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A Vegetation Classification of the Sierra del Carmen, U.S.A. and México

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Abstract—A vegetation classification to the plant association level is presented for the Sierra del Carmen in the U.S. and México. The classification was developed as part of a remote sensing-based vegetation mapping project to support trans-boundary natural resources management between Big Bend National Park, Texas and the Maderas del Carmen Protected Area across the Rio Grande in México. The classification follows the International Classification of Ecological Communities hierarchy plus an Alliance Group level to account for regional biotic communities. Based on 401 plots, 121 plant associations were identified among 42 alliances, reflecting the high diversity of the vegetation composition in the Sierra del Carmen. These ranged from Chihuahuan Desert shrublands up through Madrean montane coniferous forest. This high community diversity was driven in part by an extended elevation gradient, complex terrain, and geological substrate differences. The classification is crosswalked at the Alliance Group level with other classifications for México and the U.S.

The Sierra del Carmen is a diverse and complex desert mountain range that extends from the Big Bend country of Texas, south across the Rio Grande into northern Coahuila, México. The range is over 2,600 km^2 in area and rises from the floor of the Chihuahuan Plateau at 700 m to over 3,100 m at the summit of the Maderas del Carmen. Given its size and topographic diversity, the mountain range harbors a wide variety of ecosystems—from desert shrublands to high montane forests—and contains several endemic species and communities. While it has long been recognized as possessing highly valuable biological and scenic resources (Wauer 1992), quantitative biological investigations, particularly with respect to vegetation, have been limited.

There have been several vegetation classifications developed for Big Bend National Park and adjacent lands over the years (see Plumb 1992), but they generally do not

extend into México. For example, Plumb's (1991) classification of vegetation cover types includes only the Dead Horse Mountains portion of the Sierra del Carmen in the Big Bend National Park. Conversely, general descriptions of the vegetation on the Mexican side can be found within regional vegetation surveys of Coahuila, but there are only a few studies that focus exclusively on the mountain range itself, and these do not extend into the U.S. The earliest was Muller's (1947) description of vegetation associations and climate for the state of Coahuila. Villarreal and Valdes (1993) provide an overview of the major vegetation types of Coahuila, building on the work of Muller (1947), Rzedowski (1978), Marroquin (1977), Henrickson and Johnston (1983), and others. Specific references to the distribution of vegetation in the Maderas del Carmen can be found in Henrickson and Johnston's draft flora of the Chihuahuan Desert region (1997, unpublish. manuscript, edition 1.2).

With respect to local studies, in 1988, before the area was designated as protected, the Universidad Autonoma de Nuevo Leon (UANL) Biology Department conducted plant and animal surveys in the Maderas del Carmen, with recommendations for conservation. Vegetation and faunistic associations for the mountains were also delimited and mapped on a broad scale (1:352,000) by Jimenez and Zuniga (1991). A generalized vegetation map was produced as part of the management plan developed for the Maderas del Carmen Protected Area by the Instituto de Ecologia which also includes information on soils, geology, and animals, as well as plans to preserve, conserve, or rehabilitate defined management units (Carabias et al. 1997).

Working within this framework and seeking to build a more comprehensive view of the mountain range with respect to vegetation, we conducted a survey on both the U.S. and Mexican sides in 1997 and 1998. Based on a suite of quantitative plots, we developed a detailed hierarchical classification of plant associations that was used to support the construction of a 1:100,000-scale remote sensing-based vegetation map to be used in trans-boundary natural resources management. We present the outline of the classification here along with a crosswalk to other recent classifications for the U.S. and México. The classification, in combination with the map (available from Big Bend National Park), provides the first unified look across national boundaries at the distribution and vegetative composition of the ecosystems of the Sierra del Carmen.

Methods and Materials—*Study Area*—The study area is located in Brewster County, Texas, and northern Coahuila, México, at a latitude between 28°10' and 29°40'N and a longitude between 102°20' and 103°80'W (Fig. 1). It is made up of a mountain range

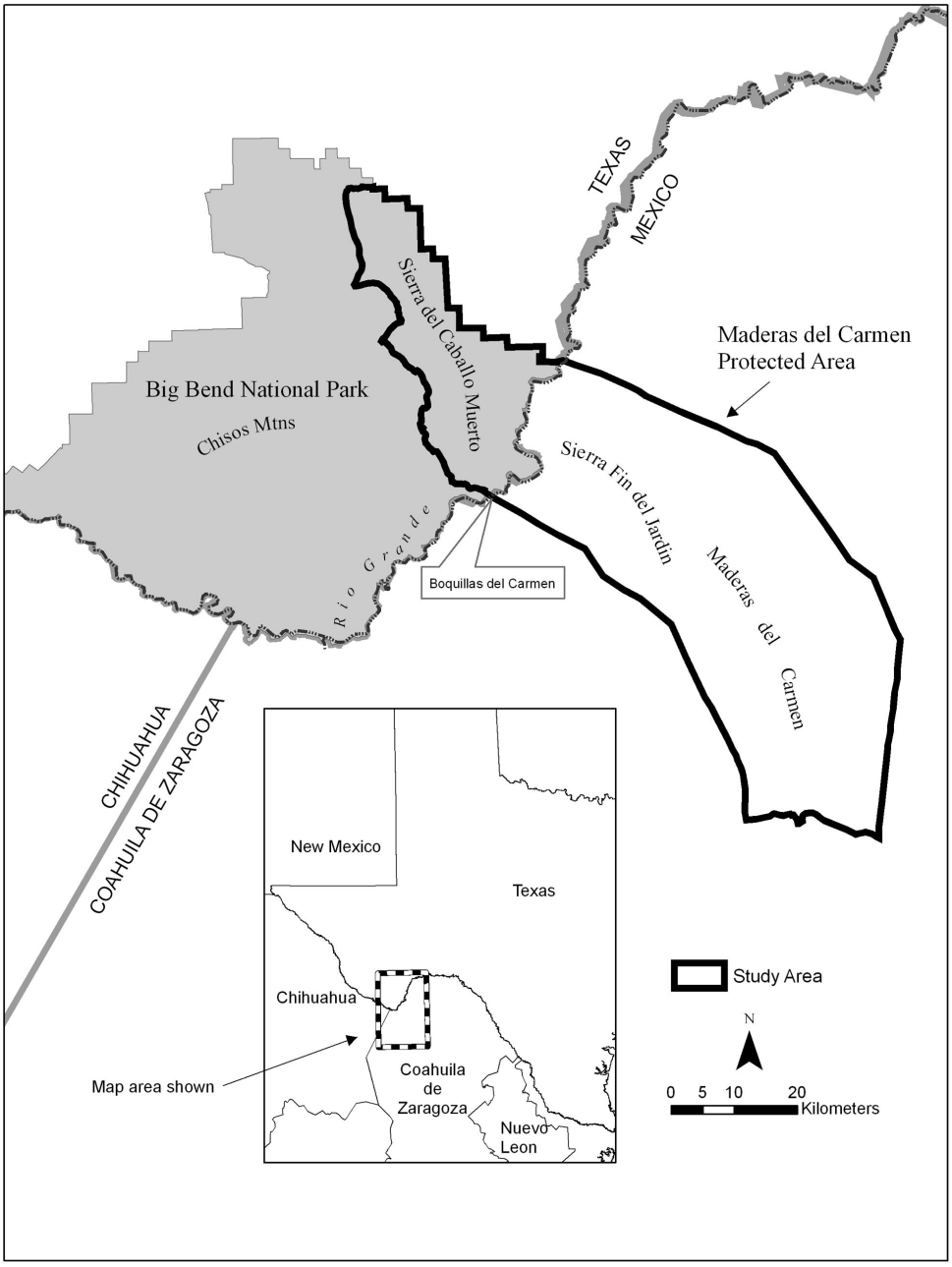

Fig. 1—Study area showing the three mountain ranges that make up the Sierra del Carmen in the U.S. and México.

trending north-northwestward with surrounding desert basins on the east and west sides, and is part of the Chihuahuan Desert region as defined by Henrickson and Johnston (1983). The total area is 261,943 hectares.

The mountain range may be divided into three broad sections based on latitude, geology, elevation, and vegetation. On the U.S. side, the Sierra del Caballo Muerto (Dead Horse Mountains) section of the range is mostly within Big Bend National Park, and is one of the most remote areas of the park. It is a large limestone fault-block mountain range dipping eastward and ranges from about 850 m to 1,600 m. Vegetation is mostly succulent desert shrubland and grassland, with some oak chaparral at the highest elevations.

Across the river on the Mexican side, the Sierra del Carmen is made up of the Sierra Fin del Jardin to the north and the Maderas del Carmen to the south, all within the boundaries of the government-designated Maderas del Carmen Protected Area (variously made up of private and collectively owned lands or ejidos). The Sierra Fin del Jardin (or El Jardin al Fin) is also a tilted sedimentary fault-block with a northeast-trending dipslope along with igneous rock intrusions that is essentially a southward extension of the Sierra del Caballo Muerto. Elevations range from about 500 m at Boquillas del Carmen to over 2,200 m at the top of the escarpment. Vegetation extends from desert shrubland and grassland on the footslopes to chaparral at mid-elevations, and pinyon-juniper-oak woodland at the highest elevations.

A moderately wide valley separates the Sierra Fin del Jardin from the Cerros el Centinela and the rest of the southern section known as the Maderas del Carmen or Sierra Maderas del Carmen. From Cerros el Centinela south the range is mostly exposed igneous volcanic rocks, commonly rhyolite and andesite, with some minor limestone exposures in the foothills. The elevations range from 700 m at the base of the mountains to over 3,100 m at the top. Along with this wide range of elevation comes a concomitant range in vegetation from desert grasslands and shrublands in the lowlands to mixed conifer forests at the highest elevations.

Geologically, the area is complex and only broadly mapped (Collins and Raney 1996), although the Boquillas area and part of the Sierra del Carmen escarpment have been mapped in detail (Maler 1989; Carpenter 1996). Much of the main mountain mass is composed of Tertiary volcanic rocks of both intrusive and extrusive origins. Inactive splatter cones are present in the northeast section of the study area near Mesa Guadalupe. The igneous units overlay several well-defined layers of Cretaceous sedimentary rock laid down when a Mesozoic sea submerged the area. Upper Cretaceous units are limestone mixed with sandstone, claystone and siltstone; Lower Cretaceous

units are predominantly limestone and metamorphic rocks (marl, chert, marble). Limestone is exposed in the foothills of the Maderas del Carmen and at the large block uplift that makes up the Sierra del Carmen—these sites were presumably beyond the reach of the Tertiary lava flows. Drainageways, arroyos, and alluvial fans are filled with Tertiary and Quaternary alluvium.

According to a map produced by the Instituto Nacional de Ecologia, there are 23 land parcels within the Maderas del Carmen Protected Area. Approximately seven of these are in collective ranches or ejidos; another seven are private ranches, and ownership of the rest is unclear. Presently, the primary land use is domestic livestock grazing. Logging occurred in the highest elevations of the Maderas del Carmen throughout much of the 20th century, but has been discontinued (logging last occurred in the 1980s). Cattle grazing and hunting have also been excluded recently from the high country of the Maderas del Carmen.

