Michx. var. *laeve* Torr. & A. Gray
Solidago altiplanities C.E.S. Taylor & R.John Taylor OK, TX (**LEst**) R
Solidago capulinensis Cockerell & D.M. Andrews CO, NM (**Raton**) R G1 | Nesom & Lowrey 2011
Solidago gattingeri Chapm. ex A. Gray AR, MO, disj TN R G3?Q
Solidago mollis Bartl. var. *angustata* Shinners OK, TX (**Red**) R G5T3
Solidago speciosa Nutt. subsp. *pallida* Porter S
Symphyotrichum eulae (Shinners) G.L. Nesom TX | known only from north-central Texas; recently collected in McLennan County (Hannick et al. 2013)
Symphyotrichum fendleri (A. Gray) G.L. Nesom R
Symphyotrichum praealtum (Poir.) G.L. Nesom var. *nebraskense* (Britton) G.L. Nesom IA, KS, NE
Symphyotrichum sericeum (Vent.) G.L. Nesom
Townsendia texensis Larsen OK, TX (**LEst**) R
Verbesina lindheimeri B.L. Rob. & Greenm. TX (**Edw**) R
Vernonia guadalupensis A. Heller TX (**Edw**) RIP | possibly of hybrid origin involving *V. baldwinii* Torr. × *V. lindheimeri* Engelm. & A. Gray (= *V.* × *guadalupensis*)

Vernonia lindheimeri A. Gray & Engelm. TX, adj MX, disj AR R
Xanthisma spinulosum (Pursh) D.R. Morgan & R.L. Hartm. var. *glaberrimum* (Rydb.) D.R. Morgan & R.L. Hartm.
Xanthisma texanum DC. var. *drummondii* (Torr. & A. Gray) A. Gray OK, TX

Berberidaceae
Berberis swaseyi Buckley TX (**Edw**) R G3

Boraginaceae
Lappula texana (Scheele) Britton var. *homosperma* A. Nelson & J.F. Macbr.
Lithospermum occidentale (Mack.) Weakly, Wistell & D. Estes [*Onosmodium occidentale* Mack.] R
Lithospermum subsetosum (Mack. & Bush) Weakly, Wistell & D. Estes [*Onosmodium subsetosum* Mack. & Bush] AR, MO, OK, disj TN R
Oreocarya cana A. Nelson [*Cryptantha cana* (A. Nelson) Payson] CO, MT, NE, SD, WY (**Niobr**) R

Brassicaceae
Cardamine carrii B.L. Turner TX (**Edw**) R | recently described (Turner 2012a) and probably of conservation concern
Dimorphocarpa candicans (Raf.) Rollins S
Erysimum asperum (Nutt.) DC.
Paysonia auriculata (Engelm. & A. Gray) O'Kane & Al-Shehbaz KS, OK, TX R
Physaria arenosa (Richardson) O'Kane & Al-Shehbaz subsp. *arenosa* R
Physaria arenosa (Richardson) O'Kane & Al-Shehbaz subsp. *argillosa* (Rollins & Shaw) O'Kane & Al-Shehbaz CO, NE, SD, WY R G5T3 | Beatty et al. 2003
Physaria bellii G.A. Mulligan CO R G2
Physaria brassicoides Rydb. R
Physaria calcicola (Rollins) O'Kane & Al-Shehbaz CO, NM (**Raton**) R G2
Physaria densiflora (A. Gray) O'Kane & Al-Shehbaz TX R
Physaria engelmannii (A. Gray) O'Kane & Al-Shehbaz OK, TX R
Physaria filiformis (Rollins) O'Kane & Al-Shehbaz AR, MO R G3/US-LT
Physaria gracilis (Hook.) O'Kane & Al-Shehbaz subsp. *nuttallii* (Torr. & A. Gray) O'Kane & Al-Shehbaz KS, OK, TX R
Physaria ovalifolia (Rydb.) O'Kane & Al-Shehbaz subsp. *alba* (Goodman) O'Kane & Al-Shehbaz KS, OK R G5?T3?
Physaria ovalifolia (Rydb.) O'Kane & Al-Shehbaz subsp. *ovalifolia* R
Physaria recurvata (A. Gray) O'Kane & Al-Shehbaz TX R
Physaria sessilis (S. Watson) O'Kane & Al-Shehbaz TX (**Edw**) R
Selenia jonesii Cory TX (**Edw**) H G3
Streptanthus petiolaris A. Gray [*Arabis petiolaris* (A. Gray) A. Gray] TX (**Edw**) R
Thelypodium wrightii A. Gray subsp. *oklahomensis* Al-Shehbaz CO, OK (**Raton**) R

