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Oklahoma Native Plant Record
Volume 22
Table of Contents

Cover photo:
Stillingia sylvatica (queen's delight) at the Lexington Wildlife Management Area, Cleveland County, Oklahoma, by Amy K. Buthod

Foreword

This issue of the *Oklahoma Native Plant Record* contains a floristic inventory of a wildlife management area and articles that address the conservation status of a native herbaceous species, the effects of year and various geographic and climatic factors on flowering time of a native herbaceous species, and the effects of fire and floods on the vegetation of a degraded grassland. These papers provide evidence of the current distribution and status of the native flora of Oklahoma and how land-use changes and abiotic factors influence it over time.

Amy Buthod from the University of Oklahoma conducted a vascular plant survey of the Lexington Wildlife Management Area in central Oklahoma. This area is dominated by Crosstimbers forest, woodland, and prairie, with some riparian woodland and wetlands. It provides habitat for four species tracked by the Oklahoma Natural Heritage Inventory, including two species that are critically imperiled in the state.

Tim Springer and Corey Moffet from the USDA Southern Plains Range Research Station conducted two recent censuses of *Phlox oklahomensis* (Oklahoma phlox) in the Gypsum Hills of northwestern Oklahoma and adjacent Kansas. Their goals were to identify factors that influence its presence, determine whether its occurrence had changed since earlier censuses twenty and forty years ago, and assess its current conservation status.

Lynn Nguyen and Jennifer Messick from the University of Central Oklahoma investigated the flowering phenology of herbarium specimens of *Collinsia violacea* (violet blue eyed Mary) collected since the late 1800s. Their goal was to determine whether flowering dates were related to year of collection as well as to various geographic and climatic variables.

Erica Corbett from Southeastern Oklahoma State University documented the changes that took place over 20 years in a grassland on the shore of Lake Texoma as natural and human-caused disturbances impacted the site.

A note by C.R. "Randy" Ledford documents the resurgence of the ceremonial use of a native sumac/tobacco mixture by the Pawnee. Traditional cultivation of a tobacco plant native to the U.S., *Nicotiana quadrivalvis*, was abandoned after the introduction of *Nicotiana tabacum*, but it is now being grown again and utilized in Pawnee ceremonies.

Please consider publishing your work in the *Oklahoma Native Plant Record.* It is listed in the Directory of Open Access Journals, is abstracted by the Centre for Agricultural Bioscience International, and can be accessed by researchers around the world.

Gloria Caddell
Managing Editor

A FLORISTIC INVENTORY OF THE OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION'S LEXINGTON WILDLIFE MANAGEMENT AREA, CLEVELAND COUNTY, OKLAHOMA

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Keywords: vascular plants, **Schoenoplectus hallii**, *crosstimbers, rare species*

ABSTRACT

This paper reports the results of a vascular plant inventory at the Oklahoma Department of Wildlife Conservation's Lexington Wildlife Management Area in Cleveland County, Oklahoma. Five hundred and six specific and infraspecific taxa in 90 families were collected. Two-hundred and ninety-six genera, 487 species, and 19 infraspecific taxa were identified. The largest families were the Poaceae with 86 taxa and the Asteraceae with 82 taxa. Sixty-eight taxa were non-native to the U.S. (13.4 % of the flora). Four species tracked by the Oklahoma Natural Heritage Inventory were found.

INTRODUCTION AND STUDY AREA

The Lexington Wildlife Management Area (LWMA) occupies 3,849 ha in Cleveland County in central Oklahoma approximately 12.0 km from the town of Lexington (Figure 1). Latitudinal extent ranges from 35.087460° – 35.058031° and longitudinal extent from -97.247320° – -97.247652°. Physiographically, the site is located within the Central Red-bed Plains geomorphic province, which consists of broad, flat plains and gently rolling hills of red sandstone and shale from the lower Permian (Curtis et al. 2008; Johnson 2008). Three soil associations are predominant at LWMA: Stephenville-Darnell Newalla Complex (approximately 19.7% of the WMA), Harrah fine sandy loam (13.8%), and the Newalla fine sandy loam (12.0%; Soil Survey Staff 2023). Approximately 0.4 % of the WMA is covered by water (Soil Survey Staff 2023). LWMA is located within the subtropical humid (Cf) climate zone, with a mean annual temperature of 15.9°C (Trewartha 1968; Oklahoma Climatological Survey 2023). Low temperatures (to -2.4°C) occur in January, while the warmest temperatures occur in July (to 27.7°C; Oklahoma Climatological Survey 2023). The month of May is typically the wettest, with an average precipitation of 13.1 cm. Mean annual precipitation is 95.6 cm (Oklahoma Climatological Survey 2023). Elevation ranges from 311.8 m to 379.5 m. Two small lakes, Smith and Dahlgren, are found at LWMA, in addition to numerous small ponds. Little Buckhead Creek runs north to south in the western part of the WMA, while Helsel Creek flows into Dahlgren Lake on the east side. The dominant potential vegetation type is Crosstimbers—a mosaic of *Schizachyrium scoparium* grassland and *Quercus stellata* and *Q. marilandica* woodland (Commission for Environmental

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Cooperation 2021). Prior to this study, there was no complete inventory of the vascular plants at LWMA. Sporadic collections were made in the 1990s and again in 2019 (TORCH Portal 2023).

METHODS

To ensure that the inventory was as complete as possible, aerial photos and the Oklahoma Department of Wildlife Conservation's Oklahoma Ecological Systems map (Diamond and Elliott 2015) were consulted to locate examples of all vegetation types present at the WMA before fieldwork began. Collection sites were selected based on these findings but were also chosen as new taxa were encountered. Voucher specimens of vascular plant taxa encountered at LWMA were taken throughout the growing seasons (March through October) of 2021 and 2022. Specimens with flowers or fruits were preferred, but sterile specimens were taken when only those could be located. Vouchers of taxa not native to the United States were collected only from naturalized populations. Manuals used for identification included Diggs et al. (1999) and Ryburn et al. (2018). Identifications were verified by comparison with specimens from the Robert Bebb Herbarium at the University of Oklahoma (OKL). Duration, growth habit, and nativity were determined using the PLANTS database (USDA-NRSC 2023); if the information from PLANTS was ambiguous, Taylor and Taylor (1991) was consulted. Classification and nomenclature follow Angiosperm Phylogeny Group IV (Stevens 2001 onwards) and the Integrated Taxonomic Information System (2023). Vegetation classifications were based on Diamond and Elliott (2015). All specimens were deposited at OKL.

RESULTS AND DISCUSSION

Five hundred and ninety vascular plant collections were made at LWMA. Five hundred and six specific and infraspecific taxa in 90 families and 296 genera were collected (Appendix A). Four of these families were ferns and allies, two were conifers, ten were monocots, and 74 were eudicots (Table 1). Four hundred and eighty-seven species and 19 infraspecific taxa were identified. Three-hundred and thirty-two taxa were perennials; there were 166 annuals and eight biennials. The largest families were the Poaceae with 86 taxa and the Asteraceae with 82 taxa. Three-hundred and thirty-four taxa were forbs, and 119 were graminoids. There were 27 trees, 18 shrubs/subshrubs, and eight vines. Four species tracked by the Oklahoma Natural Heritage Inventory (2023) were found, including *Schoenoplectus hallii*, a globally vulnerable species (Table 2). The U.S. Fish and Wildlife Service was petitioned to list *S. hallii* as a federally threatened or endangered species in 2010, but it has not been listed (Federal Register 2011).

Sixty-eight taxa were non-native to the U.S. (13.4 % of the flora). The families with the greatest numbers of exotic taxa were the Poaceae (21 taxa) and the Fabaceae (13 taxa). The genera *Bromus*, *Medicago*, and *Trifolium* had the most exotic species (five, three, and three respectively). *Pinus taeda*, which is native to southeastern Oklahoma, was also found at the WMA, but was most likely planted by a former property owner and has since naturalized.

Based on Diamond and Elliot (2015), LWMA was predicted to be dominated by seven vegetation types, and this predication was accurate. The types are not discrete; they intergrade, with many taxa found in more than one vegetation type. The predominant vegetation type encountered at the LWMA was ***Crosstimbers post oak/blackjack oak forest and woodland***. This vegetation type is dominated by *Quercus stellata* (post oak) and *Quercus marilandica* (blackjack oak) as well as *Carya texana* (black hickory), *Ulmus alata* (winged elm), and *Juniperus virginiana* (eastern red cedar). Species commonly found in the understory include *Symphoricarpos orbiculatus* (buck brush), *Toxicodendron radicans* (eastern poison ivy), *Solidago ulmifolia* (elmleaf goldenrod), and *Tridens flavus* (purpletop).

Crosstimbers pasture and prairie was the second most common vegetation type at LWMA. This type is dominated by native grass species such as *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (Indian grass), *Bothriochloa laguroides* (silver beardgrass), *Andropogon ternarius* (splitbeard bluestem,) and *Andropogon virginicus* (broomsedge bluestem). Non-native grasses are also abundant, including *Cynodon dactylon* (Bermuda grass), *Bromus commutatus* (meadow brome), and *Schedonorus arundinaceus* (tall fescue). Common shrubs found in this vegetation type include *Prunus angustifolia* (Chickasaw plum), *Rhus glabra* (smooth sumac) *Rubus aboriginum* (garden dewberry), and *Rubus allegheniensis* (Allegheny blackberry). *Ambrosia psilostachya* (western ragweed) is an abundant forb in the pasture/prairie. Other common forbs include *Amphiachyris dracunculoides* (prairie broomweed), *Croton capitatus* (hogweed), *Desmanthus illinoinensis* (Illinois bundleflower), and *Oenothera glaucifolia* (false gaura).

Another commonly encountered vegetation type was the ***South Central Interior riparian hardwood woodland***. This vegetation type is found along the creeks at the LWMA. Species found in this type include *Celtis laevigata* (sugarberry), *Ulmus americana* (American elm), *Ulmus rubra* (slippery elm), and *Acer negundo* (boxelder). *Vitis vulpina* (fox grape), *Lespedeza procumbens* (trailing lespedeza), and *Persicaria virginiana* (jumpseed) are found in the understory.

Other vegetation types found at LWMA included ***Crosstimbers young post oak/blackjack oak woodland*** and ***Crosstimbers post oak/eastern red cedar woodland***. The young post oak/blackjack woodland is found on woodland margins and consists of successional vegetation. Common species include *Quercus stellata* (post oak) and Q*uercus marilandica* (blackjack oak), *Rhus* species (sumac), *Tridens flavus* (purpletop tridens), *Smilax bona-nox* (saw greenbrier), and *Schedonorus arundinaceus* (tall fescue). Post oak/eastern red cedar woodland is dominated by *Juniperus virginiana*. Other species include *Quercus stellata* (post oak), *Cercis canadensis* (eastern redbud), *Symphoricarpos orbiculatus* (buck brush), *Elymus virginicus* (Virginia wild rye), and *Baptisia bracteata (*longbract wild indigo).

Herbaceous wetland vegetation is restricted to lake margins, ponds, seepy areas, and creek channels. Commonly encountered taxa include *Amorpha fruticosa* (desert false indigo), *Xanthium strumarium* (rough cocklebur), *Teucrium canadense* (Canada germander), *Andropogon glomeratus* (bushy bluestem), *Panicum virgatum* (switchgrass), and multiple species of *Juncus* (rushes).

Disturbed areas include sites around structures, parking lots, oil pads, and gravel roads. *Conyza canadensis* (Canadian horseweed), *Helenium amarum* (yellowdicks), *Lespedeza cuneata* (sericea lespedeza), *Oenothera curtiflora (*velvetweed*),* and *Bromus tectorum (*cheatgrass*)* are common in disturbed areas, as well as many other weedy species such as *Arenaria serpyllifolia* (thymeleaf sandwort), *Capsella bursa-pastoris* (shepherd's purse), *Taraxacum officinale* (common dandelion), and *Erodium cicutarium* (redstem stork's bill).

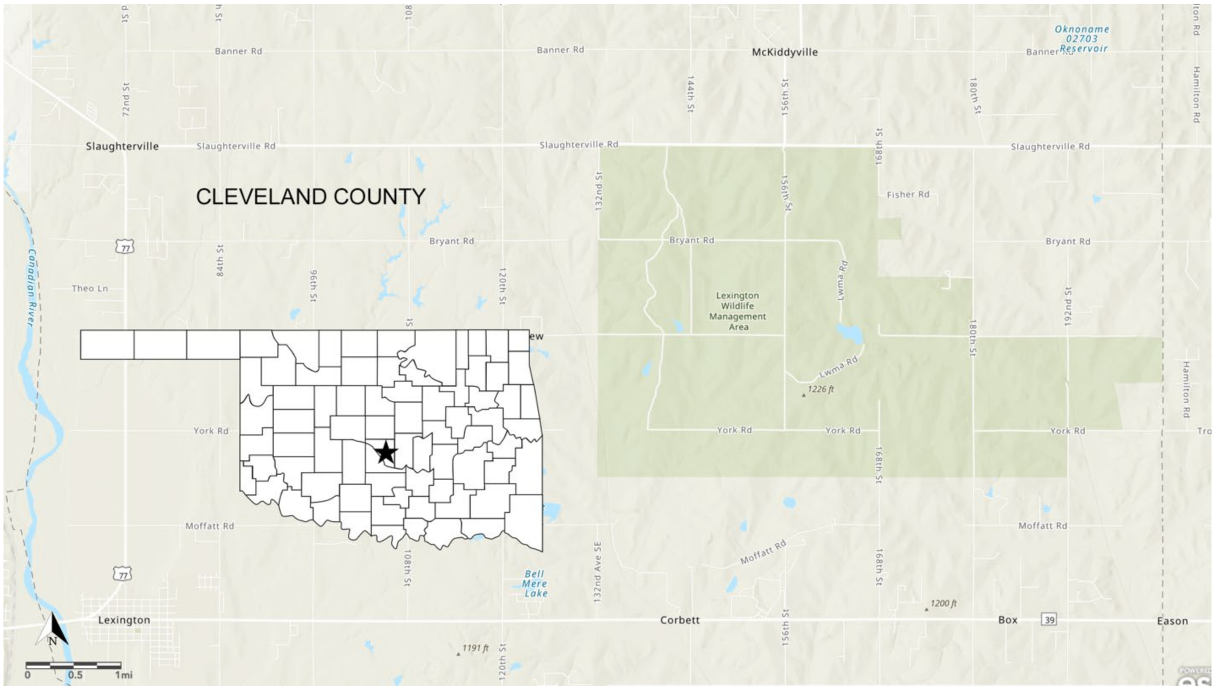

Figure 1 The Lexington Wildlife Management Area.

Table 1 Summary of the floristic inventory performed at the Lexington Wildlife Management Area by major vascular plant groups and resulting number of taxa.

Groups	Families	Genera	Specific and infraspecific taxa	Native Taxa	Nonnative Taxa	Nonnative Taxa Composition %
Ferns and Allies	4	5	5 (0.99%)	5	0	0
Conifers	2	2	2 (0.40%)	2	0	0
Magnoliids/Primitive Angiosperms	0	0	0	0	0	0
Monocots	10	60	132 (26.09%)	111	21	15.91%
Eudicots	74	229	367 (72.53%)	320	47	12.81%
TOTAL	**90**	**296**	**506**	**438**	**68**	**13.44%**

Table 2 Species located during this study that are tracked by the Oklahoma Natural Heritage Inventory (NatureServe Explorer 2023, Oklahoma Natural Heritage Inventory 2023). Status ranks are on a 1-5 scale, with a 1 indicating the taxon is critically imperiled. G ranks are at the global level and S ranks are at the subnational or state level.