Sampling Methods—The vegetation classification was based on 401 quantitative plots established as part of a survey conducted in 1997 (México) and 1998 (U.S.). Potential field plot locations were identified using raw TM imagery, an unsupervised classification of the imagery, aerial photographs, and the 1:50,000-scale maps for the study area. In addition, potential sampling sites were distributed among a wide variety of landforms and geologic substrates and at different elevations, slopes, and aspects. Final plot selection was based on field reconnaissance and identification on the ground of large stands of homogeneous vegetation representing the major vegetation types. In the field, sampling was dictated by accessibility, both in terms of permission from landowners and topography. There were few roads in the Sierra del Carmen, and most sampling plots were reached by hiking. Plots were located at least 50 m from roads or trails, and within homogenous plant associations of at least one hectare or more in size.

Plots were 400 m^2, and either circular or square. For each plot complete species lists were compiled and canopy cover visually estimated for each species over the entire plot area. The cover data was recorded using a modified Domin-Krajina scale (Mueller-Dombois and Ellenberg 1974) that groups low-cover plants into narrower ranges than high-cover percentages. Standard environmental data was recorded: slope shape, grade and aspect, surface soil texture and color, ground cover (percent rock, gravel, bare soil and litter, and basal area), elevation, surface rock type, and erosion type along with a narrative description of the site and directions. Locations were recorded usually to the nearest 10 m using a Global Positioning System (GPS).

Voucher collections were made of all plant species recorded on the plots and the specimens deposited with Dr. Jesus Valdes-Reyna at the Herbarium of the Universidad Autonoma Agraria Antonio Narro (UAAAN) in Saltillo, México. Dr. Valdes and his staff also provided consultation on species determinations on the bulk of the collection. Dr. Richard Spellenberg at New Mexico State University in Las Cruces, New Mexico determined most of the oak specimens. Species names follow the nomenclature of USDA-NRCS (2004) and Henrickson and Johnston (1997, in litt.).

Using standard agglomerative clustering and table sorting techniques (Mueller-Dumbois and Ellenberg 1974; Reynolds and Ludwig 1983), plant associations were defined and organized into a five-tiered hierarchical system based on the International Classification of Ecological Communities and the U.S. National Vegetation Classification System (Grossman et al. 1998; Anderson et al. 1998). An additional Alliance Group level was added between the Alliance and Formation levels that draws upon the classification concepts of Brown et al. (1979, 1998) and Dick-Peddie (1993). At the lowest levels, each plot was classified into an alliance based on dominant or indicator species, and then to a particular plant association based on co-dominance and/or other groups of differential species. Alliances were then placed in alliance groups, which represent the major vegetation types of the region. The alliance groups were qualitatively crosswalked to the various regional and national classifications.

Results—*A vegetation classification of the Sierra del Carmen*—A hierarchical vegetation classification of the Sierra del Carmen in the U.S. and México is outlined in Table 1. There were 119 plant associations identified within 41 alliances and arranged according to a suite of physiognomic categories that make up the higher levels of the International Classification of Ecological Communities. Of these, 33 are well established associations, i.e., represented by five or more quantitative plots or are well described in the literature. There were an additional 44 provisional associations that were represented by two through four plots, and 42 new associations with only one plot. While many of these need further confirmation, as a whole they reflect the comparatively high diversity of vegetation communities in the Sierra del Carmen.

The alliances and component plant associations were grouped into 14 alliance groups that represent the major vegetation types of the range. The highest elevations of the Maderas del Carmen (over 2,300 m) were dominated by Madrean Upper and Lower Montane Conifer Forest alliance groups, i.e., mixed conifer and pine forests, respectively, of Sierra Madrean floristic affinity. These forests were represented by the *Abies durangensis* var. *coahuilensis* (Coahuila fir), *Pseudotsuga menziesii* (Douglas-fir),

Table 1—A vegetation classification of Sierra del Carmen, United States and México. The upper four levels of the hierarchy (Class, Subclass, Group, Formation), and the six and seventh (Alliance and Plant Association) follow the International Classification of Ecological Communities: Terrestrial Vegetation of the United States (Grossman et al. 1998 and Anderson et al. 1998). The fifth level is a regional grouping of alliances (Alliance Group) similar to the Biotic Community of Brown et al. (1979). The status of a given plant association is indicated as follows: I = incipient new association represented by one quantitative plot; P = provisional association represented by two to four quantitative plots; E = established and represented by five or more plots, or well documented in the literature. The number of quantitative plots (n =) from the current study is also indicated following the status.

I. Forest
I.A. Evergreen forest
I.A.8. Temperate or subpolar needle-leaved evergreen forest
I.A.8.N.b. Rounded-crowned temperate or subpolar needle-leaved evergreen forest
Madrean Lower Montane Conifer Forest
Pinus arizonica Forest Alliance
Pinus arizonica/Danthonia spicata (E, n = 8)
Pinus arizonica/Piptochaetium pringlei (P, n = 2)
Pinus arizonica-Quercus gravesii/Bromus lanatipes (P, n = 3)
Pinus arizonica-Quercus gravesii/Schizachyrium scoparium (I, n = 1)
Pinus arizonica-Quercus hypoleucoides/Piptochaetium pringlei (P, n = 2)
Pinus arizonica-Quercus rugosa/Koeleria macrantha (I, n = 1)
I.A.8.N.c. Conical-crowned temperate or subpolar needle-leaved evergreen forest
Madrean Upper Montane Conifer Forest
Abies durangensis Forest Alliance
Abies durangensis/Chimaphila menziesii (P, n = 1)
Abies durangensis-Pinus arizonica/Piptochaetium pringlei (P, n = 2)
Abies durangensis-Quercus hypoleucoides/Piptochaetium pringlei (P, n = 2)
Pseudotsuga menziesii Madrean Forest Alliance
Pseudotsuga menziesii-Arbutus xalapensis (P, n = 2)
Pseudotsuga menziesii/Chimaphila menziesii (P, n = 2)
Pseudotsuga menziesii-Quercus hypoleucoides/Piptochaetium pringlei (P, n = 2)
Pseudotsuga menziesii-Quercus hypoleucoides/Chimaphila menziesii (E, n = 5)
I.B. Deciduous forest
I.B.2. Cold-deciduous forest
I.B.2.N.b. Montane or boreal cold-deciduous forest
Madrean Upper Montane Oak Forest
Quercus gravesii Forest Alliance
Quercus gravesii/Piptochaetium fimbriatum (P, n = 2)
Quercus gravesii/Piptochaetium pringlei (P, n = 2)
Quercus gravesii-Quercus arizonica/Muhlenbergia emersleyi (I, n = 1)
Quercus gravesii-Quercus arizonica/Nolina texana (I, n = 1)
Q*uercus gravesii-Quercus arizonica/Piptochaetium pringlei* (I, n = 1
Quercus gravesii-Quercus hypoleucoides/Piptochaetium pringlei (P, n = 2)
Quercus gravesii-Quercus laceyi/Schizachyrium scoparium (P, n = 2)

Table 1—*continued*

II. Woodland
II.A. Evergreen woodland
II.A.2. Temperate broad-leaved evergreen woodland
II.A.2.N.a. Temperate broad-leaved evergreen woodland
Madrean Lower Montane Oak Woodland
Quercus hypoleucoides Woodland Alliance
Quercus hypoleucoides-Quercus rugosa/Muhlenbergia glauca (I, n = 1)
Quercus hypoleucoides-Quercus rugosa/Senecio carlomasonii (I, n = 2)
Quercus arizonica or Q. grisea Woodland Alliance
Quercus arizonica/Arctostaphylos pungens/Schizachyrium scoparium (P, n = 3)
Quercus arizonica/Bouteloua curtipendula (E, n = 7)
Quercus arizonica/Bouteloua gracilis (I, n = 1)
Quercus arizonica/Cercocarpus montanus (P, n = 1)
Quercus arizonica/Muhlenbergia emersleyi (E, n = 8)
Quercus arizonica/Nassella tenuissima (P, n = 2)
Quercus arizonica/Schizachyrium scoparium (P, n = 3)
Quercus arizonica/Sparse Undergrowth (I, n = 1)
Quercus arizonica/Yucca faxoniana/Bouteloua curtipendula (P, n = 2)
Quercus emoryi Woodland Alliance
Quercus emoryi/Bouteloua curtipendula (E, n = 1)
II.A.4. Temperate or subpolar needle-leaved evergreen woodland
II.A.4.N.a. Rounded-crowned temperate or subpolar needle-leaved evergreen woodland
Madrean Pinyon-Juniper Woodland
Pinus cembroides Woodland Alliance
Pinus cembroides/Bouteloua curtipendula (I, n = 1)
Pinus cembroides-Cercocarpus montanus (I, n = 1)
Pinus cembroides/Muhlenbergia emersleyi (P, n = 2)
Pinus cembroides/Nolina texana (P, n = 1)
Pinus cembroides-Quercus arizonica/Muhlenbergia emersleyi (E, n = 7)
Pinus cembroides/Sparse Undergrowth (P, n = 2)
Pinus remota Woodland Alliance
Pinus remota/Bouteloua curtipendula (I, n = 1)
Pinus remota-Quercus pungens var. *pungens* (I, n = 1)
Madrean Juniper Savanna Woodland
Juniperus deppeana Woodland Alliance
Juniperus deppeana/Nassella tenuissima (I, n = 1)
Juniperus deppeana/Schizachyrium scoparium (P, n = 4)
III. Shrubland
III.A. Evergreen shrubland
III.A.2. Temperate broad-leaved evergreen shrubland

Table 1—*continued*

III.A.2.N.c. Sclerophyllous temperate broad-leaved evergreen shrubland
Chihuahuan Interior Chaparral
Fraxinus greggii Shrubland Alliance
Fraxinus greggii/Achnatherum eminens (I, n = 1)
Fraxinus greggii-Agave lechuguilla (I, n = 1)
Fraxinus greggii-Vauquelinia corymbosa ssp. *angustifolia* (P, n = 2)
Quercus mohriana Shrubland Alliance
Quercus mohriana-Ceanothus greggii (I, n = 1)
Quercus mohriana-Cercocarpus montanus (P, n = 4)
Quercus mohriana-Dasylirion leiophyllum (I, n = 1)
Quercus mohriana/Muhlenbergia emersleyi (E, n = 6)
Quercus mohriana-Yucca faxoniana/Muhlenbergia setifolia (P, n = 2)
Quercus vaseyana Shrubland Alliance
Quercus vaseyana/Bouteloua curtipendula (I, n = 1)
Quercus vaseyana-Cercocarpus montanus (I, n = 1)
III.A.5. Extremely xeromorphic evergreen shrubland
III.A.5.N.a. Broad-leaved and microphyllous evergreen extremely xeromorphic subdesert shrubland
Chihuahuan Creosotebush Desert Scrub
Larrea tridentata Shrubland Alliance
Larrea tridentata-Acacia constricta/Sparse Undergrowth (P, n = 2)
Larrea tridentata-Agave lechuguilla; (P, n = 2)
Larrea tridentata/Bouteloua ramosa (E, n = 6)
Larrea tridentata-Euphorbia antisyphilitica (E, n = 5)
Larrea tridentata-Parthenium incanum (E, n = 9)
Larrea tridentata/Sparse Undergrowth (E, n = 8)
Larrea tridentata/Tiquilia hispidissima (P, n = 2)
III.B. Deciduous shrubland
III.B.2. Cold-deciduous shrubland
III.B.2.N.a. Temperate cold-deciduous shrubland
Madrean Montane Scrub
Cercocarpus montanus Madrean Shrubland Alliance
Cercocarpus montanus-Arctostaphylos pungens (P, n = 2)
Cercocarpus montanus/Muhlenbergia emersleyi (P, n = 1)
Cercocarpus montanus/Bouteloua curtipendula; (E, n = 4)
III.B.3. Extremely xeromorphic deciduous shrubland
III.B.3.N.a. Extremely xeromorphic deciduous subdesert shrubland
Chihuahuan Mixed Desert Scrub
Acacia constricta, A. neovernicosa Shrubland Alliance
Acacia constricta-Agave havardiana (I, n = 1)
Acacia constricta-Agave lechuguilla (E, n = 5)
Acacia constricta/Bouteloua eriopoda (E, n = 4)
Acacia constricta-Opuntia engelmannii (P, n = 4)