Cactaceae
Echinocereus milleri W. Blum, Kuenzler & Oldach TX (**Edw**) R G1
Echinocereus reichenbachii (Terscheck) Britton & Rose var. *baileyi* (Rose) N.P. Taylor OK, TX R G5T3
Echinocereus reichenbachii (Terscheck) Britton & Rose var. *perbellus* (Britton & Rose) L.D. Benson CO, NM, TX R
Echinocereus coccineus Engelm. subsp. *roemeri* (Muehlenpf.) W. Blum , Mich. Lange & Rutow TX (**LUpl**) R
Opuntia mackensenii Rose var. *mackensenii* TX R | = *O. edwardsii* V.E. Grant & K.A. Grant (per Powell et al. 2008)
Sclerocactus brevihamatus (Engelm.) D.R. Hunt subsp. *tobuschii* (W.T. Marshall) N.P. Taylor TX (**Edw**) R G4T3/US-LE

Campanulaceae
Campanula reverchonii A. Gray TX (**LUpl**) R G2
Triodanis coloradoensis (Buckley) McVaugh TX (**Edw**), adj MX R
Triodanus leptocarpa (Nutt.) Nieuwl. S

Capparaceae
Cleomella angustifolia Torr S
Polanisia jamesii (Torr. & A. Gray) Iltis S

Caryophyllaceae
Minuartia michauxii (Fenzl) Farw. var. *texana* (B.L. Rob. ex Britton) Mattf. R
Paronychia depressa Nutt. ex Torr. & A. Gray CO, KS, NE, SD, WY (**Niobr**), disj NM R
Paronychia lindheimeri Engelm. & A. Gray TX (**Edw**), adj MX R
Paronychia virginica Spreng. var. *scoparia* (Small) Cory OK, TX, disj AR, MO R | Rohrer 1997

Convolvulaceae
Evolvulus arenarius R.T. Harms NM, TX S | recently described (Harms 2014) and possibly of conservation concern
Ipomoea costellata Torr. var. *edwardsiana* O'Kennon & G.L. Nesom TX (**Edw**) R G4T2
Ipomoea leptophylla Torr. S
Ipomoea shumardiana (Torr.) Shinners KS, OK, TX R G2

Crassulaceae
Sedum nuttallii Torr. & E. James ex Eaton [*S. nuttallianum* Raf.] R

Crossosomataceae
Forsellesia planiterium Ensign [*Glossopetalon planitierum* (Ensign) H. St. John] CO, NM, OK, TX (**LEst**) R
Forsellesia texensis Ensign [*Glossopetalon texense* (Ensign) H. St. John] TX (**Edw**) R G1

Cuscutaceae
Cuscuta plattensis A. Nelson NE, WY (**Niobr**), disj WA G1Q | Handley & Fertig 2002

Euphorbiaceae
Argythamnia aphoroides Müll. Arg. [*Ditaxis aphoroides* (Müll. Arg.) Pax] TX (**Edw**) R G2
Argythamnia humilis (Engelm. & A. Gray) Müll. Arg. var. *leiosperma* (Waterf.) OK, TX R
Argythamnia simulans J.W. Ingram [*Ditaxis simulans* (J.W. Ingram) Radcl.-Sm. & Govaerts] TX (**Edw**) R
Chamaesyce angusta (Engelm.) Small [*Euphorbia angusta* Engelm.] TX (**Edw**), adj MX R
Chamaesyce carunculata (Waterf.) Shinners KS, NM, OK, TX, adj MX S G3
Croton texensis Müll. Arg var. *texensis*
Euphorbia longicruris Scheele OK, TX, disj AR R
Euphorbia strictior Holz. NM, TX S G3
Stillingia texana I.M. Johnst. OK, TX, adj MX R
Tragia brevispica Engelm. & A. Gray TX R