Family	Taxon	Rank
Cyperaceae	*Schoenoplectus hallii* (A. Gray) S.G. Sm.	S1G3
Fabaceae	*Desmodium nuttallii* (Schindl.) B.G. Schub.	S1G5
Plantaginaceae	*Penstemon oklahomensis* Pennell	S3G3
Poaceae	*Panicum brachyanthum* Steud.	S2G5

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APPENDIX A
List of vascular plant taxa from the Lexington Wildlife Management Area, Cleveland County, Oklahoma.

Taxa list with duration, growth habit, vegetation type, collection number, nativity, and heritage status. A=annual, B=biennial, P=perennial; T=tree, S=shrub/subshrub, V=woody vine, F=forb, G=graminoid; DA=disturbed area, HWV=herbaceous wetland vegetation, PBFW=post oak/blackjack oak forest and woodland, PEFW=Post oak/eastern red cedar forest and woodland, PP=pasture/prairie, RHW=riparian hardwood woodland, YPBW= young post oak/blackjack oak woodland. Exotic taxa are denoted with an asterisk (*). Taxa native to the U.S. but not native to central Oklahoma are noted with a hash mark (#). Taxa tracked by the Oklahoma Natural Heritage Inventory (2023) are denoted with a dagger (†). Duration, growth habit, and nativity were determined using the PLANTS Database (USDA-NRCS 2023); if the information from PLANTS was ambiguous, Taylor and Taylor (1991) was consulted. Vegetation classifications were based on Diamond and Elliott (2015). Specimens were assigned collection numbers with the prefix *LEX*. Voucher specimens were deposited at the Robert Bebb Herbarium of the University of Oklahoma (OKL).

Acanthaceae
Ruellia humilis Nutt. (fringeleaf wild petunia); P; F; PP; LEX-206

Adoxaceae
Sambucus nigra L. ssp. *canadensis* (L.) R. Bolli (elderberry); P; S; PBFW, RHW; LEX-546
Viburnum rufidulum Raf. (rusty blackhaw) P; S; PBFW, PEFW, RHW; LEX-556

Amaranthaceae
Chenopodium pratericola Rydb. (desert goosefoot) A; F; PBFW, PEFW, YPBW; LEX-539
Chenopodium standleyanum Aellen (Standley's goosefoot); A; F; RHW; LEX-570
Cycloloma atriplicifolium (Spreng.) J.M. Coult. (winged pigweed); A; F; PP; LEX-260
Froelichia floridana (Nutt.) Moq. (cottonweed); A; F; PP; LEX-503

Amaryllidaceae
Allium canadense L. var. *fraseri* (Ownbey) Traub & Ownbey (Fraser meadow garlic); P; F; PP; LEX-164
Allium drummondii Regel (Drummond's onion); P; F; PP; LEX-073
Nothoscordum bivalve (L.) Britton (crowpoison); P; F; DA, PP; LEX-005

Anacardiaceae
Rhus aromatica Aiton (fragrant sumac); P; S; PP, YPBW; LEX-036
Rhus copallinum L. (flameleaf sumac); P; S; DA, PP; LEX-353
Rhus glabra L. (smooth sumac); P; S; PP; LEX-200
Toxicodendron radicans (L.) Kuntze (eastern poison ivy); P; V; DA, PBFW, PEFW, RHW, YPBW; LEX-323

Apiaceae
Ammoselinum popei Torr. & A. Gray (plains sandparsley); A; F; PP; LEX-064
Chaerophyllum tainturieri Hook. (hairyfruit chervil); A; F; PP; LEX-063
Daucus pusillus Michx. (southwest wild carrot); A; F; PP; LEX-209
Lomatium foeniculaceum (Nutt.) J.M. Coult. & Rose (biscuitroot); P; F; PP; LEX-003

Polytaenia nuttallii DC. (Nuttall's prairie parsley); P; F; PP; LEX-102
Sanicula canadensis L. (Canadian blacksnakeroot); B; F; PBFW, PEFW, RHW; LEX-182
Spermolepis inermis (Nutt. ex DC.) Mathias & Constance (Red River scaleseed); A; F; PP; LEX-169
**Torilis arvensis* (Huds.) Link (hedge parsley); A; F; DA, PP; LEX-199

Apocynaceae
Apocynum cannabinum L. (hemp dogbane); P; F; DA, PP; LEX-196
Asclepias amplexicaulis Sm. (bluntleaf milkweed); P; F; PP; LEX-529
Asclepias asperula (Decne.) Woodson (spider antelope horns); P; F; PP; LEX-106
Asclepias stenophylla A. Gray (slimleaf milkweed); P; F; PP; LEX-531
Asclepias tuberosa L. (butterflyweed); P; F; PP; LEX-195
Asclepias verticillata L. (eastern whorled milkweed); P; F; PP; LEX-370
Asclepias viridiflora Raf. (green milkweed); P; F; PP; LEX-578
Asclepias viridis Walter (green antelopehorn); P; F; PP; LEX-105
Gonolobus suberosus (L.) Br. var. *granulatus* (Scheele) Krings & Q.Y. Xiang (angularfruit milkvine); P; F; RHW; LEX-552

Araliaceae
Hydrocotyle verticillata Thunb. (whorled pennyroyal) P; F; HWV; LEX-382

Asparagaceae
Androstephium coeruleum (Schelle) Greene (blue funnel lily); P; F; PP; LEX-034
Yucca arkansana Trel. (Arkansas yucca); P; F; PP; LEX-116

Aspleniaceae
Asplenium platyneuron (L.) Britton, Sterns & Poggenb. (ebony spleenwort); P; F; PBFW, PEFW, RHW; LEX-466

Asteraceae
Achillea millefolium L. (common yarrow); P; F; DA, PP; LEX-121
Ageratina altissima (L.) King & H. Rob. (white snakeroot); P; F; PBFW, RHW; LEX-469
Ambrosia artemisiifolia L. (annual ragweed); A; F; YPBW; LEX-255
Ambrosia psilostachya DC. (western ragweed); A; F; DA, PP; LEX-429
Ambrosia trifida L. (great ragweed); A; F; DA, HWV; LEX-407
Amphiachyris dracunculoides (DC.) Nutt. (prairie broomweed); A; F; DA, PP; LEX-420
Antennaria neglecta Greene (field pussytoes); P; F; PEFW, YPBW; LEX-567
Antennaria parlinii Fernald (Parlin's pussytoes); P; F; PBFW, PEFW; LEX-042
Arnoglossum plantagineum Raf. (groovestem Indian plantain); P; F; PP; LEX-190
Artemisia ludoviciana Nutt. (white sagebrush); P; F; PP, YPBW; LEX-474
Bidens bipinnata L. (Spanish needles); A; F; HWV; LEX-430
Bidens aristosa (Michx.) Britton (bearded beggarticks); A; F; HWV; LEX-297
Bradburia pilosa (Nutt.) Semple (soft golden aster); A; F; DA, PP; LEX-392
Brickellia eupatorioides (L.) Shinners var. *texana* (Shinners) Shinners (false boneset); P; F; PP; LEX-572
**Carduus nutans* L. (musk thistle); B; F; DA, PP; LEX-191
Cirsium altissimum (L.) Hill (tall thistle); B; F; PBFW, PEFW, PP, YPBW; LEX-442
Cirsium undulatum (Nutt.) Spreng. (wavyleaf thistle); P; F; PP; LEX-341

Conoclinium coelestinum (L.) DC (blue mistflower); P; F; HWV; LEX-408
Conyza canadensis (L.) Cronquist (Canadian horseweed); A; F; DA, PP; LEX-405
Coreopsis grandiflora Hogg ex Sweet (largeflower tickseed); P; F; PP; LEX-220
Coreopsis tinctoria Nutt. (golden tickseed); A; F; DA, PP; LEX-359
Croptilon hookerianum (Torr. & A. Gray) House (Hooker's scratchdaisy); A; F; PP; LEX-257
Diaperia verna (Raf.) Morefield (springy pygmycudweed); A; F; DA, PP; LEX-077
Echinacea angustifolia DC. (blacksamson echinacea); P; F; PP; LEX-178
Eclipta prostrata (L.) L. (false daisy) A; F; HWV; LEX-443
Elephantopus carolinianus Raeusch. (Carolina elephantsfoot); P; F; PBFW, PEFW; LEX-450
Erechtites hieraciifolius (L.) Raf. ex DC. (burnweed); A; F; PBFW, PEFW, YPBW; LEX-295
Erigeron strigosus Muhl. ex Willd. (prairie fleabane); A; F; DA, PP; LEX-056
Eupatorium altissimum L. (tall thoroughwort); P; F; PP; LEX-456
Eupatorium perfoliatum L. (common boneset); P; F; HWV; LEX-290
Eupatorium serotinum Michx. (lateflowering thoroughwort); P; F; DA, HWV; LEX-444
Euthamia gymnospermoides Greene (Texas goldentop); P; F; PP; LEX-494
Gaillardia aestivalis (Walter) H. Rock (lanceleaf blanketflower); P; F; PP; LEX-287
Gamochaeta argyrinea G.L. Nesom (silvery cudweed); A; F; DA, PP; LEX-075
Grindelia ciliata (Nutt.) Spreng. (Spanish gold); A; F; DA, PP; LEX-435
Helenium amarum (Raf.) H. Rock (yellowdicks); A; F; DA, PP; LEX-434
Helianthus annuus L. (common sunflower); A; F; DA, PP; LEX-373
Helianthus hirsutus Raf. (hairy sunflower); P; F; YPBW; LEX-364
Helianthus maximiliani Schrad. (Maximilian sunflower); P; F; PP; LEX-457
Helianthus mollis Lam. (ashy sunflower); P; F; PP; LEX-340
Helianthus pauciflorus Nutt. (stiff sunflower); P; F; PP; LEX-417
Helianthus tuberosus L. (Jerusalem artichoke); P; F; DA, PP; LEX-574
Heterotheca subaxillaris (Lam.) Britton & Rusby (camphorweed); A ; F; DA, PP; LEX-291
Hieracium longipilum Torr. (hairy hawkweed); P; F; PBFW, PEFW; LEX-324
Hymenopappus tenuifolius Pursh (Chalkhill woolywhite); B; F; PP; LEX-150
Iva angustifolia Nutt. ex DC. (narrowleaf marsh Elder); A; F; DA, HWV; LEX-282
Lactuca ludoviciana (Nutt.) Riddell (biannual lettuce); A; F; PBFW, PEFW, YPBW; LEX-244
**Lactuca serriola* L. (prickly lettuce); A; F; DA, PP; LEX-348
Liatris punctata Hook. (dotted blazing star); P; F; PP; LEX-452
Liatris squarrosa (L.) Michx. (scaly blazing star); P; F; YPBW; LEX-401
Marshallia caespitosa Nutt. ex DC. (puffballs); P; F; PP; LEX-221
Pluchea camphorata (L.) DC. (camphorweed); P; F; HWV; LEX-502
Pluchea odorata (L.) Cass. (sweetscent); A; F; HWV; LEX-551
Pseudognaphalium obtusifolium (L.) Hilliard & B.L. Burtt (rabbit tobacco); A; F; PBFW, PEFW; LEX-491
Pyrrhopappus carolinianus (Walter) DC. (Carolina desert chicory); A; F; DA, PP; LEX-180
Pyrrhopappus grandiflorus (Nutt.) Nutt. (tuberous desert chicory); P; F; DA, PP; LEX-114
Ratibida columnifera (Nutt.) Woot. & Standl. (upright prairie coneflower); P; F; PP; LEX-214
Rudbeckia amplexicaulis Vahl (clasping coneflower); A; F; PP; LEX-346
Rudbeckia hirta L. (blackeyed Susan); P; F; PP; LEX-205
Silphium asteriscus L. (starry rosinweed); P; F; PP; LEX-327
Silphium laciniatum L. (compassplant); P; F; PP; LEX-371
Solidago altissima L. ssp. *gilvocanescens* (Rydb.) Semple (Great Plains late goldenrod); P; F; DA, HWV; LEX-272
Solidago canadensis L. (Canada goldenrod); P; F; DA, PP; LEX-516

Solidago missouriensis Nutt. (Missouri goldenrod); P; F; PP; LEX-480
Solidago nemoralis Aiton (gray goldenrod); P; F; PP; LEX-468
Solidago rigida L. (stiff-leaved goldenrod); P; F; PP; LEX-283
Solidago speciosa Nutt. (showy goldenrod); P; F; PP; LEX-515
Solidago ulmifolia Muhl. ex Willd. (elmleaf goldenrod); P; F; PBFW, PEFW, YPBW; LEX-404
**Sonchus asper* (L.) Hill (spiny sowthistle); A; F; DA; LEX-122
Symphyotrichum drummondii (Lindl.) G.L. Nesom (Drummond's aster); P; F; PBFW, PEFW, YPBW; LEX-462
Symphyotrichum ericoides (L.) G.L. Nesom (white heath aster); P; F; PP; LEX-454
Symphyotrichum oolentangiense (Riddell) G.L. Nesom (skyblue aster); P; F; PBFW, PEFW, YPBW; LEX-521
Symphyotrichum praealtum (Poir.) G.L. Nesom (willowleaf aster); P; F; PBFW, PEFW, YPBW; LEX-520
Symphyotrichum subulatum (Michx.) G.L. Nesom (eastern annual saltmarsh aster); A; F; DA, HWV; LEX-550
**Taraxacum officinale* F.H. Wigg. (common dandelion); P; F; DA; LEX-014
Tetraneuris linearifolia (Hook.) Greene (fineleaf fournerved daisy); A; F; PP; LEX-093
Thelesperma filifolium (Hook.) A. Gray (stiff greenthread); P; F; PP; LEX-218
**Tragopogon dubius* Scop. (yellow salsify); A; F; DA, PP; LEX-099
Verbesina helianthoides Michx. (gravelweed); P; F; PBFW, YPBW; LEX-530
Verbesina virginica L. (white crownbeard); P; F; PBFW, PEFW, YPBW; LEX-292
Vernonia baldwinii (Baldwin's ironweed); P; F; PP; LEX-368
Xanthium strumarium L. (rough cocklebur); A; F; HWV; LEX-441

Bignoniaceae
Campsis radicans (L.) Seem. ex Bureau (trumpet creeper); P; V; DA, YPBW; LEX-378

Boraginaceae
**Buglossoides arvensis* (L.) I.M. Johnst. (field gromwell); A; F; DA; LEX-028
Lithospermum incisum Lehm. (fringed gromwell); P; F; PP; LEX-033
Myosotis macrosperma Engelm. (largeseed forget-me-not); A; F; PBRW, PEFW, YPBW; LEX-069

Brassicaceae
Boechera canadensis (L.) Al-Shehbaz (sicklepod); B; F; PBFW, PEFW; LEX-082
**Capsella bursa-pastoris* (L.) Medik. (shepherd's purse); A; F; DA; LEX-002
**Cardamine hirsuta* L. (hairy bittercress); A; F; DA, PBFW, YPBW; LEX-021
Draba brachycarpa Nutt. ex Torr. & A. Gray (shortpod draba); A; F; DA; LEX-016
Draba cuneifolia Nutt. ex Torr. & A. Gray (wedgeleaf draba); A; F; PP; LEX-047
**Lepidium densiflorum* Schrad. (miner's pepperwort); A; F; DA; LEX-054
Lepidium oblongum Small (veiny pepperweed); A; F; DA; LEX-046
Rorippa palustris (L.) Besser (bog marshcress); A; F; HWV; LEX-071

Cactaceae
Opuntia humifusa (Raf.) Raf. (devil's tongue); P; S; PP; LEX-500

Campanulaceae
Lobelia appendiculata A. DC. (earflower lobelia); B; F; PP; LEX-149

Triodanis perfoliata (L.) Nieuwl. ssp. *biflora* (Ruix & Pav.) Lammers (clasping Venus' lookingglass); A; F; DA, PP; LEX-543
Triodanis perfoliata (L.) Nieuwl. ssp. *perfoliata* (clasping bellwort); A; F; DA, PP; LEX-174

