

**Comparison of Plant Species and Soil Traits at Sites Where *Physaria ludoviciana*
(Silvery Bladderpod) is Present or Absent in Three States**

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PROJECT OBJECTIVES

The overall goal of this research is to understand biogeographical and environmental factors that may explain why *Physaria ludoviciana* is present in some sand prairies but absent from the biological composition in others. For this project, areas where *P. ludoviciana* is growing will be compared to nearby or parallel areas where it is absent from the community structure in three different states (IL, MN, and NE). The specific objectives are to compare:

- a) Plant species composition, and
- b) Soil traits (texture, calcium, magnesium, manganese, zinc, potassium, boron, copper, iron, sodium, phosphorus, sulfur, cation exchange capacity, organic matter, buffer pH and soil pH).

INTRODUCTION

Physaria ludoviciana (Nuttal) O'Kane & Al-Shehbaz (silvery bladderpod; Brassicaceae) is distributed from Illinois north to Wisconsin, west to Montana, south to Nevada, and east to Illinois. This plant was formerly known as *Lesquerella ludoviciana* until 2002 when Al-Shehbaz and O'Kane renamed species in the genus *Lesquerella* into the genus *Physaria* based on DNA sequencing (Al-Shehbaz and O'Kane, 2002). It is

listed as an endangered plant in Illinois (Herkert and Ebinger, 2002; Illinois Department of Natural Resources, 2006), Minnesota (Minnesota Department of Natural Resources, 2007) and Wisconsin (Wisconsin Department of Natural Resources, 2004). Populations are scattered and disjunct. Other sites appearing similar to those with *P. ludoviciana* occur nearby, but *P. ludoviciana* is absent.

Parameters that influence why it occurs in some areas and not others are not understood. In previous surveys of *P. ludoviciana* populations throughout its range, eight associated plant species were found in all locations, although these surveys were limited to obvious, dominant species (Claerbout, 2003). In a detailed survey done by McClain *et al.* (2005) in Illinois at the H.A. Gleason Nature Preserve (HAGNP), only two similar species were found in areas where *P. ludoviciana* was present and absent. *P. ludoviciana* resided on nutrient poor soils in highly disturbed areas with well drained sand or gravel soils having high pH (~8), low organic matter (~2%), and high calcium (~9%) (Claerbout, 2003). Also at HAGNP, soils in areas with *P. ludoviciana* were higher in pH, NO₃-N, Ca, Mg and micronutrients than areas without *P. ludoviciana* (Coons *et al.*, 2005). None of these studies compared plant species or soils for sites with and without *P. ludoviciana* in locations beyond HAGNP in Illinois or beyond Illinois. Hence, the primary focus of this proposal was to survey plant species and to compare soils in parallel areas (within close proximity of each other) where *P. ludoviciana* is present or absent in three states. These comparisons may help to understand factors that explain why *P. ludoviciana* is present in some sand prairies but absent from others. This study will increase our understanding about survival and distribution of *P. ludoviciana*, which will aid long-term management of sand prairies to protect rare species.

The overall goal of this research was to understand biogeographical and environmental factors that may explain why *Physaria ludoviciana* is present in some sand prairies but absent from the biological composition in others. For this project, areas where *P. ludoviciana* is growing will be compared to nearby or parallel areas where it is absent from the community structure in three different states (IL, MN, and NE). The specific objectives are to compare:

- a) Plant species composition, and
- b) Soil traits (texture, calcium, magnesium, manganese, zinc, potassium, boron, copper, iron, sodium, phosphorus, cation exchange capacity, organic matter, buffer pH and soil pH).

MATERIALS AND METHODS

Site Selection

Illinois, Minnesota, and Nebraska populations were chosen as study sites. Illinois and Minnesota both have populations that are classified as endangered. Nebraska is a population that is not on the edge of the range, yet is near Illinois and Minnesota. In Illinois, the only population is at the Henry Allan Gleason Nature Preserve in Mason County. In Minnesota, the only populations are found in Goodhue County at the Hay Creek Management Unit and the city of Redwing. The southwest side of the bluff in the Hay Creek Management Unit was surveyed. In Nebraska, *P. ludoviciana* can be found scattered throughout the state. The population surveyed was on the campus of Chadron State College in Dawes County. In each state, one study site was where the population occurs, and another was in a similar area where no *P. ludoviciana* is found. The sites without *P. ludoviciana* were the Sand Prairie-Scrub Oak Nature Preserve in Mason

County, Illinois; on the southeast side of the Hay Creek Management Unit in Goodhue County, Minnesota; and at the Oglala National Grassland, Hudson Meng Bison Bonehead in Sioux County, Nebraska. All three states were visited in summer 2007.

Plant Species Composition

To survey associated plant species, quadrats (0.25m²) were placed at every meter located directly adjacent on alternating sides of a 45 meter transect. In each quadrat associated plant species were identified and estimated for percent cover using the Daubenmire canopy cover class system (Daubenmire, 1959) as modified by Cox (1996) (class 1 = 0 to 1%; class 2 = 1 to 5%; class 3 = 5 to 25%; class 4 = 25 to 50%; class 5 = 50 to 75%; class 6 = 75 to 100%). Nomenclature was according to Brodo *et al.* (2001), Kaul *et al.* (2006) and Mohlenbrock (2002). Voucher specimens were collected and prepared for deposit in the Eastern Illinois University Stover-Ebinger Herbarium. Frequency (% of quadrats where each species present), average cover (% of area covered using midpoint of class as value for each quadrat), relative frequency (% frequency for each species/sum of % frequency for all species X 100), relative cover (% average cover for each species/sum of % average cover for all species X 100) and importance value (sum of relative frequency plus relative cover) were determined for each species at each location. In addition, voucher specimens were collected for species found in each area, but not occurring in surveyed quadrats.

