RECENT FINDINGS ON THE GYPSUM FLORA OF THE RIM OF THE GUADALUPE MOUNTAINS, NEW MEXICO, U.S.A.: A NEW SPECIES OF *NERISYRENIA* (BRASSICACEAE), A NEW STATE RECORD, AND AN UPDATED CHECKLIST

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ABSTRACT

Exposures of Yeso Formation gypsum along the western escarpment (The Rim) of the Guadalupe Mountains in southeastern New Mexico were first explored botanically in 1996, which revealed the existence of two gypsophilic taxa, *Anulocaulis leiosolenus* var. *howardii* and *Mentzelia humilis* var. *guadalupensis*, both of which are only known from that area. Fieldwork by the authors has revealed another gypsophile restricted to The Rim, **Nerisyrenia hypercorax,** which is here described. The new species is similar to *N. gypsophila* and *N. mexicana*, from which it differs in having shorter, crispate fruits and smaller floral parts. We also report a new state record of *Paronychia wilkinsonii* in New Mexico and make additional observations regarding the gypsum flora of The Rim.

RESUMEN

Las exposiciones de yeso de la "Formación Yeso" en la escarpa occidental de las Montañas de Guadalupe, conocida como "The Rim," en el sureste de Nuevo México fueron inicialmente exploradas botánicamente en 1996, cuando se descubrió la existencia de dos taxones gipsófilos, *Anulocaulis leiosolenus* var. *howardii* y *Mentzelia humilis* var. *guadalupensis*, conocidos solamente de esa área. El trabajo de campo realizado recientemente por los autores, permitió descubrir otra planta gipsófila endémica restringida a dicha formación y localidad, **Nerisyrenia hypercorax,** que se describe aquí. La nueva especie es similar a *N. gypsophila* y *N. mexicana* pero difiere de ellas en los frutos más cortos, crispados y las partes florales más pequeñas. También registramos *Paronychia wilkinsonii* por primera vez para Nuevo México y proporcionamos observaciones adicionales sobre la flora de la región.

INTRODUCTION

Gypsum exposures are distributed in an island-like fashion throughout the Chihuahuan Desert region and host a diverse array of over 200 gypsophilic (i.e. occurring only on gypsum) plant species in over 35 families (Powell & Turner 1977; Moore & Jansen 2007). In the US portion of the Chihuahuan Desert, gypsum deposits are common in much of central and southern New Mexico and adjacent west Texas (Weber & Kottlowski 1959; Anderson & Dean 1995) and host a number of gypsophilic taxa that vary in distribution across the region. The dominant gypsophilic taxa in New Mexico and Texas typically include *Sporobolus nealleyi* (Poaceae), *Tiquilia hispidissima* (Boraginaceae), *Dicranocarpus parviflorus* (Asteraceae), *Sartwellia flaveriae* (Asteraceae), *Oenothera hartwegii* subsp. *filifolia* (Onagraceae), *Nerisyrenia linearifolia* (Brassicaceae), and *Acleisanthes lanceolata* (Nyctaginaceae). In addition, a number of narrowly distributed gypsophiles are found in New Mexico and west Texas. In northern New Mexico, for example, exposures of Todilto Formation gypsum are

home to the narrow endemics *Abronia bigelovii* Heimerl (Nyctaginaceae), *Mentzelia todiltoensis* N.D. Atwood & S.L. Welsh (Loasaceae), *Townsendia gypsophila* Lowrey & P.J. Knight (Asteraceae), and *Phacelia sivinskii* N.D. Atwood, P.J. Knight & Lowrey (Boraginaceae).

In southern New Mexico and adjacent west Texas a number of locally endemic gypsophiles can be found near the Guadalupe Mountains (New Mexico Rare Plant Technical Council 1999–2012). Although the mountain range itself is composed primarily of Permian limestone, gypsum is present on both the western and eastern sides of the Guadalupe Mountains as part of the Castile, Seven Rivers, and Yeso formations, and as Quaternary lacustrine deposits that are ultimately derived from the Yeso and Castile formations (Boyd 1958; King 1948; Scholle 2003). Four narrowly endemic gypsophiles are known only from the eastern side of the Guadalupe Mountains. Two of these species are found only on the Castile Formation [*Astragalus gypsodes* Barneby (Fabaceae) and *Linum allredii* Sivinski & M.O. Howard (Linaceae)], whereas the other two are found on both the Castile and Seven Rivers formations [*Amsonia tharpii* Woodson (Apocynaceae) and *Eriogonum gypsophilum* Wooton & Standl. (Polygonaceae)]. The narrowly endemic *Lepidospartum burgessii* B.L. Turner (Asteraceae) is known only from the southwestern side of the Guadalupe Mountains, on the east side of Crow Flats and Salt Basin in Quaternary lacustrine gypsum deposits. The western escarpment of the Guadalupe Mountains, known as The Rim, is composed mostly of San Andres Formation limestone, but gypsum of the Yeso Formation outcrops frequently near the base of The Rim, occasionally forming extensive exposures such as those near the mouth of Pup Canyon (Figs. 1, 2). These gypsum outcrops were unexplored by botanists prior to 1996–97, when the Pup Canyon gypsum was first systematically collected by M. Howard, R. Spellenberg, and T. Wootten (Spellenberg & Wootten 1999). These explorations led to the discovery and description of two gypsophiles, *Anulocaulis leiosolenus* var. *howardii* (Nyctaginaceae) and *Mentzelia humilis* var. *guadalupensis* (Loasaceae).

The gypsum at the base of The Rim is remote, and much of it is difficult to access; consequently, the flora of this area remains relatively poorly known. In August and September 2013 the authors visited the gypsum exposures along The Rim of the Guadalupe Mountains in support of an ongoing project to understand the evolutionary history of the Chihuahuan Desert gypsophilic flora. This fieldwork revealed the existence of a new gypsophilic taxon that appears to be restricted to The Rim, *Nerisyrenia hypercorax*, which is here described. We also report new floristic observations for this region, including a state record of the rare *Paronychia wilkinsonii* S. Watson and an updated checklist of plants currently known from the gypsum of The Rim (Appendix 1).