Cannabaceae
Celtis laevigata Willd. (sugarberry); P; T; PBFW, PEFW, YPBW; LEX-111

Caprifoliaceae
Symphoricarpos orbiculatus Moench (buck brush); P; S; PBFW, PEFW, YPBW; LEX-422

Caryophyllaceae
**Arenaria serpyllifolia* L. (thymeleaf sandwort); A; F; DA; LEX-109
**Cerastium glomeratum* Thuill. (sticky chickweed); A; F; DA; LEX-012
**Cerastium pumilum* W. Curtis (European chickweed); A; F; DA; LEX-013
Paronychia jamesii Torr. & A. Gray (James' nailwort); P; F; PP; LEX-263
Silene antirrhina L. (catchfly); A; F; DA, PP; LEX-232
**Stellaria pallida* (Dumort.) Crép. (common chickweed); A; F; DA; LEX-017

Celastraceae
Celastrus scandens L. (staffvine); P; V; PBFW, PEFW, YPBW; LEX-152
**Euonymus fortunei* (Turcz.) Hand.-Maz. (winter creeper); P; S; PBFW, YPBW; LEX-067

Cistaceae
Lechea mucronata Raf. (hairy pinweed); P; F; PP; LEX-329
Lechea tenuifolia Michx. (narrowleaf pinweed); P; F; PP; LEX-328

Commelinaceae
Commelina erecta L. (erect dayflower); P; F; HWV, PP; LEX-314
Tradescantia ohiensis Raf. (Ohio spiderwort); P; F; PP; LEX-130

Convolvulaceae
Cuscuta cuspidata Engelm. (cusp dodder); P; F; PP; LEX-280
Cuscuta pentagona Engelm. var. *pentagona* (fiveangled dodder); A; F; DA, PP; LEX-532
Evolvulus nuttallianus Schult. (prostrate Evolvulus); P; F; PP; LEX-330
**Ipomoea hederacea* Jacq. (entireleaf morningglory); A; F; DA; LEX-249

Cornaceae
Cornus drummondii C.A. Mey. (roughleaf dogwood); P; T; PBFW, PEFW, YPBW; LEX-233

Cupressaceae
Juniperus virginiana L. (eastern red cedar); P; T; PBFW, PEFW, YPBW; LEX-120

Cyperaceae
Carex albicans Willd. ex Spreng. (whitetinge sedge); P; G; PBFW, PEFW; LEX-019
Carex aureolensis Steud. (golden cattail sedge); P; G; HWV; LEX-138
Carex austrina Mack. (southern sedge); P; G; PP; LEX-586
Carex brevior (Dewey) Mack. (fescue sedge); P; G; HWV; LEX-137

Carex bushii Mack. (Bush's sedge); P; G; PP; LEX-131
Carex flaccosperma Dewey (thinfruit sedge); P; G; PBFW, PEFW; LEX-136
Carex granularis Muhl. ex Willd. (limestone meadow sedge); P; G; PBFW, PEFW; LEX-139
Carex gravida L.H. Bailey (heavy sedge); P; G; PP; LEX-133
Carex leavenworthii Dewey (Leavenworth's sedge); P; G; PP; LEX-587
Carex microdonta Torr. & Hook. (littletooth sedge); P; G; HWV; LEX-132
Carex vulpinoidea Michx. (common fox sedge); P; G; PP; LEX-135
Cyperus acuminatus Torr. & Hook. ex Torr. (taperleaf flatsedge); P; G; HWV; LEX-308
Cyperus echinatus (L.) Alph. Wood (globe flatsedge); P; G; DA, PP; LEX-381
Cyperus lupulinus (Spreng.) Marcks (Great Plains flatsedge); P; G; PP; LEX-541
Cyperus pseudovegetus Steud. (marsh flatsedge); P; G; HWV; LEX-238
Cyperus strigosus L. (strawcolored flatsedge); P; G; HWV; LEX-319
Eleocharis geniculata (L.) Roem. & Schult. (Canada spikesedge); A; G; HWV; LEX-548
Eleocharis obtusa (Willd.) Schult. (blunt spikesedge); A; G; HWV; LEX-237
Fimbristylis autumnalis (L.) Roem. & Schult. (slender fimbry); A; G; HWV; LEX-448
Fimbristylis puberula (Michx.) Vahl (hairy fimbry); P; G; PP; LEX-162
Fimbristylis vahlii (Lam.) Link (Vahl's fimbry); A; G; HWV; LEX-459
Fuirena simplex Vahl (western umbrella sedge); P; G; HWV; LEX-309
Rhynchospora harveyi W. Boott (Harvey's beaksedge); P; G; PP; LEX-163
†*Schoenoplectus hallii* (A. Gray) S.G. Sm. (Hall's bulrush); A; G; HWV; LEX-560; S1G3
Scirpus atrovirens Willd. (dark green bulrush); P; G; HWV; LEX-145
Scirpus pendulus Muhl. (pendulous bulrush); P; G; HWV; LEX-074
Scleria ciliata Michx. (fringed nutrush); P; G; PP; LEX-166

Ebenaceae
Diospyros virginiana L. (eastern persimmon); P; T; PBFW, PEFW, YPBW; LEX-087

Equisetaceae
Equisetum x *ferrissii* Clute (pro sp.) (Ferriss' horsetail); P; F; HWV; LEX-259

Euphorbiaceae
Acalypha gracilens A. Gray (slender copperleaf); A; F; PP; LEX-246
Acalypha monococca (Engelm. ex A. Gray) Lill. W. Mill. & Gandhi (slender threeseed mercury); A; F; PBFW; LEX-247
Acalypha rhomboidea Raf. (Virginia threeseed mercury); A; F; RHW; LEX-523
Acalypha virginica L. (Virginia copperleaf); A; F; RHW; LEX-563
Cnidoscolus texanus (Müll. Arg.) Small (Texas bullnettle); P; F; DA, PP; LEX-211
Croton capitatus Michx. (hogweed); A; F; DA, PP; LEX-302
Croton glandulosus L. var. *lindheimeri* Müll. Arg. (tropic croton); A; F; DA; LEX-394
Croton monathogynus Michx. (prairie tea); A; F; DA, PP; LEX-355
Euphorbia corollata L. (flowering spurge); P; F; PP; LEX-425
Euphorbia cyathophora Murray (fire on the mountain); A; F; PBFW, PEFW, YPBW; LEX-413
**Euphorbia davidii* Subils (David's spurge); A; F; DA; LEX-575
Euphorbia dentata Michx. (toothed spurge); A; F; PBFW, PEFW, PP, YPBW; LEX-276
Euphorbia maculata L. (milk purslane); A; F; DA, PP; LEX-300
Euphorbia marginata Pursh (snow on the mountain); A; F; PP; LEX-418
Euphorbia nutans Lag. (eyebane); A; F; DA, PP; LEX-505

Euphorbia spathulata Lam. (roughpod spurge); A; F; PP; LEX-192
Euphorbia stictospora Engelm. (slimseed sandmat); A; F; DA; LEX-549
Stillingia sylvatica L. (queen's delight); P; F; PP; LEX-294
Tragia betonicifolia Nutt. (betonyleaf noseburn); P; F; PP; LEX-184

Fabaceae
Acacia angustissima (Mill.) Kuntze (prairie acacia); P; F; PP; LEX-374
Amorpha canescens Pursh (leadplant); P; F; PP; LEX-351
Amorpha fruticosa L. (desert false indigo); P; S; HWV; LEX-101
Amphicarpaea bracteata (L.) Fernald (American hog peanut); A; F; PBFW, PEFW, RHW; LEX-431
Apios americana Medik. (groundnut); P; F; HWV; LEX-554
Astragalus crassicarpus Nutt. (groundplum milkvetch); P; F; PP; LEX-080
Baptisia australis (L.) R. Br. (blue wild indigo); P; F; PP; LEX-108
Baptisia bracteata Muhl. Ex Elliott (longbract wild indigo); P; F; PBFW, PEFW; LEX-431
Cercis canadensis L. (eastern redbud); P; T; PBFW, PEFW, YPBW; LEX-035
Chamaecrista fasciculata (Michx.) Greene (partridge pea); A; F; DA, PP; LEX-339
Chamaecrista nictitans (L.) Moench (sensitive partridge pea); A; F; PP; LEX-440
Clitoria mariana L. (pigeonwings); P; F; PBFW, PEFW, YPBW; LEX-403
Crotalaria sagittalis L. (arrowhead rattlebox); P; F; PP; LEX-345
Dalea aurea Nutt. ex Fraser (golden prairie clover); P; F; PP; LEX-361
Dalea candida Michx. ex Willd. (white prairie clover); P; F; PP; LEX-236
Dalea enneandra Nutt. ex Fraser (nineanther prairie clover); P; F; PP; LEX-336
Dalea purpurea Vent. (purple prairie clover); P; F; PP; LEX-360
Desmanthus illinoensis (Michx.) MacMill. ex B.L. Rob. & Fernald (Illinois bundleflower); P; F; DA, PP; LEX-213
Desmanthus leptolobus Torr. & A. Gray (slenderlobe bundleflower); P; F; PP; LEX-477
Desmodium glutinosum (Muhl. ex Willd.) Alph. Wood (pointedleaf ticktrefoil); P; F; RHW; LEX-566
Desmodium marilandicum (L.) DC. (smooth small leaf ticktrefoil); P ; F; PP; LEX-476
†*Desmodium nuttallii* (Schindl.) B.G. Schub. (Nuttall's ticktrefoil); P; F; PP; LEX-526; S1G5
Desmodium obtusum (Muhl. ex Willd.) DC. (stiff ticktrefoil); P; F; PBFW, YPBW; LEX-492
Desmodium paniculatum (L.) DC. (panicledleaf ticktrefoil); P; F; PBFW, YPBW; LEX-490
Desmodium sessilifolium (Torr.) Torr. & A. Gray (sessileleaf ticktrefoil); P; F; PP; LEX-342
Desmodium viridiflorum (L.) DC. (velvetleaf ticktrefoil); P; F; PBFW, YPBW; LEX-475
Galactia regularis (L.) Britton, Sterns & Poggenb. (eastern milkpea); P; F; PP; LEX-426
**Kummerowia striata* (thunb.) Schindl. (Japanese clover); A; F; DA; LEX-267
**Lathyrus hirsutus* L. (Caley pea); A; F; DA; LEX-535
**Lespedeza cuneata* (Dum. Cours.) G. Don (sericea lespedeza); P; F; DA, PP; LEX-433
Lespedeza procumbens Michx. (trailing lespedeza); P; F; RHW; LEX-582
Lespedeza stuevei Nutt. (tall lespedeza); P; F; PP; LEX-446
Lespedeza virginica (L.) Britton (slender lespedeza); P; F; PP; LEX-421
**Medicago lupulina* L. (black medick); A; F; DA; LEX-544
**Medicago minima* (L.) L. ex Bartal. (burr medick); A; F; DA; LEX-066
**Medicago sativa* L. (alfalfa); P; F; PP; LEX-203
**Melilotus albus* Medik. (white sweetclover); A; F; PP; LEX-197
**Melilotus officinalis* (L.) Lam. (yellow sweetclover); A; F; DA, PP; LEX-198
Mimosa nuttallii (DC. ex Britton & Rose) B.L. Turner (Nuttall's sensitivebriar); P; F; PP; LEX-181
Neptunia lutea (Leavenw.) Benth. (yellow puff); P; F; PP; LEX-335

Psoralidium tenuiflorum (Pursh) Rudb. (slimflower scurfpea); P; F; PP; LEX-115
Rhynchosia latifolia Nutt. ex Torr. & A. Gray (prairie snoutbean); P; F; PP; LEX-243
Robinia pseudoacacia L. (black locust); P; T; PBFW, PEFW, YPBW; LEX-455
Strophostyles helvola (L.) Elliott (amberique-bean); A; F; PBFW, PEFW, YPBW; LEX-414
Strophostyles leiosperma (Torr. & A. Gray) Piper (slickseed fuzzybean); A; F; PBFW, PEFW, YPBW; LEX-410
Stylosanthes biflora (L.) Britton, Sterns & Poggenb. (sidebeak pencilflower); P; F; PP; LEX-222
Tephrosia virginiana (L.) Pers. (Virginia tephrosia); P; F; PBFW, PEFW, YPBW; LEX-545
**Trifolium campestre* Schreb. (lesser hop clover); A; F; DA; LEX-061
**Trifolium pratense* L. (red clover); B; F; DA; LEX-068
**Trifolium repens* L. (white clover); P; F; DA; LEX-029
Vicia caroliniana Walter (Carolina vetch); P; F; DA; LEX-148
**Vicia sativa* L. (garden vetch); A; F; DA; LEX-027
**Vicia villosa* Roth (winter vetch); A; F; DA; LEX-527

Fagaceae
Quercus marilandica Münchh. (blackjack oak); P; T; PBFW, PEFW, YPBW; LEX-110
Quercus muehlenbergii Engelm. (chinkapin oak); P; T; PBFW, RHW; LEX-119
Quercus shumardii Buckley (Shumard's oak); P; T; PBFW, PEFW; LEX-525
Quercus stellata Wangenh. (post oak); P; T; PBFW, PEFW, YPBW; LEX-117
Quercus velutina Lam. (black oak); P; T; PBFW, PEFW, YPBW; LEX-076

Gentianaceae
Sabatia angularis (L.) Pursh (squarestem rosegentian); A; F; PP; LEX-337
Sabatia campestris Nutt. (meadow pink); A; F; DA, PP; LEX-400

Geraniaceae
**Erodium cicutarium* (L.) L'Hér. ex Aiton (redstem stork's bill); A; F; DA; LEX-113
Geranium carolinianum L. (Carolina crane's bill); A; F; DA; LEX-059

Grossulariaceae
Ribes aureum Pursh var. *villosum* DC. (golden currant); P; S; RHW; LEX-007

Haloragaceae
**Myriophyllum spicatum* L. (Eurasian water milfoil); P; F; HWV; LEX-299
Myriophyllum verticillatum L. (whorled watermilfoil); P; F; HWV; LEX-234

Heliotropiaceae
Heliotropium tenellum (Nutt.) Torr. (pasture heliotrope); A; F; DA, PP; LEX-376

Hypericaceae
Hypericum drummondii (Grev. & Hook.) Torr. & A. Gray (nits and lice); A; F; PP; LEX-343
Hypericum hypericoides (L.) Crantz (St. Andrew's cross); P; F; PBFW, PEFW, YPBW; LEX-365
Hypericum punctatum Lam. (spotted St. Johnswort); P; F; PBFW, PEFW, YPBW; LEX-383

Iridaceae
Sisyrinchium campestre E.P. Bicknell (prairie blue-eyed grass); P; F; PP; LEX-040

Sisyrinchium pruinosum E.P. Bicknell (dotted blue-eyed grass); P; F; PP; LEX-070

Juglandaceae
Carya illinoinensis (Wangenh.) K. Koch (pecan); P; T; RHW; LEX-498
Carya texana Buckley (black hickory); P; T; PBFW, PEFW, YPBW; LEX-518

Juncaceae
Juncus diffusissimus Buckley (slimpod rush); P; G; HWV; LEX-332
Juncus dudleyi Wiegand (Dudley's rush); P; G; HWV; LEX-161
Juncus effusus L. (common rush); P; G; HWV; LEX-185
Juncus marginatus Rostk. (grassleaf rush); P; G; HWV; LEX-159
Juncus scirpoides Lam. (needlepod rush); P; G; HWV; LEX-261
Juncus tenuis Willd. (field rush); P; G; DA, PP; LEX-142

