

Some floristic characteristics of the northern Chihuahuan Desert: a search for its northern boundary

Esteban H. Muldavin

Biology Department, University of New Mexico, Albuquerque, New Mexico, 18731, U.S.A. E-mail: muldavin@sevilleta.unm.edu

An index of Chihuahuan floristic affinity was constructed to characterize the floristic variation over a 5° latitudinal gradient in the northern Chihuahuan Desert, with an emphasis on evaluating northern boundary conditions. The index was based on evaluating the ranges of 494 species from 590 vegetation plots from *Bouteloua eriopoda* and *B. gracilis* grasslands and *Larrea tridentata* scrub, distributed among four sites along the gradient. The most northern site, the Sevilleta National Wildlife Refuge (34°N latitude), while maintaining a complement of primarily southern distributed species, had the lowest index values and the fewest Chihuahuan endemics (3%) and Southwestern desert species (19%) in general. At the intermediate sites (Jornada/Tularosa basins and Otero Mesa), one and two degrees further south, index values increased conspicuously along with number of Chihuahuan endemics (7%) and the Southwestern desert species (37%). At 29°N latitude, the Sierra del Carmen Protected Area in northern Mexico was the furthest southern site. It represented typical hot and dry Chihuahuan Desert conditions where Chihuahuan endemics comprised 29% of species complement and Southwestern desert species made up 55%. With respect to floristic boundaries, the Sevilleta was clearly transitional to the southern Shortgrass Prairie and Intermountain (Great Basin-Colorado Plateau) provinces. While it supported several grassland and shrubland associations that maintained their overall Chihuahuan character, there were also several associations with primarily northern affinities, and also a set unique to the Sevilleta, reflecting its ecotonal nature. The results show that sound biosystematics, biogeographical analyses and indices like those presented here can provide an important context for questions in synecology, plant ecology, and conservation biology.

KEYWORDS: biome boundaries, *Bouteloua eriopoda*, *Bouteloua gracilis*, Chihuahuan Desert, floristic biogeography, *Larrea tridentata*.

INTRODUCTION

The current northern limit of diploid populations of *Larrea tridentata* (Sessé & Moc. ex DC.) Coville is just five km south of Albuquerque, in north-central New Mexico, U.S.A. Given that *Larrea* is one of the defining elements of Chihuahuan Desert scrub vegetation, the populations near Albuquerque also represent to many the northern boundary of the desert itself (Fig. 1a). But does the simple presence of a key indicator species really reflect the presence of an entire floristic province or biome? Similarly, *Bouteloua eriopoda* (Torr.) Torr. is also considered to be a Chihuahuan Desert grassland indicator, but it extends even further north into southern Utah and southern Colorado. Where are the actual northern limits of the Chihuahuan Desert as a floristic entity, and by extension, an ecosystem? In contrast, *Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths is a characteristic species of the shortgrass and mixedgrass prairies of the Great Plains that extend from northeastern New

Mexico and west Texas northward to Canada. Yet, *B. gracilis* is also found throughout the Southwest and into Mexico (Fig. 1b). Granted, as one moves southward, the *B. gracilis*-dominated grasslands become smaller and less functional as Prairie ecosystems, but when do they also no longer represent that ecosystem in terms of its floristic elements? Following McLaughlin (1994), the problem then becomes, how do floristic entities segregate themselves in ecological space, and how does this floristic structure inform our ecological understanding beyond the analysis of dominants or any particular species of interest?

To address these questions, I present a relatively simple floristic index based on species distributions and presence-absence that can be used to characterize grasslands and scrub communities in terms of their Chihuahuan Desert affinity. This index makes use of established synecological and phytogeographic classifications that were developed in a multivariate framework of plot databases and floras, respectively. The vegetation