Soil Traits

Using a soil corer, 18 soil cores from the top 5-10 cm of soil were taken randomly throughout each site. Cores were combined for each site, and a 450 g subsample was sent to A & L Analytical Laboratories, Inc. (Memphis TN) for a analysis of fertility (calcium,

magnesium, manganese, zinc, potassium, boron, copper, iron, sodium, phosphorus, sulfur, cation exchange capacity, organic matter, buffer pH and soil pH) and texture.

Comparisons were made to determine differences and similarities between sites with and without *P. ludoviciana* using a Principle Component Analysis (PCA).

RESULTS

Plant Species Composition

The top three species at each site were identified based on their importance values. The top three plant species at the site in Illinois where *P. ludoviciana* was present were *Ambrosia psilostachya* DC. (western ragweed), *Eragrostis trichodes* (Nutt.) A.W. Wood (sand lovegrass), and *Schizachyrium scoparium* (Michx.) Nash (little bluestem) (Table 1). At the site in Illinois where *P. ludoviciana* was absent the top three species were *Schizachyrium scoparium* (Michx.) Nash (little bluestem), *Dichanthelium villosissimum* (Nash) Freckm (hairy panic grass), and *Opuntia humifusa* (Raf.) Raf. (eastern prickly-pear) (Table 2). The site in Minnesota with *P. ludoviciana* had *Bouteloua curtipendula* (Michx.) Torr. (sideoats grama), *Schizachyrium scoparium* (Michx.) Nash (little bluestem) and *Andropogon gerardii* Vitman (big bluestem) as the top three species (Table 3). The Minnesota site with *P. ludoviciana* absent had *Schizachyrium scoparium* (Michx.) Nash (little bluestem), *Bouteloua* sp. Lag (grama grass), and *Andropogon gerardii* Vitman (big bluestem) as the top 3 species (Table 4). In Nebraska at the site with *P. ludoviciana* present, *Carex filifolia* Nutt. (threadleaf sedge), *Heterostipa comata* (Trin. & Rupr.) Barkworth. (needle grass) and *Vulpia octoflora* (Walter) Rydb. (sixweeks-fescue) were the top 3 species (Table 5). *Heterostipa comata* (Trin. & Rupr.) Barkworth. (needle grass), *Carex filifolia* Nutt. (threadleaf sedge)

and *Carex eleocharis* L.H. Bailey (sedge) as the top 3 species at the site without *P. ludoviciana* (Table 6). All of the plants found are typical grasses and forbs common in sand prairies.

More different species were at sites where *P. ludoviciana* was present than at those where absent (Table 7). The greatest number of species was in Nebraska and the least were in Illinois. In Nebraska very little bare ground was observed and sandy outcrops were fewer.

Nonvascular plants were found in two of the sites. At the Sand Prairie-Scrub Oak (Illinois site with *P. ludoviciana* absent), *Cladina rangiferina* (L.) Nyl (reindeer lichen), *Cladonia cristatella* Tuck. (British soldier lichen), and an unknown moss were found. At the Minnesota site with *P. ludoviciana* present, an unknown moss was present in the quadrats. Also, some other vascular plant species were found in the area surveyed, but not in the quadrats. These species were typically forbs and grasses (Table 8).

Soil Traits

Table 9 shows that soils with *P. ludoviciana* were either sand or loamy sand, whereas soil without *P. ludoviciana* were either sand, loamy sand, or sandy loam. Sites with *P. ludoviciana* had an average pH of 7.9 whereas sites without had an average pH of 6.9. Percent organic matter was lower in sites with *P. ludoviciana*, at 0.6% and 1.3% in Minnesota and Nebraska respectively, compared to sites without *P. ludoviciana* at 3.3% and 2.9%, in Minnesota and Nebraska respectively; except in Illinois where it was about the same (1.2 to 1.1%) at both sites. Trends for macronutrients (phosphorus, potassium, calcium, magnesium, and sulfur) and micronutrients (boron, copper, iron, manganese, zinc and sodium) in soils were inconsistent when *P. ludoviciana* was present or absent.

Figure 1 shows a Principle Component Analysis (PCA) for soil parameters. For soil parameters measured, this analysis does not simply compare how one parameter varies from site to site, but rather how the suite of parameters changes in the different sites. The PCA combines parameters into a Principle Component Axis, which retained 76% of the variation. Less variability occurred in areas with *P. ludoviciana* present compared to areas without *P. ludoviciana*. Therefore a greater difference occurred between the presence and absence sites of *P. ludoviciana* than between states. No one soil characteristic made the solid difference rather it was a collection of variables that defined the soil.

DISCUSSION

Populations were surveyed in three different states where *P. ludoviciana* was present and where *P. ludoviciana* was absent. In Claerbout (2003) four states where *P. ludoviciana* was present were surveyed, but only dominant plant species were noted which limited conclusions that could be drawn because differences in the number of associated plant species in each state could be due to the partial identification. McClain *et al.* (2005) found typical associated plant species in areas with and without *P. ludoviciana* to be typical sand prairie forbs and grasses of active, partially stabilized and stabilized sand prairie blow outs. In our study of associated plant species we see typical grass species as being dominant such as representatives from the Cyperaceae and Poaceae families. More species were found in sites where *P. ludoviciana* was present than where absent. Nebraska had a greater number of species than Illinois or Minnesota. In Illinois and Minnesota, the top three species consistently included *Schizachyrium scoparium* (Michx.) Nash (little bluestem) regardless of whether *P. ludoviciana* was present or

absent. In Minnesota, *Andropogon gerardii* Vitman (big bluestem) was in the top three species at both sites with and without *P. ludoviciana*. In Nebraska, two of the top three species were the same at sites with and without *P. ludoviciana*, i.e. *Carex filifolia* Nutt. (threadleaf sedge) and *Heterostipa comata* (Trin. & Rupr.) Barkworth. (needle grass). Hence, associated species did not show clear differences at sites with and without *P. ludoviciana*.