Table 1—*continued*

Acacia constricta-Parthenium incanum (E, n = 1)
Flourensia cernua Shrubland Alliance
Flourensia cernua/Sparse Undergrowth (E, n = 1)
Fouquieria splendens Shrubland Alliance
Fouquieria splendens-Agave lechuguilla-Euphorbia antisyphilitica (P, n = 2)
Fouquieria splendens/*Aristida purpurea* (I, n = 1)
Leucophyllum minus Shrubland Alliance
Leucophyllum minus-Agave lechuguilla (I, n = 1)
Leucophyllum minus-Dasylirion leiophyllum (I, n = 1)
Mimosa aculeaticarpa Shrubland Alliance
Mimosa aculeaticarpa-Aloysia gratissima (E, n = 6)
Mimosa aculeaticarpa-Aloysia gratissima/*Bouteloua curtipendula* (I, n = 1)
Mimosa aculeaticarpa-Aloysia gratissima/*Bouteloua gracilis* (P, n = 3)
Mimosa aculeaticarpa/*Bouteloua curtipendula* (E, n = 5)
Mimosa aculeaticarpa/*Bouteloua gracilis* (I, n = 1)
Mimosa aculeaticarpa/*Bouteloua ramosa* (I, n = 1)
Chihuahuan Mesquite Desert Scrub
Prosopis glandulosa Shrubland Alliance
Prosopis glandulosa-Aloysia gratissima (I, n = 1)
Prosopis glandulosa/*Aristida purpurea* (P, n = 1)
Prosopis glandulosa/*Bouteloua eriopoda* (E, n = 1)
Prosopis glandulosa/*Bouteloua gracilis* (E, n = 4)
Prosopis glandulosa-Flourensia cernua/Sparse Undergrowth (P, n = 2)
Prosopis glandulosa-Parthenium incanum (P, n = 2)
Prosopis glandulosa/*Pleuraphis mutica* (E, n = 3)
IV. Dwarf-shrubland
IV.A. Evergreen dwarf-shrubland
IV.A.2. Extremely xeromorphic evergreen dwarf-shrubland
IV.A.2.N.a. Extremely xeromorphic evergreen subdesert dwarf-shrubland
Chihuahuan Dwarf Desert Scrub
Agave lechuguilla Dwarf-shrub Alliance
Agave lechuguilla-Euphorbia antisyphilitica (E, n = 8)
Agave lechuguilla-Hechtia texensis (P, n = 2)
Euphorbia antisyphilitica Dwarf-shrub Alliance
Euphorbia antisyphilitica-Dasylirion leiophyllum (I, n = 1)
Parthenium incanum Dwarf-shrub Alliance
Parthenium incanum-Agave lechuguilla (E, n = 8)
Parthenium incanum-Dasylirion leiophyllum (I, n = 1)
Parthenium incanum-Euphorbia antisyphilitica (P, n = 2)
Parthenium incanum-Parthenium argentatum (I, n = 1)
V. Herbaceous Vegetation
V.A. Perennial graminoid vegetation
V.A.5. Temperate or subpolar grassland

Table 1—*continued*

V.A.5.N.e. Short sod/bunch temperate or subpolar grassland
Madrean Mesa-Foothill Grassland
Bouteloua eriopoda Herbaceous Alliance
Bouteloua eriopoda-Aristida purpurea (E, n = 1)
Bouteloua gracilis Herbaceous Alliance
Bouteloua gracilis-Bouteloua curtipendula (E, n = 7)
Bouteloua gracilis-Monotypic Stand (E, n = 1)
Bouteloua gracilis-Nassella tenuissima (P, n = 2)
Bouteloua ramosa Herbaceous Alliance
Bouteloua ramosa-Bouteloua curtipendula (P, n = 2)
Bouteloua hirsuta Herbaceous Alliance
Bouteloua hirsuta-Bouteloua curtipendula (E, n = 1)
Bouteloua hirsuta-Bouteloua gracilis (E, n = 5)
Bouteloua hirsuta-Nassella tenuissima (I, n = 1)
Bouteloua hirsuta-Schizachyrium scoparium (I, n = 1)
Aristida purpurea Herbaceous Alliance
Aristida purpurea-Heteropogon contortus (P, n = 3)
Bouteloua barbata Herbaceous Alliance
Bouteloua barbata-Chloris virgata (I, n=1)
Pleuraphis mutica Herbaceous Alliance
Pleuraphis mutica/Monotypic Stand (E, n = 1)
V.A.7. Temperate or subpolar grassland with a sparse shrub layer
V.A.7.N.h. Medium-tall temperate grassland with a sparse xeromorphic (often thorny) shrub layer
Chihuahuan Foothill-Piedmont Desert Grassland
Bouteloua curtipendula Shrub Herbaceous Alliance
Bouteloua curtipendula/*Dasylirion leiophyllum* (E, n = 23)
Bouteloua curtipendula/*Viguiera dentata* (E, n = 5)
Bouteloua curtipendula/*Yucca thompsoniana* (P, n = 3)
Bouteloua curtipendula/*Yucca faxoniana* (I, n = 1)
Muhlenbergia emersleyi Shrub Herbaceous Alliance
Muhlenbergia emersleyi/*Dasylirion leiophyllum* (I, n = 1)
Muhlenbergia emersleyi/*Yucca thompsoniana* (I, n = 1)
Muhlenbergia setifolia Shrub Herbaceous Alliance
Muhlenbergia setifolia-Bouteloua hirsuta/*Agave lechuguilla* (P, n = 2)
Muhlenbergia setifolia/*Dasylirion leiophyllum* (I, n = 1)
V.A.7.N.m. Short temperate or subpolar grassland with a sparse xeromorphic (evergreen and/or deciduous) shrub layer
Chihuahuan Foothill-Piedmont Desert Grassland
Bouteloua gracilis Shrub Herbaceous Alliance
Bouteloua gracilis/*Viguiera stenoloba* (I, n = 1)
Bouteloua gracilis/*Yucca thompsoniana* (P, n = 2)
Bouteloua hirsuta Shrub Herbaceous Alliance

Table 1—*continued*

Bouteloua hirsuta/*Dasylirion leiophyllum* (I, n = 1)
Bouteloua hirsuta/*Yucca faxoniana* (I, n = 1)
Bouteloua eriopoda Shrub Herbaceous Alliance
Bouteloua eriopoda/*Dasylirion leiophyllum* (P, n = 4)
Bouteloua ramosa Shrub Herbaceous Alliance
Bouteloua ramosa/*Dasylirion leiophyllum* (E, n = 14)
V.A.8. Temperate or subpolar grassland with a sparse dwarf-shrub layer
V.A.8.N.a. Short temperate or subpolar lowland grassland with a sparse needle-leaved or microphyllous dwarf-shrub layer
Chihuahuan Foothill-Piedmont Desert Grassland
Bouteloua eriopoda Dwarf-shrub Herbaceous Alliance
Bouteloua eriopoda/*Agave havardiana* (I, n = 1)
Bouteloua eriopoda/*Parthenium incanum* (E, n = 1)
Bouteloua ramosa Dwarf-shrub Herbaceous Alliance
Bouteloua ramosa/*Agave lechuguilla* (E, n = 6)
Bouteloua ramosa/*Euphorbia antisyphilitica* (E, n = 5)
Pleuraphis mutica Dwarf-shrub Herbaceous Alliance
Pleuraphis mutica/*Agave lechuguilla* (I, n = 1)

or *Pinus arizonica* (Arizona pine) Alliances with a wide variety of associations. Canopies were often dense (on average at least 60% canopy closure) with a sub-canopy or shrub layer dominated by a wide variety of oaks such as *Quercus rugosa* (netleaf oak), *Q. hypoleucoides* (silverleaf oak), *Q. arizonica* (Arizona white oak), *Q. grisea* (gray oak), or *Q. gravesii* (Graves oak). *Cupressus arizonica* (Arizona cypress) and *Pinus strobiformis* (southwestern white pine) are other common canopy associates. The herb layer can be sparse, or, where the canopies were more open, a significant grass cover can develop with a wide variety of grasses such as *Piptochaetium pringlei* (Pringle needlegrass), *Danthonia spicata* (poverty danthonia), and *Bromus lanatipes* (wooly brome). Intermixed among the conifer forest, particularly in cool canyons, were deciduous Upper Montane Oak Forests dominated by *Q. gravesii* that lacked significant coniferous elements.

At mid elevations (1,450 to 2,500 m) of the mountains and on mesa tops, the forests gave way to Madrean Lower Montane Oak Woodlands dominated by evergreen oaks such as *Q. hypoleucoides* (silverleaf oak), *Q. arizonica* (Arizona white oak), and *Q. emoryi* (Emory oak), along with scattered conifers. There were also low-statured conifer-dominated Madrean Pinyon-Juniper Woodlands characterized by *Pinus cembroides* (Mexican pinyon) or *P. remota* (papershell pinyon), with various junipers as codominants or subdominants (*Juniperus ashei, J. erythrocarpa, J. flaccida,* and *Juniperus deppeana*).

Understories were quite varied as indicated by the 22 associations described among these alliances. Most have grassy undergrowths, and those with open tree canopies and dominated solely by junipers were considered Madrean Juniper Savanna Woodland (e.g., the *Juniperus deppeana* Alliance). Others were decidedly shrubby in the understory and were dominated by "chaparral" species such as *Arctostaphylos pungens* (pointleaf manzanita), *Cercocarpus montanus* (mountain mahogany), and *Q. vaseyana* (Vasey's sandpaper oak). On sites that have been repeatedly burned or that are exceptionally rocky, either Madrean Montane Scrub dominated by *Cercocarpus* prevailed or at lower elevation Chihuahuan Interior Chaparral characterized by the *Fraxinus greggii* (desert ash), *Q. mohriana* (Mohr's shin oak) and *Q. vaseyana* alliances.