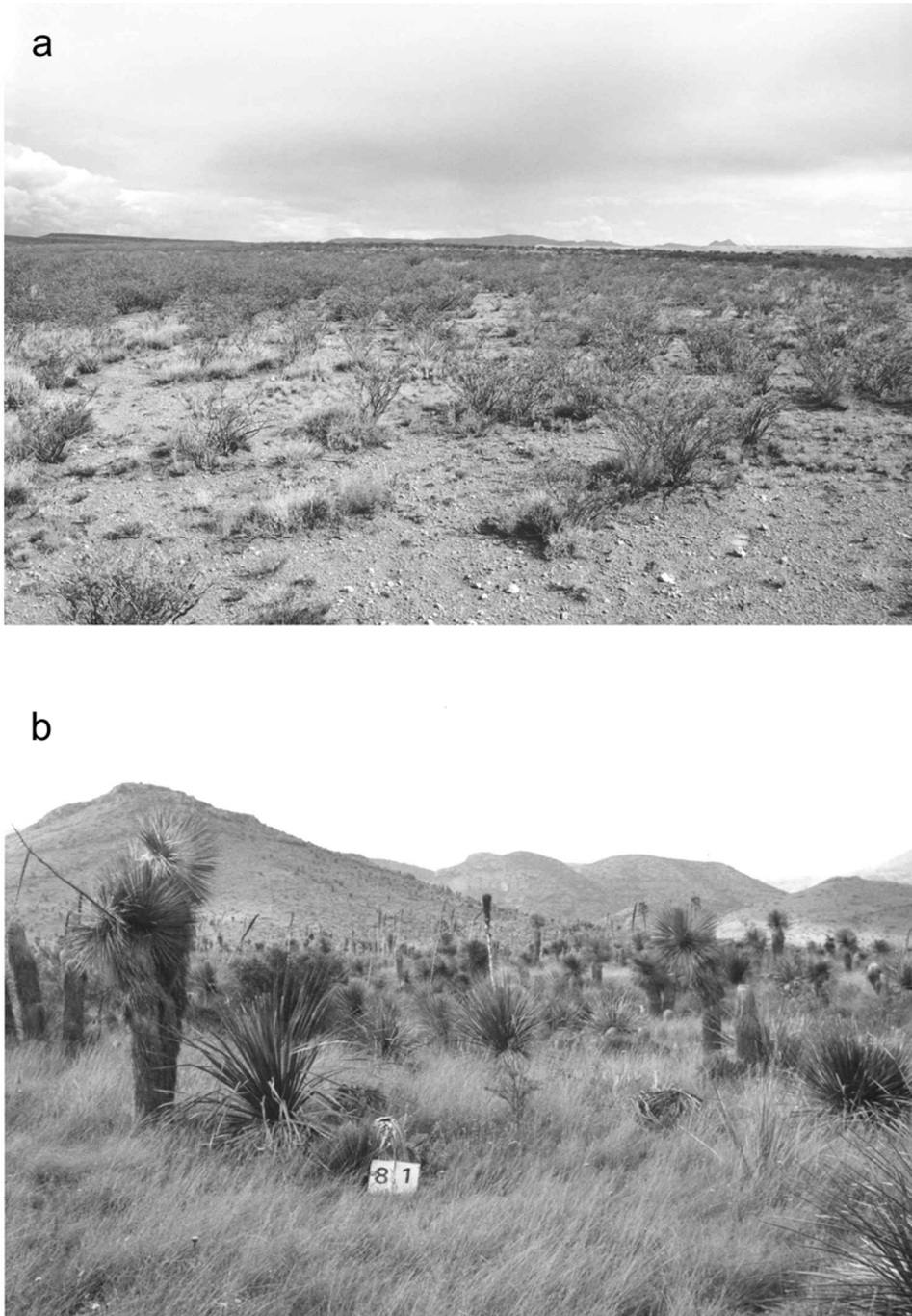


Fig. 1. Examples of northern Chihuahuan Desert communities at the edges of their range. a, *Larrea tridentata*/*Dasyochloa pulchella* scrub near its northern limit on the Sevilleta National Wildlife Refuge in central New Mexico; b, *Bouteloua gracilis*/*Yucca thompsoniana* grasslands approaching their southern limit in the Sierra del Carmen Protected Area in northern Mexico.

classifications allow the stratification of a problem in an ecological context, whereas the floristic classifications provide a consistent framework categorizing species distributional characteristics. But the entire enterprise is

predicated on sound biosystematics for the region, without which biogeography and synecological analysis become problematic at best.

I use the index, along with distributional information

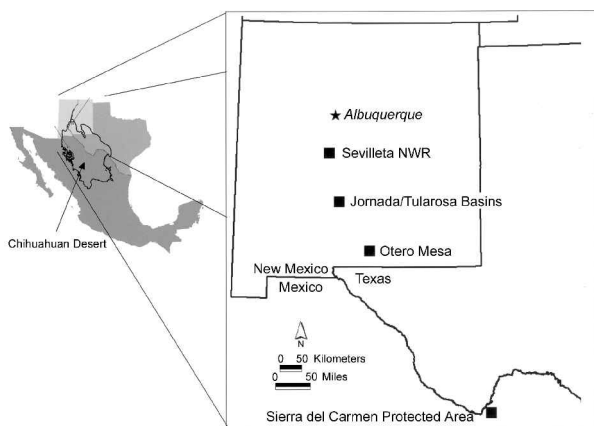


Fig. 2. Study sites were distributed along a five-degree latitude axis in northern Chihuahuan Desert.

on individual species and plant associations, to examine floristic structures along a latitudinal gradient from north-central New Mexico to the Sierra del Carmen in northeastern Mexico. Although a wide variety of grassland and desert vegetation types occurs across this latitudinal gradient (some 500 plant associations among 50 alliances), the emphasis here is on *Larrea*, *B. eriopoda* and *B. gracilis*-dominated vegetation communities as indicators of floristic and ecological boundaries. In addition, these communities are the focus of intensive research on desertification processes (Schlesinger & al., 1990), ecological interactions from the plant to biome level (Gosz & Sharpe, 1989; Gosz, 1991; Peters, 2000) and biodiversity conservation (Muldavin & al., 2000). Hence, there is an opportunity here to bring the knowledge base of biosystematics together with biogeography to better inform current ecological and conservation biology issues in the region.