A NEW SPECIES OF *NERISYRENIA*

Nerisyrenia Greene is a small genus, including 7 (Rollins 1993), 8 (Al-Shehbaz 2012), 9 (Bacon 1978), or 11 (Turner 1993) species. The most recent monograph of the genus is that of Bacon (1978). Nomenclature of *Nerisyrenia* and characteristics of previously-published species below are based on this work and the subsequent paper by Turner (1993). *Nerisyrenia* is restricted to the Chihuahuan Desert region and has a remarkable affinity for gypsum. All the species are gypsophiles except the widespread and variable *Nerisyrenia camporum* (A. Gray) Greene. These gypsophilic taxa are largely allopatric with respect to one another, and collectively they occupy gypsum exposures from central New Mexico to northern San Luis Potosí (Bacon 1978). In the United States, only two taxa were previously known: *N. camporum* and *N. linearifolia*. The discovery of *N. hypercorax* adds yet another gypsophilic species to the genus and to the flora of New Mexico. The visit to Pup Canyon by the authors on 20 Aug 2013 coincided with the filming of Episode 5 of the educational video series Plants Are Cool Too!, which can be viewed at http://www.youtube.com/watch?v=a16mBFTkrks.

Nerisyrenia hypercorax P.J. Alexander & M.J. Moore, sp. nov. (**Figs. 3, 4**) TYPE: U.S.A. NEW MEXICO. Otero Co.: W-facing gypsum slopes of The Rim of the Guadalupe Mountains, just N of Pup Canyon, 32.37803°N, 105.07308°W, 1339 m; scattered in diverse gypsophilic community on relatively barren gypsum, with no single dominant species; subshrubs to 25 cm tall, petals white, not senescing lavender, leaves somewhat succulent, never linear, 20 Aug 2013 (fl, fr), *M.J. Moore et al. 2272* (HOLOTYPE: NMC; ISOTYPES: MEXU, OC, TEX/LL, UNM).

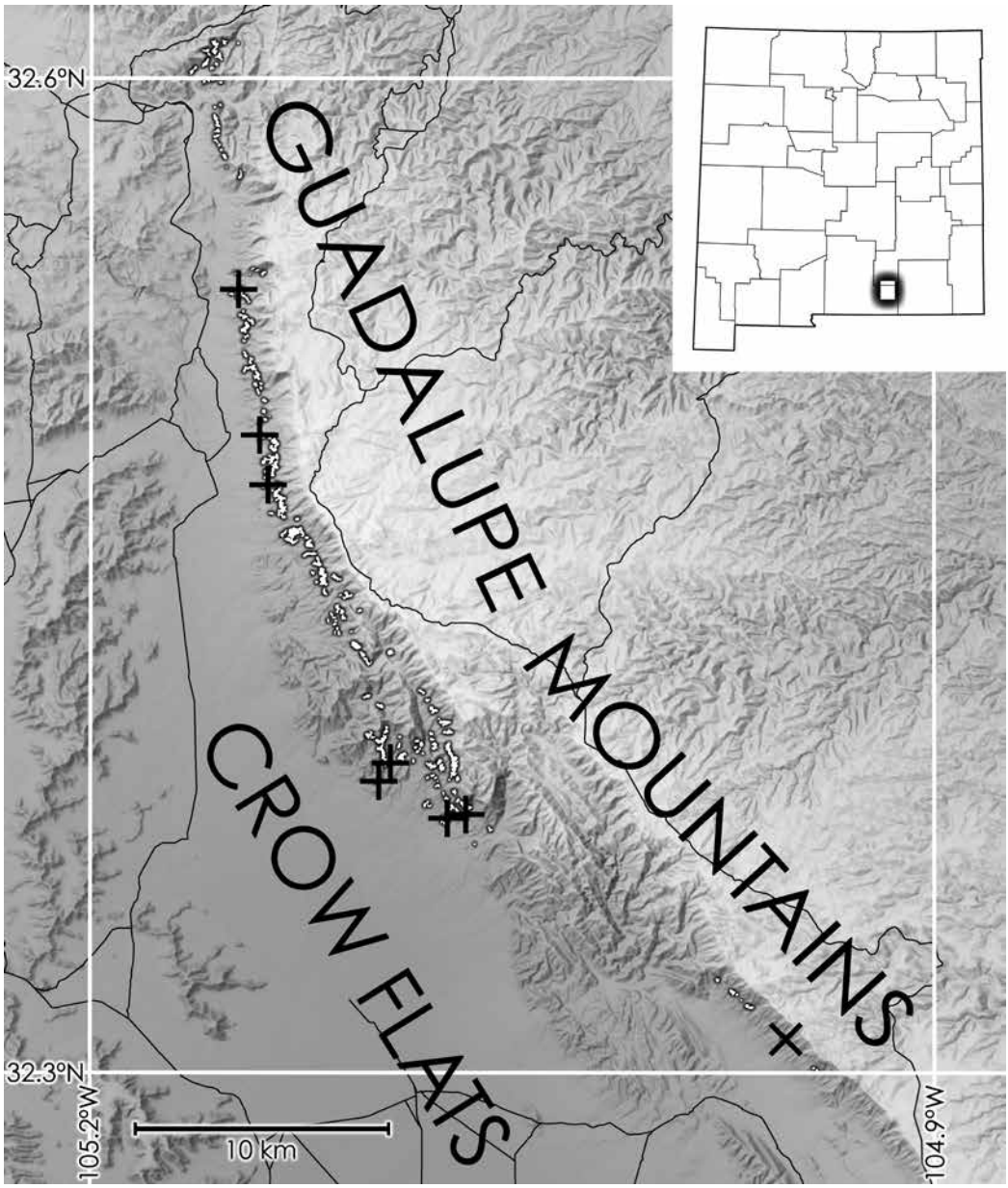

Fig. 1. Known distribution of *N. hypercorax* ("+"), closest known population of *N. linearifolia* ("×"), and approximate distribution of Yeso Formation gypsum outcrops along the Guadalupe Mountains rim (shown in white with dark outline).