Krameriaceae
Krameria lanceolata Torr. (trailing ratany); P; F; PP; LEX-193

Lamiaceae
Agastache nepetoides (L.) Kuntze (catnip giant hyssop); P; F; PP; LEX-590
Hedeoma hispida Pursh (rough pennyroyal); P; F; PP; LEX-177
Hedeoma reverchonii (A. Gray) A. Gray (Reverchon's false pennyroyal); P; F; PP; LEX-321
**Lamium amplexicaule* L. (common henbit); A; F; DA; LEX-008
Lycopus americanus Muhl. ex W.P.C. Bartram (water horehound); P; F; HWV; LEX-313
Monarda fistulosa L. (wild bergamont); P; F; PP; LEX-387
Salvia azurea Michx. ex Lam. (blue sage); P; F; PP; LEX-579
Scutellaria parvula Michx. (small skullcap); P; F; PP; LEX-084
Teucrium canadense L. (Canada germander); P; F; HWV; LEX-391

Lentibulariaceae
Utricularia gibba L. (humped bladderwort); P; F; HWV; LEX-318

Linaceae
Linum rigidum Pursh (orange flax); A; F; PP; LEX-171
Linum sulcatum Riddell (grooved yellow flax); A; F; PP; LEX-245

Linderniaceae
Lindernia dubia (L.) Pennell (moistbank pimpernel); A; F; HWV; LEX-436

Loganiaceae
Mitreola petiolata (J.F. Gmel.) Torr. & A. Gray (lax hornpod); A; F; HWV; LEX-412

Lythraceae
Ammannia coccinea Rottb. (valley redstem); A; F; HWV; LEX-485
Lythrum alatum Pursh (winged lythrum); P; F; HWV; LEX-388
Rotala ramosior (L.) Koehne (lowland toothcup); A; F; HWV; LEX-271

Malvaceae
Callirhoe alcaeoides (Michx.) A. Gray (plains poppymallow); P; F; PP; LEX-104
Callirhoe involucrata (Torr. & A. Gray) A. Gray (purple poppymallow); P; F; PP; LEX-207
Sida abutilifolia Mill. (spreading fanpetals); P; F; DA; LEX-279

Menispermaceae
Cocculus carolinus (L.) DC. (redberry moonseed); P; F; PBFW, PEFW, YPBW; LEX-296

Molluginaceae
Mollugo verticillata L. (carpetweed); A; F; DA; LEX-347

Montiaceae
Phemeranthus parviflorus (Nutt.) Kiger (sunbright); P; F; PP; LEX-589

Moraceae
Morus alba L. (white mulberry); P; T; PBFW, PEFW, YPBW; LEX-473
Morus rubra L. (red mulberry); P; T; PBFW, PEFW, YPBW; LEX-230

Nelumbonaceae
Nelumbo lutea Willd. (American lotus); P; F; HWV; LEX-380

Nyctaginaceae
Mirabilis albida (Walter) Heimerl (white four o'clock); P; F; PP; LEX-252

Oleaceae
Ligustrum sinense Lour. (Chinese privet); P; S; PBFW, PEFW, YPBW; LEX-472

Onagraceae
Ludwigia alternifolia L. (bushy seedbox); P; F; HWV; LEX-386
Ludwigia palustris (L.) Elliott (marsh primrose willow); P; F; HWV; LEX-144
Ludwigia peploides (Kunth) P.H. Raven (floating primrose); P; F; HWV; LEX-153
Oenothera berlandieri (Spach) Steud. (Berlandier's sundrops); P; F; PP; LEX-078
Oenothera curtiflora W.L. Wagner & Hoch (velvetweed); A; F; DA, PP; LEX-293
Oenothera filiformis (Small) W.L. Wagner & Hoch (longflower beeblossom); A; F; DA; LEX-298
Oenothera glaucifolia W.L. Wagner & Hoch (false gaura); P; F; PP; LEX-427
Oenothera laciniata Hill (cutleaf eveningprimrose); P; F; DA, PP; LEX-086
Oenothera linifolia Nutt. (threadleaf sundrop); A; F; PP; LEX-223
Oenothera macrocarpa Nutt. (bigfruit evening primrose); P; F; PP; LEX-216
Oenothera rhombipetala Nutt. ex Torr & A. Gray (fourpoint evening primrose); P; F; PP; LEX-402
Oenothera speciosa Nutt. (showy evening primrose); P; F; PP; LEX-126
Oenothera villosa Thunb. (hairy evening primrose); P; F; DA; LEX-509

Ophioglossaceae
Botrychium virginianum (L.) Sw. (rattlesnake fern); P; F; RHW; LEX-571
Ophioglossum engelmannii Prantl (limestone adder's tongue); P; F; PP; LEX-125

Orobanchaceae
Agalinis fasciculata (Elliott) Raf. (beach false foxglove); A; F; PP; LEX-268
Agalinis heterophylla (Nutt.) Small (prairie false foxglove); A; F; PP; LEX-274
Buchnera americana L. (American bluehearts); P; F; PP; LEX-372
Castilleja indivisa Engelm. (entireleaf Indian paintbrush); A; F; PP; LEX-103

Oxalidaceae
Oxalis corniculata L. (yellow Oxalis); P; F; DA; LEX-044
Oxalis violacea L. (violet woodsorrel); P; F; PBFW, PEFW, PP, YPBW; LEX-026

Passifloraceae
Passiflora incarnata L. (purple passionflower); P; F; DA, PP; LEX-286

Penthoraceae
Penthorum sedoides L. (ditch stonecrop); P; F; HWV; LEX-397

Phrymaceae
Mimulus alatus Aiton (sharpwing monkeyflower); P; F; HWV; LEX-411
Phryma leptostachya L. (lopseed); P; F; PBFW, PEFW, RHW, YPBW; LEX-231

Phytolaccaceae
Phytolacca americana L. (pokeweed); P; F; DA, PP; LEX-284

Pinaceae
#*Pinus taeda* L. (loblolly pine); P; T; PP; LEX-555

Plantaginaceae
Leucospora multifida (Michx.) Nutt. (narrowleaf paleseed); A; F; HWV; LEX-331
Nuttallanthus texanus (Scheele) D.A. Sutton (Texas toadflax); A; F; DA, PP; LEX-143
Penstemon cobaea Nutt. (cobea beardtongue); P; F; PP; LEX-123
†*Penstemon oklahomensis* Pennell (Oklahoma penstemon); P; F; PP; LEX-094; S3G3
Plantago aristata Michx. (largebracted plantain); A; F; PP; LEX-204
Plantago patagonica Jacq. (wooly plantain); A; F; PP; LEX-055
Plantago virginica L. (Virginia plantain); A; F; PP; LEX-062
**Veronica arvensis* L. (rock speedwell); A; F; DA; LEX-043
Veronica peregrina L. (purslane speedwell); A; F; PP; LEX-096
**Veronica persica* Poir. (winter speedwell); A; F; DA; LEX-018

Poaceae
Agrostis hyemalis (Walter) Britton, Sterns & Poggenb. (winter bentgrass); P; G; PP; LEX-173
Andropogon gerardii Vitman (big bluestem); P; G; PP; LEX-338
Andropogon glomeratus (Walter) Britton, Sterns & Poggenb. (bushy bluestem); P; G; HWV; LEX-464
Andropogon ternarius Michx. (splitbeard bluestem); P; G; PP; LEX-467
Andropogon virginicus L. (broomsedge bluestem); P; G; PP; LEX-460
Aristida basiramea Engelm. ex Vasey (forked threeawn); A; G; PP; LEX-482
Aristida desmantha Trin. & Rupr. (curly threeawn); A; G; PP; LEX-496
Aristida oligantha Michx. (prairie threeawn); A; G; DA, DA, PP; LEX-481

Aristida purpurascens Poir. (arrowfeather threeawn); P; G; PP; LEX-495
Aristida purpurea Nutt. var. *purpurea* (purple threeawn); P; G; PP; LEX-147
Aristida purpurea Nutt. var. *wrightii* (Nash) Allred (Wright's threeawn); P; G; PP; LEX-240
**Bothriochloa ischaemum* (L.) Keng (yellow bluestem); P; G; DA, PP; LEX-202
Bothriochloa laguroides (DC.) Herter (silver beardgrass); P; G; PP; LEX-363
Bouteloua curtipendula (Michx.) Torr. (sideoats grama); P; G; PP; LEX-357
Bouteloua dactyloides (Nutt.) Columbus (buffalograss); P; G; PP; LEX-091
Bouteloua hirsuta Lag. (hairy grama); P; G; PP; LEX-333
Bouteloua rigidiseta (Steud.) Hitchc. (Texas grama); P; G; PP; LEX-225
**Bromus catharticus* Vahl (rescuegrass); A; G; PP; LEX-095
**Bromus commutatus* Schrad. (meadow brome); A; G; DA; LEX-128
**Bromus hordeaceus* L. (soft brome); A; G; PP; LEX-176
Bromus pubescens Muhl. Ex Willd. (hairy woodland brome); P; G; PBFW, PEFW, YPBW; LEX-092
**Bromus racemosus* L. (bald brome); A; G; PP; LEX-129
**Bromus tectorum* L. (cheatgrass); A; G; DA; LEX-030
Cenchrus incertus M.A. Curtis (field sandbur); P; G; DA, PP; LEX-488
Chasmanthium latifolium (Michx.) H.O. Yates (Indian woodoats); P; G; RHW; LEX-384
Coleataenia anceps (Michx.) Soreng (beaked panicum); P; G; PBFW, PEFW, YPBW; LEX-453
Coleataenia longifolia (Torr.) Soreng ssp. *rigidula* (Bosc ex Nees) Soreng (redtop panicgrass); P; G; HWV; LEX-581
**Cynodon dactylon* (L.) Pers. (Bermuda grass); P; G; DA, PP; LEX-366
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark var. *acuminatum* (tapered rosettegrass); P; G; PBFW, PEFW, YPBW; LEX-265
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark var. *fasciculatum* (Torr.) Freckmann (western panicgrass); P; G; PBFW, PEFW, YPBW; LEX-151
Dichanthelium dichotomum (L.) Gould (cypress panicgrass); P; G; PBFW, PEFW, YPBW; LEX-083
Dichanthelium laxiflorum (Lam.) Gould (openflower rosette grass); P; G; PP; LEX-172
Dichanthelium malacophyllum (Nash) Gould (softleaf rosettegrass); P; G; PP; LEX-168
Dichanthelium oligosanthes (Schult.) Gould (Heller's rosette grass); P; G; PP; LEX-079
Dichanthelium ovale (Elliott) Gould & C.A. Clark (eggleaf rosette grass); P; G; PBFW, PEFW, YPBW; LEX-547
Dichanthelium scoparium (Lam.) Gould (velvet panicum); P; G; HWV; LEX-289
Dichanthelium sphaerocarpon (Elliott) Gould (roundseed panicum); P; G; PP; LEX-179
Digitaria ciliaris (Retz.) Koeler (fingergrass); A; G; PP; LEX-486
**Digitaria ischaemum* (Schreb.) Muhl. (small crabgrass); A; G; DA; LEX-510
Echinochloa muricata (P. Beauv.) Fernald (rough barnyard grass); A; G; HWV; LEX-254
**Eleusine indica* (L.) Gaertn. (goosegrass); A; G; DA; LEX-447
Elymus canadensis L. (Canada wildrye); P; G; PBFW, PEFW, YPBW; LEX-175
Elymus glabriflorus (Vasey ex L.H. Dewey) Scribn. & C.R. Ball (Southeastern wildrye); P; G; PBFW, PEFW; LEX-305
Elymus virginicus L. (Virginia wild rye); P; G; PBFW, PEFW, YPBW; LEX-242
**Eragrostis barrelieri* Daveau (Mediterranean lovegrass); A; G; PP; LEX-322
**Eragrostis curvula* (Schrad.) Nees (weeping lovegrass); P; G; PP; LEX-219
Eragrostis hirsuta (Michx.) Nees (bigtop lovegrass); P; G; PP; LEX-517
Eragrostis secundiflora J. Presl ssp. *oxylepis* (Torr.) S.D. Koch (red lovegrass); P; G; PP; LEX-325
Eragrostis spectabilis (Pursh) Steud. (purple lovegrass); P; G; PP; LEX-479
Festuca paradoxa Desv. (clustered fescue); P; G; PBFW, PEFW, RHW, YPBW; LEX-266

Gymnopogon ambiguus (Michx.) Britton, Sterns & Poggenb. (bearded skeletongrass); P; G; PP; LEX-416
Hordeum pusillum Nutt. (little barley); A; G; DA, PP; LEX-089
Leersia oryzoides (L.) Sw. (rice cutgrass); P; G; HWV; LEX-463
Leersia virginica Willd. (white grass); P; G; RHW; LEX-428
Leptochloa panicea (Retz.) Ohwi (mucronate sprangletop); A; G; HWV; LEX-281
**Lolium perenne* L. (perennial rye grass); P; G; DA, PP; LEX-227
Mnesithea cylindrica (Michx.) de Koning & Sosef (Carolina jointail); P; G; PP; LEX-229
Muhlenbergia capillaris (Lam.) Trin. (hairawn muhly); P; G; PBFW, PEFW, YPBW; LEX-524
Muhlenbergia paniculata (Nutt.) Columbus (tumblegrass); P; G; PP; LEX-228
Muhlenbergia sobolifera (Muhl. ex Willd.) Trin. (rock muhly); P; G; PEFW; LEX-239
†*Panicum brachyanthum* Steud. (prairie panicgrass); A; G; YPBW; LEX-513; S2G5
Panicum capillare L. (ticklegrass); A; G; PP; LEX-350
Panicum dichotomiflorum Michx. (western witchgrass); A; G; HWV; LEX-258
Panicum virgatum L. (switchgrass); P; G; HWV; LEX-439
**Paspalum distichum* L. (knotgrass); P; G; HWV; LEX-154
Paspalum floridanum Michx. (Florida Paspalum); P; G; PP; LEX-310
Paspalum setaceum Michx. (thin Paspalum); P; G; PP; LEX-303
Phalaris caroliniana Walter (Carolina canarygrass); A; G; PP; LEX-533
**Poa annua* L. (annual bluegrass); A; G; DA, PEFW; LEX-006
**Poa pratensis* L. (Kentucky bluegrass); A; G; PBFW, PEFW, YPBW; LEX-097
**Schedonorus arundinaceus* (Schreb.) Dumort. (tall fescue); P; G; PBFW, PEFW, YPBW; LEX-157
Schizachyrium scoparium (Michx.) Nash (little bluestem); P; G; PP; LEX-423
Setaria parviflora (Poir.) Kerguélen (knotted bristlegrass); P ; G; PP; LEX-170
**Setaria pumila* (Poir.) Roem. & Schult. (yellow bristlegrass); A; G; DA, PP; LEX-312
**Setaria viridis* (L.) P. Beauv. (green bristlegrass); A; G; DA, PP; LEX-262
Sorghastrum nutans (L.) Nash (Indian grass); P; G; PP; LEX-424
**Sorghum halepense* (L.) Pers. (Johnsongrass); P; G; DA, PP; LEX-201
Sphenopholis obtusata (Michx.) Scribn. (prairie wedgescale); P; G; PP; LEX-085
Sporobolus cryptandrus (Torr.) A. Gray (sand dropseed); P; G; PP; LEX-507
Sporobolus pyramidatus (Lam.) Hitchc. (whorled dropseed); P; G; PP; LEX-478
Steinchisma hians (Elliott) Nash (gaping grass); P; G; HWV; LEX-285
Tridens flavus (L.) Hitchc. (purpletop); P; G; PBFW, PEFW, YPBW; LEX-437
Urochloa fusca (Sw.) B.F. Hansen & Wunderlin (browntop signalgrass); A; G; DA; LEX-277
**Vulpia bromoides* (L.) Gray (brome fescue); A; G; DA; LEX-155
**Vulpia myuros* (L.) C.C. Gmel. (rattail fescue); A; G; DA, PP; LEX-065
Zizaniopsis milacea (Michx.) Döll & Asch. (giant cutgrass); P; G; HWV; LEX-187