MATERIALS AND METHODS

Study area. — There were several plot datasets available that had potential for analyzing floristic patterns. I chose four that were distributed across five degrees of latitude along the eastern side of the Northern Chihuahuan Desert, and that were from reserves with limited human impacts (Fig. 2). The Sierra del Carmen Protected Area is the furthest southern site at 29°N latitude and is located in northern Mexico across the Rio Grande from Big Bend National Park, Texas. The Sierra del Carmen Protected Area encompasses some of the lowest elevation sites of the Chihuahuan Plateau (580–800 m) and provides the context for what consti-

tutes definitive desert conditions. The Jornada and Tularosa basins (33° 20' N lat) and Otero Mesa (32° 20' N lat) represent intermediate sites that occur in south-central New Mexico and extend into Texas. The elevations in the Jornada/Tularosa basins and Otero Mesa range from 1,300 m to 1,600 m. These intermediate sites also provide a test of the boundary between the Chihuahuan and Mogollon Floristic Districts as defined by McLaughlin (1992). The furthest northern site is the Sevilleta National Wildlife Refuge (NWR) at 34°20'N lat and 75 km south of Albuquerque. The Sevilleta National Wildlife Refuge offers a special opportunity to analyze northern Chihuahuan Desert boundary conditions because both *Larrea* and *B. eriopoda* approach their northern limit there, while extensive *B. gracilis* stands diminish significantly southward from the refuge. Furthermore, several ecological and floristic maps show the Sevilleta at or near a northern boundary for Chihuahuan Desert or Madrean entities (Brown & Lowe, 1980; McLaughlin, 1992; Dick-Peddie, 1993; Bailey & al., 1994; Reichenbacher & al., 1998).

All of the sites have precipitation regimes that are dominated by summer rainfall (70–80% of the mean annual precipitation). Annual precipitation is similar across the sites, with an average of 245 mm on the Sevilleta, 265 mm in the Jornada/Tularosa basins, 255 mm on Otero Mesa, and 250 mm in the Sierra del Carmen. Mean annual temperatures gradually increase going south: 13.5°C at the Sevilleta; 14.5°C for the Jornada/Tularosa basins; 16.3°C on Otero Mesa, and 20°C in the Sierra del Carmen Protected Area. Winters are relatively mild, even at the Sevilleta (2°C mean winter temperature), but summers can be extremely hot (31°C is the mean high at the Sevilleta and in the Sierra del Carmen).

Floristic analysis. — To analyze differences among sites and vegetation communities, a weighted presence-absence floristic index was constructed based on the regional distribution of individual species found among a subset of vegetation plots from the four datasets. First, all selected species in the dataset were evaluated and classified into floristic groups based on their geographic ranges, and then weighting values applied to each floristic group with respect to their Chihuahuan affinity. For every plot in the dataset, the average weight among species present was computed and used as an index, along with other distributional data, to compare sites and vegetation associations.

The four datasets used were originally developed as part of vegetation classification and mapping projects conducted over the past decade by the New Mexico Natural Heritage Program (NMNHP) for various agencies (final reports are available from the author). The data, consisting of over 6,000 vegetation plots, or

Table 1. General floristic structure among the four sample sites (ordered from north to south). See Methods for descriptions of distributional classes. I = floristic index weights; n = number of vegetation plots at the site; % = percentage of species in that distribution class; and N Sp = number of species in that distribution class. Subtotals are provided for all northern, southern and miscellaneous species.

Distribution	Site I	Sevilleta NWR (n = 113)		Jornada/Tularosa (n = 281)		Otero Mesa (n = 153)		Sierra del Carmen (n = 43)		All sites (n = 590)	
		%	N Sp	%	N Sp	%	N Sp	%	N Sp	%	N Sp
Southern species											
Chihuahuan (E)	2	2.7	6	7.1	23	8.3	15	29.0	36	13.0	64
Apachian (W)	2	0.5	1	0.6	2	0.0		0.0		0.8	4
Madrean (Apachian & Chihuahuan)	2	9.6	21	19.8	64	17.7	32	15.3	19	17.8	88
SW deserts (Madrean and Sonoran)	2	5.5	12	9.9	32	11.0	20	8.9	11	8.3	41
SW deserts & Shortgrass Prairie	1	8.7	19	9.9	32	11.0	20	8.1	10	8.9	44
SW deserts & Colo. Plateau	1	11.4	25	8.6	28	9.4	17	7.3	9	8.3	41
SW deserts, Colo. Plat. & Shortgrass Prairie	1	26.0	57	18.8	61	24.3	44	19.4	24	16.4	81
All southern species		64.4	141	74.7	242	81.8	148	87.9	109	73.5	363
Northern species											
Shortgrass & Mixedgrass Prairie	-2	0.9	2	0.6	2	0.6	1	0.0		0.8	4
Intermountain	-2	3.2	7	0.9	3	0.0		0.0		1.6	8
Prairie and Intermountain	-2	3.7	8	3.1	10	0.6	1	0.8	1	3.0	15
Prairie & Madrean	-1	0.5	1	0.6	2	0.0		0.0		0.6	3
Intermountain & SW deserts	-1	2.3	5	1.5	5	0.6	1	0.0		1.6	8
IntMtn. & Prairie & SW Deserts	-1	6.8	15	4.9	16	4.4	8	2.4	3	4.3	21
All northern species		17.4	38	11.7	38	6.1	11	3.2	4	11.9	59
Miscellaneous species											
Widespread, local endemics and introduced	0	18.3	40	13.6	44	12.2	22	8.9	11	14.6	72
Totals		100.0	219	100.0	324	100.0	181	100.0	124	100.0	494