Similar to *N. gypsophila* J.D. Bacon and *N. mexicana* (J.D. Bacon) B.L. Turner but differing in having shorter (usually 5–12 mm, vs. > 15 mm), crispate, incurved fruits and smaller floral parts; crispate fruits are apparently unique in the genus.

Suffrutescent perennials or subshrubs, not rhizomatous; individuals more or less hemispherical, 1–2.5 (–3.5) dm tall. Moderately pubescent throughout, trichomes mostly appressed, sessile or short-stalked (stalks to 0.05 mm), predominately dendritically 5-branched (rays to 0.25 mm), some trichomes 3-rayed to dendritically

Fig. 2. Habitat of *N. hypercorax*: **A.** at the type locality; **B.** at the site of *Alexander 1330*.

7-branched. **Stems** branched throughout, 3–6 from a branched, woody caudex, older woody stems to 1 cm in diameter, herbaceous stems to 1 mm diameter. **Cauline leaves** succulent, strongly overlapping, 3–6 times longer than wide, the larger (18–)22–40(–48) mm long, (4–)6–12(–14) mm wide, oblanceolate to spatulate, attenuate at the base and obtuse to acute at the apex, margins entire to weakly sinuate or, rarely, obscurely sinuate-dentate. **Flowers** with sepals (3.0–)4.0–6.0 mm long, 1.0–1.5 mm wide, broadly lanceolate in outline. Petals white, not fading purple on senescence, (rarely fading very pale lavender), 7–9 mm long, 3.5–4.5 mm wide, obovate to spatulate in outline, blade margins entire, dilate and denticulate at base. Stamens weakly tetradynamous, 2.5–5.5 mm long, anthers medifixed, straight and 1.5–1.8 mm long at anthesis, curling with

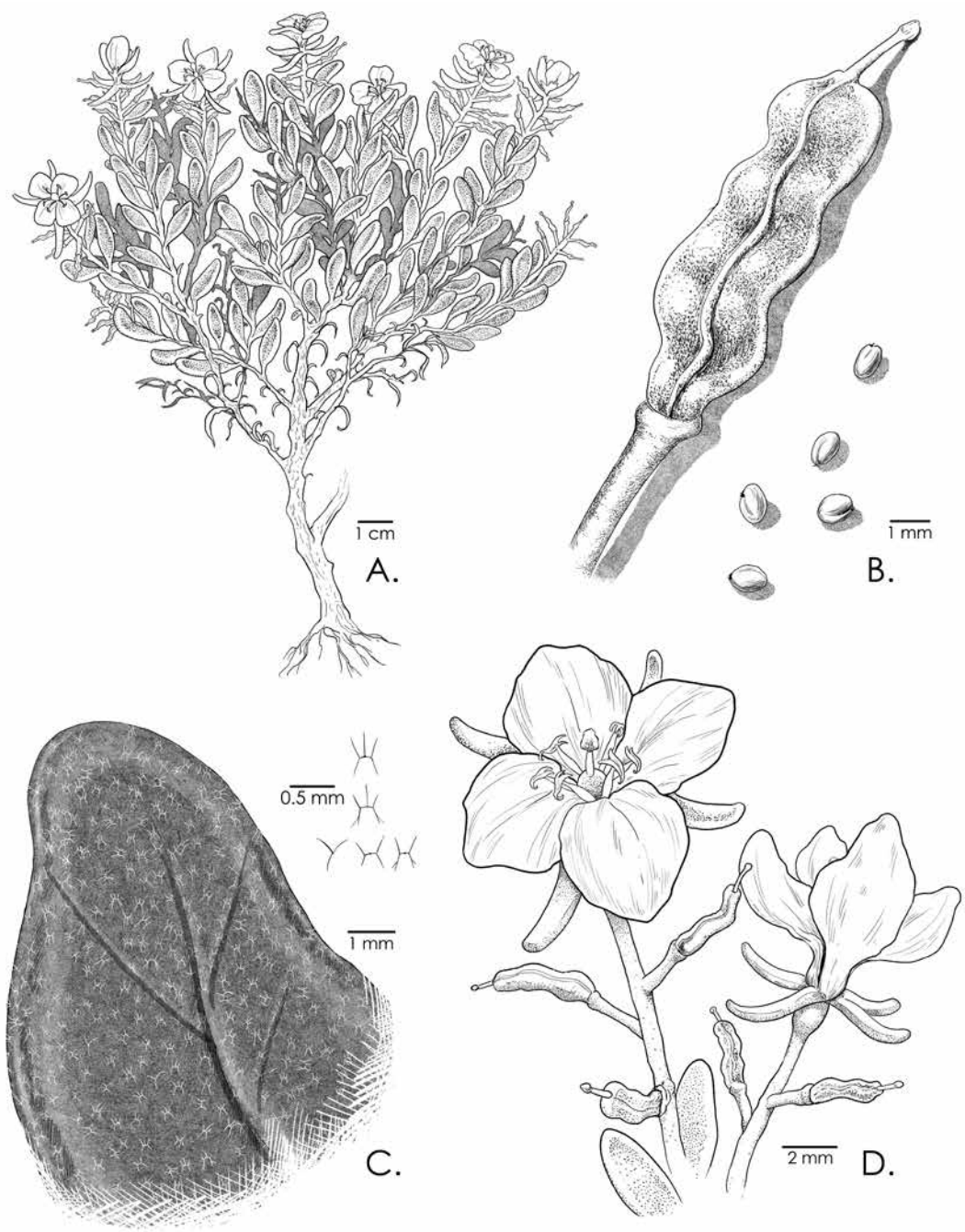

Fig. 3. Line drawing of *N. hypercorax*, based on *P.J. Alexander 1324* and *M.J. Moore et al. 2272*. **A.** Plant habit. **B.** Mature fruit and seeds. **C.** Apex of a cauline leaf and enlarged view of leaf trichome forms. **D.** Flowers and immature fruit. Illustration by Avery Liell-Kok.