Fabaceae
Amorpha canescens Pursh
Amorpha nana Nutt.
Amorpha roemeriana Scheele TX (**Edw**) R G3
Astragalus barrii Barneby MT, NE, SD, WY R G3 | Ladyman 2006a
Astragalus ceramicus Sheldon var. *filiformis* (A. Gray) F.J. Herm. S
Astragalus crassicarpus Nutt. var. *berlanderi* Barneby TX (**Edw**) G5T3
Astragalus crassicarpus Nutt. var. *trichocalyx* (Nutt.) Barneby R
Astragalus gracilis Nutt.
Astragalus hyalinus M.E. Jones CO, KS, MT, NE, WY (**Niobr**) R
Astragalus kentrophyta A. Gray var. *kentrophyta* R
Astragalus lindheimeri Engelm. ex A. Gray OK, TX R
Astragalus mollissimus Torr. var. *coryi* Tidestr. TX (**Edw**) R G5T3
Astragalus mollissimus Torr. var. *mollissimus*
Astragalus plattensis Nutt. ex Torrey & A. Gray
Astragalus puniceus Osterh. var. *puniceus* CO, NM, OK (**Raton**), disj TX R G4T3?Q

Astragalus racemosus Pursh var. *racemosus*
Astragalus reflexus Torr. & A. Gray TX R G3
Astragalus sericoleucus A. Gray CO, KS, NE, WY (**Niobr**), disj NM R
Astragalus siliceous Barneby NM R G3
Astragalus wittmannii Barneby NM (**Raton**) R G3
Astragalus wrightii A. Gray TX R
Baptisia australis (L.) R. Br. var. *minor* (Lehm.) Fernald
Dalea arenicola (Wemple) B.L. Turner S
Dalea enneandra Nutt. R
Dalea hallii A. Gray TX (**Rev**) R G3
Dalea lanata Spreng. S | Turner (2006) extracted *D. austrotexana* B.L. Turner and *D. glaberrima* S. Watson from Barneby's (1977) broader circumscription of *D. lantata*
Dalea reverchonii (S. Watson) Shinners TX (**Rev**) R G2 | Taylor & O'Kennon 2013
Dalea sabinalis (S. Watson) Shinners TX (**Edw**) R GH | species has not been collected or reported since the 1950s and may be extinct (Poole et al. 2007)
Dalea tenuifolia (A. Gray) Shinners R
Dalea tenuis (J.M. Coult.) Shinners TX R
Dalea villosa (Nutt.) Spreng. S | *D. villosa* var. *grisea* (Torr. & A. Gray) of AR, LA, and east TX recognized by Turner et al. (2003) as *D. grisea* (Torr. & A. Gray) Shinners
Desmanthus leptolobus Torr. & A. Gray R
Desmodium illinoense A. Gray
Desmodium tweedyi Britton OK, TX R G3
Galactia texana (Scheele) A. Gray TX (**Edw**) R
Indigofera minuata Ortega var. *texana* (Buckley) B.L. Turner TX (**LUpl**) R
Lathyrus decaphyllus Pursh [*L. polymorphus* Nutt. (Broich 2009)] S [includes var. *incanus* (J.G. Sm. & Rydb.) Broich]
Lespedeza leptostachya Engelm. IA, IL, MN, WI G3/US-LT
Lespedeza texana Britton OK, TX, adj MX R
Lupinus plattensis S. Watson
Mimosa roemeriana Scheele OK, TX R
Mimosa rupertiana B.L. Turner S
Oxytropis lambertii Pursh var. *articulata* (Greene) Barneby R
Pediomelum argophyllum (Pursh) J.W. Grimes
Pediomelum cuspidatum (Pursh) Rydb. R
Pediomelum cyphocalyx (A. Gray) Rydb. TX R G3
Pediomelum digitatum (Nuttall ex Torrey & A. Gray) J.W. Grimes
Pediomelum esculentum (Pursh) Rydb.
Pedomelum hypogaeum (Nutt. ex Torr. & A. Gray) Rydb. var. *hypogaeum* R
Pediomelum hypogaeum (Nutt. ex. Torr. & A. Gray) Rydb. var. *scaposum* (A. Gray) J.W. Grimes TX R
Pediomelum latestipulatum (Shinners) Mahler var. *appressum* (Ockendon) Gandhi & L.E. Br. TX (**Edw**) R
Pediomelum latestipulatum (Shinners) Mahler var. *latistipulatum* TX R
Pediomelum linearifolium (Torr. & A. Gray) J.W. Grimes R
Pediomelum reverchonii (S. Watson) Rydb. OK, TX (**Rev**) R G3
Pomaria brachycarpa (A. Gray) B.B. Simpson TX (**Edw**) R G2
Styphnolobium affine (Torr. & A. Gray) Walp. [*Sophora affinis* Torr. & A. Gray] OK, TX, disj AR, LA R