As for soil characteristics Claerbout (2003) showed that areas with *P. ludoviciana* prefer a sandy habitat and blowing sand with low soil fertility and low water holding capacity as well as high pH (~8), low organic matter (~2%), and high calcium (~9%). Coons, *et al.* (2005) showed that areas sampled where *P. ludoviciana* was present had higher calcium, magnesium, manganese, zinc, soluble salts, nitrate-nitrogen and cation exchange capacity but lower phosphorus and sulfur than areas without *P. ludoviciana*. Our soil data showed differences in all soil characteristics between the presence and absence of *P. ludoviciana* rather than between the states.

Our study and others by Claerbout (2003) and Coons *et al.* (2005) suggest that the ability of *P. ludoviciana* to survive depends more on its ability to arrive and establish in an area than it does on the associated plant species and soil characteristics. The ability of *P. ludoviciana* to survive in harsh growing conditions was the most striking similarity between the populations throughout the surveyed sites. Associated plant species were consistent throughout the range of *P. ludoviciana* and were identified as typical grassland and dry sand prairie forbs and grasses. Although soil characteristics showed differences, areas with and without *P. ludoviciana* did not have a consistent characteristic that defined them. Therefore *P. ludoviciana* could be an early succession plant that is able to

establish in harsh conditions. The disjunct populations could be a result of poor seed dispersal and therefore instead of associated plant species or soil characteristics being the limiting factor, establishment, population viability and seed dispersal could be the limiting factors.

Table 1: Frequency (%), average cover (% of total area), relative frequency, relative cover and importance values for vascular plant species at the Henry Allan Gleason Nature Preserve in Mason County, Illinois where *Physaria ludoviciana* was present.

Species	Frequency	Average Cover	Relative Frequency	Relative Cover	Importance Value
<i>Ambrosia psilostachya</i> DC. (western ragweed)	91	8.70	17.04	22.04	39.08
<i>Asclepias verticillata</i> L. (whorled milkweed)	13	0.12	2.43	0.30	2.73
<i>Asclepias viridiflora</i> Raf. (green milkweed)	4	0.40	0.75	1.01	1.76
<i>Aster oblongifolius</i> Nutt. (aromatic aster)	7	0.03	1.31	0.08	1.39
<i>Bouteloua hirsuta</i> Lag. (hairy grama)	64	3.51	11.99	8.89	20.88
<i>Calamovilfa longifolia</i> (Hook.) Scribn. (prairie sandreed)	18	1.01	3.37	2.56	5.93
<i>Chamaecrista fasciculata</i> (Michx.) Greene (showy partridge pea)	18	0.37	3.37	0.94	4.31
<i>Chamaesyce geyeri</i> (Engelm.) Small. (geyer's spurge)*	4	0.02	0.75	0.05	0.80
<i>Commelina erecta</i> L. (dayflower)	16	0.51	3.00	1.29	4.29
<i>Conyza canadensis</i> (L.) Cronquist (horseweed)	16	0.73	3.00	1.85	4.85
<i>Coreopsis lanceolata</i> L. (lance-leaf tickseed)	4	0.08	0.75	0.20	0.95
<i>Eragrostis trichodes</i> (Nutt.) A.W. Wood (sand lovegrass)	80	9.43	14.98	23.89	38.87
<i>Euphorbia corollata</i> L. (flowering spurge)	9	0.48	1.69	1.22	2.91
<i>Heterotheca camporum</i> (Greene) Shinnars	13	1.14	2.43	2.89	5.32
<i>Koeleria macrantha</i> (Ledeb.) Schult. (Junegrass)	2	0.01	0.37	0.03	0.40
<i>Lepidium</i> sp. L. (pepper-grass, hoary cress)	2	0.07	0.37	0.18	0.55
<i>Lespedeza capitata</i> Michx. (round-head bush clover)	9	0.16	1.69	0.41	2.10
<i>Liatris aspera</i> Michx. (rough blazing star)	20	1.23	3.75	3.12	6.87
<i>Lithospermum croceum</i> Fern. (hairy puccoon)*	2	0.33	0.37	0.84	1.21
<i>Oenothera rhombipetala</i> Nutt. Ex Torr. & A. Gray (fourpoint evening-primrose)	7	0.03	1.31	0.08	1.39
<i>Opuntia humifusa</i> (Raf.) Raf. (eastern prickly-pear, bigroot prickly-pear, western prickly-pear)	24	2.17	4.49	5.50	9.99
<i>Phlox bifida</i> Beck. (cleft phlox)*	20	0.32	3.75	0.81	4.56
<i>Physaria ludoviciana</i> (Nutt.) O'Kane & Al-Shehbaz (silvery bladderpod)	27	0.73	5.06	1.85	6.91
<i>Salsola tragus</i> L. (Russian thistle)*	2	0.01	0.37	0.03	0.40
<i>Schizachyrium scoparium</i> (Michx.) Nash (little bluestem)	60	6.49	11.24	16.44	27.68
<i>Strophostyles helvola</i> (L.) Elliott (wild bean)	2	1.39	0.37	3.52	3.89
Totals		39.47	100	100	200
Bare ground and litter		64.30			

Nomenclature used for vascular plants was Kaul *et al.* 2006 unless denoted by * when nomenclature was Mohlenbrock, 2002.

Table 2: Frequency (%), average cover (% of total area), relative frequency, relative cover and importance values for vascular plant species at the Sand Prairie-Scrub Oak Nature Preserve in Mason County, Illinois where *Physaria ludoviciana* was absent.