At elevations around 1,200 m Madrean Mesa and Foothill grasslands were common and were represented primarily by the *Bouteloua gracilis* (blue grama), *B. curtipendula* (sideoats grama), *B. hirsuta* (hairy grama), and *Muhlenbergia emersleyi* (bull muhly) alliances. The lower foothills and alluvial fan piedmonts (bajadas) were characterized by Chihuahuan Foothill-Piedmont Semi-desert Grasslands and particularly by the *B. ramosa* (chino grama) and *B. eriopoda* (black grama) Alliances. These associations had a conspicuous shrub element such as *Dasylirion leiophyllum* (smooth sotol) or *Yucca thompsoniana* (beaked yucca), but the shrubs do not typically dominate.

Chihuahuan Desert shrubland communities were common among the lower foothills and dominated the majority of the bajadas and desert basins. In these associations shrub cover usually exceeded 25% and clearly dominated over grasses. The *Larrea tridentata* (creosotebush), *Prosopis glandulosa* (honey mesquite), *Mimosa aculeaticarpa* (catclaw mimosa), and *Acacia constricta* and *A. neovernicosa* (whitethorn) alliances are the most prevalent. At the lowest elevations (640 m), Chihuahuan Dwarf Shrublands with alliances dominated by succulents, such as *Agave lechuguilla* (lechuguilla), *Euphorbia antisyphilitica* (candelilla), *Jatropha dioica* (rubber plant), and *Hechtia texensis* (false agave) were conspicuous, often cloaking large expanses of limestone outcrops. There were also floristic influences that extend in from the east that were representative of Tamaulipan Thorn Scrub, such as the *Leucophyllum minus* (Big Bend silverleaf) Alliance.

Relation to Other Vegetation Classifications—The classification developed here has a high degree of detail, but in its general outline can be compared to other classifications that cover the area. To do so, we concentrated on the Alliance Group level and crosswalked the groups to three Mexican classifications (Rzedowski 1978; Jimenez and Zuniga 1991; and Villarreal and Valdes 1993); the biotic communities classification of Brown et al. (1979, 1998) that covers the southwestern U.S. and northern México; Plumb's (1993) mapping classification for Big Bend National Park, TX, and NatureServe's Ecological

Table 2—A crosswalk between the alliance groups and other vegetation classifications that apply to the Sierra del Carmen.

Alliance Group, this study	Brown et al. (1979, 1998) American SW (U.S. & México)	Rzedowski (1978) México	Villarreal & Valdez (1993) Coahuila, México
Madrean Upper Montane Conifer Forest	Madrean Montane Conifer Forest (Mixed Conifer Series)	Coniferous Forest	White Fir Forest
Madrean Lower Montane Conifer Forest	Madrean Montane Conifer Forest (Pine Series): Madrean Evergreen woodland (Oak-Pine Series)		Pine Forest
Madrean Upper Montane Oak Forest		Oak Forest	Oak Forest
Madrean Lower Montane Oak Woodland	Madrean Evergreen Woodland (Encinal)		
Madrean Pinyon-Juniper Woodland			
Madrean Juniper Savanna Woodland			
Madrean Montane Scrub	Madrean Montane Scrub	Xeric Shrubland	Submontane Shrubland
Chihuahuan Interior Chaparral	Chihuahuan Interior Chaparral		
Chihuahuan Creosotebush Desert Scrub	Chihuahuan Desert Scrub (Creosotebush-Tarbush Series; Whitethorn Series)		Microphyllous Desert Scrub
Chihuahuan Mixed Desert Scrub			
Chihuahuan Mesquite Desert Scrub	Chihuahuan Desert Scrub (Mesquite Series)		
Chihuahuan Dwarf Desert Scrub	Chihuahuan Desert Scrub (Mixed Scrub-Succulent Series		Rosette-leaved (rosetófilo) Shrubland
Madrean Mesa-Foothill Grassland		Pastizal	Zacatal
Chihuahuan Foothill-Piedmont Desert Grassland	Semi-desert Grassland		

Table 2—*continued*

Jimenez & Zuniga (1991) Maderas del Carmen	Plumb (1993) Big Bend National Park, U.S.	Comer et al. (2003) NatureServe Ecological Systems
Pine-Oak-Douglas fir-White Fir Forest	Oak-Ponderosa-Cypress	Madrean Upper Montaine Conifer-Oak Forest & Woodland
Pine-Oak-Cypress Forest; Oak-Pine-Juniper Forest; Oak-Pine Forest		Madrean Pine-Oak Forest & Woodland
		Madrean Pine-Oak Forest & Woodland
Oak-Juniper-Cypress Forest	Mixed Oak	Madrean Encinal
Pinyon Pine Forest	Pinyon-Oak-Juniper; Pinyon Talus	Madrean Pinyon-Juniper Woodland
	Pinyon-Juniper Grass	Madrean Juniper Savanna
	Oak Scrub	
High elevation spinose shrubland; Mid-elevation spinose shrubland; Spinose "izotal"	Creosote-Lechuguilla-Grass; Creosote-Lechuguilla-Prickly Pear; Creosote-Yucca-Grass	Chihuahuan Creosotebush Basin Desert Scrub
	Creosote-Tarbush	Chihuahuan Mixed Desert & Thorn Scrub
		Chihuahuan Mesquite Upland Scrub
"Izotal," low-elevation, sub-shrub shrubland (in part)	Lechuguilla-Candelilla-Hechtia	Chihuahuan Succulent Desert Scrub
"Izotal," low-elevation, sub-shrub shrubland (in part)	Forest Meadow	Chihuahuan Piedmont Semi-Desert Grassland
	Lechuguilla-Grass; Viguiera-Lechuguilla-Grass; Sotol-Lechuguilla-Grass; Yucca-Sotol	Desert Grassland

Systems of the United States classification (Comer et al. 2003). The crosswalk is based on a qualitative comparison of descriptions provided by the authors (Table 2).

In general all the classification schemes identified elements among coniferous forest, oak woodland, desert shrubland, and grassland, and those that covered the largest areas were the ones with the broadest categories (e.g., Rzedowski 1978). While Villarreal and Valdes' (1993) classification for Coahuila, México was somewhat generalized, they did identify separate white fir and pine forest groups, and a *rosetófilo* or succulent desert shrubland. They also include a submontane (chaparral-like) shrubland that corresponds to the Madrean Montane Scrub and Chihuahuan Interior Chaparral combination of this study and Brown et al. 1998. Jimenez and Zuniga's (1991) classification differs the most from the other classifications: pine-oak forest is subdivided into three categories based on dominant species, and desert scrub vegetation is separated according to elevation and morphology of the dominant plants. In their classification they subsume montane shrubland into pinyon-pine forest, and their "*Izotal*" most closely corresponds to the grassland class of the other classifications, but also has characteristics of dwarf desert shrubland.

The Plumb (1993) classification represents a set of mapping categories derived from his earlier association classification for Big Bend National Park (Plumb 1991). Approximate corollaries can be found among his categories to most of our alliance groups, but he did not identify a separate mixed-conifer forest, i.e., he included *Pseudotsuga* within his Oak-Ponderosa-Cypress class. With respect to Brown et al. (1979 & 1998), our alliance groups more often correspond to their series designations rather than their higher level biotic communities. The Ecological Systems of Comer et al. (2003) conform well to our Alliance Groups, but that is to be expected since they had access to our database while developing their classification. Overall, our Alliance Groups tend to represent more detail at this intermediate classification level than other studies, e.g., the identification of separate groups such as Madrean Upper Montane Oak Forest dominated by deciduous oaks, open Madrean Juniper Savanna, Madrean Montane Scrub dominated by *Cercocarpus*, Chihuahuan Mesquite Desert Scrub, and Madrean Mesa-Foothill grassland with a limited shrub component.

Species Diversity—A total of 495 species were recorded during the ground survey (Appendix 1). This is about one-third the number recorded for Big Bend National Park, but represents only two seasons of work. Regardless, we evaluated the relative species diversity structure among major vegetation types with 'species/plot' curves showing the cumulative number of new species gained with each added plot (Fig. 2). Grassland and shrubland, which have the highest number of plots, are the only ones that approached

an asymptote with respect to new species acquired with an increased number of plots. Thus, even the high numbers of samples in this study were not sufficient to capture the diversity across all vegetation types. A comparison of all vegetation types at a point where there are an equal number of plots (n=14) shows montane shrubland with the highest number of species, followed by grasslands, oak forest and oak woodlands, then coniferous forest, and finally, desert shrublands.

Several endemics were found in the Sierra del Carmen as well as new records of common species. The endemics include *Hedeoma johnstonii* (Johnston's pennyroyal), *Tilia mexicana* (Mexican basswood), and *Quercus carmenensis* (Mexican oak). *Muhlenbergia montana* (mountain muhly), a common species in the Rocky Mountains, was recorded for the first time in the Sierra del Carmen. The white oaks in this range are a complex of *Quercus carmenensis*, *Q. mohriana, Q. arizonica,* and *Q. vaseyana*, and are unlike any described oak complex in México (Spellenberg, pers. comm).

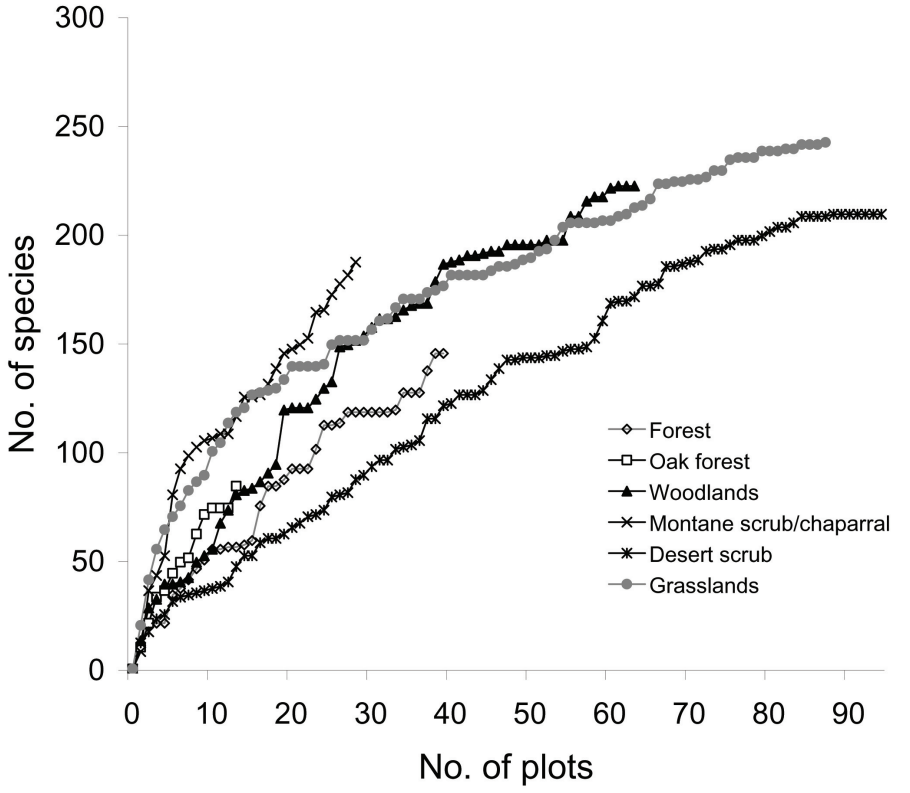

Fig. 2—Cumulative species/plot diversity curves for the major vegetation types of the Sierra del Carmen.