Polygalaceae
Polygala incarnata L. (procession flower); A; F; PP; LEX-194
Polygala verticillata L. (whorled milkwort); A; F; PP; LEX-224

Polygonaceae
Eriogonum longifolium Nutt. (longleaf eriogonum); P; F; PP; LEX-288
**Fallopia convolvulus* (L.) Á. Löve (black bindweed); A; F; DA; LEX-536
**Fallopia scandens* (L.) Houlb (climbing false buckwheat); P; F; YPBW; LEX-251
Persicaria hydropiperoides (Michx.) Small (swamp smartweed); A; F; HWV; LEX-235

Persicaria lapathifolia (L.) Gray (curlytop knotweed); A; F; HWV; LEX-409
Persicaria setacea (Baldwin) Small (bog smartweed); P; F; HWV; LEX-316
Persicaria virginiana (L.) Gaertn. (jumpseed); P; F; RHW; LEX-573
**Rumex crispus* L. (curly dock); P; F; DA, HWV; LEX-189
Rumex hastatulus Baldwin (heartwing dock); P; F; HWV; LEX-186

Portulacaceae
**Portulaca oleracea* L. (purslane); A; F; HWV; LEX-585

Potamogetonaceae
Potamogeton nodosus Poir. (longleaf pondweed); P; F; HWV; LEX-141

Primulaceae
Androsace occidentalis Pursh (western rockjasmine); A; F; DA; LEX-001
Samolus valerandi L. (seaside brookweed); P; F; HWV; LEX-270

Ranunculaceae
Anemone berlandieri Pritz. (tenpetal thimbleweed; P; F; PP; LEX-048
Delphinium carolinianum Walter ssp. *virescens* (Nutt.) R.E. Brooks (Carolina larkspur); P; F; DA, PP; LEX-210
Ranunculus sceleratus L. (cursed buttercup); A; F; HWV; LEX-072

Rosaceae
Agrimonia parviflora Aiton (manyflowered groovebur); P; F; PP; LEX-256
Fragaria virginiana Duchesne (Virginia strawberry); P; F; DA; LEX-025
Geum canadense Jacq. (white avens); P; F; PBFW, PEFW, YPBW; LEX-212
Prunus angustifolia Marshall (Chickasaw plum); P; S; PP; LEX-011
Prunus gracilis Engelm. & A. Gray (Oklahoma plum); P; S; PP; LEX-528
Prunus mexicana S. Watson (Mexican plum); P; T; PBFW, PEFW, YPBW; LEX-023
**Pyrus calleryana* Decne. (Callery pear); P; T; PBFW, PP; LEX-112
Rosa foliolosa Nutt. ex Torr. & A. Gray (white prairie rose); P; F; PP; LEX-208
**Rosa multiflora* Thunb. (multiflora rose); P; S; RHW; LEX-558
Rubus aboriginum Rydb. (garden dewberry); P; S; PP; LEX-059
Rubus allegheniensis Porter (Allegheny blackberry); P; S; PP; LEX-587

Rubiaceae
Cephalanthus occidentalis L. (common buttonbush); P; S; HWV; LEX-356
**Cruciata pedemontana* (Bellardi) Ehrend. (piedmont bedstraw); A; F; DA; LEX-058
Diodella teres (Walter) Small (poorjoe); A; F; DA; LEX-390
Diodia virginiana L. (Virginia buttonweed); P; F; HWV; LEX-389
Galium aparine L. (bedstraw); A; F; DA; LEX-100
Galium circaezans Michx. (licorice bedstraw); P; F; PBFW, PEFW, YPBW; LEX-158
Galium virgatum Nutt. (southwest bedstraw); A; F; DA; LEX-057
Houstonia pusilla Schoepf (tiny bluet); A; F; DA; LEX-010
Stenaria nigricans (Lam.) Terrell (diamondflowers); P; F; PP; LEX-215

Salicaceae
Populus deltoides W. Bartran ex Marshall (plains cottonwood); P; T; DA; LEX-508
Salix nigra Marshall (black willow); P; T; HWV; LEX-098

Sapindaceae
Acer negundo L. (boxelder); P; T; RHW; LEX-124
Sapindus saponaria L. var. *drummondii* (Hook. & Arn.) L.D. Benson (western soapberry); P; T; PBFW, PEFW, YPBW; LEX-471

Sapotaceae
Sideroxylon lanuginosum Michx. (gum bully); P; T; PBFW, PEFW, YPBW; LEX-118

Scrophulariaceae
**Verbascum thapsus* L. (common mullein); B; F; DA; LEX-415

Simaroubaceae
**Ailanthus altissima* (Mill.) Swingle (tree of heaven); P; T; DA; LEX-537

Smilacaceae
Smilax bona-nox L. (saw greenbrier); P; V; PBFW, PEFW, YPBW; LEX-052
Smilax tamnoides L. (bristly greenbrier); P; V; PBFW, PEFW, YPBW; LEX-344

Solanaceae
Physalis heterophylla Nees (clammy groundcherry); P; F; DA; LEX-160
Physalis pubescens L. (groundcherry); A; F; PP; LEX-307
Solanum carolinense L. (Carolina horsenettle); P; F; DA, PP; LEX-183
Solanum dimidiatum Raf. (western horsenettle); P; F; DA, PP; LEX-349
Solanum rostratum Dunal (buffalobur nightshade); A; F; DA, PP; LEX-367
Solanum ptychanthum Dunal (West Indian nightshade); A; F; DA, PP; LEX-352
Solanum elaeagnifolium Cav. (silverleaf nightshade); P; F; DA, PP; LEX-375

Tetrachondraceae
Polypremum procumbens L. (juniper leaf); A; F; HWV; LEX-540

Typhaceae
Typha domingensis Pers. (southern cattail); P; F; HWV; LEX-320

Ulmaceae
Ulmus alata Michx. (winged elm); P; T; PBFW, PEFW, YPBW; LEX-037
Ulmus americana L. (American elm); P; T; PBFW, PEFW, RHW; LEX-419
Ulmus rubra Muhl. (slippery elm); P; T; PBFW, PEFW, RHW; LEX-127

Urticaceae
Boehmeria cylindrica (L.) Sw. (smallspike false nettle); P; F; HWV; LEX-445

Valerianaceae
Valerianella radiata (L.) Dufr. (beaked cornsalad); A; F; DA, PP; LEX-088

Verbenaceae
Glandularia canadensis (L.) Nutt. (rose verbena); P; F; PP, YPBW; LEX-004
Phyla lanceolata (Michx.) Greene (lanceleaf frogfruit); P; F; HWV; LEX-385
Verbena halei Small (slender verbena); P; F; PP; LEX-060
Verbena stricta Vent. (tall vervain); P; F; DA, PP; LEX-511
Verbena urticifolia L. (white vervain); P; F; PBFW, YPBW; LEX-396

Violaceae
Viola bicolor Pursh (field pansy); A; F; DA; LEX-009
Viola sororia Willd. (common blue violet); A; F; PBFW, PEFW, YPBW; LEX-038
Viola villosa Walter (Carolina violet); P; F; PBFW, PEFW, YPBW; LEX-020

Vitaceae
Ampelopsis arborea (L.) Koehne (peppervine); P; S; DA, RHW; LEX-557
Ampelopsis cordata Michx. (heartleaf peppervine); P; V; PBFW, PEFW; LEX-465
Vitis cinerea (Engelm.) Engelm. ex Millard var. *helleri* (L.H. Bailey) M.O. Moore (Heller's grape); P; V; PBFW, PEFW; LEX-497
Vitis vulpina L. (fox grape); P; V; RHW; LEX-553

Woodsiaceae
Woodsia obtusa (Spreng.) Torr. (bluntlobe cliff fern); P; F; RHW; LEX-559

ASSESSMENT OF OKLAHOMA PHLOX (*PHLOX OKLAHOMENSIS*: POLEMONIACEAE) IN THE GYPSUM HILLS OF NORTHWESTERN OKLAHOMA AND SOUTHERN KANSAS

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ABSTRACT

Phlox oklahomensis Wherry, Oklahoma phlox, occurs within the tall grass prairie of the southern Flint Hills of Kansas, and other populations occur within the southern mixed grass prairie of the Gypsum Hills of northwestern Oklahoma and southern Kansas. The first census of Oklahoma phlox in northwestern Oklahoma and southern Kansas was conducted over a three-year period (1980-1982). The second and third censuses occurred approximately 20 years after the first census, in 2002 and 2003. Since the 1980s two major wildfires and several droughts have occurred throughout its distribution range. The goals of this research were to compare the 1980-1982 census and the 2002 and 2003 censuses of Oklahoma phlox to censuses conducted in 2020 and 2021 and assess the current status of the species. In addition, we used a geographic information system (GIS) to identify factors that influence the likelihood of finding Oklahoma phlox in the region. The final census found that the occurrence of Oklahoma phlox has not changed significantly over the last 40 years. Populations thrive in areas where the fire interval is >5 years, and it commonly occurs on the upper elevations of the landscape on hilltops and/or ridges where the slope is > 7%. Although plants were observed on all landscape exposures, populations occur more frequently on west and northwest facing slopes. The authors recommend an S3 ranking for Oklahoma phlox.

INTRODUCTION

Oklahoma phlox (Figure 1), *Phlox oklahomensis* Wherry, was described in 1944 by E. T. Wherry from plant materials collected approximately 21 km (13 miles) north of Mooreland, Oklahoma (Woodward County) by H. C. Benke #5017, holotype (F, Field Museum of Natural History, Chicago, IL), on 22 April 1929. *Phlox oklahomensis* is a perennial herb that grows up to 15 cm high with a lavender, pink, or white corolla with a notch at the tip of each lobe. Its leaves are linear-lanceolate, opposite, and up to 2 cm long (Wherry 1955). It is classified in the tribe Polemonieae of the family Polemoniaceae. Populations of Oklahoma phlox are reported to occur in Butler, Chautauqua, Comanche, Cowley, and Elk counties of Kansas and in Woods and Woodward counties of Oklahoma (Springer and Tyrl 1989).

Figure 1 *Phlox oklahomensis* Wherry from Woods County, Oklahoma. Photographs by Tim Springer.

The distribution of Oklahoma phlox is not continuous, e.g., populations of *P. oklahomensis* occur within the tall grass prairie of the southern Flint Hills of Kansas and other populations occur within the southern mixed grass prairie of the Gypsum Hills of northwestern Oklahoma and adjacent Kansas. Wherry (1955) hypothesized that populations of *P. oklahomensis* of the Gypsum Hills were once continuous with populations of the Flint Hills, and that intermediate populations have been destroyed due to farming and land misuse. Ayensu and DeFilipps (1970) published their inventory of endangered and threatened plants of the United States and listed Oklahoma phlox as a threatened plant species due to its restricted geographical distribution. However, in 1980 the U.S. Fish and Wildlife Service reclassified *P. oklahomensis* as a Category 3C species, i.e., 'Taxa that have proven to be more abundant or widespread than was previously believed and/or those that are not subject to any identifiable threat. Should further research or changes in land use indicate significant decline in any of these taxa, they may be re-evaluated for possible inclusion in Categories 1 or 2 of endangered or threatened.' These listings did, however, justify the need for comprehensive research of *P. oklahomensis*.

A census of Oklahoma phlox populations was conducted over a three-year period (1980-1982) in the Gypsum Hills of northwestern Oklahoma and adjacent Kansas using land survey sections to determine its distribution (Springer 1983).

This census created a baseline for future monitoring of the species. Approximately 20 years after the first census, second and third censuses of Oklahoma phlox were conducted in 2002 and 2003, respectively (Springer and Tyrl 2003). Since 1982 two major wildfires and several droughts have occurred over the range of Oklahoma phlox in the Gypsum Hills of northwestern Oklahoma and adjacent Kansas; therefore we undertook a fourth and fifth census of the species in 2020 and 2021. The goals of this research were 1) to compare the censuses of *P. oklahomensis* to previous censuses; 2) assess the status of the species; and 3) identify factors that appear to influence the likelihood of finding Oklahoma phlox within the region.

METHODS

In previous censuses, land survey sections adjacent to public roads were visually surveyed to determine the presence or absence of Oklahoma phlox (Springer and Tyrl 1989, 2003). This was accomplished by driving public roadways of Woods and Woodward counties, Oklahoma, and Comanche County, Kansas. If a phlox population occurred within a land survey section, the section was counted. In April 2020 and 2021, we conducted similar censuses of Oklahoma phlox in northwestern Oklahoma and adjacent southern Kansas, except that we used a smartphone global positioning system (GPS) application to determine the coordinates of each Oklahoma phlox population encountered. These GPS locations were converted to land survey sections using Earth Point© Tools for Google Earth (Earth Point© 2021) and summarized to land survey sections. Areas previously visited were reexamined and, to determine a more accurate distribution of Oklahoma phlox, areas of similar soil types and habitats were examined outside its known distribution range. The relative abundance of phlox plants was noted but was not quantified for populations. GPS data calculated the length of survey route as 523.6 km in April 2020 and 2021. Since GPS data were not used in the three previous censuses, lengths of survey routes are unknown. In 2020 and 2021 the part of the survey route that was uncultivated on both sides of the roadway was 380.3 km. The route where cultivation had occurred on one side of the roadway was 89.0 km and the remaining 54.3 km was cultivated on both sides. The "cultivated" classification was based on the 2020 cropland data layer (USDA-NASS 2021) and photo interpretation of the most recent satellite data available on Google Maps in 2021.

For 2020 and 2021 data, we assembled elevation, soil, and fire history geospatial datasets for the study area into a geographic information system (GIS) to identify factors that may influence the distribution of the species. Soil mapping spatial data for each county were obtained from the USDA-NRCS, Web Soil Survey (Soil Survey Staff, USDA-NRCS 2022). The various soil mapping units encountered were grouped by component composition irrespective of slope or other phase characteristics. One hundred and one unique soil map units were encountered by sampling the survey route and the units were combined to form 37 soil mapping unit groups based on component composition. All single component soil mapping units (i.e., soil mapping units with only one named soil series or miscellaneous land type, such as rock outcrop) with the same named component were grouped together even though they may have a different map unit symbol because they were mapped in a different county or have a different slope class or other phase characteristic. For complex soil mapping units with only two components, the grouped units shared the same composition but in different proportions and, as above, with different phase characteristics. Soil map units composed of three components were included in the same group if at least one component was in common with all other members of the group. The fire history data were the monitoring trends in burn severity (MTBS) dataset described in Picotte et al. (2020) that covers the period 1984 through 2020. Based on the first author's observations, there was no evidence of fire anywhere along the survey route in 2021 and we feel confident the 1984 to 2020 MTBS dataset can also be used to represent 2021 along the survey route as well. We utilized the fire polygons layer from the MTBS. The elevation dataset (DEM) used was the 30-m national elevation dataset available to download for each county from the USDA-NRCS, Geospatial Data Gateway (2022). The DEM was used to derive additional geospatial datasets including slope, slope aspect, and topographic position indexes (TPIs) at four scales. The slope and aspect rasters were calculated in the database using the st_slope and st_aspect functions in the POSTGIS extension for PostgreSQL. For the TPIs we wrote our own procedures in the R language to implement the TPI method given in De Reu et al. (2013) and Weiss (2001). The topographic position index characterizes a location's elevation in relationship to the average elevation of the surrounding landscape, where the surrounding landscape is defined as the area covered by an annulus centered on the location. The annulus has an outside radius given as the scale radius and the inside radius is defined as the outside radius minus the band width. The radiuses used for the four TPI scales were 2000 m, 1000 m, 300 m, and 150 m (67, 33, 10, and 5 DEM cells away) and the band width was always 60 m (2 cell widths). A TPI near zero signifies the site is on a plain that may or may not be sloping; a large positive TPI, depending on the scale, implies the site is on a mound (local scale), hill, ridge, or interfluve (regional scale); and a large negative TPI signifies the site is in a gully (local scale), swale, or large valley (regional scale).