Species	Frequency	Average Cover	Relative Frequency	Relative Cover	Importance Value
<i>Ambrosia psilostachya</i> DC. (western ragweed)	29	0.86	5.81	3.08	8.89
<i>Aristida tuberculosa</i> Nutt. (needle grass)*	51	0.26	10.22	0.93	11.15
<i>Bouteloua hirsuta</i> Lag. (hairy grama)	2	0.01	0.40	0.04	0.44
<i>Calamovilfa longifolia</i> (Hook.) Scribn. (prairie sandreed)	16	0.30	3.21	1.08	4.29
<i>Carex muhlenbergii</i> Schk. (Muhlenberg's sedge)	22	0.33	4.41	1.18	5.59
<i>Carex</i> sp. L. unknown B (sedge)	2	0.01	0.40	0.04	0.44
<i>Commelina erecta</i> L. (dayflower)	20	1.88	4.01	6.74	10.75
<i>Conyza canadensis</i> (L.) Cronquist (horseweed)	73	1.73	14.63	6.20	20.83
<i>Crotonopsis linearis</i> Michx. (rushfoil)*	24	0.18	4.81	0.65	5.46
<i>Cyperus schweinitzii</i> Torr. (Schweinitz's flatsedge)	13	0.07	2.61	0.25	2.86
<i>Dichanthelium villosissimum</i> (Nash) Freckm. (hairy panic grass)*	51	4.78	10.22	17.14	27.36
<i>Eragrostis spectabilis</i> (Pursh) Steud. (purple lovegrass)	2	0.07	0.40	0.25	0.65
<i>Eragrostis trichodes</i> (Nutt.) A.W. Wood (sand lovegrass)	11	0.38	2.20	1.36	3.56
<i>Krigia virginica</i> (L.) Willd. (dwarf dandelion)*	31	0.27	6.21	0.97	7.18
<i>Lespedeza capitata</i> Michx. (round-head bush clover)	7	0.41	1.40	1.47	2.87
<i>Liatris aspera</i> Michx. (rough blazing star)	2	0.33	0.40	1.18	1.58
<i>Lithospermum croceum</i> Fern. (hairy puccoon)*	2	0.01	0.40	0.04	0.44
<i>Oenothera rhombipetala</i> Nutt. Ex Torr. & A. Gray (fourpoint evening-primrose)	4	0.08	0.80	0.29	1.09
<i>Opuntia humifusa</i> (Raf.) Raf. (eastern prickly-pear)	33	5.27	6.61	18.90	25.51
<i>Paspalum pubiflorum</i> Rupr. (bead grass)	33	0.50	6.61	1.79	8.40
<i>Schizachyrium scoparium</i> (Michx.) Nash (little bluestem)	67	9.49	13.43	34.03	47.46
<i>Tradescantia ohiensis</i> Raf. (spiderwort)	4	0.67	0.80	2.40	3.20
Totals		27.89	100	100	200
Bare ground and litter		47.44			

Nomenclature used for vascular plants was Kaul *et al.* 2006 unless denoted by * when nomenclature was Mohlenbrock, 2002.

Table 3: Frequency (%), average cover (% of total area), relative frequency, relative cover and importance values for vascular plant species at the Hay Creek Management Unit in Goodhue County, Minnesota where *Physaria ludoviciana* was present.

Species	Frequency	Average Cover	Relative Frequency	Relative Cover	Importance Value
<i>Ambrosia psilostachya</i> DC. (western ragweed)	70	1.02	11.67	2.90	14.57
<i>Andropogon gerardii</i> Vitman (big bluestem)	20	5.52	3.33	15.67	19.00
<i>Arabis lyrata</i> L. (sand cress)*	17	0.25	2.83	0.71	3.54
<i>Artemisia campestris</i> L. (field sagewort, Great Plains wormwood)	40	0.70	6.67	1.99	8.66
<i>Aster sericeus</i> Vent. (silky aster)	3	0.10	0.50	0.28	0.78
<i>Bouteloua curtipendula</i> (Michx.) Torr. (sideoats grama)	80	11.45	13.33	32.51	45.84
<i>Bouteloua hirsuta</i> Lag. (hairy grama)	7	0.52	1.17	1.48	2.65
<i>Calamovilfa longifolia</i> (Hook.) Scribn (prairie sandreed)	27	0.55	4.50	1.56	6.06
<i>Carex tonsa</i> (Fern.) Bicknell	10	0.13	1.67	0.37	2.04
<i>Castilleja coccinea</i> (L.) Spreng (Indian paintbrush)*	3	0.50	0.50	1.42	1.92
<i>Coreopsis palmata</i> Nutt. (finger coreopsis)	7	0.03	1.17	0.09	1.26
<i>Euphorbia corollata</i> L. (flowering spurge)	10	0.05	1.67	0.14	1.81
<i>Hedeoma hispida</i> Pursh (rough false pennyroyal)	20	0.10	3.33	0.28	3.61
<i>Helianthus divaricatus</i> L. (woodland sunflower)*	30	0.65	5.00	1.85	6.85
<i>Lepidium densiflorum</i> Schrader (pepper-grass)	20	0.10	3.33	0.28	3.61
<i>Lithospermum canescens</i> (Michx.) Lehm. (hoary puccoon)	10	0.05	1.67	0.14	1.81
<i>Lithospermum incisum</i> Lehm (fringed puccoon)	13	0.07	2.17	0.20	2.37
<i>Panicum leibergii</i> (Vasey) Scribn (leiberg panicum)	20	0.83	3.33	2.36	5.69
<i>Panicum linearifolium</i> Scribn. ex Britton (slimleaf panicum)	27	0.63	4.50	1.79	6.29
<i>Physaria ludoviciana</i> (Nutt.) O'Kane & Al-Shehbaz (silvery bladderpod)	23	0.28	3.83	0.80	4.63
<i>Prunus susquehanae</i> Willd (sand cherry)*	3	0.02	0.50	0.06	0.56
<i>Quercus</i> sp. L. (oak)	3	0.02	0.50	0.06	0.56
<i>Schizachyrium scoparium</i> (Michx.) Nash (little bluestem)	57	7.97	9.50	22.63	32.13
<i>Senecio plattensis</i> Nutt. (prairie ragwort)	10	0.05	1.67	0.14	1.81
<i>Silene antirrhina</i> L. (sleepy catchfly)	3	0.02	0.50	0.06	0.56
<i>Solidago nemoralis</i> Aiton subsp. <i>Decemflora</i> (DC.) Brammall ex Semple (gray goldenrod)	20	1.32	3.33	3.75	7.08
<i>Sporobolus cryptandrus</i> (Torr.) A. Gray (sand dropseed)	10	0.22	1.67	0.62	2.29
<i>Sporobolus heterolepis</i> (A. Gray) A Gray (prairie dropseed)	7	1.35	1.17	3.83	5.00
<i>Tradescantia ohiensis</i> Raf. (spiderwort)	23	0.60	3.83	1.70	5.53
unknown forb B (possible Hairbell)	7	0.12	1.17	0.34	1.51
Totals		35.22	100	100	200
Bare ground and litter		57.8			

Nomenclature used for vascular plants was Kaul *et al.* 2006 unless denoted by * when nomenclature was Mohlenbrock, 2002

Table 4: Frequency (%), average cover (% of total area), relative frequency, relative cover and importance values for vascular plant species at the Hay Creek Management Unit in Goodhue County, Minnesota where *Physaria ludoviciana* was absent.