Discussion—The high vegetative diversity of the Sierra del Carmen can be attributed in part to its geographic location, e.g., the mountain range is positioned at the northern end of the Sierra Madre Orientale cordillera and between the Chihuahuan Desert and Tamaulipan Thornscrub vegetation provinces. It is the first major mountain mass that intercepts storm systems from the Gulf of Mexico to the east. The resultant precipitation at high elevations contributes to the maintenance of mixed conifer and deciduous oak forests characteristic of the Madrean biotic province (Muller 1947; Pase and Brown 1982). Higher precipitation on the east side may also contribute to the formation and maintenance of extensive grasslands found on the footslopes there. Lowland elevation on the east side of the range was typical of the Chihuahuan Desert, but there were elements of desert Tamaulipan Thornscrub (as defined by Muller 1947), although 'pure' Tamaulipan Thornscrub occurs further to the east at lower elevations (Brown et al. 1998). The west side, however, experiences a double rain-shadow effect whereby storms from the east are blocked by the Sierra del Carmen mountain mass and storms originating in the Pacific Ocean and Gulf of California are blocked by the main mass of the Sierra Madre Occidentale (Muller 1947). This creates the most arid conditions within the study site at low elevations on the west side. Here, vegetation is similar to that of the Trans-Pecos region of the Chihuahuan Desert in west Texas and southern New Mexico (Muller 1947; MacMahon 1988).

In addition, because it is at the southern end of the chain of 'island' mountain ranges that extends northward from the Chisos Mountains in Big Bend National Park to the Organ Mountains in southern New Mexico, many of the forest and woodland associations of the Sierra del Carmen have similarities to those found in the southwestern United States, differing mainly where a given dominant is replaced by a closely related species to the north. For example, the associations of the *Pinus arizonica* Alliance are similar in terms of elevation range, community composition, and stand structure to those found in the *Pinus ponderosa* Alliance described for southeastern Arizona and southwestern New Mexico (Muldavin et al. 1996). *Pinus arizonica* and *Pinus ponderosa* are closely related, with *P. arizonica* often referred to as a southern variety of *P. ponderosa*. Similarly, there are *Abies concolor* and *Pseudotsuga* associations that are described from the southern Rocky Mountains that are similar in composition to the *Abies durangensis* var. *coahuilensis* and *Pseudotsuga* types here. Many *Pinus edulis* associations from New Mexico and west Texas correspond to *Pinus cembroides* and *P. remota* communities. Likewise, there are oak and chaparral associations throughout the zone of the U.S.-México borderlands similar to those found in the Sierra del Carmen, but further west,

species with their center of distribution in the Sierra Madre Orientale are replaced by those found in the Sierra Madre Occidentale (Muldavin and DeVelice 1987).

Superimposed on this complex geographic structure are striking differences in geology across the Sierra del Carmen. In arid areas, at the same elevations, more shrubs tend to occur on limestone soils and more grasses on igneous soils. This is because the coarser, more easily weathered soils of igneous substrates allow for better infiltration of falling water than the more clayey, impermeable soils of limestone where water is more likely to run off (Aide and Van Auken 1985). Weathering affects soil depth and structure and thus microsite availability. Slight differences in substrate material cause differential weathering that creates loamy skeletal soils at high elevations and gravelly or fine soils alternating with rocky outcrops at lower elevations. The southern Maderas del Carmen is composed primarily of volcanic rhyolitic substrates, whereas the remainder of the range is primarily fault-blocked sedimentary limestones (the middle Mexican portion—or the Sierra Fin del Jardin, and the northern Sierra del Caballo Muerto in Big Bend National Park). Although elevation plays a role, substrate differences lead to a noticeable contrast in vegetation from extensive woodlands and grasslands on volcanic-derived soils in the south, to predominantly desert grasslands and desert scrub on limestone soils past the Cerros el Centinela in the north. Vegetation differences attributable to substrate were also apparent on the west side where scrubby limestone hills alternate with grasslands on igneous slopes.

Furthermore, based on the map by Plumb (1991, 1992, and 1993) for Big Bend National Park, the southern Maderas del Carmen is more similar to the volcanic Chisos Mountains than to the limestone portions of the Sierra del Carmen. The Chisos Mountains share many of the same woodland, forest and grassland communities, although they lack significant elements such as *Abies durangensis* var. *coahuilensis*, and stands tend to be more fragmented there with less overall coverage.

The middle limestone section of the Sierra del Carmen in México (Sierra Fin del Jardin) have strong similarities to the Sierra del Caballo Muerto of Big Bend National Park. In the heart of the Sierra Fin del Jardin there are considerable amounts of oak and pinyon woodlands as well as mesa grasslands, which are not strongly represented in the Sierra del Caballo Muerto. But further north, as one approaches the Rio Grande, there are remote canyonlands that appear to be dominated by succulent desert scrub similar to the low elevations of the Sierra del Caballo Muerto directly across the river. Along the western mountain fronts in the U.S. and México, the vegetation is very similar with desert grasslands and succulent desert scrub cloaking the slopes and alluvial fan piedmonts.

While the vegetation classification presented here is the most detailed work on vegetation in the Sierra del Carmen conducted to date, there is still much to be learned about this rugged and remote mountain range in both México and the U.S. We strongly recommend further botanical and faunal surveys to enhance our understanding of differences and similarities while lending support to the management of these biological resources across the Rio Grande between Big Bend National Park and the Maderas del Carmen Protected Area.

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Appendix 1—A checklist of plant species for the Sierra del Carmen vegetation survey conducted in 1997 (México) and 1998 (Big Bend National Park, TX). Nomenclature follows Henrickson and Johnston (1997) and USDA-NRCS (2004). Frequency refers to the number of plot occurrences.

Family	Scientific name	Frequency
Acanthaceae	*Carlowrightia linearifolia* (Torr.) Gray	3
Acanthaceae	*Dyschoriste linearis* (Torr. & Gray) Kuntze	9
Acanthaceae	*Ruellia parryi* Gray	3
Acanthaceae	*Siphonoglossa pilosella* (Nees) Torr.	2
Acanthaceae	*Tetramerium nervosum* Nees	1
Aceraceae	*Acer grandidentatum* Nutt.	1
Agavaceae	*Agave havardiana* Trel.	64
Agavaceae	*Agave lechuguilla* Torr.	115
Agavaceae	*Dasylirion leiophyllum* Engelm. ex Trel.	115
Agavaceae	*Nolina texana* Wats.	1
Agavaceae	*Yucca constricta* Buckl.	1
Agavaceae	*Yucca faxoniana* (Trel.) Sarg.	47
Agavaceae	*Yucca thompsoniana* Trel.	51
Agavaceae	*Yucca torreyi* Shafer	18
Agavaceae	*Yucca treculeana* Carr.	3
Amaranthaceae	*Amaranthus hybridus* L.	2
Amaranthaceae	*Amaranthus palmeri* S. Wats.	1
Amaranthaceae	*Froelichia arizonica* Thornb.	1
Amaranthaceae	*Iresine heterophylla* Standl.	1
Amaranthaceae	*Tidestromia lanuginosa* (Nutt.) Standl.	7
Anacardiaceae	*Rhus microphylla* Engelm. ex Gray	4
Anacardiaceae	*Rhus trilobata* Nutt.	14
Anacardiaceae	*Rhus virens* Lind. ex Gray	11
Anacardiaceae	*Rhus virens* Lindh. ex A. Gray var. *choriophylla* (Woot. & Standl.) L.D. Benson	16
Anacardiaceae	*Rhus virens* Lindheimer ex Gray var. *virens*	2
Apiaceae	*Aletes acaulis* (Torr.) Coult. & Rose	1
Apiaceae	*Osmorhiza mexicana* Griseb.	1
Apiaceae	*Pseudocymopterus montanus* (Gray) Coult. & Rose	1
Apocynaceae	*Macrosiphonia lanuginosa* (Mart. & Gal.) Hemsl. var. *macrosiphon* (Torr.) Henrickson, comb. nov. ined.	13
Asclepiadaceae	*Asclepias latifolia* (Torr.)Raf.	1
Asclepiadaceae	*Asclepias texana* Heller	1
Asclepiadaceae	*Cynanchum kunthii* (Dcne.) Standl.	2
Asteraceae	*Achillea millefolium* var. *occidentalis* DC.	25
Asteraceae	*Ageratina hyssopina* Gray	4
Asteraceae	*Ageratina wrightii* (Gray) King & H.E. Robbins	2
Asteraceae	*Amphiachryis dracunculoides* (DC.) Nutt.	1
Asteraceae	*Anaphalis margaritacea* (L.) Benth. & Hook. f.	1
Asteraceae	*Artemisia ludoviciana* Nutt.	42

Appendix 1—*continued*

Family	Scientific name	Frequency
Asteraceae	*Baccharis pteronioides* DC.	3
Asteraceae	*Bahia absinthifolia* Benth.	7
Asteraceae	*Bidens pilosa* L.	1
Asteraceae	*Brickellia betonicifolia* Gray	1
Asteraceae	*Brickellia grandiflora* (Hook) Nutt.	1
Asteraceae	*Brickellia nelsonii* Rob.	2
Asteraceae	*Brickellia veronicaefolia* (H.B.K.) Gray	3
Asteraceae	*Chaptalia texana* Greene	1
Asteraceae	*Cirsium pringlei* (S Wats.) Petrak	1
Asteraceae	*Cirsium texanum* Buckl.	2
Asteraceae	*Conoclinium greggii* (Gray) Small	1
Asteraceae	*Conyza canadensis* (L.) Cronq.	1
Asteraceae	*Cosmos parviflorus* (Jacq.) Pers.	1
Asteraceae	*Dyssodia papposa* (Vent.) Hitchc.	2
Asteraceae	*Erechtites hieracifolia* (L.) Raf.	1
Asteraceae	*Ericameria laricifolia* (Gray) Shinners	22
Asteraceae	*Erigeron flagellaris* Gray	1
Asteraceae	*Erigeron modestus* Gray	7
Asteraceae	*Flourensia cernua* DC.	26
Asteraceae	*Gnaphalium oxyphyllum* DC	2
Asteraceae	*Grindelia havardii* Steyermark	5
Asteraceae	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby	6
Asteraceae	*Gymnosperma glutinosum* (Spreng.) Less	34
Asteraceae	*Helianthella mexicana* Gray	1
Asteraceae	*Helianthus nuttallii* Torr. & Gray	1
Asteraceae	*Heliomeris longifolia* (B.L. Rob. & Greenm.) Cockerell var. *longifolia*	6
Asteraceae	*Heliomeris multiflora* Nutt.	4
Asteraceae	*Heterotheca fulcrata* (Greene) Shinners	5
Asteraceae	*Hieracium carneum* Greene	1
Asteraceae	*Hieracium fendleri* Schultz-Bip	5
Asteraceae	*Jefea brevifolia* (Gray) Strother	22
Asteraceae	*Liatris punctata* Hook.	4
Asteraceae	*Machaeranthera blephariphylla* (Gray) Shinners	1
Asteraceae	*Machaeranthera pinnatifida* (Hook.) Shinners var. *pinnatifida*	4
Asteraceae	*Melampodium leucanthum* Torr. & Gray	13
Asteraceae	*Packera millelobata* (Rydb.) W.A. Weber & A. Löve	5
Asteraceae	*Parthenium argentatum* Gray	5
Asteraceae	*Parthenium hysterophorus* L.	3
Asteraceae	*Parthenium incanum* Kunth	60
Asteraceae	*Porophyllum scoparium* Gray	5
Asteraceae	*Pseudognaphalium canescens* W.A. Weber ssp. *canescens*	1
Asteraceae	*Pseudognaphalium pringlei* (Gray) A. Anderb.	3
Asteraceae	*Psilostrophe tagetina* (Nutt.) Greene	1
Asteraceae	*Ratibida columnifera* (Nutt.) Woot. & Standl.	1