After these datasets were assembled, the layers were sampled at all points where phlox sites were recorded in 2020 and 2021 and at a set of 1000 random points. The random points were selected from within a 30 m buffer along that portion of the survey route where at least one side of the route was not cultivated (i.e., everything except the 54.3 km cultivated on both sides). The sampling was done using R software by intersecting the points with the attribute layers and appending the attribute information to the points.

The attribute data for the sites where phlox was observed in 2020 and 2021 were compared with the attribute data for the random sites to determine whether phlox sites differ from random sites and, if so, how they differ. For each attribute, a table was constructed with the counts of each attribute value associated with phlox sites, and the expectation was derived from the counts of each attribute value associated with the set of random points. A χ^2 analysis was done for each table to determine if the overall distribution differed between the phlox sites and the random sites and, if the test was significant, two by two tables were constructed to test whether each attribute value was observed less often, more often, or about as often as expected by chance at phlox sites.

The data from the 2020 and 2021 surveys are published on Ag Data Commons (https://doi.org/10.15482/USDA.ADC/1529120). Included in this dataset are three KML format files and a data dictionary describing the tabular variables found in the other three files in CSV format. One KML format file contains the geographic coordinates, soil, fire history, and topographic characteristics of each location where phlox populations were observed along the survey route in each year and another file contains the same for a set of 1000 random points along the survey route. The last KML format file gives the geometry of the survey route and whether the segment was cultivated on either side of the route in 2020 and 2021.

RESULTS AND DISCUSSION

It has been 40 years since the first census of Oklahoma phlox in northwestern Oklahoma and adjacent Kansas. Over that period, short- and long-term droughts have occurred in the region, the driest years occurring in 2011-2012 (Weather records from the Southern Plains Range Research Station, USDA Agricultural Research Service, Woodward, Oklahoma). Wildfires have occurred in the known range of Oklahoma phlox in Woods County, Oklahoma and Comanche County, Kansas in February 1996 and again in March 2016, and consecutive wildfires over parts of the known range of *P. oklahomensis* in Woodward County, Oklahoma in March 2017 and April 2018.

Five censuses of Oklahoma phlox have been conducted in which public roadways were driven and surveyed visually (as far as the eye could see) to determine the presence or absence of Oklahoma phlox. The first census occurred over a three-year period, 1980-1982, the second occurred in 2002, the third in 2003, the fourth in 2020, and the fifth in 2021. The first census verified the presence of Oklahoma phlox in 56 and 19 survey sections in Woods and Woodward counties, Oklahoma, respectively, and four sections in Comanche County, Kansas (Springer 1983). The number of survey sections averaged over the 2002 and 2003 censuses was 51.0 and 27.5 survey sections for Woods and Woodward counties of Oklahoma, respectively, and 4.5 sections in Comanche County of Kansas (Springer and Tyrl 2003). Similarly, the number of survey sections averaged over the 2020 and 2021 censuses was 45.0 and 33.5 for Woods and Woodward counties of Oklahoma, respectively, and 7.0 sections in Comanche County of Kansas (Table 1). Combining the data over the last two censuses, the total number of phlox observation sites was 529 in 99 land survey sections. Thirty-one

Table 1 Land survey sections containing one or more populations of *Phlox oklahomensis* Wherry in censuses conducted in 1980−1982, 2002, 2003, 2020, and 2021.

	Number of Sections with Populations		
	Oklahoma		Kansas
Survey Years	Woods Co.	Woodward Co.	Comanche Co.
1980−1982	56	19	4
2002	34	16	2
2003	68	39	7
2020	39	26	7
2021	51	41	7

percent of the 529 observation sites were identified in 2020 and 69% were identified in 2021 (some observation sites may be common to both years). Thus, the data suggest that the number of land survey sections has not drastically changed over the 40-year period (Table 1). The low census counts in 2002 and 2020 can be explained by below average fall and winter precipitation in 2001-2002 and again in 2019-2020. Springer et al. (2013) suggested that the variation in the number of sections found among years was correlated with fall and winter precipitation, i.e., when below average fall and winter precipitation occurs, fewer phlox populations are observed, and conversely when above average fall and winter precipitation occurs, more populations are observed. Thus, abundant fall and winter precipitation is important in the life cycle of Oklahoma phlox.

Based on the 38-year burn history, the distribution of the number of burns during this time period differed between phlox sites and randomly selected sites ($\chi^2 = 35.4$, df = 3, $P < 0.0001$). Oklahoma phlox was less likely to occur on unburned areas or areas burned three times over the 38-year period (Figure 2). Phlox was observed only once in an area that received three wildfires over the 38-year period; however, eight observations would have been expected by chance. There were 240 observations of phlox on unburned areas. This was 82% of what was expected. Where fire occurred once or twice during the period of record, significantly more phlox observations occurred than expected by chance (149 and 139 observations and 1.2 and 1.4 times as many as expected by chance, respectively).

We also defined phlox populations along the survey route according to the year from last burn (areas not burned during the 38-year period were classified as burned before 1984). Populations of phlox were not proportionately distributed among each of the years from last burned classes ($\chi^2 = 428.1$, df = 6, $P < 0.0001$, Figure 3). As expected, phlox observations in areas burned before 1984, 55.6% of the survey route, were underrepresented. This is

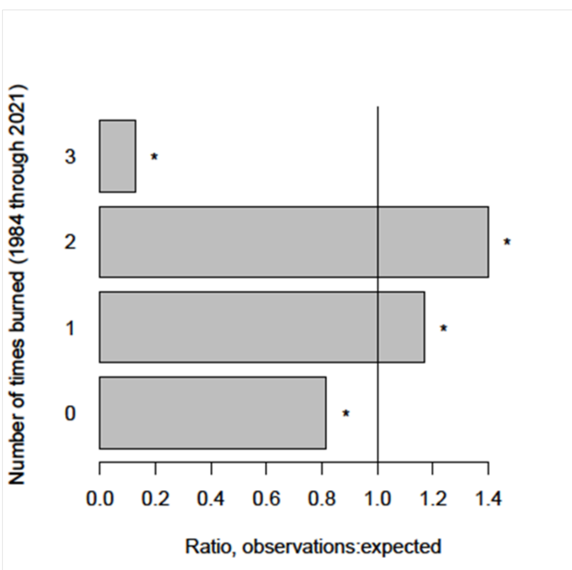

Figure 2 The ratio of the number of sites where *Phlox oklahomensis* Wherry was observed to the number of sites expected by chance for each area along the survey route with a different number of burns in the previous 37 years (1984 to 2021).

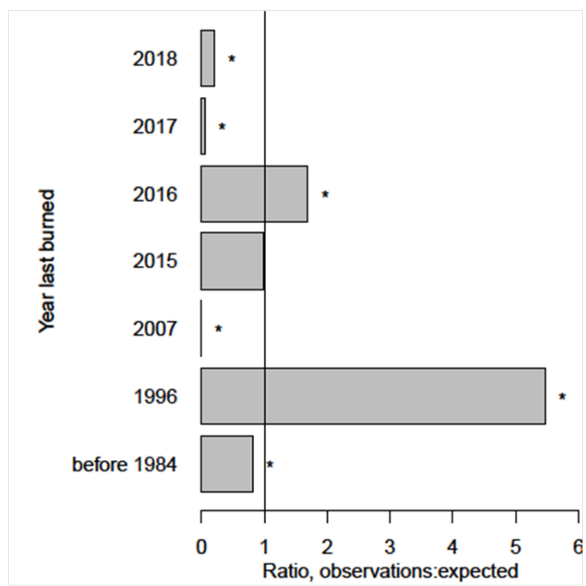

Figure 3 The ratio of the number of sites where *Phlox oklahomensis* Wherry was observed to the number of sites expected by chance for each area along the survey route with a different year last burned.

identical to the result shown above for areas that were not burned but, irrespective of how many times burned, only in areas last burned in 2015 (4.0% of the survey route) are phlox sites represented in proportion to chance expectation. The areas last burned in 2007 (1.0% of the survey), 2017 (7.3% of survey), and 2018 (9.9% of survey) have significantly fewer phlox sites than expected, and the areas last burned in 2016 (19.4% of the route) and especially in 1996 (2.8% of the route) had significantly more phlox observations than expected by chance. The areas last burned in 2016 had approximately 70% more phlox sites than expected, and areas last burned in 1996 had nearly 5.5 times as many phlox sites as expected by chance. Thus, prescribed fires would be beneficial to Oklahoma phlox in areas where fires have not occurred over a long period of time. However, a high frequency of prescribed fires may reduce the number of individuals in a phlox population.

We also considered each sampling year separately and defined fire history in terms of years since last burned in the sampling year. Areas sampled in 2020 with 24 years since last burned and correspondingly areas sampled in 2021 with 25 years since last burned had more phlox observations than would be expected by chance (Figure 4). In 2020, all other years since last burned, except four years since last burned, had fewer phlox observations than expected by chance. In 2020, the four years since last burned had more than expected, but in 2021 the corresponding areas with five years since last burned had phlox observations in proportion to what was expected by chance. Also in 2021, the six years since last burned areas had phlox observations in proportion to what was expected by chance and areas with the other four levels of years since last burned (3, 4, 14, and 37 years) had fewer phlox sites observed than expected by chance. Therefore, it may take five to six years for phlox populations to fully recover after a wildfire, although long durations

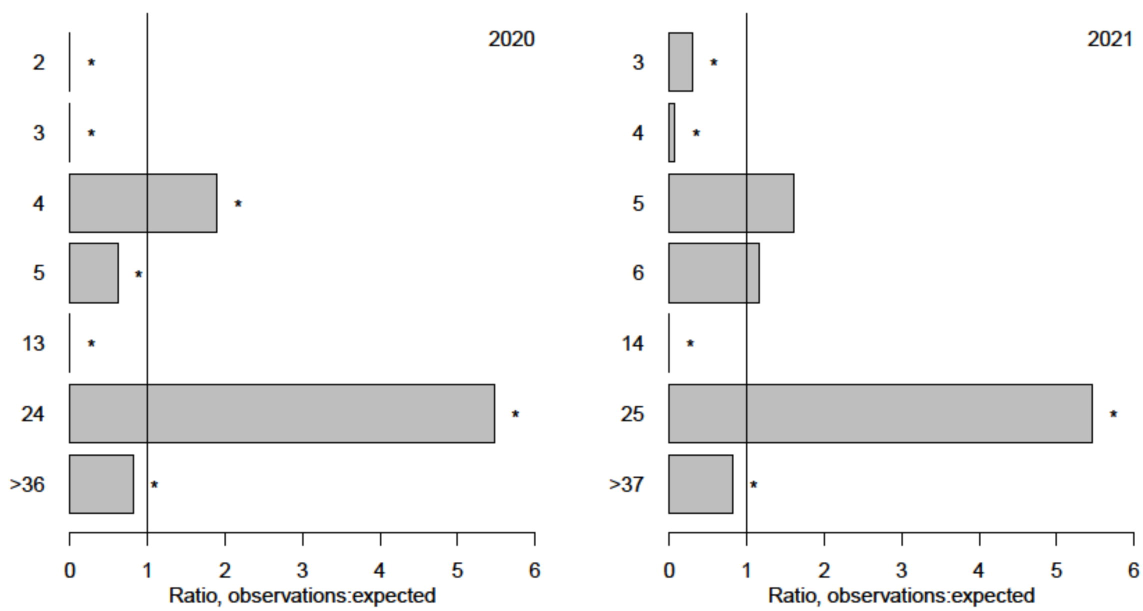

Figure 4 The ratio of the number of sites where *Phlox oklahomensis* was observed to the number of sites expected by chance for each area having a different number of years since last burned for surveys completed along the route in 2020 and 2021.

without fire significantly reduced the number of phlox populations encountered along the survey route, as evidenced by the data where sites were unburned for 36 or 37 years (Figure 4). This may be due to the accumulative effects of eastern red cedar (*Juniperus virginiana* L.) growth or the growth of other woody plant species. Thus, a 10-to-15-year burn cycle may be the best management practice for Oklahoma phlox.

The random sites and phlox population sites were found on a total of 37 unique soil mapping unit groups and Oklahoma phlox was observed in most of these groups (25) in proportion to the chance expectation, but phlox was found less than expected in seven soil mapping unit groups and more than expected in five soil mapping unit groups ($\chi^2 = 464.1$, df = 36, $P < 0.0001$). The 12 soil map units with phlox observations either significantly more or less than expected are plotted in Figure 5 as the observed:expected ratio.

The elevations above sea level for the phlox sites and randomly selected sites along the survey ranged from 456 m to 656 m. The elevation of the phlox sites averaged 591 m which was significantly greater than the randomly selected sites (539 m, $P < 0.0001$). The observed slopes in the dataset ranged from < 0.25% to 37.0%. Sites where phlox was observed averaged 7.2% slope which was significantly steeper than the average for the randomly selected sites along the survey route (5.6%, $P < 0.0001$). When we reclassified slope into six slope classes, phlox was less likely to be observed on slopes of <5% compared with that of chance, phlox was equally likely to occur on slopes of 5 to 7%, and phlox was expected to occur more often where slopes were >7% (Figure 6). Springer and Tyrl (1989) reported that *P. oklahomensis* was observed near rocky outcrops where competition from plants and accessibility to livestock is reduced. Furthermore, steep slopes are not conducive to human activity.

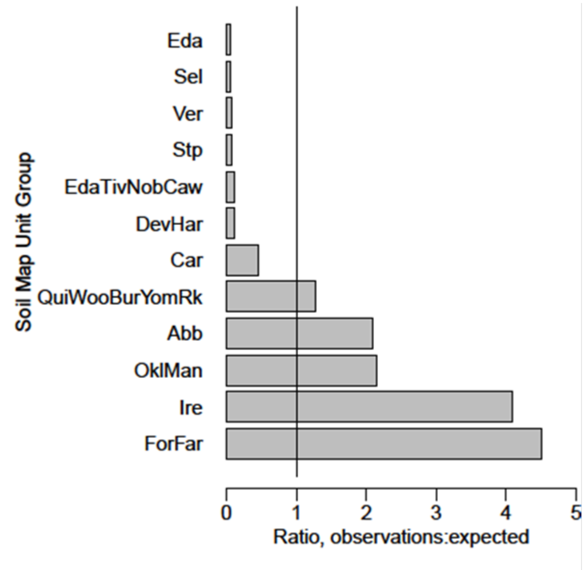

Figure 5 The ratio of the number of sites where *Phlox oklahomensis* Wherry was observed to the number of sites expected by chance for each area having a different soil map unit group. Shown in this figure are only the map unit groups where the number observed differs significantly from the expectation. Of the 37 groups encountered, seven had fewer and five had more Oklahoma phlox observation than expected by chance. The remaining 25 soil map unit groups had Oklahoma phlox observations in proportion to the expectation based on the area available. Eda, Eda soils; Sel, Selman soils; Ver, Vernon soils; Stp, St. Paul soils; EdaTivNobCaw, Eda-Tivoli-Nobscot-Carwile complex; DevHar, Devol-Harteman complex; Car, Carey soils; QuiWoodBurYomRk, Quinlan-Woodward-Burson-Yomont-Rocky outcrop soils; Abb, Abbie soils; OklMan, Oklark-Mansic soils; Ire, Irene soils; ForFar, Fortyone-Farry soils.