Fagaceae
Quercus havardii Rydb. NM, OK, TX S | AZ, NM, & UT populations formerly considered *Q. havardii* var. *tuckeri* S.L. Welsh now recognized as *Q. welshii* R.A. Denham

Fumariaceae
Corydalis curvisiliqua Engelm. subsp. *grandibracteata* (Fedde) G.B. Ownbey CO, KS, OK, TX

Gentianaceae
Centaurium beyrichii (Torr. & A. Gray) B.L. Rob. OK, TX R
Eustoma russellianum (Hook.) G. Don ex Sweet | Turner 2014
Frasera coloradensis (C.M. Rogers) D.M. Post CO (**Raton**) R G3 | Naumann 1991
Zeltnera texensis (Griseb.) G. Mans. ex J.S. Pringle [*Centaurium texense* (Griseb.) Fernald] AR, MO, OK, TX R

Lamiaceae
Brazoria enquistii M.W. Turner TX (**LUpl**) S G2
Hedeoma acinoides Scheele OK, TX R
Hedeoma reverchonii (A. Gray) A. Gray OK, TX R
Monarda clinopodiodes A. Gray KS, OK, TX, disj LA S
Monarda punctata L. var. *intermedia* (E. L. McClint. & Epling) Waterf. TX S
Monarda stanfieldii Small TX (**LUpl**) S G3
Salvia engelmannii A. Gray TX R
Scutellaria bushii Britton AR, MO R G3
Scutellaria resinosa Torr. KS, OK, TX R
Warnockia scutellarioides (Engelm. & A. Gray) M.W. Turner OK, TX R

Linaceae
Linum berlandieri Hook.
Linum compactum A. Nelson
Linum rigidum Pursh

Loaceae
Eucnide bartonioides Zucc. var. *edwardsiana* B.L. Turner TX (**Edw**) R | recently described (Turner 2012b) and probably of conservation concern
Mentzelia chrysantha Engelm. ex K. Brandegee CO (**Ark**) R G2 | Anderson, D.G. 2006
Mentzelia nuda (Pursh) Torr. & A. Gray S
Mentzelia strictissima (Wooton & Standl.) J. Darl. NM, TX (**Mesc**) S

Lythraceae
Lythrum ovalifolium Koehn TX (**Edw**), adj MX RIP G3

Malvaceae
Callirhoe alcaeoides (Michx.) A. Gray
Callirhoe bushii Fernald AR, KS, MO, OK R G3
Callirhoe digitata Nutt. AR, MO, OK R
Callirhoe involucrata (Torr. & A. Gray) A. Gray var. *involucrata*
Callirhoe pedata (Nutt. ex Hook.) A. Gray AR, OK, TX R
Callirhoe scabriuscula B.L. Rob. TX (**Red**) S G2/US-LE

Martyniaceae
Proboscidea sabulosa Correll NM, TX (**Mesc**), adj MX S G3

Nyctaginaceae
Mirabilis carletonii (Standl.) Standl. | recognized in some regional floras (GPFA 1986; Clark 1996; Kelso 2007) but placed in *M. glabra* (S. Watson) Standl. by Turner (1993) and in FNA (vol. 4, 2003)
Mirabilis exaltata (Standl.) Standl. KS, OK, TX G3 | recognized in some regional floras (GPFA 1986) but placed in *M. glabra* (S. Watson) Standl. by Turner (1993) and in FNA (vol. 4, 2003)
Mirabilis gigantea (Standl.) Shinners TX (**Rev**) S
Mirabilis rotundifolia (Greene) Standl. CO (**Ark**) R G2