Species	Frequency	Average Cover	Relative Frequency	Relative Cover	Importance Value
<i>Amorpha canescens</i> Nutt. ex Pursh (leadplant)	23	1.73	3.30	3.59	6.89
<i>Andropogon gerardii</i> Vitman (big bluestem)	50	6.52	7.18	13.53	20.71
<i>Arabis lyrata</i> L. (sand cress) *	3	0.10	0.43	0.21	0.64
<i>Asclepias viridiflora</i> Raf. (green milkweed)	13	0.23	1.87	0.48	2.35
<i>Aster oolentangiensis</i> Riddle (azure aster)	3	0.10	0.43	0.21	0.64
<i>Aster sericeus</i> Vent. (silky aster)	10	0.22	1.44	0.46	1.90
<i>Bouteloua</i> sp. Lag (grama grass)	87	7.60	12.50	15.77	28.27
<i>Carex</i> sp L. unknown A (sedge)	30	1.53	4.31	3.17	7.48
<i>Carex tonsa</i> (Fern.) Bicknell	57	2.48	8.19	5.15	13.34
<i>Castilleja sessiliflora</i> Pursh (dwarf Indian paintbrush)	17	0.73	2.44	1.51	3.95
<i>Comandra umbellata</i> (L.) Nutt. (false/bastard toadflax)	10	0.22	1.44	0.46	1.90
<i>Dalea purpurea</i> Venten (purple prairie-clover)	10	0.13	1.44	0.27	1.71
<i>Euphorbia corollata</i> L. (flowering spurge)	40	1.82	5.75	3.78	9.53
<i>Liatris</i> sp. Gaertn ex. Schreb. (gayfeather, blazing star)	50	2.85	7.18	5.91	13.09
<i>Linum sulcatum</i> Riddell (grooved flax)	7	0.03	1.01	0.06	1.07
<i>Lithospermum canescens</i> (Michx.) Lehm. (hoary puccoon)	3	0.02	0.43	0.04	0.47
<i>Lobelia</i> sp. L. (lobelia, cardinal flower)	17	0.33	2.44	0.68	3.12
<i>Panicum linearifolium</i> Scribn. ex Britton (slimleaf panicum)	23	1.68	3.30	3.49	6.79
<i>Rhus glabra</i> L. (smooth sumac)	13	0.80	1.87	1.66	3.53
<i>Schizachyrium scoparium</i> (Michx.) Nash (little bluestem)	73	13.02	10.49	27.02	37.51
<i>Senecio plattensis</i> Nutt. (prairie ragwort)	37	0.27	5.32	0.56	5.88
<i>Sisyrinchium atlanticum</i> Bickn (blue-eyed grass)*	33	0.17	4.74	0.35	5.09
<i>Solidago nemoralis</i> Aiton subsp. <i>Decemflora</i> (DC.) Bramm ex Semple (gray goldenrod)	33	0.17	4.74	0.35	5.09
<i>Sporobolus heterolepsis</i> (A. Gray) A. Gray (prairie dropseed)	27	4.97	3.88	10.31	14.19
unknown forb B (possibly Hairbell)	17	0.25	2.44	0.52	2.96
unknown grass A	3	0.10	0.43	0.21	0.64
<i>Viola pedatifida</i> G. Don (prairie violet)	7	0.12	1.01	0.25	1.26
Totals		48.19	100	100	200
Bare ground and litter		33.22			

Nomenclature used for vascular plants was Kaul *et al.* 2006 unless denoted by * when nomenclature was Mohlenbrock, 2002.

Table 5: Frequency (%), average cover (% of total area), relative frequency, relative cover and importance values for vascular plant species on the campus of Chadron State College in Dawes County, Nebraska where *Physaria ludoviciana* was present.