Appendix 1—*continued*

Family	Scientific name	Frequency
Asteraceae	*Roldana hartwegii* (Benth.) H. Rob. & Brettel	17
Asteraceae	*Senecio flaccidus* Less. var. *douglasii* (DC.) B.L. Turner & T.M. Barkley	1 1
Asteraceae	*Senecio parryi* A. Gray	12
Asteraceae	*Senecio scalaris* Greene	1
Asteraceae	*Senecio spartioides* Torr. & A. Gray var. *multicapitatus* (Greenm. ex Rydb.) S.L. Welsh	5
Asteraceae	*Senecio toluccanus* DC.	2
Asteraceae	*Solidago muelleri* Standl.	1
Asteraceae	*Solidago velutina* DC.	2
Asteraceae	*Stevia odontophylla* Gray	1
Asteraceae	*Stevia ovata* Willd.	1
Asteraceae	*Stevia salicifolia* Cav.	7
Asteraceae	*Stevia serrata* Cav.	2
Asteraceae	*Symphyotrichum ericoides* (L.) Nesom var. *ericoides*	1
Asteraceae	*Tetraneuris scaposa* (DC.) Greene	2
Asteraceae	*Thelesperma megapotamicum* (Spreng.) Kuntze	1
Asteraceae	*Thelesperma simplicifolium* Gray	2
Asteraceae	*Thymophylla acerosa* (DC.) Strother	28
Asteraceae	*Thymophylla pentachaeta* (DC.) Small	11
Asteraceae	*Thymophylla setifolia* Lag. var. *radiata* (A. Gray) Strother	7
Asteraceae	*Trixis californica* Kellogg	3
Asteraceae	*Verbesina rothrockii* Robins. & Greenm.	4
Asteraceae	*Viguiera cordifolia* Gray	10
Asteraceae	*Viguiera dentata* (Cav.) Spreng.	20
Asteraceae	*Viguiera dentata* (Cav.) Spreng. var *dentata*	2
Asteraceae	*Viguiera stenoloba* Blake	54
Asteraceae	*Wedelia texana* (Gray) B.L. Turner	1
Asteraceae	*Zinnia acerosa* (DC.) Gray	9
Asteraceae	*Zinnia grandiflora* Nutt.	3
Berberidaceae	*Mahonia trifoliata* (Moric.) Fedde	18
Betulaceae	*Alnus* P. Mill.	1
Bignoniaceae	*Tecoma stans* (L.) Juss. ex Kunth.	10
Boraginaceae	*Mertensia* Heller	1
Boraginaceae	*Tiquilia canescens* (DC.) A. Richards	10
Boraginaceae	*Tiquilia greggii* (Torr. & Gray) A. Richards	13
Boraginaceae	*Tiquilia hispidissima* (Torr. & Gray) A. Richards	8
Brassicaceae	*Lesquerella fendleri* (Gray) S. Wats.	6
Brassicaceae	*Lesquerella purpurea* (Gray) Wats.	1
Brassicaceae	*Lesquerella valida* Greene	1
Bromeliaceae	*Hechtia texensis* S. Wats.	24
Cactaceae	*Ariocarpus fissuratus* (Engelm.) K. Schum.	10
Cactaceae	*Coryphantha* (Engelm.) Lem.	15
Cactaceae	*Cylindropuntia imbricata* (Haw.) F.M. Knuth	3
Cactaceae	*Cylindropuntia kleiniae* (DC.) F.M. Knuth	9

Appendix 1—*continued*

Family	Scientific name	Frequency
Cactaceae	*Cylindropuntia leptocaulis* (DC.) F.M. Knuth	27
Cactaceae	*Echinocactus horizonthalonius* Lem.	5
Cactaceae	*Echinocactus texensis* Hopffer	1
Cactaceae	*Echinocereus dasyacanthus* Engelm.	12
Cactaceae	*Echinocereus enneacanthus* Englem.	1
Cactaceae	*Echinocereus stramineus* (Engelm.) F. Seitz	5
Cactaceae	*Echinocereus triglochidiatus* Engelm.	5
Cactaceae	*Echinocereus viridiflorus* Engelm. var. *chloranthus* (Engelm.) Backeb.	1
Cactaceae	*Epithelantha micromeris* (Engelm.) Weber ex. Britt & Rose	6
Cactaceae	*Escobaria tuberculosa* (Engelm.) Britt. & Rose	3
Cactaceae	*Escobaria vivipara* (Nutt.) Buxbaum var. *vivipara*	10
Cactaceae	*Ferocactus hamatacanthus* (Muehlenpford)Britt.& Rose	
Cactaceae	*Grusonia schottii* (Engelm.) H. Rob.	8
Cactaceae	*Lophophora williamsii* (Lem. ex Salm-Dyck) Coult.	1
Cactaceae	*Mammillaria heyderi* Muehlenpfordt	10
Cactaceae	*Opuntia engelmannii* Salm-Dyck	128
Cactaceae	*Opuntia macrocentra* Engelm.	13
Cactaceae	*Opuntia phaeacantha* Engelm.	9
Cactaceae	*Opuntia rufida* Engelm.	8
Cactaceae	*Opuntia* x *spinosibacca* Anthony	33
Cactaceae	*Sclerocactus* Britt. & Rose	1
Campanulaceae	*Campanula rotundifolia* L.	3
Campanulaceae	*Lobelia cardinalis* L.	1
Campanulaceae	*Lobelia gruina* Cav.	2
Campanulaceae	*Triodanis coloradensis* (Buckl.) McVaugh	2
Caprifoliaceae	*Lonicera albiflora* Torr. & Gray	2
Caprifoliaceae	*Symphoricarpos* Boehm.	1
Caryophyllaceae	*Drymaria glandulosa* K.Presl	1
Caryophyllaceae	*Paronychia jamesii* Torr. & Gray	4
Caryophyllaceae	*Stellaria cuspidata* Willd. ex Schlect.	1
Celastraceae	*Mortonia sempervirens* A. Gray	2
Chenopodiaceae	*Atriplex canescens* (Pursh) Nutt.	5
Chenopodiaceae	*Chenopodium album* L.	1
Chenopodiaceae	*Salsola tragus* L.	4
Commelinaceae	*Commelina dianthifolia* Delile	1
Commelinaceae	*Commelina erecta* L.	1
Commelinaceae	*Commelina erecta* L. var. *angustifolia* (Michx.) Fernald	1
Commelinaceae	*Tradescantia crassifolia* Cav.	1
Commelinaceae	*Tradescantia leiandra* Torrey	2
Commelinaceae	*Tradescantia pringlei* Wats.	1
Convolvulaceae	*Dichondra brachypoda* Woot. & Standl.	2
Convolvulaceae	*Evolvulus alsinoides* L.	1
Convolvulaceae	*Ipomoea collina* House	2

Appendix 1—*continued*

Family	Scientific name	Frequency
Cornaceae	*Cornus sericea* L. ssp. *sericea*	2
Crassulaceae	*Sedum* L.	1
Crossosomataceae	*Glossopetalon spinescens* Gray	1
Cupressaceae	*Cupressus arizonica* Greene	12
Cupressaceae	*Juniperus ashei* Buchh.	3
Cupressaceae	*Juniperus deppeana* Steud.	47
Cupressaceae	*Juniperus erythrocarpa* Cory	2
Cupressaceae	*Juniperus flaccida* Schlecht	23
Cupressaceae	*Juniperus monosperma* (Engelm.) Sarg.	5
Cyperaceae	*Carex* L.	4
Dennstaestiaceae	*Pteridium aquilinum* (L.) Kuhn.	2
Dryopteridaceae	*Cystopteris fragilis* (L.) Bernh.	1
Ebenaceae	*Diospyros texana* Scheele	1
Ephedraceae	*Ephedra aspera* Engelm. ex S. Wats.	12
Ephedraceae	*Ephedra torreyana* S. Wats.	1
Ephedraceae	*Ephedra trifurca* Torr. ex S. Wats.	5
Ericaceae	*Arbutus xalapensis* Kunth.	24
Ericaceae	*Arctostaphylos pungens* Kunth.	12
Euphorbiaceae	*Acalypha phleoides* Cav.	1
Euphorbiaceae	*Bernardia obovata* I.M. Johnston	4
Euphorbiaceae	*Chamaesyce cinerascens* Small	2
Euphorbiaceae	*Chamaesyce fendleri* (Torr. & Gray) Small	10
Euphorbiaceae	*Chamaesyce villifera* (Scheele) Small	1
Euphorbiaceae	*Croton dioicus* L.	1
Euphorbiaceae	*Croton fruticulosus* Engelm. ex Torr.	2
Euphorbiaceae	*Croton incanus* HBK	1
Euphorbiaceae	*Croton pottsii* (Koltzsch) Muell.-Arg.	1
Euphorbiaceae	*Croton suaveolens* Torr.	4
Euphorbiaceae	*Euphorbia antisyphilitica* Zucc.	51
Euphorbiaceae	*Jatropha dioica* Cerv.	29
Euphorbiaceae	*Tragia amblyodonta* (Muell.-Arg.) Pax & Hoffmann	1
Fabaceae	*Acacia angustissima* (P. Mill.) Kuntze	2
Fabaceae	*Acacia constricta* Benth.	45
Fabaceae	*Acacia farnesiana* (L.) Willd.	1
Fabaceae	*Acacia greggii* Gray	32
Fabaceae	*Acacia greggii* var. *wrightii* Benth.	4
Fabaceae	*Acacia neovernicosa* Isley	2
Fabaceae	*Acacia roemeriana* Scheele	2
Fabaceae	*Astragalus carminis* Barneby	2
Fabaceae	*Calliandra conferta* Benth.	9
Fabaceae	*Calliandra eriophylla* Benth.	1
Fabaceae	*Calliandra humilis* Benth.	2
Fabaceae	*Calliandra humilis* var. *humilis* Benth.	2
Fabaceae	*Canavalia villosa* Benth.	1