Onagraceae
Oenothera canescens Torr. & Frém. H
Oenothera capillifolia Scheele subsp. *capillifolia* [*Calylophus berlandlieri* Spach subsp. *pinifolius* (Englemann) Towner] OK, TX, disj LA R
Oenothera cinerea (Wooton & Standl.) W. L. Wagner & Hoch subsp. *cinerea* [*Gaura villosa* Torr. subsp. *villosa*] S
Oenothera coloradensis (Rydb.) W.L. Wagner & Hoch [*Gaura neomexicana* Wooton subsp. *coloradensis* (Rydb.) P.H. Raven & D.P. Greg.] CO, NE, WY (**Niobr**) H G3T2/US-LT | Fertig 2000
Oenothera coryi W.L. Wagner TX (**Red**) R G3
Oenothera engelmannii (Small) Munz S

Oenothera glaucifolia W.L. Wagner & Hoch [*Stenosiphon linifolius* (Nutt. ex James) Heynh.] R
Oenothera harringtonii W.L. Wagner, Stockh. & W.M. Klein CO, NM (**Raton**) R G3 | Ladyman 2005
Oenothera macrocarpa Nutt. subsp. *fremontii* (S. Watson) W.L. Wagner KS, NE R G5T3
Oenothera macrocarpa Nutt. subsp. *incana* (A. Gray) W.L. Wagner KS, NM, OK, TX (**LEst**) R G5T3?
Oenothera macrocarpa Nutt. subsp. *macrocarpa* R
Oenothera macrocarpa Nutt. subsp. *oklahomensis* (Norton) W.L. Wagner KS, OK, TX (**Red**) R G5T3?
Oenothera rhombipetala Nutt. ex Torr. & A. Gray S
Oenothera serrulata Nutt.
Oenothera suffulta (Engelm. & A. Gray) W.L. Wagner & Hoch subsp. suffulta [*Gaura suffulta* Engelm. & A. Gray] OK, TX
Oenothera triangulata (Buckley) W.L. Wagner & Hoch [*Gaura triangulata* Buckley] OK, TX (**Red**) R G3

Orobanchaceae
Agalinis densiflora (Benth.) S.F. Blake KS, OK, TX G3
Agalinis edwardsiana Pennell TX (**Edw**) R
Castilleja citrina Pennell KS, OK, TX R | Nesom & Egger 2014
Castilleja genevievana G.L. Nesom TX (**Edw**), adj MX R G3 | Nesom & Egger 2014
Castilleja purpurea (Nutt.) G. Don KS, OK, TX, disj MO R
Castilleja lindheimeri A. Gray [*C. purpurea* (Nutt.) G. Don var. *lindheimeri* (A. Gray) Shinners] TX (**Edw**) R G5T3 | Nesom & Egger 2014

Papaveraceae
Argemone aurantiaca G.B. Ownbey TX (**Edw**) R
Argemone hispida A. Gray R
Argemone polyanthemos (Fedde) G.B. Ownbey S
Argemone squarrosa Greene subsp. *squarrosa* S

Plantaginaceae
Penstemon albidus Nutt.
Penstemon auriberbis Pennell CO, NM (**Raton**) R
Penstemon buckleyi Pennell S
Penstemon cobaea Nutt. R
Penstemon grandiflorus (Nutt.) S
Penstemon guadalupensis A. Heller TX (**Edw**) R G3
Penstemon helleri Small TX (**Edw**) R | sometimes placed in *P. triflorus* A. Heller (Diggs et al. 1999)
Penstemon haydenii S. Watson NE, disj WY S G1/US-LE | long thought to be endemic to the Nebraska Sandhills until outlying populations were discovered in central WY (Heidel 2012)
Penstemon oklahomensis Pennell OK, TX G3
Penstemon triflorus A. Heller TX (**Edw**) R G3
Penstemon versicolor Pennell CO (**Ark**) R G3?
Seymeria texana (A. Gray) Pennell TX (**Edw**) R G3