Fig. 4. *Nerisyrenia hypercorax*. **A.** Flower at the type locality. **B.** Fruit at the site of *P.J. Alexander 1324*. **C.** Plant habit at the type locality.

age, filaments 2.0–4.5 mm long. Ovary tomentose, 2–4 mm long, 0.8–1.5 mm wide, style glabrous, 1.3–2.2 mm long, stigma deltoid-sagittate, 0.5–0.8 mm long, somewhat decurrent on the style. **Infructescences** compact, (1.5–)2.0–4.5(–6.5) cm long, with 5–15(–20) fruits, middle internodes 1–5 mm long, pedicels straight, ascending to, infrequently divaricate, (3–)4–9(–13) mm long. **Siliques** obcompressed (angustiseptate), oblong, rounded-

truncate at apex, not tapered to style, incurved, crispate (tortuose), 5–12(–16) mm long, 2.2–3.0 mm wide, inner surfaces of the valves glabrous; replum 0.8–1 mm wide. Ovules 20–40 per silique, seeds broadly elliptic to broadly ovate, 0.8–1 mm long, 0.6–0.7 mm wide, somewhat flattened, about half as thick as wide, yellow-orange.

Etymology.—The specific epithet refers to the distribution of the species, above Crow Flats.

Phenology.—Flowering specimens have been collected from late July to early September, while specimens with mature fruits have been collected in August and early September.

Geography and habitat.—*Nerisyrenia hypercorax* occurs on gypsum of the Yeso Formation on the west side of the Guadalupe Mountains, at the mouth of Pup Canyon and north-northwest for ca. 20 km, between 1300 and 1600 m. *Nerisyrenia hypercorax* has been found at every site within this band that has been visited by botanists.

Distinction from other Nerisyrenia.—In the treatment by Bacon (1978), *N. hypercorax* keys to *Nerisyrenia gypsophila* J.D. Bacon, a gypsophile found throughout east central Chihuahua. However, it is perhaps morphologically closer to *Nerisyrenia mexicana* (J.D. Bacon) B.L. Turner, a gypsophile of southeastern Coahuila, southern Nuevo León, and adjacent San Luis Potosí and Tamaulipas, which has similarly short pedicels and styles. Nevertheless, *N. hypercorax* differs from these two species by its shorter fruits and smaller floral parts. For example, it is distinguished from both species by its shorter siliques (5–125–12 mm vs. 17–30 for *N. gypsophila* and 15–27 for *N. mexicana*), shorter anthers (1.5–1.8 mm vs. 2.4–3.4 and 2.5–3.5, respectively), smaller petals (7–9 mm long, 3.5–4.5 mm wide, vs. 9.5–11.5 × 4.5–8.5 in *N. gypsophila*, and 8.5–13 × 5.0–8.5 in *N. mexicana*), usually shorter filaments (2.5–4.5 mm vs. 4–6 in both *N. gypsophila* and *N. mexicana*), and usually shorter infructescences (2–4.5 cm vs. 4–30 and 6–19, respectively). From *N. gypsophila* it is further distinguished by its shorter sepals (4–6 mm vs. 6.5–8.5), usually shorter pedicels (5–9 mm vs. 8–12), shorter styles (1.3–2.2 mm vs. 2.7–4.0), and incurved rather than straight siliques. The crispate fruits of *N. hypercorax*, present in all individuals observed, are apparently unique in the genus and most readily distinguish this species from other *Nerisyrenia*.

Previously, only two species of *Nerisyrenia* were known from New Mexico: the gypsophilic *N. linearifolia* and the morphologically and edaphically variable *N. camporum*. *Nerisyrenia linearifolia* is found on gypsum throughout the southern two-thirds of the state and in adjacent western Texas, while *N. camporum* is the most widespread species in the genus, common along the Rio Grande Valley and the southern third of the New Mexico as well as in southwestern Texas and the Mexican states of Chihuahua, Coahuila, Durango, Nuevo León, Tamaulipas, and Zacatecas. While *N. hypercorax* shares the broader leaves of *N. camporum*, it differs from this species in a number of respects, principally in its more suffruticose habit (vs. herbaceous to weakly suffrutescent perennial), entire leaf margins (vs. typically dentate leaves), relatively compact inflorescences that only slightly exceed the leaves (vs. elongate inflorescences that greatly exceed the leaves), and its petals, which do not turn pale lavender or purple upon senescence as in *N. camporum*. Indeed, *N. hypercorax* shares all of these character states with its gypsum-loving cousin *N. linearifolia*, although the broad, shorter leaves, generally smaller flower parts, and shorter, crispate fruits of the former serve to easily distinguish it from the latter. A key to *Nerisyrenia* in New Mexico is provided below.

KEY TO THE *NERISYRENIA* SPECIES OF NEW MEXICO

1. Leaves linear, all less than 5 mm wide ____ **N. linearifolia**
1. Leaves oblanceolate, spatulate, or obovate, the larger more than 5 mm wide
   2. Fruits crispate, less than 15 mm long; infructescences less than 7 cm long; petals less than 5 mm wide, remaining white ____ **N. hypercorax**
   2. Fruits not crispate, more than 15 mm long; infructescences more than 7 cm long; petals more than 5 mm wide, fading lavender ____ **N. camporum**

Although *N. camporum* and *N. linearifolia* can be found growing together in New Mexico, so far as is known neither species co-occurs with *N. hypercorax*. The authors have found *N. hypercorax* at five sites but did not observe any other *Nerisyrenia* at these sites. There are only two previous *Nerisyrenia* specimens from this band of gypsum in regional herbaria, both *N. hypercorax*.