“relevés”, were entered into the NMNHP database with full floristic and vegetation classification attributes. Each plot has been classified into a vegetation type according

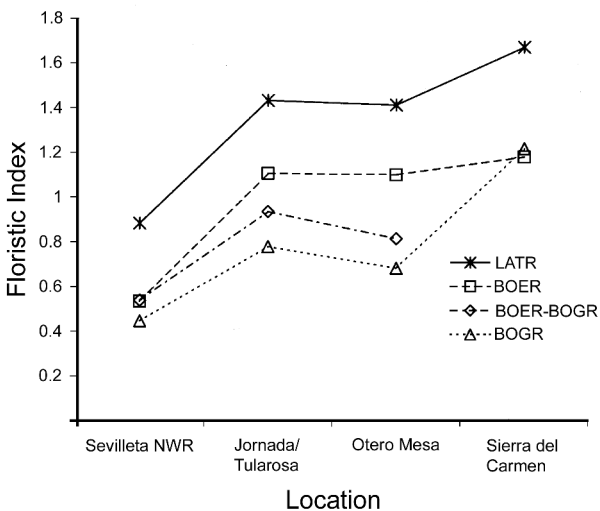


Fig. 3. Plot of the floristic index of Chihuahuan Desert affinity versus site, stratified by alliance. The Sevilleta NWR is at the northern end of the latitudinal gradient; the Sierra del Carmen at the southern end. LATR = *Larrea tridentata*; BOER = *B. eriopoda*; BOGR = *B. gracilis*.

to the National Vegetation classification system (Anderson & al., 1998; Grossman & al., 1998) whose fundamental units are the alliance and plant association. For our purposes here, alliances are essentially dominance types, and plant associations are the subunits of alliances representing repeated assemblages across landscapes.

From the database, 590 plots were selected that were dominated by either *Larrea*, *B. eriopoda*, or *B. gracilis*. Each plot was 400 sq. meters in size and had a complete species list from within the plot and from the surrounding stand, along with cover data. The data were all collected by competent botanical technicians and the identifications supported by voucher specimens that have been deposited in the University of New Mexico Herbarium. The 590 plots yielded 494 species, subspecies, and varieties for analysis. Generic level and above identifications were not considered since their distributions are often ambiguous at the regional level.

To evaluate species geographic ranges, I used state and regional floras (Kearny & Peebles 1964; Correll & Johnston, 1979; Martin & Hutchins, 1980; Webber, 1987; Welsh & al., 1987; Weber, 1990; Allred, 1993; Powell, 1994; Henrickson & Johnston, 1997; Powell, 1998), along with various online databases (PLANTS,

CalFLORA, Digital Atlas of the Vascular Plants of Utah). For the purposes here, disjunct and/or adventive populations were ignored. Based on the ranges from these sources, the distribution of each species (including subspecies and varieties) was classified following the floristic classification of McLaughlin (1992) for the western U.S.A., which in turn was a refined delineation of Cronquist (1982). For floristic elements east of the Rocky Mountains, I followed Cronquist (1982) in broad outline, but for finer subdivisions of his North American Prairie Province, I referred to Sims (1988), e.g., Shortgrass, Mixedgrass and Tallgrass Prairies.

Any given species might fall into one or more of the elements defined by McLaughlin (1992) or Cronquist (1982), depending on how widespread it was. To incorporate this variability, species were further grouped according to the generalness of their distribution and their central tendency (Table 1). There were seven classes for species with predominantly southerly distributions and six classes for northern species. The southern group corresponds approximately to the Madrean Region of McLaughlin (1992), and northern group to the Cordilleran Region of McLaughlin (1992) plus the North American Prairies Province (also referred to as the Great Plains) of Cronquist (1982).