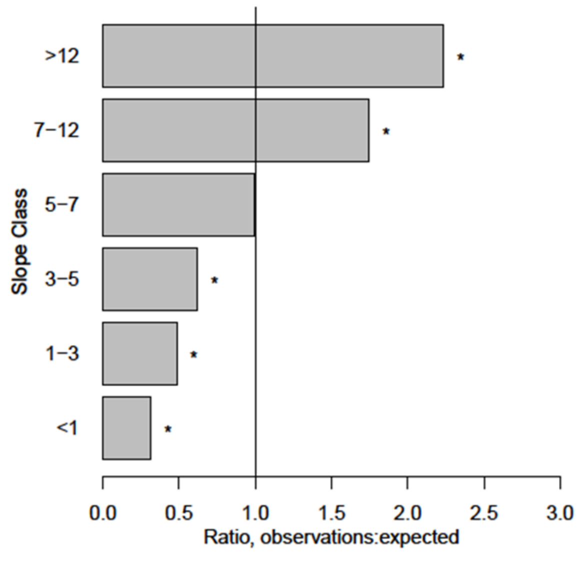

Figure 6. The ratio of the number of sites where *Phlox oklahomensis* Wherry was observed to the number of sites expected by chance for each area along the survey route with a different slope class.

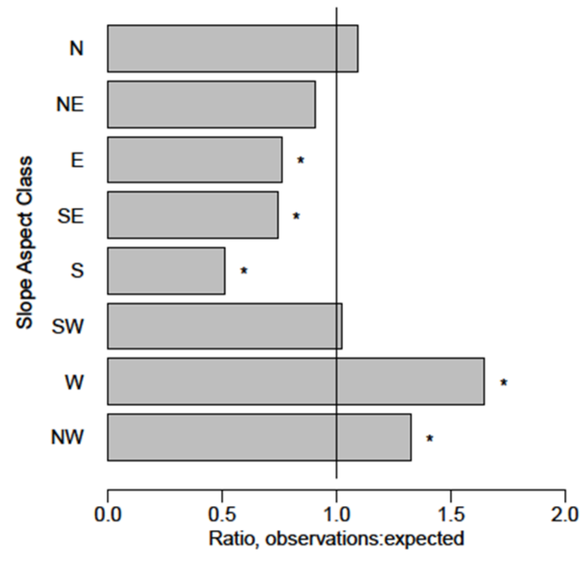

Figure 7. The ratio of the number of sites where *Phlox oklahomensis* Wherry was observed to the number of sites expected by chance for each area along the survey route with a different slope aspect class.

The mean slope aspect also differed between phlox observation sites (201°) and randomly selected sites (178°, $P < 0.0001$). To better understand the effect of slope aspect we reclassified aspect to one of the four cardinal or four primary intercardinal directions. It is clear from this analysis that E to S facing slopes have significantly fewer phlox observation sites than expected by chance and W to NW facing slopes have more phlox sites than expected by chance (Figure 7). The N to NE and SW facing slopes have phlox sites in proportion to the chance expectation. In contrast, Springer and Tyrl (1989) reported that plants were observed on all landscape exposures, but that plants preferred the cooler north-facing slopes.

Collectively the topographic position indexes at all four scales evaluated were greater at the phlox observation sites than the randomly selected sites along the survey route. The 150 m TPI averaged 2.1 for phlox sites compared with 0.7 for randomly selected sites ($P < 0.0001$). Likewise, the mean of the other three TPI scales was significantly greater for the phlox observation sites (300 m = 3.5, 1000 m = 7.3, and 2000 m = 11.0) than for the random sites (300 m = 1.2, 1000 m = 2.3, 2000 m = 4.1, for all TPI mean comparisons $P < 0.0001$). At each scale, the mode of the TPI distribution for random sites was near the means, but for the phlox observation sites the modes of the TPI distributions were greater than the means, and the greater the TPI scale the larger the difference between the mean and the mode (Figure 8). For comparison, a TPI near zero signifies a site of a flat or near continuous slope, a large positive TPI implies the site is on a hill or ridge, and a large negative TPI signifies the site is in a valley or gulley. Thus, Oklahoma phlox more commonly occurs on the upper elevations of the landscape on hills or ridges.

In summary, Oklahoma phlox is a hardy species. It has endured moderate to severe drought and untimely wildfires over the past 40 years. Land use in the Gypsum Hills has not changed significantly and consists

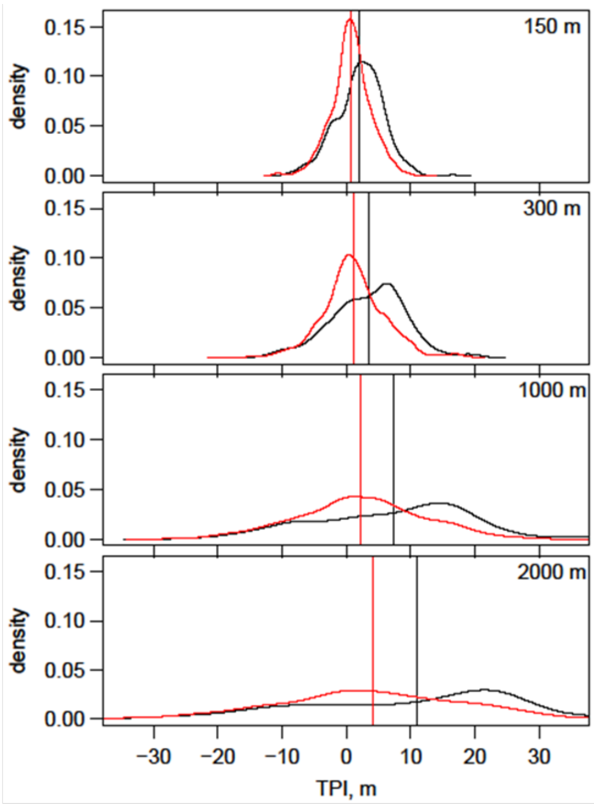

Figure 8 Distribution of the topographic position index (TPI, m) computed at 4 scales from 150 m to 2000 m for sites where *Phlox oklahomensis* Wherry was found (black curve) and random sites along the survey route (red curve). The means of the distributions are plotted as vertical lines on each panel and the mode is the peak of distributions.

primarily of cattle production (ranching). Much of the data collected through GIS agree with field observations; however, new data suggest a burn cycle of 10-to-15 years may be beneficial to the species' long-term survival. In addition, conducting a census in a single year may give false impressions of the species' status and stability, as shown by the data from 2001 and 2002 and again in 2020 and 2021. In each case fewer phlox observations were made in 2001 and 2020 compared with 2002 and 2021. Human activity that significantly disturbs the landscape is detrimental to the abundance of Oklahoma phlox.

Status of *Phlox oklahomensis* in 2021

The status of Oklahoma phlox has not changed significantly over the past 40 years. It was initially designated a Category 3C species by the U.S. Fish and Wildlife Service (1980 FR 45:82557). It is currently ranked as 'imperiled' (S2) at the state level (ONHI, 2017) and as 'vulnerable' (G3) at the global level (NatureServe 2023). The S2 designation states that the species is 'imperiled-at high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it especially vulnerable to extirpation from the state,' and the G3 designation states that the species is 'vulnerable-at moderate risk of extinction or elimination due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors' (NatureServe 2023).

Woods County, Oklahoma appears to be the epicenter of the distribution range in the Gypsum Hills of northwestern Oklahoma and southern Kansas. Based on the censuses of 2020 and 2021 and the fact that populations appear to be stable over the past 40 years, and on close observations of several populations within this range, we suggest a change to the ONHI listing of S2 to an S3 ranking. The S3 ranking is like the G3 ranking and would align the state ranking with the global ranking.

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ANALYSIS OF A PLANT'S RESPONSE TO CLIMATE CHANGE FACTORS THROUGH THE USE OF HERBARIUM RECORDS: *COLLINSIA VIOLACEA* NUTT. (PLANTAGINACEAE)

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ABSTRACT

Climate change has resulted in various changes to the phenology of species, and some of these changes have been documented through the use of herbarium specimens. Understanding how plants react to changes in the environment can give scientists insight into how plants have been responding and will respond to the continuing consequences of climate change as well as how to approach biodiversity conservation. In this study, herbarium records of *Collinsia violacea* Nutt. ranging from 1895 to 2014 were utilized to show the trends of the first and peak flowering dates with regard to various geographic and climatic variables using regression analysis. The results from simple linear regression analyses showed a trend of the flowering times for first and peak flowering dates occurring earlier over the years; however, the relationship was not significant. The multiple linear regression full model for first flowering indicated increases in latitude, longitude, and mean monthly temperatures were associated with delayed flowering while increases in monthly minimum and maximum temperatures were associated with earlier flowering. The full model for peak flowering showed that peak flowering was delayed with increases in latitude, longitude, and maximum monthly temperature. The reduced models, with highly correlated variables removed, indicated significant delays in first flowering and peak flowering with increases in latitude, longitude, and mean monthly temperature, but no significant relationship between monthly precipitation and flowering time. Further research is needed to fully understand the implications of these changes.

INTRODUCTION

The average global temperature has increased 1.1°C since 1880 and is projected to continue to increase (IPCC 2014). This increase in temperature has resulted in loss of sea ice, intense temperature changes, shifts in the geographic ranges of plants and animals, and changes to the phenology of plants (NASA 2022). Plant phenology is defined as the timing of species' phenophases (e.g., leaf-out, flowering, and fruiting) and provides an indication of change due to internal and external factors (Keatley and Hudson 2010; Morellato et al. 2013; Parmesan and Hanley 2015). Plant phenology can be affected by a wide range of variables including temperature, precipitation, and day length. The effects of the ongoing changes to the climate have become apparent in plants over the years. Changes of plant phenology can vary based on the species (Calinger et al. 2013; Pearson 2019). Spring is important in terms of phenological events, as many plants start showing signs of emergence from the winter (Keatley and Hudson 2010). Phenological observations have been used for centuries to allow for the understanding of our environment (Keatley and Hudson 2010). A wealth of long-term data is held within herbaria globally and can be utilized to document changes in plant phenology (Davis et al. 2015; Jones and Daehler 2017; Hufft et al. 2018; Pearson 2019). With herbarium specimens being digitized globally, researchers can now easily access them to conduct large scale studies.

Numerous studies have shown the utility of using herbarium specimens to investigate climate change impacts (Davis et al. 2015; Jones and Daehler 2017). Previous studies have primarily focused on the effects of temperature on flowering times; however, there have been mixed results. Lima et al. (2021) found that climate change has caused inconsistent patterns in flowering and fruiting times across different species. Calinger et al. (2013) and Gallagher and Leishman (2009) found that the increase in temperature caused by climate change has caused plants to flower at an earlier date. Pearson (2019) found that spring flowering species flowered 1.8 - 2.3 days earlier per 1°C increase in spring temperatures. However, Sherry et al. (2011) found that warm temperatures delayed flowering by 6.2 days.

In this study, we used herbarium specimens (Jones and Daehler 2017; Hufft et al. 2018) to assess the impacts of year as well as specific geographic and climatic factors (latitude, longitude, elevation, precipitation, mean temperature, and maximum and minimum temperatures) on the flowering time of *Collinsia violacea* Nutt., an Oklahoma native spring flowering plant.

Collinsia violacea is native to the United States with a center of distribution in Missouri, Arkansas, Oklahoma, and Kansas (USDA, NRCS 2024). It is on the state endangered species list in Illinois, with an isolated population in Shelby County (Taft et al. 2009). According to NatureServe (2024), it is critically imperiled in Illinois, with a rank of S1; imperiled in Texas, with a rank of S2; and vulnerable in Kansas, with a rank of S3. As there are various factors that could affect the decline of this species, it is important to monitor it to determine if there are any trends among the Illinois population and populations native to other states. In Oklahoma, *C. violacea* grows mainly in the eastern half of the state (USDA, NRCS 2024) and is commonly found in "sandy or rocky soils, dry open areas, and woodlands" (Flora of North America Editorial Committee 2019). *Collinsia violacea* has also been collected in Comanche County in southwestern Oklahoma. While western Oklahoma is drier than the eastern half of the state, these *C. violacea* specimens were collected in wetter microhabitats near creeks and draws in or near the Wichita Mountains Wildlife Refuge (Hoagland et al. 2022). Flowering begins in late March and can last until early June. It can multiply quickly and easily by reseeding, sometimes forming large colonies. As seedlings develop in late fall, they can survive harsh winters and start budding in early March (Arkansas Native Plant Society 2022).

Oklahoma is home to over 3,700 plant taxa, including subspecies and varieties, mainly due to variation in the state's climate and physiographic and geological features. Temperature and precipitation of Oklahoma decrease along a gradient from east to west. The eastern area of the state is very moist due to the Gulf of Mexico, while the western area is significantly drier (Tyrl et al. 2017). Average annual precipitation in Oklahoma can range from as much as 56 inches in the southeast and decrease to 16 inches in the northwest (Arndt 2003). Average annual temperature ranges from approximately 16°C (62°F) in the southeast to approximately 14°C (58°F) in the northwest (Arndt 2003). The average growing season ranges from 225 to 230 days in the southern part of the state and decreases to 175 to 195 days in the panhandle. Oklahoma is often described as flat; however, its topographical features include rolling hills, narrow canyons, mesas, and deep ravines (Tyrl et al. 2017). The elevation of Oklahoma ranges from 88 m (289 ft) to 1,516 m (4975 ft) (Arndt 2003). Additionally, Oklahoma soils are very diverse, ranging from sand to clay to loam (Tyrl et al. 2017). According to Frankson et al. (2022), Oklahoma temperatures have increased 0.6°F since the early 1900s, and are predicted to have an "unprecedented" increase this century. Although they indicate there is no clear trend in changes in precipitation, they note that increased temperatures will lead to increased evaporation and drought intensity.

We utilized digitized herbarium records dating back to the 1890s to analyze the phenological response of *C. violacea* to climate change. Our null hypothesis was that there is no significant relationship between flowering time of *C. violacea* in Oklahoma and our selected variables.

METHODS

Digitized herbarium specimens of *C. violacea* collected from Oklahoma were used to investigate the effects of year and the effects of geographic and climatic factors on flowering phenology. Specimen records of *C. violacea* were downloaded from the Southeast Regional Network of Expertise and Collections Database (SERNEC 2022) and access to images of specimens housed in the Robert Bebb Herbarium (OKL) at the University of Oklahoma, Norman, OK, was requested. There was a total of 684 collected specimens in the original dataset. Specimen records without images were excluded before evaluating phenophase. Flowering phenology was evaluated based on pre-flowering (no flower buds open), first flowering (at least 25% of flower buds open), peak flowering (at least 50% of the flower buds open), and last flowering (the terminal flower buds on branches open) (Haggerty et al. 2013). After determining the phenophase of each specimen, we excluded those without a clear locality, exact collection date, specimens with a phenophase of pre-flowering or last flowering, and specimens without roots present. This resulted in a total of 253 specimens for first flowering ranging from 1895 to 2014 and a total of 252 specimens for peak flowering ranging from 1913 to 2009. No specimens were assigned to the last flowering category.

In addition to the Oklahoma *C. violacea,* we investigated the Illinois *C. violacea* specimens. As there is a limited population in Illinois, there was a total of 18 collected specimens in the Illinois dataset. We requested rare species viewer permissions in SERNEC to access images of the Illinois specimens. Phenophase assessment was identical to that used for the Oklahoma *C. violacea*. After determining the phenophase of each specimen, we excluded one specimen because it was categorized with a phenophase of last flowering. This resulted in a total of eight specimens for first flowering ranging from 1947 to 1971 and a total of nine specimens for peak flowering ranging from 1947 to 1971.