Paratypes.—**U.S.A. New Mexico. Chaves Co.:** Lincoln National Forest, W slope of the Guadalupe Mountains ca. 1.5 mi N of Otero county line, 32.53752°N 105.14758°W, elev. 1579 m, limestone interbedded with gypsum, 23 Jul 2012 (fl), *K.D. Heil 34399* (SJNM). **Otero Co.:** W base of the Guadalupe Mountains E of Piñon Creek, 1.9 mi S of the Chaves County line, 1.7 mi NE of Tanner Ranch, 32.4936°N 105.1399°W (WGS84), elev. 1540 m, along small incised ravines in a SW-facing, reddish gypsum outcrop, 2 Sep 2013 (fl, fr), *P.J. Alexander 1324* (DUKE, MEXU, MO, NMC, OC); W base of the Guadalupe Mountains E of Piñon Creek, 2.9 mi S of the Chaves County line, 1.2 mi ENE of Tanner Ranch, 32.4786°N 105.1369°W (WGS84), elev. 1550 m, along a narrow arroyo deeply incised in gypsum, 1 Sep 2013 (fl, fr), *P.J. Alexander 1330* (DUKE, MEXU, MO, NMC, OC); 49 km NNE of Dell City, Texas, W base of Guadalupe Mts., N of mouth of Pup Canyon, 32.37917°N 105.06650°W, elev. 1460 m, gypseous slopes on upper bajada, W-facing, 5 Aug 1997 (fr), *R.W. Spellenberg 12442* (NMC); west base of the Guadalupe Mountains, 2.0 mi E of Johnson Tanks and 2.6 mi WNW of the mouth of Pup Canyon, 32.38921°N 105.09743°W (WGS84), elev. 1330 m, small outcrop of gypseous clay near the mouth of a small limestone canyon, 28 Aug 2014 (fl, fr), *P.J. Alexander & M.O. Howard 1463* (MO, NMC, OC); west base of the Guadalupe Mountains, 2.2 mi E of Johnson Tanks and 2.6 mi NW of the mouth of Pup Canyon, 32.39478°N 105.09323°W (WGS84), elev. 1360 m, gypseous clay cutbanks in a small limestone canyon, immediately below large expanses of open gypsum, 28 Aug 2014 (fl, fr), *P.J. Alexander & M.O. Howard 1464* (NMC, OC, UNM).

FLORA OF THE YESO FORMATION GYPSUM ALONG THE RIM

Spellenberg and Wootten (1999) compiled a list of 59 vascular plant taxa occurring on Yeso Formation gypsum at The Rim from their fieldwork on the north side of Pup Canyon and a site northeast of Tanner Ranch. Fieldwork by the authors and additional visits to the area by K. Heil and associates at San Juan College and R. Worthington of the University of Texas at El Paso have increased our knowledge of the gypsum flora of The Rim from Pup Canyon and to the north-northwest for ca. 20 km. This expanded list includes 74 vascular plant taxa in 27 plant families and is provided in Appendix 1. The endemics *Mentzelia humilis* var. *guadalupensis* and *Nerisyrenia hypercorax* are found throughout this band of gypsum, while *Anulocaulis leiosolenus* var. *howardii* has been found only on gypsum in the immediate vicinity of Pup Canyon.

There are several additional small outcrops of Yeso Formation gypsum southeast of Pup Canyon on the east side of Big Dog Canyon that have not previously been botanically explored. The first author visited one of these sites in September 2013 to determine if *N. hypercorax* is present. None of the narrow endemics of The Rim were found at this site. Instead of *N. hypercorax* and *M. humilis* var. *guadalupensis*, the more widespread *N. linearifolia* and *M. humilis* var. *humilis* were found at Big Dog Canyon, while no *Anulocaulis* was seen. A list of 37 vascular plant taxa in 20 families observed at the site is provided in Appendix 2.

PARONYCHIA WILKINSONII, A NEW STATE RECORD

On limestone adjacent to Yeso Formation gypsum, the first author found *Paronychia wilkinsonii*, here first reported from New Mexico: U.S.A. New Mexico. Otero Co.: west base of the Guadalupe Mountains east of Piñon Creek, 2.9 miles south of the Chaves County line, 0.9 miles east-northeast of Tanner Ranch, 32.4786°N 105.1421°W (WGS84), elev. 1490 m, gentle west slope, limestone cobble, 2 Sep 2013 (fl, fr), *P.J. Alexander 1329* (NMC, OC, RM). This is a rare species previously known only from outcrops of novaculite (a form of chert comprised primarily of microcrystalline quartz) in the Marathon Basin of western Texas and a few scattered sites in the Mexican states of Chihuahua and Coahuila (Poole et al. 2007). This population in New Mexico is ca. 300 km disjunct from the nearest known populations near Marathon.

DISCUSSION

The presence of at least three locally endemic gypsophiles at Pup Canyon and neighboring gypsum sites along The Rim implies that little gene flow has occurred between gypsum at The Rim and other gypsum exposures, allowing allopatric speciation, and it further raises the possibility that conditions supporting the long-term persistence of gypsophiles may have characterized The Rim for all or much of the Pleistocene. During full-glacial periods of the Pleistocene, New Mexico experienced a significantly cooler and wetter climate, resulting in the replacement of "typical" Chihuahuan Desert vegetation with grassland and savanna that is similar to that seen in central New Mexico today (Van Devender 1990, Elias & Van Devender 1992). The southerly location of The Rim in New Mexico, its relatively low elevation, and its west-facing aspect may have resulted in a warmer, drier microclimate during full-glacial periods, helping to maintain the semi-arid character of the site

over time. Even today the gypsum exposures along The Rim are relatively thinly vegetated compared to most other gypsum deposits in the Chihuahuan Desert (Fig. 2), which likely results in part from this warmer, drier microclimate. Moreover, the gypsum substrate itself may have helped promote community stability for gypsophilic taxa during the wetter periods of the Pleistocene by reducing or preventing the growth of non-gypsophilic plant taxa, which often have great difficulty establishing and persisting on gypsum (Damschen et al. 2012; Escudero et al. 2014; Moore et al. 2014). Ongoing phylogenetic and phylogeographic studies of the Chihuahuan Desert gypsum flora in the lab of Michael Moore at Oberlin College will help to test this hypothesis and will shed light on the evolutionary relationships of the unique gypsum flora at Pup Canyon.