Polemoniaceae
Ipomopsis congesta (Hook.) V.E. Grant var. *pseudotypica* (Constance & Rollins) Dorn MT, SD, WY R G5T3?
Phlox alyssifolia Greene R
Phlox andicola E.E. Nelson
Phlox drummondii Hook. subsp. *johnstonii* (Wherry) Wherry TX (**Red**) S G5T3
Phlox drummondii Hook. subsp. *mcallesteri* (Whitehouse) Wherry TX S
Phlox oklahomensis Wherry KS, OK R G3 | Springer & Tyrl 1989
Phlox pilosa L. subsp. *fulgida* Wherry
Phlox pilosa L. subsp. *longipilosa* (Waterf.) Locklear [*P. longipilosa* Waterf.] OK R G2Q
Phlox roemeriana Scheele TX R
Phlox villosissima (A. Gray) Small subsp. *latisepala* (Wherry) Locklear [*P. pilosa* L. subsp. *latisepala* Wherry]: TX (**Rev**), disj MX
Phlox villosissima (A. Gray) Small subsp. *villosissima* [*P. pilosa* L. subsp. *riparia* Wherry] TX (**Edw**) RIP | Locklear 2009, 2011

Polygonaceae
Eriogonum alatum Torr. var. *glabriusculum* Torr. NM, OK, TX (**LEst**) R
Eriogonum aliquantum Reveal NM (**Raton**) R G3
Eriogonum annuum Nutt. S
Eriogonum correllii Reveal OK, TX (**LEst**) R G2
Eriogonum helichrysoides (Gandoger) Prain in B.D. Jackson et al. [*E. effusum* Nutt. var. *rosmarinoides* Benth.] KS R G4G5T2?
Eriogonum jamesii Benth. var. *simplex* Gandoger KS R G5T2
Eriogoum nealleyi J.M. Coult. TX (**Edw**) R G2
Eriogonum nebraskense Rydb. CO, NE, WY (**Niobr**) R | possibly of hybrid origin involving *E. effusum* Nutt. × *E. pauciflorum* Pursh (= *E.* × *nebraskense*); also recognized as *E. pauciflorum* Pursh var. *nebraskense* (Rydb.) Reveal
Eriogonum pauciflorum Pursh var. *gnaphalodes* (Benth.) Reveal CO, NE, WY (**Niobr**) R
Eriogonum pauciflorum Pursh var. *pauciflorum* R
Eriogonum tenellum Torr. var. *ramosissimum* Benth. TX (**LUpl**) R G5T3
Eriogonum visheri A. Nelson MT, ND, SD R G3 | Ladyman 2006c
Polygonum texense M.C. Johnst. TX H

Ranunculaceae
Delphinium carolinianum Walter var. *virescens* (Nutt.) R.E. Brooks
Delphinium treleasei Bush ex K.C. Davis AR, MO R G3

Rhamnaceae
Condalia hookeri M.C. Johnst. var. *edwardsiana* (Cory) M.C. Johnst. TX (**Edw**) R G5T1Q

Rosaceae
Crataegus turnerorum Enquist TX (**Edw**) RIP G3Q
Prunus minutiflora Engelm. TX (**Edw**) R
Prunus pumila L. var. *besseyi* (L.H. Bailey) Waugh
Rosa foliolosa Nutt. ex Torr. & A. Gray

Rubiaceae
Galium texense A, Gray AR, OK, TX R
Hedyotis nigricans (Lam.) Fosberg var. *papillacea* B.L. Turner NM, TX (**LEst**) R G5T3 | variety not recognized by Terrell (1986) who placed it in synonymy under *Stenaria nigricans* (Lam.) Terrell, but Turner considers it a distinct entity occurring primarily in the northern Texas panhandle (Turner 1995, 1997; Turner et al. 2003)

Scrophulariaceae
Besseya bullii (Eaton) Rydb. IA, IL, IN, MI, MN, OH, WI R G3

Solanaceae
Chamaesaracha darcyi Averett OK, TX (**Red**) R
Chamaesaracha edwardsiana Averett TX (**Edw**) R