Species	Frequency	Average Cover	Relative Frequency	Relative Cover	Importance Value
<i>Andropogon hallii</i> (Hack.) J. Wipff (sand bluestem)	4	0.40	0.58	0.53	1.11
<i>Artemisia campestris</i> L. (field sagewort, Great Plains wormwood)	7	0.09	1.02	0.12	1.14
<i>Artemisia filifolia</i> Torr. (sandsage)	9	0.42	1.31	0.55	1.86
<i>Artemisia frigida</i> Willd. (fringed sage, prairie sagwort)	4	0.08	0.58	0.11	0.69
<i>Asclepias pumila</i> (A. Gray) Vail (plains milkweed)	9	0.53	1.31	0.70	2.01
<i>Asclepias viridiflora</i> Raf. (green milkweed)	2	0.01	0.29	0.01	0.30
<i>Aster falcatus</i> Lindl. (western heath aster)	9	1.01	1.31	1.33	2.64
<i>Artemisia campestris</i> L. (field sagewort, Great Plains wormwood)	7	0.09	1.02	0.12	1.14
<i>Bouteloua gracilis</i> (Wild. ex Kunth) Lag. ex Griffiths (blue grama)	40	1.99	5.81	2.62	8.43
<i>Bromus japonicus</i> Thunb. ex Murr. (Japanese brome, hairy chess)	38	3.26	5.52	4.29	9.81
<i>Bromus squarrosus</i> L. (one-way brome)	2	0.07	0.29	0.09	0.38
<i>Bromus tectorum</i> L. (downy brome, cheat, cheatgrass)	2	0.01	0.29	0.01	0.30
<i>Calamovilfa longifolia</i> (Hook.) Scribn (prairie sandreed)	16	1.66	2.33	2.18	4.51
<i>Calylophus serrulatus</i> (Nutt.) P.H. Raven (plains evening-primrose)	2	0.01	0.29	0.01	0.30
<i>Carex eleocharis</i> L.H. Bailey (sedge)	2	0.01	0.29	0.01	0.30
<i>Carex filifolia</i> Nutt. (threadleaf sedge)	98	26.99	14.24	35.52	49.76
<i>Carex heliophila</i> Mack. (sedge)	4	0.13	0.58	0.17	0.75
<i>Comandra umbellata</i> (L.) Nutt. (false/bastard toadflax)	11	0.11	1.60	0.14	1.74
<i>Conyza canadensis</i> L. Conquist (horseweed, mare's-tail)	9	0.04	1.31	0.05	1.36
<i>Eriogonum annuum</i> Nutt. (annual wild-buckwheat)	2	0.01	0.29	0.01	0.30
<i>Erysimum asperum</i> (Nutt.) DC. (western wallflower)	2	0.01	0.29	0.01	0.30
<i>Gaura coccinea</i> Pursh (scarlet gaura, scarlet bee-blossom)	22	0.17	3.20	0.22	3.42
<i>Heterostipa comata</i> (Trin. & Rupr.) Barkworth. (needle grass)*	100	21.03	14.53	27.67	42.20
<i>Koeleria macrantha</i> (Ledeb.) Schult (Junegrass)	22	1.73	3.20	2.28	5.48
<i>Lepidium densiflorum</i> Schrader (pepper-grass, hoary grass)	16	0.08	2.33	0.11	2.44
<i>Leucocrinum montanum</i> Nutt. ex A. Gray (star lily)	7	0.09	1.02	0.12	1.14
<i>Liatris punctata</i> Hook. (gayfeather, blazing-star)	9	0.10	1.31	0.13	1.44
<i>Lithospermum</i> sp. L. (puccoon, gromwell)	2	0.01	0.29	0.01	0.30
<i>Lygodesmia juncea</i> (Pursh) D. Don ex Hook (skeletonweed)	13	0.07	1.89	0.09	1.98
<i>Medicago lupulina</i> L. (black medic)	2	0.01	0.29	0.01	0.30
<i>Opuntia fragilis</i> (Nutt.) Haw. (little prickly-pear)	7	0.03	1.02	0.04	1.06
<i>Penstemon angustifolius</i> Nutt. ex Pursh (narrowleaf beardtongue)	2	0.01	0.29	0.01	0.30

<i>Phlox andicola</i> E.E. Nelson (plains phlox)	11	0.06	1.60	0.08	1.68
<i>Physaria ludoviciana</i> (Nutt.) O'Kane & Al-Shehbaz (silvery bladderpod)	4	0.13	0.58	0.17	0.75
<i>Plantago patagonica</i> Jacq. (woolly plantain)	4	0.02	0.58	0.03	0.61
<i>Poa secunda</i> J. Presl (candy bluegrass)	20	0.64	2.91	0.84	3.75
<i>Psoraleidum lanceolatum</i> (Pursh) Rydb. (lemon scurf pea, lance leaf scurf-pea)	4	0.02	0.58	0.03	0.61
<i>Psoraleidum tenuiflorum</i> (Pursh) Rydb (slender- flowered scurf-pea, wild alfalfa)	4	0.02	0.58	0.03	0.61
<i>Tradescantia occidentalis</i> (Britton) Smyth	20	0.16	2.91	0.21	3.12
<i>Tragopogon dubius</i> Scop (goat's beard, western salsify, Jonny-go-to-sleep-at noon)	11	0.28	1.60	0.37	1.97
<i>Vulpia octoflora</i> (Walter) Rydb. (sixweeks-fescue)	98	9.60	14.24	12.63	26.87
<i>Yucca glauca</i> Nutt. (yucca)	31	4.80	4.50	6.32	10.82
Totals		75.99	100	100	200

Nomenclature used for vascular plants was Kaul *et al.* 2006 unless denoted by * when nomenclature was Mohlenbrock, 2002.

Table 6: Frequency (%), average cover (% of total area), relative frequency, relative cover and importance values for vascular plant species at the Oglala National Grassland, Hudson Meng Bison Bonehead in Sioux County, Nebraska where *Physaria ludoviciana* was absent.