APPENDIX 1

The following list includes all species known to occur on gypsum of The Rim from Pup Canyon northward. All species listed by Spellenberg and Wootten (1999) are included. The list is supplemented by observations made by the authors and specimens collected by R. Worthington, K. Heil, S. O'Kane, D. Schleser, and L. Urban. Species are followed by all known herbarium specimens and deposition of specimens is indicated by herbarium codes following Index Herbariorum (Thiers 1997–2013). If no specimens are listed, the species has been observed in the field, either by Spellenberg and Wootten (1999) or by the present authors, but no voucher has been collected. Unfortunately, the remoteness of the area and logistic constraints has prevented complete collection of the gypsum flora of The Rim. We have opted to provide as complete an account as possible, despite lack of vouchers for some species. Nomenclature below the rank of family follows Allred and Ivey (2012), families follow APG III (2009), and most herbarium specimen data are available online (SEINet 2009–2013).

Amaranthaceae: *Atriplex canescens* (Pursh) Nutt.; *Tidestromia suffruticosa* (Torr.) Standl. var. *suffruticosa*: *Spellenberg & Wootten 12481* (NMC), *Moore et al. 2278* (OC, NMC, TEX/LL, MEXU).

Anacardiaceae: *Rhus microphylla* Engelm.

Apocynaceae: *Amsonia longiflora* Torr. var. *salpignatha* (Woodson) McLaughlin: *Spellenberg et al.12434* (NMC, NY, UNM), *Spellenberg et al. 12441* (NMC, NY), *Spellenberg & Wootten 12474* (NMC, NY), *Spellenberg & Wootten 12501* (NMC, NY); *Asclepias macrotis* Torr.: *Spellenberg & Wootten 12507* (NMC, NY), *Heil 34405* (SJNM).

Asparagaceae: *Dasylirion leiophyllum* Engelm. ex Trel.; *Nolina texana* S. Watson: *Heil 34400* (SJNM); *Yucca elata* (Engelm.) Engelm.; *Yucca treculeana* Carrière.

Asteraceae: *Artemisia ludoviciana* Nutt.; *Brickellia laciniata* A. Gray; *Gaillardia multiceps* Greene; *Gutierrezia microcephala* (DC.) A. Gray; *Haploësthes greggii* A. Gray var. *texana* (J.M. Coult.) I.M. Johnst.: *Spellenberg et al. 12437* (NMC), *Heil 34397* (SJNM), Moore *et al. 2274* (OC, NMC, TEX/LL, MEXU); *Parthenium incanum* Kunth: *Heil 34394* (SJNM); *Porophyllum scoparium* A. Gray: *Spellenberg et al. 12436* (NMC, UC), *Worthington 30289* (UNM, UTEP); *Sartwellia flaveriae* A. Gray: *Worthington 30282* (UNM, UTEP); *Sidneya tenuifolia* (A. Gray) E.E. Schill. & Panero; *Thelesperma megapotamicum* (Spreng.) Kuntze: *Moore et al. 2279* (OC, NMC, TEX/LL, MEXU); *Thymophylla acerosa* (DC.) Strother: *Spellenberg & Wootten 12484* (NMC); *Thymophylla pentachaeta* (DC.) Small var. *belendinium* (DC.) Strother: *Spellenberg & Wootten 12475* (NMC, NY), *Spellenberg & Wootten 12483* (BRIT); *Xanthisma spinulosum* (Pursh) D.R. Morgan & R.L. Hartm. var. *chihuahuanum* (B.L. Turner & R.L. Hartm.) D.R. Morgan & R.L. Hartm.: *Spellenberg & Wootten 12505* (NMC).

Boraginaceae: *Nama carnosum* C.L. Hitchc.: *Spellenberg & Wootten 12503* (NMC), *Alexander 1325* (NMC, OC); *Tiquilia greggii* (Torr. & A. Gray) A.T. Richardson: *Moore et al. 2281* (OC, NMC, TEX/LL, MEXU); *Tiquilia hispidissima* (Torr.) A.T. Richardson: *Spellenberg & Wootten 12502* (NMC), *Moore et al. 2275* (MEXU, NMC, OC, TEX/LL).

Brassicaceae: *Nerisyrenia hypercorax* P.J. Alexander & M.J. Moore: *Spellenberg et al. 12442* (NMC), *Heil 34399* (SJNM), *Moore et al. 2272* (MEXU, NMC, OC, TEX/LL), *Alexander 1324* (DUKE, MEXU, MO, NMC, OC), *Alexander 1330* (DUKE, MEXU, MO, NMC, OC).

Cactaceae: *Coryphantha tuberculosa* (Engelm.) A. Berger: *Spellenberg & Wootten 12482* (NMC); *Cylindropuntia imbricata* (Haw.) F.M. Knuth; *Echinocactus horizonthalonius* Lemaire; *Echinocereus dasyacanthus* Engelm.: *Spellenberg & Wootten 12486* (NMC); *Opuntia macrocentra* Engelm.: *Spellenberg & Wootten 12487* (NMC), *Spellenberg & Wootten 12488* (NMC); *Opuntia phaeacantha* Engelm.

Ephedraceae: *Ephedra aspera* S. Watson: *Spellenberg & Wootten 12473* (NMC).

Euphorbiaceae: *Chamaesyce fendleri* (Torr. & A. Gray) Small: *Spellenberg & Wootten 12458* (NMC), *Spellenberg & Wootten 12471* (NY); *Chamaesyce serrula* (Engelm.) Wooton & Standl.: *Alexander 1332* (NMC); *Croton dioicus* Cav.

Fabaceae: *Dalea formosa* Torr.; *Dermatophyllum guadalupense* (B.L. Turner & A.M. Powell) B.L. Turner: *Urban 5072* (NMC); *Vachellia vernicosa* (Britton & Rose) Seigler & Ebinger.

Fouquieriaceae: *Fouquieria splendens* Engelm.

Krameriaceae: *Krameria erecta* Schult.: *Spellenberg & Wootten 12478* (NMC).

Lamiaceae: *Hedeoma nana* (Torr.) Briq.: *Spellenberg & Wootten 12479* (NMC), *Heil 34396* (SJNM).

Linaceae: *Linum vernale* Wooton: *Spellenberg & Wootten 12480* (NMC).