Valerianaceae
Valerianella amarella (Lindh. ex Engelm.) Krok R
Valerianella ozarkana Dyal AR, MO, OK R G3
Valerianella stenocarpa (Engelm.) Krok TX (**Edw**) RIP G3
Valerianella texana Dyal TX (**LUpl**) R G2

Violaceae
Viola peditifida G. Don

Vitaceae
Parthenocissus heptaphylla (Buckley) Small TX (**Edw**)
Vitis acerifolia Raf.
Vitis cinerea (Engelm.) Millardet var. *helleri* (L.H. Bailey) M.O. Moore TX
Vitis monticola Buckley TX (**Edw**)

APPENDIX 2

CENTRAL GRASSLAND ENDEMIC PLANTS OF CONSERVATION CONCERN

The following taxa are plants of conservation concern based on NatureServe global conservation status rankings (G-rankings pertain to species, T-rankings to subspecific taxa). See Table 2 for more detailed descriptions of these rankings. Taxa also listed by the U. S. Fish and Wildlife Service as threatened or endangered are indicated by **LT** or **LE.** Taxa are arranged by center of endemism, if so associated, using the following abbreviations: Ark= Arkansas Valley Barrens; Edw = Edwards Plateau; LEst = Llano Estacado Escarpments; LUpl = Llano Uplift; Mesc = Mescalero-Monahans Dunes; Niobr = Niobrara-Platte Tablelands; Raton = Raton Tablelands; Red = Red Bed Plains; Rev = Reverchon Rocklands. State(s) and province(s) of occurrence are indicated.

Critically imperiled (G1/T1)		
Condalia hookeri		
var. *edwardsiana*	Edw	TX
Echinocereus milleri	Edw	TX
Elymus texensis	Edw	TX
Forsellesia texensis	Edw	TX
Perityle warnockii	Edw	TX
Cuscuta plattensis	Niobr	NE, WY
Solidago capulinensis	Raton	CO, NM
Echinacea paradoxa		
var. *neglecta*	Rev	OK
Senecio quaylei	Rev	TX
Yucca necopina	Rev	TX
Aschisma kansanum		KS
Hymenoxys perpygaema		TX
Molendoa ogalalensis		KS, NE
Penstemon haydenii LE		NE, WY
Imperiled (G2/T2)		
Oonopsis puebloensis	Ark	CO
Mentzelia chrysantha	Ark	CO
Mirabilis rotundifolia	Ark	CO
Argythamnia aphoroides	Edw	TX
Eriogonum nealleyi	Edw	TX
Ipomoea costellata		
var. *edwardsiana*	Edw	TX
Pomaria brachycarpa	Edw	TX
Eriogonum correllii	LEst	OK, TX
Brazoria enquistii	LUpl	TX
Campanula reverchonii	LUpl	TX
Isoetes lithophila	LUpl	TX
Packera texensis	LUpl	TX
Tradescantia pedicellata	LUpl	TX
Valerianella texana	LUpl	TX
Cyperus onerosus	Mesc	TX
Helianthus neglectus	Mesc	NM, TX
Oenothera coloradensis LT	Niobr	CO, NE, WY
Eurybia horrida	Raton	CO, NM
Nolina greenei	Raton	CO, NM, OK
Oonopsis monocephala	Raton	CO
Packera spellenbergii	Raton	NM
Physaria calcicola	Raton	CO, NM
Callirhoe scabriuscula LE	Red	TX
Dalea reverchonii	Rev	TX
Asclepias meadii LT		IA, IL, IN, KS, MO, WI
Echinacea paradoxa		
var. *paradoxa*		AR, MO
Eriogonum helichrysoides		KS
Eriogonum jamesii		
var. *simplex*		KS
Grindelia inornata		CO, NM
Ipomoea shumardiana		KS, OK, TX
Phlox pilosa		
subsp. *longipilosa*		OK
Physaria bellii		CO
Vulnerable (G3/T3)		
Parthenium tetraneuris	Ark	CO
Penstemon versicolor	Ark	CO
Amorpha roemerana	Edw	TX
Astragalus crassicarpus		
var. *berlanderii*	Edw	TX
Astragalus mollissimus		
var. *coryi*	Edw	TX
Berberis swaseyi	Edw	TX
Brickellia dentata	Edw	TX
Brickellia eupatorioides		
var. *gracillima*	Edw	TX
Castilleja genevievana	Edw	TX
Castilleja lindheimeri	Edw	TX
Crataegus turnerorum	Edw	TX
Hesperaloe parviflora	Edw	TX
Lythrum ovalifolium	Edw	TX
Penstemon guadalupensis	Edw	TX
Penstemon triflorus	Edw	TX
Perityle lindheimeri		
var. *halmiifolia*	Edw	TX
Perityle lindheimeri		
var. *lindheimeri*	Edw	TX
Sclerocactus brevihamatus		
subsp. *tobuschii* LE	Edw	TX
Selenia jonesii	Edw	TX
Seymeria texana	Edw	TX
Valerianella stenocarpa	Edw	TX
Yucca reverchonii	Edw	TX
Hedyotis nigricans		
var. *papillacea*	LEst	NM, TX
Oenothera macrocarpa		
subsp. *incana*	LEst	KS, NM, OK, TX
Eriogonum tenellum		
var. *ramosissimum*	LUpl	TX
Monarda stanfieldii	LUpl	TX
Ephedra coryi	Mesc	NM, TX
Eurytaenia hinckleyi	Mesc	NM, TX
Proboscidea sabulosa	Mesc	NM, TX
Parthenium alpinum	Niobr	CO, NM, WY
Astragalus puniceus		
var. *puniceus*	Raton	CO, NM, OK, TX
Astragalus wittmannii	Raton	NM
Eriogonum aliquantum	Raton	NM