Species	Frequency	Average Cover	Relative Frequency	Relative Cover	Importance Value
<i>Andropogon hallii</i> (Hack.) J. Wipff (sand bluestem)	4	0.13	0.52	0.12	0.64
<i>Artemisia frigida</i> Willd. (fringed sage, prairie sagwort)	60	5.37	7.81	4.96	12.77
<i>Asclepias viridiflora</i> Raf. (green milkweed)	2	0.01	0.26	0.01	0.27
<i>Aster falcatus</i> Lindl. (western heath aster)	16	0.57	2.08	0.53	2.61
<i>Astragalus gilviflorus</i> E. Sheldon (plains orophaca)	2	0.01	0.26	0.01	0.27
<i>Bouteloua gracilis</i> (Wild. ex Kunth) Lag. ex Griffiths (blue grama)	33	1.16	4.30	1.07	5.37
<i>Bromus japonicus</i> Thunb. ex Murr. (Japanese brome, hairy chess)	69	3.16	8.98	2.92	11.90
<i>Carex eleocharis</i> L.H. Bailey (sedge)	49	11.99	6.38	11.07	17.45
<i>Carex fillifolia</i> Nutt. (threadleaf sedge)	76	19.91	9.90	18.38	28.28
<i>Carex heliophila</i> Mack. (sedge)	7	1.79	0.91	1.65	2.56
<i>Cirsium undulatum</i> (Nutt.) Spreng. (wavy-leaf thistle)	4	0.02	0.52	0.02	0.54
<i>Dalea purpurea</i> Venten (purple prairie-clover)	9	0.21	1.17	0.19	1.36
<i>Elymus lanceolatus</i> (Scribn. & J.G. Smith) Gould (wild-rye, wheatgrass)	51	8.41	6.64	7.76	14.40
<i>Elymus smithii</i> (Rydb.) Gould (western wheatgrass)	18	0.37	2.34	0.34	2.68
<i>Erigeron canus</i> A. Gray (hoary fleabane)	2	0.07	0.26	0.06	0.32
<i>Erysimum asperum</i> (Nutt.) DC. (western wallflower)	4	0.13	0.52	0.12	0.64
<i>Gaura coccinea</i> Pursh (scarlet gaura, scarlet bee-blossom)	16	0.13	2.08	0.12	2.20
<i>Heterostipa comata</i> (Trin. & Rupr.) Barkworth. (needle grass)*	84	30.74	10.94	28.37	39.31
<i>Koeleria macrantha</i> (Ledeb.) Schult (Junegrass)	47	2.89	6.12	2.67	8.79
Fabaceae	2	0.01	0.26	0.01	0.27
<i>Lepidium densiflorum</i> Schrader (pepper-grass)	11	0.06	1.43	0.06	1.49
<i>Leucocrinum montanum</i> Nutt. ex A. Gray (star lily)	7	0.09	0.91	0.08	0.99
<i>Liatris punctata</i> Hook. (gayfeather, blazing-star)	13	0.61	1.69	0.56	2.25
<i>Linum compactum</i> A. Nelson (bushy flax)	2	0.01	0.26	0.01	0.27
<i>Lithospermum incisum</i> Lehm. (fringed puccoon)	4	0.02	0.52	0.02	0.54
<i>Lupinus plattensis</i> S. Watson (Platte lupine)	29	2.10	3.78	1.94	5.72
<i>Oxytropis lambertii</i> Pursh (purple locoweed)	4	0.34	0.52	0.31	0.83
<i>Penstemon albidus</i> Nutt. (white beardtongue)	2	0.01	0.26	0.01	0.27
<i>Phlox andicola</i> E.E. Nelson (plains phlox)	33	1.42	4.30	1.31	5.61
<i>Plantago patagonica</i> Jacq. (woolly plantain)	9	0.04	1.17	0.04	1.21
<i>Poa pratensis</i> L. (Kentucky bluegrass)	2	0.01	0.26	0.01	0.27
<i>Psoralidium tenuiflorum</i> (Pursh) Rydb (slender-flowered scurf-pea, wild alfalfa)	7	0.09	0.91	0.08	0.99
<i>Schizachyrium scoparium</i> (Michx.) Nash (little bluestem)	36	9.78	4.69	9.03	13.72
<i>Tragopogon dubius</i> Scop. (goat's beard, western salsify, Johnny-go-to-sleep-at-noon)	4	0.08	0.52	0.07	0.59
<i>Vulpia octoflora</i> (Walter) Rydb. (sixweeks-fescue)	24	0.12	3.13	0.11	3.24
<i>Xanthium spinosum</i> L. (spiny cocklebur)	2	0.01	0.26	0.01	0.27
<i>Yucca glauca</i> Nutt. (yucca)	24	6.48	3.13	5.98	9.11

Totals	108.35	100	100	200
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Table 7: Total number of vascular species in sites with *Physaria ludoviciana* present or absent.

	Illinois	Minnesota	Nebraska
Present	26	30	42
Absent	22	27	37

Table 8: Associated plant species found in surveyed areas but not in quadrats.

Minnesota <i>P. ludoviciana</i> present	Minnesota <i>P. ludoviciana</i> absent
<i>Amorpha canescens</i> Nutt. ex Pursh (leadplant)	<i>Asclepias verticillata</i> L. (whorled milkweed)
<i>Antennaria neglecta</i> Greene (pussytoes, ladies'-tobacco)	<i>Campanula rotundifolia</i> L. (harebell, bluebell, bells of Scotland)
<i>Asclepias viridiflora</i> Raf. (green milkweed)	<i>Delphinium carolinianum</i> Walt. (wild blue larkspur)*
<i>Castilleja sessiliflora</i> Pursh. (dwarf Indian paintbrush)	<i>Dichanthelium linearifolium</i> (Scribn.) Gould. (panic grass)*
<i>Cornus racemosa</i> Lam. (gray dogwood)*	<i>Erigeron canus</i> A. Gray (hoary fleabane)
<i>Dalea purpurea</i> Venten (purple prairie-clover)	<i>Scutellaria leonardii</i> Epling (small skullcap)*
<i>Delphinium carolinianum</i> Walt. (wild blue larkspur)*	unknown grass B
<i>Dianthus armeria</i> L. (deptford pink)	
<i>Dichanthelium linearifolium</i> (Scribn.) Gould. (panic grass)*	
<i>Dichanthelium oligosanthes</i> (Schult.) Gould. (panic grass)*	
<i>Erigeron strigosus</i> Muhl. ex Willd (daisy fleabane, prairie fleabane, rough fleabane)	
<i>Heterostipa sparta</i> (Trin.) Barkworth (porcupine grass)*	
<i>Koeleria macrantha</i> (Ledeb.) Schult (Junegrass)	
<i>Liatris pycnostachya</i> Michx. (blazing star)	
<i>Mirabilis</i> sp. L. (four-o'clock)	
<i>Prunus americana</i> Marsh (American plum)	
<i>Sorghastrum nutans</i> (L.) Nash (Indian grass)	
unknown forb C (possible Harebell)	
unknown grass	
unknown moss	
Nebraska <i>P. ludoviciana</i> present	Nebraska <i>P. ludoviciana</i> absent
<i>Antennaria neglecta</i> Greene (pussytoes, ladies' tobacco)	<i>Lilium</i> sp. L. (lily)
<i>Asclepias verticillata</i> L. (whorled milkweed)	<i>Opuntia</i> sp. Mill. (prickly-pear)
<i>Erysimum repandum</i> L. (bushy wallflower)	unknown mosses
<i>Onagraceae</i> unknown species	
<i>Orbexilum</i> sp. Rydb*	
<i>Oenothera perennis</i> L. (little sundrops)	

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Table 9: Soil pH, fertility and texture analysis for soil samples from colonies with *Physaria ludoviciana* present or absent.