Loasaceae: *Cevallia sinuata* Lag.: *Worthington 30285* (UNM, UTEP); *Mentzelia humilis* (A. Gray) J. Darl. var. *guadalupensis* Spellenb.: *Spellenberg & Wootten 12440* (NMC), *Spellenberg & Wootten 12455* (NMC, NY, TEX, UNM), *Spellenberg & Wootten 12500* (NMC, RM), *Worthington 30287* (UCR, UTEP), *Heil & O'Kane 33495* (SJNM), *Heil & Schleser 34725* (SJNM), *Moore et al. 2273* (MEXU, NMC, OC, TEX/LL).

Malvaceae: *Sphaeralcea coccinea* (Nutt.) Rydb.: *Spellenberg & Wootten 12476* (NMC).

Nyctaginaceae: *Acleisanthes lanceolata* (Wooton) R.A. Levin: *Spellenberg & Wootten 12452* (NMC), *Spellenberg & Wootten 12499* (NMC), *Heil & Schleser 34726* (SJNM), *Moore et al. 2277* (MEXU, NMC, OC, TEX/LL); *Allionia incarnata* L. var. *incarnata*; *Anulocaulis leiosolenus* (Torr.) Standl. var. *howardii* Spellenb. & Wootten: *Wootten & Howard s.n.* (NMC), *Spellenberg et al. 12433* (NMC, NY, UNM), *Spellenberg et al. 12435* (NMC), *Spellenberg et al. 12438* (NMC), *Worthington 30288* (UCR, UTEP), *Heil & O'Kane 33493* (SJNM), *Moore et al. 2270* (MEXU, NMC, OC, TEX/LL); *Cyphomeris gypsophiloides* (M. Martens & Galeotti) Standl.: *Heil & Schleser 34722* (SJNM); *Mirabilis linearis* (Pursh) Heimerl: *Spellenberg & Wootten 12506* (NMC).

Oleaceae: *Menodora scabra* A. Gray: *Heil 34403* (SJNM).

Onagraceae: *Oenothera hartwegii* Benth. subsp. *filifolia* (Eastw.) W.L. Wagner & Hoch: *Spellenberg & Wootten 12472* (NMC), *Heil 34401* (SJNM), *Moore et al. 2276* (OC, NMC, US); *Oenothera suffrutescens* (Seringe) W.L. Wagner & Hoch.

Poaceae: *Achnatherum curvifolium* (Swallen) Barkworth: *Spellenberg & Wootten 12477* (NMC, NY); *Aristida purpurea* Nutt. var. *nealleyi* (Vasey) Allred: *Spellenberg & Wootten 12453* (NMC); *Aristida pansa* Wooton & Standl. var. *pansa*: *Spellenberg & Wootten 12456* (NMC); *Bothriochloa laguroides* (DC.) Herter subsp. *torreyana* (Steud.) Allred & Gould: *Spellenberg & Wootten 12459* (NMC); *Bouteloua warnockii* Gould & Kapadia: *Spellenberg et al. 12443* (NMC), *Heil 34392* (SJNM); *Dasyochloa pulchella* (Kunth) Willd. ex Rydb.; *Digitaria cognata* (Schult.) Pilg. subsp. *pubiflora* Wipff & Hatch: *Spellenberg & Wootten 12457* (NMC); *Enneapogon desvauxii* P. Beauv.; *Setaria leucopila* (Scribn. & Merr.) K. Schum.; *Sporobolus cryptandrus* (Torr.) A. Gray: *Spellenberg & Wootten 12504* (NMC); *Sporobolus nealleyi* Vasey: *Moore et al. 2271* (MEXU, NMC, OC, TEX/LL); *Tridens muticus* (Torr.) Nash var. *muticus*: *Spellenberg & Wootten 12454* (NMC), *Heil & Schleser 34720* (SJNM).

Polygonaceae: *Eriogonum havardii* S. Watson: *Spellenberg et al. 12439* (NMC), *Heil & O'Kane 33494* (SJNM, UNM), *Heil 34404* (SJNM).

Pteridaceae: *Astrolepis cochisensis* (Goodd.) D.M. Benham & Windham subsp. *chihuahuensis* D.M. Benham: *Spellenberg et al. 12444* (NMC), *Alexander 1333* (NMC); *Cheilanthes feei* T. Moore: *Alexander 1331* (WICH).

Rosaceae: *Fallugia paradoxa* (D. Don) Endl.

Rubiaceae: *Hedyotis nigricans* (Lam.) Fosberg var. *nigricans*: *Spellenberg et al. 12445* (NMC), *Moore et al. 2282* (MEXU, NMC, OC, TEX/LL); *Hedyotis* cf. *nigricans* (Lam.) Fosberg: *Moore et al. 2284* (OC, NMC, TEX/LL, MEXU).

Solanaceae: *Chamaesaracha pallida* Averett: *Heil 34402* (SJNM), *Alexander 1326* (NMC); *Nicotiana trigonophylla* Dunal.

Verbenaceae: *Aloysia wrightii* A. Heller.

APPENDIX 2

The following list includes all species observed by the first author on gypsum on the east side of Big Dog Canyon. Specimen vouchers and nomenclature are as described for Appendix 1.

Amaranthaceae: *Atriplex canescens*.

Asparagaceae: *Dasylirion leiophyllum*; *Yucca elata*.

Asteraceae: *Bahia absinthifolia* Benth.; *Gutierrezia microcephala*; *Haploësthes greggii* var. *texana*: *Alexander 1318* (NMC, OC); *Parthenium incanum; Porophyllum scoparium*; *Sartwellia flaveriae*; *Sidneya tenuifolia*; *Thelesperma megapotamicum*; *Thymophylla acerosa* (DC.) Strother.

Boraginaceae: *Tiquilia hispidissima*: *Alexander 1317* (NMC, OC).

Brassicaceae: *Nerisyrenia linearifolia* (S. Watson) Greene: *Alexander 1319* (NMC, OC).

Cactaceae: *Echinocereus dasyacanthus*; *Opuntia phaeacantha*.

Ephedraceae: *Ephedra aspera*.

Euphorbiaceae: *Chamaesyce fendleri*; *Croton dioicus*.

Fabaceae: *Dalea wrightii* A. Gray.

Fouquieriaceae: *Fouquieria splendens*.

Lamiaceae: *Salvia lycioides* A. Gray: *Alexander 1315* (NMC).