Among southern species, the two most restricted groups were Chihuahuan and Apachian. The Chihuahuan group was made up of regional endemics with predominantly central or eastern distributions on the Chihuahuan Plateau, extending northward into southern New Mexico and the Trans-Pecos of Texas. Similarly, the Apachian

group represents those species restricted to the northwestern Chihuahuan Plateau and up into southwestern New Mexico, and southeastern and central Arizona. These correspond approximately to the Chihuahuan and Apachian subprovinces of McLaughlin (1992). The next level up is “Madrean”, species found in both the Chihuahuan and Apachian subprovinces. Then there are four classes of species that would generally be considered Southwestern, but with differing degrees of range restriction. There are strictly Southwestern desert species found only in the Chihuahuan, Sonoran, and Mojave deserts (the Madrean and Sonoran Provinces of McLaughlin, 1992). Then there are Southwestern species that extend either into the southern Shortgrass Prairie, the Colorado Plateau, or both.

Among northern species a similar pattern was followed: two restricted groups of North American Prairie (Great Plains) or Intermountain endemics, and a third group that fell in both provinces (and likely the intervening Cordilleran Province). There were species that had a limited extension from the Prairies in the Madrean Province (Chihuahuan and Apachian), and Intermountain species that extended southward into the Chihuahuan, Sonoran and Mojave deserts (Southwestern extension). Lastly, there were species found in the Intermountain, Prairies, and Southwestern deserts, but still with predominantly northern distributions. Species that were more broadly distributed than any of these classes were lumped under “widespread”. Species with local distributions that were ambiguous with respect to floristic classification were labeled as “local endemics”, and intro-

Table 2. *Bouteloua eriopoda* plant associations in the Sevilleta National Wildlife Refuge, New Mexico, with their Index of Chihuahuan Desert affinity mean values and standard deviations (s.d.), and regional distributions. N = other sites north of the Sevilleta NWR; SEV = Sevilleta NWR; J/T = Jornada/Tularosa basins; OM = Otero Mesa; SDC = Sierra del Carmen Protected Area; S = other southern (Chihuahuan) sites; n = number of plots.

Plant association	n	Index	s.d.	Distribution					
				N	SEV	J/T	OM	SDC	S
<i>Bouteloua eriopoda</i> / <i>Muhlenbergia torreyi</i>	1	0.44			X				
<i>Bouteloua eriopoda</i> / <i>Bouteloua gracilis</i>	20	0.44	0.23	X	X	X	X		X
<i>Bouteloua eriopoda</i> / <i>Bouteloua curtipendula</i>	2	0.44	0.12		X	X	X		
<i>Bouteloua eriopoda</i> / <i>Yucca glauca</i>	9	0.47	0.34		X				
<i>Bouteloua eriopoda</i> / <i>Ephedra torreyana</i>	12	0.47	0.26		X	X	X		
<i>Bouteloua eriopoda</i> / <i>Pleuraphis jamesii</i>	8	0.49	0.21		X				
<i>Stipa neomexicana</i> / <i>Bouteloua eriopoda</i>	1	0.50			X	X	X		
<i>Bouteloua eriopoda</i> / <i>Oryzopsis hymenoides</i>	1	0.63			X				
<i>Bouteloua eriopoda</i> / <i>Dalea formosa</i>	4	0.63	0.11		X				
<i>Bouteloua eriopoda</i> / <i>Parthenium incanum</i>	2	0.66	0.26			X	X	X	
<i>Bouteloua eriopoda</i> / <i>Sporobolus flexuosus</i>	2	0.70	0.14			X			X
<i>Bouteloua eriopoda</i> / <i>Tridens muticus</i>	1	0.75							X
<i>Bouteloua eriopoda</i> / <i>Scleropogon brevifolius</i>	1	0.75							X
<i>Bouteloua eriopoda</i> / <i>Tiquilia canescens</i>	3	1.08	0.08						

duced or alien species were also separated (a species list with range attributes is available upon request from the author).

For the purposes of building a floristic index, each of these classes was assigned weight in terms of “northernness” or “southernness” (Table 1). The weighting was kept relatively simple with the Southwestern desert species as a group getting a value of 2, while those that extended northward into the southern Shortgrass Prairie and the southern Colorado Plateau received weight of 1. In contrast, restricted northern species received a weight of -2, and those that extended southwards a -1. Since widespread, local endemics, and introduced species lend little information on regional (natural) distributions, they were excluded from the index. The index was computed by summing the weights of all valid species in a plot and then dividing by the number of species. This would yield a value of 2.0 for plots completely composed of species restricted to Southwestern deserts. Similarly, if a plot was composed of all northern restricted species, the value would be -2.0. Index values were computed for each plot in the sample set, and mean values then derived for individual plant associations among the *B. eriopoda*, *B. gracilis*, and *Larrea tridentata* alliances.