Site	IL ^a present	MN ^b present	NE ^c present	IL ^d absent	MN ^e absent	NE ^f absent
Group	a	a	a	b	b	b
pH	8.1	8.2	7.4	5.3	7.8	7.7
Buffer pH				6.81		
P (ppm)	12	4	16	30	19	19
K (ppm)	38	13	249	32	55	321
Ca (ppm)	1611	242	2027	157	1956	5455
Mg (ppm)	118	64	173	25	342	163
S (ppm)	10	4	6	9	18	6
B (ppm)	0.4	0.5	0.4	0.5	2.3	0.8
Cu (ppm)	0.8	0.6	0.6	0.6	1.4	0.8
Fe (ppm)	53	25	25	65	49	18
Mn (ppm)	44	225	21	14	174	27
Zn (ppm)	3.4	1.1	0.4	1.4	5.6	0.6
Na (ppm)	17	13	20	15	19	23
OM (%)	1.2	0.6	1.3	1.1	3.3	2.9
OM-ENR (ppm)	34	27.5	35	33	55	51
CEC (meq/100g)	7.4	1.5	10.0	1.4	10.6	23.7
K (%)	1.2	2.1	6.0	5.5	1.3	3.3
Ca (%)	86.0	63.7	80.1	44.3	72.9	90.9
Mg (%)	12.2	32.7	13.3	13.7	24.7	5.3
H (%)	0	0	0	30.6	0	0
Na (%)	1	3.8	0.9	4.7	0.8	0.4
K:Mg	0.10	0.06	0.44	0.39	0.05	0.61
Texture	sand	sand	loamy sand	sand	loamy sand	sandy loam
Sand (%)	96	100	80	96	76	64
Silt (%)	4	0	18	4	24	32
Clay (%)	0	0	2	0	0	4

^aIL was located in Mason County, Illinois, 2 km south of Goofy Ridge, Illinois at the Henry Allan Gleason Nature Preserve

^bMN was located 2 miles south of Red Wing, Northern Goodhue County at Richard J. Dorer Memorial Hardwood State Forest, Hay Creek Management Unit, Northwest side of a bluff

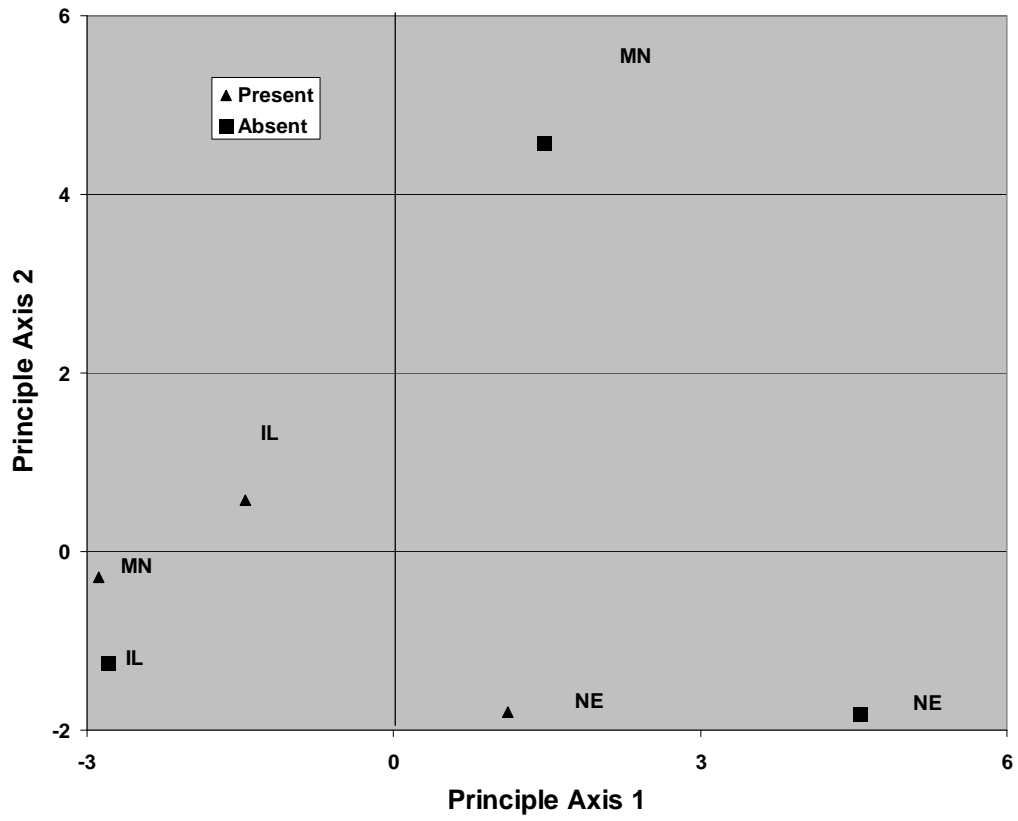
^cNE was located in Dawes County on the campus of Chadron State College, southeast side of the water tower

^dIL was located in Mason County at the Sand Prairie-Scrub Oak Nature Preserve

^eMN was located 2 miles south of Red Wing in Northern Goodhue County at Richard J. Dorer Memorial Hardwood State Forest, Hay Creek Management Unit, Southeast side of bluff

^fNE was located in Sioux County, part of the Oglala National Grassland, Hudson Meng Bison Bonehead

Figure 1: A Principle Component Analysis showing how the suite of soil parameters interact together.



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