Loasaceae: *Cevallia sinuata; Mentzelia humilis* (A. Gray) J. Darl. var. *humilis*: *Alexander 1321* (NMC, OC).

Nyctaginaceae: *Acleisanthes lanceolata: Alexander 1316* (NMC, OC); *Allionia incarnata* var. *incarnata*.

Oleaceae: *Menodora scabra*.

Onagraceae: *Oenothera suffrutescens*.

Poaceae: *Bouteloua curtipendula* Torr.; *Enneapogon desvauxii; Muhlenbergia porteri* Scribn. ex Beal; *Sporobolus nealleyi*: *Alexander 1320* (NMC, OC); *Tridens muticus* var. *muticus*.

Pteridaceae: *Astrolepis cochisensis* subsp. *chihuahuensis*.

Rosaceae: *Fallugia paradoxa*.

Rubiaceae: *Hedyotis nigricans* var. *nigricans*.

Verbenaceae: *Aloysia wrightii*.

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REFERENCES

Allred, K.W. & R.D. Ivey. 2012. Flora Neomexicana III: An illustrated identification manual. Published by the authors at http://lulu.com.

Al-Shehbaz, I.A. 2012. A generic and tribal synopsis of the Brassicaceae (Cruciferae). Taxon 61(5): 931–954.

Anderson, R.Y. & W.E. Dean. 1995. Filling the Delaware Basin: Hydrologic and climatic controls on the Upper Permian Castile Formation varved evaporite. In: The Permian of Northern Pangea, Volume 2: Sedimentary basins and economic resources. P.A. Scholle, T.M. Peryt, & D.S. Ulmer-Scholle, eds. Springer Berlin Heidelberg, Berlin, Germany. Pp. 61–78.

APG III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. J. Linn. Soc. 161:105–121.

Bacon, J.D. 1978. Taxonomy of *Nerisyrenia* (Cruciferae). Rhodora 80(822):159–227.

Boyd, D.W. 1958. Permian sedimentary facies, central Guadalupe Mountains, New Mexico. State Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico, U.S.A.

Damschen, E.I., S. Harrison, D.D. Ackerley, B.M. Fernandez-Going, & B.L. Anacker. 2012. Endemic plant communities on special soils: early victims or hardy survivors of climate change? J. Ecol. 100:1122–1130.

Elias, S.A. & T.R. Van Devender. 1992. Insect fossil evidence of late Quaternary environments in the northern Chihuahuan Desert of Texas and New Mexico: Comparisons with the paleobotanical record. S.W. Naturalist 37:101–116.

Escudero, A., S. Palacio, F.T. Maestre, & A.L. Luzuriaga. 2014. Plant life on gypsum: a review of its multiple facets. Biol. Reviews: Early View. DOI: 10.1111/brv.12092

King, P.B. 1948. Geology of the southern Guadalupe Mountains. United States Geological Survey, Professional Paper 215. http://www.nps.gov/history/history/online_books/gumo/215/index.htm

Moore, M.J. & R.K. Jansen. 2007. Origins and biogeography of gypsophily in the Chihuahuan Desert plant group *Tiquilia* subg. *Eddya* (Boraginaceae). Syst. Bot. 32: 392–414.

Moore, M.J., J.F. Mota, N.A. Douglas, H. Flores Olvera, & H. Ochoterena. 2014. The ecology, assembly, and evolution of gypsophile floras. In: Plant ecology and evolution in harsh environments. N. Rajakaruna, R. Boyd, & T. Harris, eds. Nova Science Publishers, Hauppauge, New York, U. S. A. Pp. 97–128.

New Mexico Rare Plant Technical Council. 1999–2012. New Mexico rare plants. Albuquerque, New Mexico, U.S.A. http://nmrareplants.unm.edu (Latest update: 30 Mar 2012).

Powell, A.M. & B.L. Turner. 1977. Aspects of the plant biology of the gypsum outcrops of the Chihuahuan Desert. In: Transactions of the symposium on the biological resources of the Chihuahuan Desert region, United States and Mexico, Sul Ross State University, Alpine, Texas, 17–18 October 1974. R.H. Wauer & D.H. Riskind, eds. National Park Service Transactions and Proceedings Series, Number 3. U.S. Department of the Interior, Washington, DC, U.S.A. Pp. 315–325.

Poole, J.M., W.R. Carr, D.M. Price, & J.R. Singhurst. 2007. Rare plants of Texas: A field guide. Texas Parks and Wildlife Department, Austin, Texas, U.S.A.

Rollins, R.C. 1993. The Cruciferae of Continental North America. Stanford University Press, Stanford, California, U.S.A.

Scholle, P.A. 2003. Geologic map of New Mexico, scale 1:500,000. New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico, U.S.A.

SEINet (Southwest Environmental Information Network). 2009–2013. http://swbiodiversity.org/seinet/index.php (Accessed Sep–Nov 2013).

Spellenberg, R.W. & T. Wootten. 1999. Vascular plants on a gypsum outcrop in southern New Mexico: A listing, a new variety and taxonomic realignments in the *Anulocaulis leiosolenus* complex (Nyctaginaceae), and a new variety of *Mentzelia humilis* (Loasaceae). Sida 18(4):987–999.

Thiers, B. 1997–2013. Index Herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden, New York, New York, U.S.A. http://sweetgum.nybg.org/ih/ (Accessed Nov 2013).

Turner, B.L. 1993. New species and combinations in *Nerisyrenia* (Brassicaceae) of Mexico. Phytologia 75:231–234.

Van Devender, T.R. 1990. Late Quaternary vegetation and climate of the Chihuahuan Desert, United States and Mexico. In: Packrat middens: The last 40,000 years of biotic change. J.L. Betancourt, T.R. Van Devender, & P.S. Martin, eds. University of Arizona Press, Tucson, Arizona, U.S.A. Pp. 104–133.

Weber, R.H. & F.E. Kottlowski. 1959. Gypsum resources of New Mexico. State Bureau of Mines and Mineral Resources Bulletin 68. New Mexico Institute of Mining and Technology, Socorro, New Mexico, U.S.A.