RESULTS

General latitudinal trends. — All sites were dominated by a strong southern species component, but among sites there was a definite trend of increasing Chihuahuan character moving from the Sevilleta in the north to the Sierra del Carmen in the south (Table 1). With respect to the Sevilleta, while nearly 65% of the species among *Larrea*-, *B. eriopoda*-, and *B. gracilis*-dominated communities had southerly distributions, only

18% would be considered Chihuahuan, Apachian, Madrean, or Southwestern desert species (ranks of 2), and among those only about 3% would be considered Chihuahuan endemics. Moving south to the intermediate sites of the Jornada/Tularosa basins and Otero Mesa (from 75 to 250 km south of the Sevilleta), the desert species component increased quickly from 18% to 37%. These sites picked up species such as *Acacia constricta* Benth., *A. neovernicosa* Isely, *Flourensia cernua* DC., *Fouquieria splendens* Engelm., *Viguiera stenoloba* Blake, *Nolina microcarpa* S. Wats., *Dasyllirion wheeleri* S. Wats., *Yucca torreyi* Shafer, and *Yucca elata* (Engelm.) Engelm. that are not part of the Sevilleta *Larrea* scrub and *Bouteloua* grasslands. Between the Jornada/Tularosa and Otero Mesa there were no significant differences evident. The Otero Mesa plots do not include *Agave lechuguilla* Torr., a classical indicator of Chihuahuan Desert grasslands and scrub, but it is known to occur approximately 30 km further south.

Moving south an additional 450 km to the Sierra del Carmen, desert species increased an additional 17%, reaching nearly 55% of the sample flora, and the overall southerly component increased to 88%. This included 29% Chihuahuan endemics such as *Agave lechuguilla*, *Jefea brevifolia* (A. Gray) Strother, *Euphorbia antisiphilitica* Zucc., *Bernardia obovata* I.M. Johnston, *Dasyllirion leiophyllum* Engelm. ex Trel., *Bouteloua ramosa* Scribn. ex Vasey, *Yucca faxoniana* (Trel.) Sarg., and *Yucca thompsoniana* Trel.

Although northerly species comprised only 12% of all species, an opposite trend of decreasing concentration moving from north to south was still detectable. The highest concentration was on the Sevilleta and is represented by species such as *Yucca glauca* Nutt., *Opuntia polyacantha* Haw., *Bouteloua hirsuta* Lag., *B. gracilis*, *Pleuraphis jamesii* Torr., *Achnatherum hymenoides*

Table 3. *Bouteloua gracilis* plant associations on the Sevilleta National Wildlife Refuge, with their Index of Chihuahuan Desert affinity mean values and standard deviations (s.d.), and regional distributions. N = other sites north of the Sevilleta NWR; SEV = Sevilleta NWR; J/T = Jornada/Tularosa basins; OM = Otero Mesa; SDC = Sierra del Carmen Protected Area; S = other southern (Chihuahuan) sites; n = number of plots.

Plant association	n	Index	s.d.	Distribution					
				N	SEV	J/T	OM	SDC	S
<i>Bouteloua gracilis</i> / <i>Muhlenbergia torreyi</i>	2	0.20	0.42	X	X				
<i>Bouteloua gracilis</i> / <i>Yucca glauca</i>	2	0.26	0.22	X	X				
<i>Bouteloua gracilis</i> / <i>Muhlenbergia arenacea</i>	1	0.33			X				
<i>Bouteloua gracilis</i> / <i>Pleuraphis jamesii</i>	3	0.47	0.24	X	X				
<i>Bouteloua gracilis</i> / <i>Lycurus phleoides</i>	1	0.57		X	X				
<i>Bouteloua gracilis</i> / <i>Scleropogon brevifolius</i>	3	0.58	0.17		X	X	X		
<i>Bouteloua gracilis</i> / <i>Yucca baccata</i>	1	0.60			X	X	X		
<i>Bouteloua gracilis</i> / <i>Opuntia clavata</i>	2	0.88	0.17		X				

(Roemer & J.A. Schultes) Barkworth, *Pascopyrum smithii* (Rydb.) A. Löve, *Sphaeralcea coccinea* (Nutt.) Rydb., and *Krascheninnikovia lanata* (Pursh) A.D.J. Meeuse & Smit. By the time the Sierra del Carmen was reached, *Bouteloua hirsuta* and *B. gracilis* were about all that remained of the northern representatives. Also of note, the widespread species followed a similar trend of decreasing proportion from north to south that corresponds to the increasing Chihuahuan endemism found in the Sierra del Carmen.

Community-level trends. — When the sites were stratified by vegetation alliances, additional patterns emerged within the general north-to-south trend of increasing southern desert species dominance (Fig. 3). Based on the higher floristic index values, the *Larrea*-dominated scrub communities were more “Chihuahuan” than their complementary grassland types. Even on the Sevilleta, the index for *Larrea* communities was nearly twice that of either *B. eriopoda* or *B. gracilis* types, suggesting that these desert scrub communities might have a distinctive character decidedly different from their grassland counterparts.

Among grasslands, *B. eriopoda* grasslands followed a similar north-to-south trend, but the index values were considerably lower, suggesting that there were fewer “desert” species among grasslands than among the more xeric scrub types. At the intermediate sites of the Jornada/Tularosa basins and Otero Mesa, there was a gradient from relatively high index values for *B. eriopoda*-*B. gracilis* types, to grasslands solely dominated by *B. gracilis*. Although this would support the concept that dominants can be indicators of overall floristic composition, the distinction appears to fall away at either end of the distributional spectrum. On the Sevilleta, *B. eriopoda* and mixed stands converged towards *B. gracilis*,

while in the Sierra del Carmen, *B. gracilis* types converged on *B. eriopoda* types (mixed stands were not sampled in the Sierra del Carmen).