Appendix 1—*continued*

Family	Scientific name	Frequency
Fabaceae	*Centrosema* (DC.) Benth.	1
Fabaceae	*Cologania angustifolia* Kunth.	1
Fabaceae	*Cologania pallida* Rose	1
Fabaceae	*Dalea bicolor* Humb. & Bonpl. ex Willd. var. *argyraea* (A. Gray) Barneby	5
Fabaceae	*Dalea formosa* Torr.	8
Fabaceae	*Dalea frutescens* Gray	5
Fabaceae	*Dalea greggii* Gray	18
Fabaceae	*Dalea lanata* Spreng.	2
Fabaceae	*Dalea nana* Torr. ex A. Gray var. *carnescens* Kearney & Peebles	1
Fabaceae	*Desmanthus velutinis* Scheele	1
Fabaceae	*Desmodium lindheimeri* Vail.	2
Fabaceae	*Desmodium psilophyllum* Schlecht.	7
Fabaceae	*Eysenhardtia texana* Scheele.	11
Fabaceae	*Galactia canescens* Benth.	2
Fabaceae	*Hoffmannseggia* Cav.	4
Fabaceae	*Leucaena retusa* Benth.	28
Fabaceae	*Lotus oroboides* (HBK) Kearn. and Peeb.	5
Fabaceae	*Mimosa aculeaticarpa* Ortega var. *biuncifera* (Benth.) Barneby	86
Fabaceae	*Mimosa emoryana* Benth.	1
Fabaceae	*Oxytropis* spp Pursh	3
Fabaceae	*Phaseolus filiformis* Benth.	4
Fabaceae	*Prosopis glandulosa* Torr.	72
Fabaceae	*Rhynchosia senna* Gillies ex Hook. var. *texana* (Torr. & A. Gray) M.C. Johnst.	1
Fabaceae	*Senna lindheimeriana* (Scheele) Irwin & Barneby	1
Fabaceae	*Senna orcuttii* (Britt. & Rose) Irwin & Barneby	3
Fabaceae	*Sophora secundiflora* (Ort.) Lag. ex DC	3
Fabaceae	*Trifolium* L.	1
Fabaceae	*Vicia ludoviciana* Nutt.	1
Fagaceae	*Quercus arizonica* Sarg.	49
Fagaceae	*Quercus carmenensis* C.H. Muller	8
Fagaceae	*Quercus emoryi* Torr.	8
Fagaceae	*Quercus gambelii* Nutt.	4
Fagaceae	*Quercus gravesii* Sudw.	33
Fagaceae	*Quercus grisea* Liebm.	18
Fagaceae	*Quercus hypoleucoides* A. Camus	34
Fagaceae	*Quercus laceyi* Small	15
Fagaceae	*Quercus mohriana* Buckl.	23
Fagaceae	*Quercus muehlenbergii* Englem.	8
Fagaceae	*Quercus pungens* Liebm.	3
Fagaceae	*Quercus vaseyana* Buckley	8
Fagaceae	*Quercus rugosa* Nee	12
Fouquieriaceae	*Fouquieria splendens* Engelm.	33

Appendix 1—*continued*

Family	Scientific name	Frequency
Garryaceae	*Garrya ovata* Benth.	8
Garryaceae	*Garrya ovata* Benth. ssp. *lindheimeri* (Torr.) Dahling	2
Gentianaceae	*Halenia recurva* (Sm.) Allen	2
Geraniaceae	*Geranium caespitosum* James	4
Geraniaceae	*Geranium richardsonii* Fisch. & Trautv.	1
Grossulariaceae	*Ribes leptanthum* Gray	1
Hydrangeaceae	*Fendlera rupicola* Gray	3
Hydrangeaceae	*Philadelphus microphyllus* Gray	2
Hydrophyllaceae	*Nama hispidum* Gray	1
Hydrophyllaceae	*Phacelia congesta* Hook.	1
Iridaceae	*Sisynchrium dimorphum* R. Oliv.	1
Iridaceae	*Sisyrinchium convolutum* Nocca	1
Koeberliniaceae	*Koeberlinia spinosa* Zucc.	9
Krameriaceae	*Krameria grayi* Rose & Painter	12
Krameriaceae	*Krameria lanceolata* Torr.	1
Lamiaceae	*Hedeoma johnstonii* Irving	4
Lamiaceae	*Hedeoma nana* (Torr) Briq.	2
Lamiaceae	*Hedeoma plicata* Torr.	4
Lamiaceae	*Marrubium vulgare* L.	1
Lamiaceae	*Monarda citriodora* Cerv. ex Lag. ssp. *citriodora*	1
Lamiaceae	*Monarda fistulosa* L. ssp. *fistulosa* var. *menthifolia* (Graham) Fernald	1
Lamiaceae	*Monarda pectinata* Nutt.	4
Lamiaceae	*Monarda pringlei* Fern.	4
Lamiaceae	*Prunella vulgaris* L.	1
Lamiaceae	*Salvia farinacea* Benth.	6
Lamiaceae	*Salvia greggii* Gray	6
Lamiaceae	*Salvia pinguifolia* (Fern.) Woot. & Standl.	1
Lamiaceae	*Salvia regla* Cav.	32
Lamiaceae	*Scutellaria resinosa* Torr.	1
Lamiaceae	*Stachys coccinea* Jacq.	1
Liliaceae	*Allium drummondii* Regel	3
Liliaceae	*Maianthemum stellatum* (L.) Link	1
Linaceae	*Linum schiedeanum* Schlecht. & Cham.	1
Linaceae	*Linum vernale* Woot.	1
Loganiaceae	*Buddleja marrubiifolia* Benth	3
Loganiaceae	*Emorya suaveolens* Torr.	4
Malvaceae	*Abutilon malacum* S. Wats.	1
Malvaceae	*Herissantia crispa* (L.) Briz.	1
Malvaceae	*Hibiscus coulteri* Harvey ex. Gray	4
Malvaceae	*Pavonia lasiopetala* Scheele.	1
Malvaceae	*Sida abutifolia* P. Mill.	1
Malvaceae	*Sida elliottii* Torr. & Gray	1
Malvaceae	*Sphaeralcea angustifolia* (Cav.) G. Don	1

Appendix 1—*continued*

Family	Scientific name	Frequency
Monotropaceae	*Monotropa hypopithys* L.	2
Nyctaginaceae	*Boerhavia linearifolia* Gray	1
Nyctaginaceae	*Cyphomeris gypsophiloides* (Mart. & Gal.) Standl.	2
Oleaceae	*Forestiera angustifolia* Torr.	2
Oleaceae	*Fraxinus cuspidata* Torr.	2
Oleaceae	*Fraxinus greggii* Gray	22
Oleaceae	*Fraxinus velutina* Torr.	1
Oleaceae	*Menodora longiflora* Gray	2
Oleaceae	*Menodora scabra* Gray	22
Oleaceae	*Menodora scoparia* Engelm.	3
Onagraceae	*Gaura calcicola* Raven & Gregory	1
Orchidaceae	*Corallorrhiza striata* Lindl.	1
Oxalidaceae	*Oxalis alpina* (Rose) Rose ex R. Knuth	1
Oxalidaceae	*Oxalis corniculata* L.	1
Phytolaccaceae	*Rivinia humilis* L.	2
Pinaceae	*Abies durangensis* Martínez var. *coahuilensis* (I.M) Johnst.) Martínez	7
Pinaceae	*Pinus cembroides* Zucc.	47
Pinaceae	*Pinus remota* (Little) Bailey and Hawksworth	4
Pinaceae	*Pinus strobiformis* Engelm.	31
Pinaceae	*Pseudotsuga menziesii* (Mirbel) Franco	20
Poaceae	*Achnatherum eminens* (Cav.) Barkworth	3
Poaceae	*Achnatherum lobatum* (Swallen) Barkworth	1
Poaceae	*Agrostis scabra* Willd.	4
Poaceae	*Aristida adscensionis* L.	22
Poaceae	*Aristida arizonica* Vasey	1
Poaceae	*Aristida brownii* Warnock	1
Poaceae	*Aristida divaricata* Humb. & Bonpl. ex Willd.	9
Poaceae	*Aristida havardii* Vasey	2
Poaceae	*Aristida purpurea* Nutt.	78
Poaceae	*Aristida purpurea* Nutt. var. *nealleyi* (Vasey) Allred	2
Poaceae	*Aristida purpurea* Nutt. var. *purpurea*	1
Poaceae	*Aristida purpurea* Nutt. var. *wrightii* (Nash) Allred	1
Poaceae	*Aristida schiedeana* Trin. & Rupr. var. *orcuttiana* (Vasey) Allred & Valdés-Reyna	4
Poaceae	*Aristida ternipes* Cav.	2
Poaceae	*Blepharoneuron tricholepis* (Torr.) Nash	4
Poaceae	*Bothriochloa barbinodis* (Lag.) Herter	36
Poaceae	*Bothriochloa laguroides* (DC.) Herter	9
Poaceae	*Bothriochloa laguroides* (D.C.) Herter ssp. *torreyana* (Steud.) Allred & Gould	1
Poaceae	*Bouteloua barbata* Lag.	3
Poaceae	*Bouteloua curtipendula* (Michx.) Torr.	162
Poaceae	*Bouteloua eriopoda* (Torr.) Torr.	28
Poaceae	*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths	92