Frasera coloradensis	Raton	CO
Oenothera harringtonii	Raton	CO, NM
Oenothera coryi	Red	TX
Oenothera macrocarpa subsp. *oklahomensis*	Red	KS, OK, TX
Oenothera triangulata	Red	OK, TX
Phlox drummondii subsp. *johnstonii*	Red	TX
Solidago mollis var. *angustata*	Red	OK, TX
Dalea hallii	Rev	TX
Pediomelum reverchonii	Rev	OK, TX
Yucca pallida	Rev	TX
Agalinis densiflora		KS, OK, TX
Ambrosia linearis		CO
Astragalus barrii		MT, NE, SD, WY
Astragalus siliceous		NM
Astragalus reflexus		TX
Besseya bullii		IA, IL, IN, MI, MN, OH, WI
Carex shinnersii		AR, KS, OK, TX
Chamaesyce carunculata		KS, NM, OK, TX
Chenopodium cycloides		CO, KS, NE, NM, TX
Delphinium treleasei		AR, MO
Desmodium tweedyi		OK, TX
Dieteria canescens var. *nebraskana*		NE, SD
Echinacea atrorubens		KS, OK, TX
Echinocereus reichenbachii var. *baileyi*		OK, TX
Eriogonum visheri		MT, ND, SD
Euphorbia strictior		NM, TX
Ipomopsis congesta var. *pseudotypica*		MT, SD, WY
Lespedeza leptostachya LT		IA, IL, MN, WI
Liatris glandulosa		TX
Matelea edwardsensis		TX
Mirabilis exaltata		KS, OK, TX
Oenothera macrocarpa subsp. *fremontii*		KS, NE
Oonopsis engelmannii		CO, KS
Oonopsis foliosa		CO
Pediomelum cyphocalyx		TX
Penstemon oklahomensis		OK, TX
Phlox oklahomensis		KS, OK
Physaria arenosa subsp. *argillosa*		CO, NE, SD, WY
Physaria filiformis LT		AR, MO
Physaria ovalifolia subsp. *alba*		KS, OK
Platanthera praeclara LT		MB; IA, KS, MN, MO, ND, NE, OK, SD
Scutellaria bushii		AR, MO
Solidago gattingeri		AR, MO
Valerianella ozarkana		AR, MO, OK
Possibly extinct (GH)		
Dalea sabinalis	Edw	TX

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