Imbedded in the structure presented in Fig. 3 is a high degree of variability. For example, if we look closer at the Sevilleta and examine individual plant associations, the apparent convergence on *B. gracilis* grasslands also has a gradient structure (Table 2). The index values for individual *B. eriopoda* associations fell into two distinct groups: those above, and those at or below 0.5. Those with the higher values tended to be shrubbier and co-dominated by species with strong southern affinities, and the associations are not known to extend north of the Sevilleta (e.g., the *B. eriopoda/Parthenium incanum* Plant Association or PA). In contrast, those below 0.5 tended to be co-dominated by northern species or by species that are known to have ranges that extend into the southern Shortgrass Prairie or the southern Colorado Plateau (e.g., the *B. eriopoda/Ephedra torreyana* PA).

Similarly, *B. gracilis* associations fell into two groups (Table 3). Those with index values above 0.5 had southern affinities and all other known occurrences of the associations were south of the Sevilleta (*B. gracilis-Scleropogon brevifolius* and *B. gracilis/Yucca baccata* PAs). Conversely, those below 0.5 are known only from the Sevilleta and further north. Those associations that have values approaching 0.2 are well represented in the southern Shortgrass Prairie of southern Colorado and eastern New Mexico (e.g., *B. gracilis/Y. glauca* and *B. gracilis/Muhlenbergia torreyi*).

Although more limited, even *Larrea* associations exhibited a gradient structure within the Sevilleta (Table 4). With the exception of *Larrea tridentata/Pleuraphis jamesii* PA, all the *Larrea* associations had index values above 0.5, suggesting relatively strong Chihuahuan Desert affinities. The shrubby *Larrea tridentata/*

Table 4. *Larrea tridentata* plant associations on the Sevilleta National Wildlife Refuge, with their Index of Chihuahuan Desert affinity mean values and standard deviations (s.d.), and regional distributions. N = other sites north of the Sevilleta NWR; SEV = Sevilleta NWR; J/T = Jornada/Tularosa basins; OM = Otero Mesa; SDC = Sierra del Carmen Protected Area, and S = other southern (Chihuahuan) sites; n = number of plots.

Plant association	n	Index	s.d.	Distribution					
				N	SEV	J/T	OM	SDC	S
<i>Larrea tridentata/Pleuraphis jamesii</i>	3	0.46	0.26		X				
<i>Larrea tridentata-Gutierrezia sarothrae</i>	1	0.67			X				X
<i>Larrea tridentata/Scleropogon brevifolius</i>	2	0.80	0.28		X	X	X		X
<i>Larrea tridentata/Muhlenbergia porteri</i>	2	0.83	0.01		X	X	X		X
<i>Larrea tridentata/Bouteloua eriopoda</i>	13	0.91	0.34		X	X	X		X
<i>Larrea tridentata/Erioneuron pulchellum</i>	4	0.93	0.40		X	X	X		X
<i>Larrea tridentata/Sporobolus airoides</i>	1	1.00			X	X	X		X
<i>Larrea tridentata/Sparse</i>	2	1.04	0.22		X	X	X	X	X
<i>Larrea tridentata-Parthenium incanum</i>	1	1.60			X	X	X	X	X

Parthenium incanum association with its score of 1.6 is on par with scores for it and similar associations in the Sierra del Carmen in Mexico. In contrast, the *Larrea tridentata*/*Pleuraphis jamesii* association, with its relatively low index value, is known only from the Sevilleta, and possibly represents a unique new assemblage concordant with the northerly historical expansion of *Larrea*.

DISCUSSION

Floristic and ecological entities do not always explicitly converge for a number of reasons. Floristic elements, be they provinces, regions, etc., are commonly defined and mapped on the basis of many species from floras that can range over numerous vegetation communities. Hence, they are information-rich but tend to have generalized, abstract boundaries. In contrast, ecologically defined elements, such as ecoregions or biomes, are often mapped on the dominance of one or a few species or physical elements leading to boundaries that can be very precise, but that can be ambiguous with respect to what biodiversity they actually represent (information-poor). Here, I have attempted to bring the two approaches together by constructing a floristic index based on specific plant associations that enables the exploration of floristic entities in a particular ecological context. In this case, the focus was on the contact between the Chihuahuan Desert and the Colorado Plateau/southern Shortgrass Prairie floristic elements as expressed by communities dominated by either *Larrea*, *B. eriopoda*, or *B. gracilis*.