Appendix 1—*continued*

Family	Scientific name	Frequency
Poaceae	*Bouteloua hirsuta* Lag.	50
Poaceae	*Bouteloua ramosa* Scribn. ex Vasey	79
Poaceae	*Bouteloua trifida* Thurb.	4
Poaceae	*Bromus anomalus* Ruprecht ex Fournier	3
Poaceae	*Bromus ciliatus* L.	5
Poaceae	*Bromus lanatipes* (Shear) Rydb.	17
Poaceae	*Bromus polyanthus* Scribn.	9
Poaceae	*Chloris virgata* Sw.	2
Poaceae	*Danthonia spicata* (L.) Beauv.	7
Poaceae	*Dasyochloa pulchella* (Kunth) Willd. ex Rydb.	25
Poaceae	*Digitaria californica* (Benth.) Henr.	10
Poaceae	*Digitaria cognata* (Schultes) Pilger	5
Poaceae	*Elymus arizonicus* (Schrib. & Sm.) Gould	2
Poaceae	*Elymus elymoides* (Raf.) Swezey	1
Poaceae	*Elymus trachycaulus* (Link.) Gould ex Shinners	1
Poaceae	*Eragrostis barrelieri* Daveau	1
Poaceae	*Eragrostis intermedia* Hitchc.	57
Poaceae	*Erioneuron avenaceum* (H.B.K.) Tateoka	1
Poaceae	*Erioneuron nealleyi* Vasey	1
Poaceae	*Erioneuron pilosum* (Buckl.) Nash	4
Poaceae	*Festuca arizonica* Vasey	10
Poaceae	*Glyceria striata* (Lam.) A.S. Hitchc.	1
Poaceae	*Hesperostipa neomexicana* (Thurb. ex Coult.) Barkworth	1
Poaceae	*Heteropogon contortus* (L.) Beauv. ex Roemer & Schultes	42
Poaceae	*Koeleria macrantha* (Ledeb.) Schultes	15
Poaceae	*Leptochloa dubia* (Kunth) Nees	34
Poaceae	*Lycurus phleoides* Kunth	22
Poaceae	*Lycurus setosu*s (Nutt.) C.G. Reeder	26
Poaceae	*Melica porteri* Scribn.	1
Poaceae	*Muhlenbergia arenacea* (Buckl.) A.S. Hitchc.	1
Poaceae	*Muhlenbergia arenicola* Buckl.	2
Poaceae	*Muhlenbergia dubia* Fourn. ex Hemsl.	2
Poaceae	*Muhlenbergia emersleyi* Vasey	73
Poaceae	*Muhlenbergia glauca* (Nees) Jackson	17
Poaceae	*Muhlenbergia montana* (Nutt.) Hitchc.	13
Poaceae	*Muhlenbergia parviglumis* Vasey	13
Poaceae	*Muhlenbergia pauciflora* Buckl.	2
Poaceae	*Muhlenbergia porteri* Scribn. ex Beal	3
Poaceae	*Muhlenbergia richardsonis* (Trin.) Rydb.	2
Poaceae	*Muhlenbergia rigens* (Benth.) A.S. Hitchc.	2
Poaceae	*Muhlenbergia rigida* (H.B.K.)Kunth.	8
Poaceae	*Muhlenbergia setifolia* Vasey	16
Poaceae	*Muhlenbergia tenuifolia* (Kunth) Trin.	5
Poaceae	*Nassella tenuissima* (Trin.) Barkworth	19

Appendix 1—*continued*

Family	Scientific name	Frequency
Poaceae	*Panicum bulbosum* Kunth	39
Poaceae	*Panicum hallii* Vasey	50
Poaceae	*Piptochaetium fimbriatum* (H.B.K.) Hitchc.	22
Poaceae	*Piptochaetium pringlei* (Scribn.) Parodi	41
Poaceae	*Pleuraphis mutica* Buckl.	14
Poaceae	*Schizachyrium sanguineum* (Retz.) Alston var. *hirtiflorum* (Nees) Hatch	3
Poaceae	*Schizachyrium scoparium* (Michx.) Nash	67
Poaceae	*Scleropogon brevifolius* Phil.	4
Poaceae	*Setaria leucopila* (Scrib. & Merr.) K. Schum.	32
Poaceae	*Sorghastrum nutans* (L.) Nash	2
Poaceae	*Sorghum halepense* (L.)Pers.	1
Poaceae	*Sphenopholis obtusata* (Michx.) Scribn.	1
Poaceae	*Sporobolus contractus* Hitchc.	2
Poaceae	*Sporobolus cryptandrus* (Torr.) Gray	2
Poaceae	*Tridens muticus* (Torr.) Nash	44
Poaceae	*Tripsacum dactyloides* (L.) L.	1
Polemoniaceae	*Gilia rigidula* Benth.	2
Polemoniaceae	*Loeselia greggii* S. Wats.	2
Polemoniaceae	*Polemonium foliosissimum* Gray	1
Polygalaceae	*Polygala alba* Nutt.	3
Polygalaceae	*Polygala barbeyana* Chod.	1
Polygonaceae	*Eriogonum hemipterum* (T.&G.)Stokes	2
Polygonaceae	*Eriogonum jamesii* Benth.	2
Polygonaceae	*Eriogonum wrightii* Torr. ex Benth.	16
Polygonaceae	*Polygonum lapathifolium* L.	1
Polypodiaceae	*Pleopeltis guttatum* (Maxon) E.G. Andr. & Windham	2
Polypodiaceae	*Pleopeltis polylepis* (Roem. ex Kunze) T. Moore var. *erythrolepis* (Weath.) T. Wendt	2
Polypodiaceae	*Pleopeltis riograndensis* (T. Wendt) Andrews and Windham	4
Portulacaceae	*Portulaca pilosa* L.	1
Pteridaceae	*Argyrochosma microphylla* (Mett. ex Kuhn) Windham	2
Pteridaceae	*Astrolepis cochisensis* (Goodding) Benham & Windham	6
Pteridaceae	*Bommeria hispida* (Mett. ex Kuhn) Underwood	7
Pteridaceae	*Cheilanthes eatonii* Baker	6
Pteridaceae	*Notholaena aschenborniana* Klotzch	17
Pteridaceae	*Notholaena standleyi* Maxon	2
Pteridaceae	*Pellaea ovata* (Desv.) Weatherby	2
Pteridaceae	*Pellaea ternifolia* (Cav.) Link.	1
Pyrolaceae	*Chimaphila menziesii* (R. Br. ex D.Don) Spreng.	13
Pyrolaceae	*Chimaphila umbellata* ssp. *acuta* (Rydb.) Hulten	1
Ranunculaceae	*Aquilegia chrysantha* Gray	1
Ranunculaceae	*Clematis drummondii* Torr. & Gray	1
Ranunculaceae	*Ranunculus peruvianus* Pers.	6

Appendix 1—*continued*

Family	Scientific name	Frequency
Ranunculaceae	*Ranunculus petiolaris* DC.	1
Ranunculaceae	*Thalictrum fendleri* Engelm. ex Gray	1
Rhamnaceae	*Adolphia infesta* (H.B.K.) Meisn.	1
Rhamnaceae	*Ceanothus fendleri* Gray	8
Rhamnaceae	*Ceanothus greggii* Gray	7
Rhamnaceae	*Condalia ericoides* (Gray) M.C. Johnston	4
Rhamnaceae	*Condalia viridis* I.M.Johnst.	1
Rhamnaceae	*Condalia warnockii* M.C. Johnston	13
Rhamnaceae	*Frangula betulifolia* (Greene) V. Grub. ssp. *betulifolia*	2
Rhamnaceae	*Ziziphus obtusifolia* (Hook ex Torr. & Gray) Gray	12
Rosaceae	*Cercocarpus fothergilloides* Kunth var. *mojadensis* (Schneid.) Henrickson	1
Rosaceae	*Cercocarpus montanus* Raf.	37
Rosaceae	*Cercocarpus montanus* Raf. var. *glaber* (S. Watson) F.L. Martin	1
Rosaceae	*Cercocarpus montanus* Raf. var. *paucidentatus* (S. Watson) F.L. Martin	2
Rosaceae	*Crataegus tracyi* Ashe ex Egglest.	1
Rosaceae	*Holodiscus discolor* (Pursh) Maxim.	5
Rosaceae	*Holodiscus dumosus* (Nutt. ex Hook.) Heller	2
Rosaceae	*Physocarpus monogynus* (Torr.) Coult.	2
Rosaceae	*Potentilla thurberi* var. *atrorubens*	1
Rosaceae	*Prunus serotina* Ehrh.	3
Rosaceae	*Prunus virginiana* L.	1
Rosaceae	*Purshia ericifolia* (Torr. ex Gray) Henrickson	6
Rosaceae	*Rosa woodsii* Lindl.	2
Rosaceae	*Rosa woodsii* Lindl. var. *maderensis* Henrickson	1
Rosaceae	*Rubus idaeus* L.	2
Rosaceae	*Rubus idaeus* L. ssp. *strigosus* (Michx.) Maxim.	1
Rosaceae	*Vauquelinia corymbosa* Humb. & Bonpl. ssp. *angustifolia* (Rydb.) Hess & Henrickson	6
Rubiaceae	*Bouvardia ternifolia* (Cav.) Schlecht.	6
Rubiaceae	*Galium microphyllum* (Gray) Hemsl.	1
Rubiaceae	*Hedyotis intricata* Fosberg	1
Rubiaceae	*Houstonia acerosa* (Gray) Gray ex Benth. & Hook.	1
Rubiaceae	*Stenaria nigricans* (Lam.) Terrell var. *nigricans*	1
Salicaceae	*Populus tremuloides* Michx.	1
Salicaceae	*Salix lucida* Muhl. ssp. *lasiandra* (Benth.) E. Murray	1
Salicaceae	*Salix riskindii* M.C. Johnst.	1
Sapindaceae	*Sapindus saponaria* L.	1
Saxifragaceae	*Fendlera rigida* I.M.Johnst.	1
Saxifragaceae	*Heuchera* L.	1
Scrophulariaceae	*Castilleja lanata* Gray	2
Scrophulariaceae	*Castilleja scorzonerifolia* HBK.	4
Scrophulariaceae	*Castilleja sessiliflora* Pursh	1

Appendix 1—*continued*

Family	Scientific name	Frequency
Scrophulariaceae	*Leucophyllum frutescens* (Berl.) I.M. Johnston	4
Scrophulariaceae	*Leucophyllum minus* Gray.	6
Scrophulariaceae	*Maurandella antirrhiniflora* (Humb. & Bonpl. ex Willd.) Rothm.	2
Scrophulariaceae	*Penstemon baccharifolius* Hook.	4
Scrophulariaceae	*Penstemon henricksonii* Straw	1
Selaginellaceae	*Selaginella lepidophylla* (Hook. & Grev.) Spring	21
Solanaceae	*Lycium berlandieri* Dunal	2
Solanaceae	*Solanum elaeagnifolium* Cav.	2
Tiliaceae	*Tilia mexicana* Schlecht.	2
Ulmaceae	*Celtis laevigata* var. *reticulata* (Torr.) L. Benson	3
Ulmaceae	*Celtis pallida* Torr.	9
Verbenaceae	*Aloysia gratissima* (Gill. and Hook.) Troncoso	42
Verbenaceae	*Aloysia wrightii* Heller ex Abrams	4
Verbenaceae	*Bouchea spathulata* Torr.	7
Verbenaceae	*Glandularia bipinnatifida* (Nutt.) Nutt.	1
Verbenaceae	*Glandularia bipinnatifida* var. *bipinnatifida* (Nutt.) Nutt.	1
Verbenaceae	*Lantana achyranthifolia* Desf.	14
Verbenaceae	*Verbena bracteata* Lag. & Rodr.	2
Verbenaceae	*Verbena halei* Small.	1
Verbenaceae	*Verbena neomexicana* (Gray) Small	3
Verbenaceae	*Verbena neomexicana* var. *neomexicana* (Gray) Small	3
Vitaceae	*Cissus incisa* Des Moulins	1
Vitaceae	*Parthenocissus vitacea* (Knerr) Hitchc.	1
Vitaceae	*Vitis arizonica* Engelm.	2
Vitaceae	*Vitis cinerea* var. *helleri* (Bailey) M.O.Moore	1
Zygophyllaceae	*Guajacum angustifolium* Engelm.	18
Zygophyllaceae	*Kallstroemia* Scop.	1
Zygophyllaceae	*Larrea tridentata* (Sesse & Moc. ex DC.) Coville	69