With respect to *Larrea* communities, the analysis suggests that a key indicator species such as *Larrea* can to some degree signal the presence or boundary of an entire biome. Index values for *Larrea* associations declined from south to north, but remained relatively high when compared to *B. eriopoda*-dominated or *B. gracilis*-dominated grasslands. Even at the Sevilleta, *Larrea* communities had distinctively Chihuahuan attributes not found in adjacent communities, but if the northerly character of the *Larrea tridentata*/*Pleuraphis jamesii* association is any indication, this distinctiveness needs to be tested further against desert scrub out-groups with strong northern species affinities.

The value of *B. eriopoda* as an indicator of Chihuahuan Desert grasslands is less clear. At the intermediate sites (Jornada/Tularosa basins and Otero Mesa) and in the Sierra del Carmen, *B. eriopoda*-dominated desert grasslands appear to be well expressed floristic/ecological entities. Even as they reached their northern limits at the Sevilleta, many of the *B. eriopoda* associations sustained high index values, and hence their integrity as Chihuahuan Desert grasslands. But others

were either unique to the Sevilleta or found only going north, well beyond the previously delineated ecological or floristic boundaries of the Chihuahuan Desert. Hence, *B. eriopoda* dominance alone is not enough to designate an association as a Chihuahuan Desert grassland; the entire floristic complement needs to be taken into account.

The same follows for *B. gracilis* grasslands, but with a reverse latitudinal structure. More or less typical *B. gracilis* grasslands representative of the southern Shortgrass Prairie are present on the Sevilleta, but give way to completely different plant associations in the Sierra del Carmen in Mexico, ones with relatively high Chihuahuan floristic index values and little connection to the Shortgrass Prairie except for the dominant grass species. Hence, it would be better to consider them as Chihuahuan Desert grasslands, both compositionally and functionally, rather than spatial disjuncts of the Shortgrass Prairie.

Overall, the data presented here generally support the contention that the Sevilleta lies in a tension zone between the Chihuahuan Desert and the southern Shortgrass Prairie and Colorado Plateau/Great Basin biomes (Gosz, 1991). While the transitional nature of the Sevilleta as depicted here is in keeping with how it has been mapped ecologically in the past (Brown & Lowe, 1980; Dick-Peddie, 1993; Bailey & al., 1994), the quantitative floristic basis for those delineations has not always been evident. More specifically, the lower floristic index values on the Sevilleta relative to the sites to the south, together with the lack of significant numbers of Chihuahuan Desert endemics and the greater preponderance of northern-distributed species, suggest that vegetation on the Sevilleta is approaching the boundary between these floristic regions or biomes. In addition, the majority of plant associations from the *B. eriopoda* and *Larrea* alliances were at their northern limits on the Sevilleta, while those associations from the *B. gracilis* Alliance with index values below 0.5 were generally not found any further south. An explicit test against northern out-group associations is still required, both to the northeast and northwest, and the next step will be to assemble the appropriate species-level datasets for the analysis.

Indices such as the one presented here and the associated analysis can have broader applications in plant ecology, synecology, and conservation biology. Explicitly defining the biosystematic and biogeographical settings helps ensure that ecological problems are properly stated and appropriately scaled. For example, on the Sevilleta, the differences between *B. gracilis*- and *B. eriopoda*-dominated grasslands in terms of floristic structure (and implied ecological differences) are not as great as the difference between the grasslands in general and *Larrea* scrub at the site. There were some differences

among grassland plant associations as well as *Larrea* associations with respect to Chihuahuan desert affinity, which suggests that these communities need to be more thoroughly explored in terms of floristic-ecological linkages in the transition zone.

With respect to vegetation classifications, understanding the biogeographic structure of a vegetation pattern is critical to creating classification hierarchies that are meaningful in an evolutionary as well as ecological context. For example, the index presented here might be used instead of, or in support of, complex multivariate analysis to clearly designate alliances or sub-alliances of associations with Chihuahuan floristic affinity, versus some other province or biome. With that designation comes a wealth of evolutionary history and ecological information about the species that makes up the assemblage that might otherwise be lost in a more typological classification based solely on dominance and/or character species. By extension, there are implications for the conservation of biodiversity because vegetation classifications play an integral role in the analysis of landscapes for their biodiversity value. Vegetation classifications that are strongly rooted in good biosystematics and biogeography are more likely to produce the right information for setting biodiversity conservation goals.

ACKNOWLEDGEMENTS

Yvonne Chauvin, Glenn Harper, Steven Yanoff, Sarah Wood, Elizabeth Milford, Sanam Radjy, Becky Yeager, Jamie Thomson, Susan Gear, Denis Kearns, Kimberly Taugher, Patty Hoban, Roby Wallace, Norm Douglas, Teri Neville and Marisela Pondo Moreno contributed the detailed field data that made this project possible. Rebecca Keeshen provided editorial assistance. This study was supported by grants from the National Science Foundation to the University of New Mexico (DEB-0080529) as part of the Sevilleta Long Term Ecological Research (LTER). This is Sevilleta LTER publication number 266. Additional financial support was provided by the New Mexico Natural Heritage Program, University of New Mexico.

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