The collection locality information on each herbarium specimen label was utilized to georeference decimal degree coordinates. Specimens were georeferenced using GEOLocate (Rios et al. 2005) to obtain latitude and longitude. With the decimal degree coordinates, the historical climate data were collected using the PRISM model provided by the PRISM Climate Group (2015). The climate variables included the average monthly temperature (°F), average monthly maximum and minimum temperatures (°F), and average monthly precipitation (in) for the month the specimen was collected. In addition to the climate data, elevation (ft) data of four km resolution were obtained for each specimen. The collection date of each specimen was converted to the day of the year (DOY), with Jan 1 representing day one.

Statistical analyses were performed using R version 4.2.2 (R Core Team 2022). Linear regression (with a significance level of 0.05) was performed to determine whether there was a relationship between the collection DOY and the year. First flowering and peak flowering phenophases were combined and analyzed to determine if any general relationships were present. Then each phenophase was analyzed separately to determine whether a relationship was present for first and peak flowering. The regression equation slopes were evaluated as indicators of changes in flowering times. Negative slope values indicated the species was exhibiting earlier flowering dates, while positive slope values indicated delayed flowering dates (Primack et al. 2004; Haggerty et al. 2013; Jones and Daehler 2017). To determine whether there was a relationship between the day of the year (response variable) and the potential explanatory variables of year, elevation, latitude, longitude, precipitation, mean temperature , and maximum and minimum temperatures (Park and Mazer 2018) multiple linear regression analyses were conducted, using the combined flowering dataset and then on the individual phenophase datasets. Prior to the multiple regression analyses, simple linear regression was run for each variable against day of year. Multiple regression was then run for each of the three datasets using all variables except those that were not significant based on the simple linear regression. Then to determine whether any variables were correlated with one another, a Pearson correlation test was performed. Reduced models were run with the highly correlated (Pearson correlation coefficient ≥ 0.70) variables removed. Finally, we compared the multiple regression models using the *performance* function in the R package performance (Ludecke et al. 2021) to determine the best fit model based on the obtained Akaike Information Criterion (AIC) values.

RESULTS

Five hundred and five herbarium specimens of Oklahoma *C. violacea* were examined, ranging from 1895 to 2014. Of the 505 specimens, 253 specimens were categorized as first flowering and 252 specimens were categorized as peak flowering.

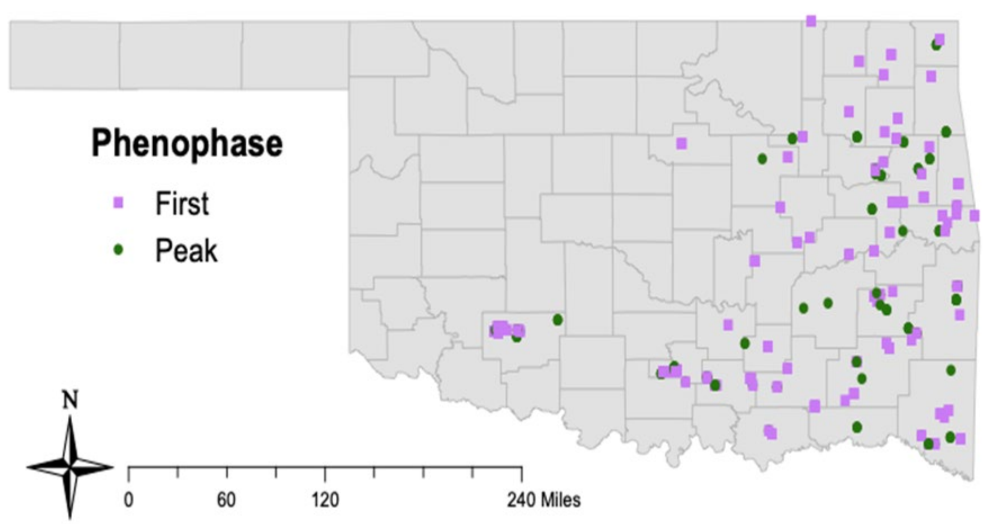

Figure 1 Distribution of herbarium records of *Collinsia violacea* Nutt. in Oklahoma from 1895 to 2014

They were scattered throughout the eastern region of Oklahoma, with a few locations (representing 70 specimens) from the southwestern part of the state (Figure 1). The frequency of specimens in the first flowering phenophase varied among years, but there was a good representation of the species around the 1930s, 1940s, and 1970s. The frequency distribution of specimens in the peak flowering phenophase was somewhat

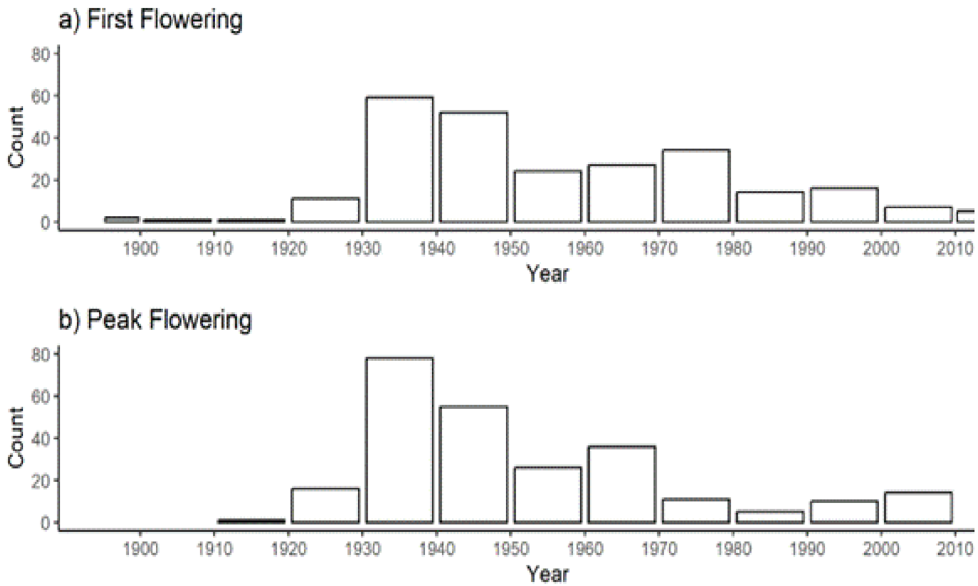

Figure 2 Counts of Oklahoma *Collinsia violacea* Nutt. specimens based on year of specimen collection. a) specimens in first flowering phenophase. b) specimens in peak flowering phenophase.

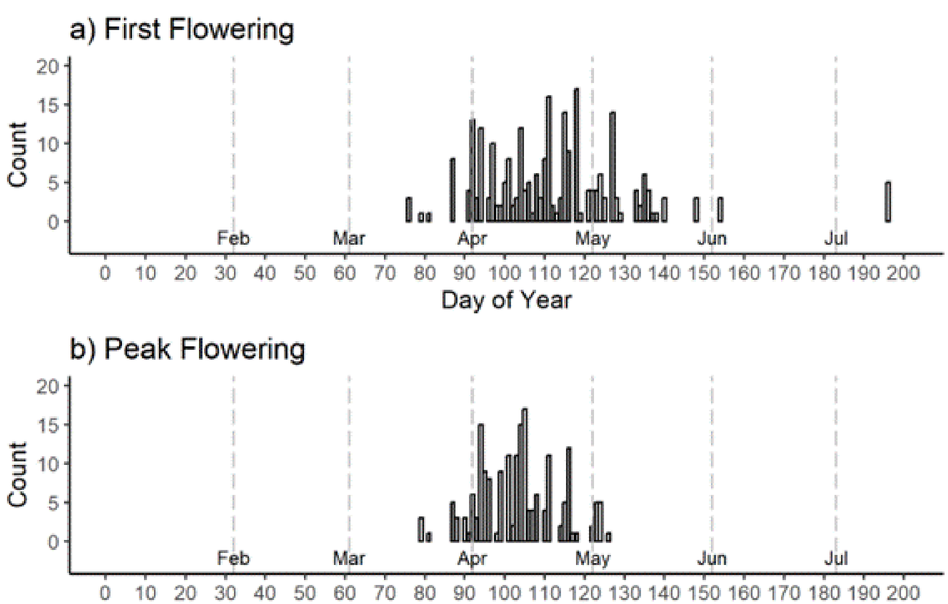

Figure 3 Counts of Oklahoma *Collinsia violacea* Nutt. specimens based on day of the year of specimen collection. a) specimens in first flowering phenophase. b) specimens in peak flowering phenophase. Grey dashed lines represent the first day of a month.

scattered but there was a large number of specimens from the mid-1930s to 1960s (Figure 2). The dates of collection of the species were similar for both first and peak flowering ranging around April (Figure 3).

Linear regression of day of year and year for both first and peak phenophases

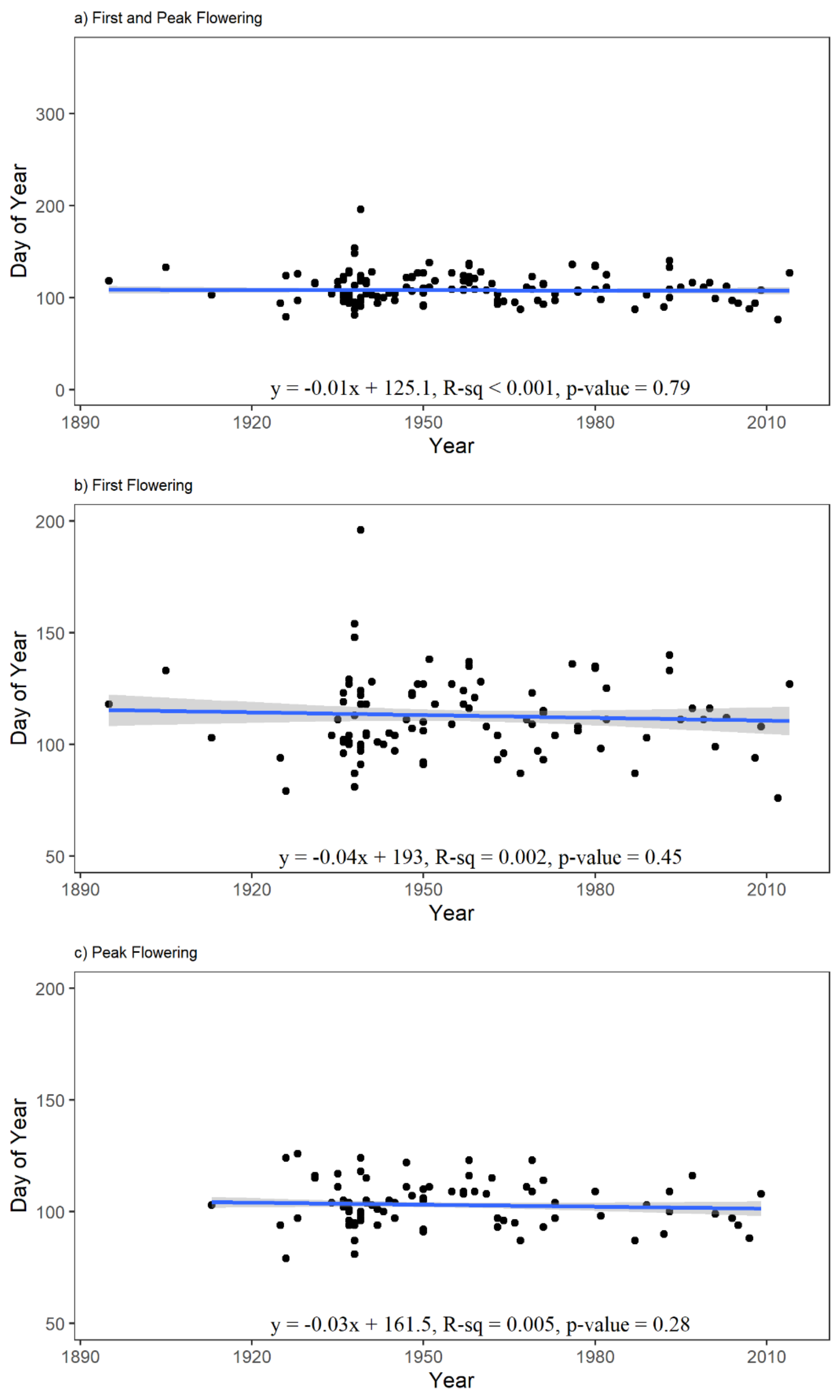

Figure 4 Scatterplots displaying trend of each phenophase on day of the year of collection versus year of collection for Oklahoma *Collinsia violacea* Nutt. a) combination of first and peak flowering, b) first flowering, and c) peak flowering.

combined resulted in a statistically insignificant negative relationship with a slope of -0.01 (Figure 4a; $R^2 < 0.001$, $p = 0.79$). Linear regression of first flowering phenophase also resulted in a negative association, with a slope of -0.04 (Figure 4b; $R^2 = 0.002$, $p = 0.45$, 95% CI = -0.147, 0.065). The slope indicates that the Oklahoma *C. violacea* plants in the first flowering phenophase were collected, on average, about 0.04 days earlier per year over the sampled time period, but the regression was not significant. Linear regression of peak flowering phenophase had a negative relationship with a slope of -0.03 (Figure 4c; $R^2 = 0.005$, $p = 0.28$, 95% CI = -0.084, 0.023), indicating that the Oklahoma *C. violacea* plants in the peak flowering phenophase were collected, on average, about 0.03 days earlier per year, but this regression was not significant.

Simple linear regression using each explanatory variable individually showed all variables excluding year to be statistically significant for all three datasets (Table 1). For all three datasets, the individual variable regression coefficients were negative for year and elevation; all other variables had positive regression coefficients (Table 1). As year was not significant alone, we removed this variable prior to proceeding with the multiple regression analyses.

Multiple regression retaining all variables for the combined phenophases dataset found only latitude ($p < 0.001$) and longitude ($p < 0.001$) statistically significant. This model explained 49% of the variation in flowering and both significant variables had positive regression coefficients (adjusted $R^2 = 0.49$; Table 2). For the first flowering dataset multiple regression retaining all variables found all variables (latitude $p = 0.02$, longitude $p < 0.001$, minimum temperature $p = 0.02$, mean temperature $p = 0.02$, maximum temperature $p = 0.02$) except precipitation and elevation statistically significant while explaining 55% of the variation in first flowering (adjusted $R^2 = 0.55$; Table 2). Of these significant variables, minimum temperature and maximum temperature had negative regression coefficients and the remaining significant variables had positive regression coefficients (Table 2). The peak flowering dataset analysis found latitude ($p < 0.001$), longitude ($p = 0.04$), and maximum temperature ($p = 0.05$) statistically significant and these had positive regression coefficients (Table 2).

The Pearson correlation test showed elevation, minimum temperature, and maximum temperature to be highly correlated with many variables, thus these three variables were removed and multiple regression was run again on the three datasets using the remaining variables as reduced models. For the combined phenophases dataset, the reduced variable multiple regression explained 49% of the variation in day of year. In this model latitude ($p < 0.001$), longitude ($p < 0.001$), and mean temperature ($p < 0.001$) were statistically significant while precipitation ($p = 0.76$) was not significant (Table 2). For the first flowering phenophase, the reduced variable model explained 54% of the variation. Latitude ($p = 0.01$), longitude ($p < 0.001$), and mean temperature ($p < 0.001$) were again statistically significant and precipitation ($p = 0.18$) was not significant. The reduced variable model explained 31% of the variation of flowering times for the peak flowering phenophase. In this model latitude ($p < 0.001$), longitude ($p < 0.001$), and mean temperature ($p < 0.001$) were statistically significant while precipitation ($p = 0.57$) was not significant. In all three reduced models, all significant variables had positive regression coefficients. In the multiple regression model performance comparisons, the reduced variable models only slightly performed better for the combined phenophases dataset (AIC = 3,893.54; Table 2) and the peak flowering dataset (AIC = 1,732.6; Table 2). The full model retaining all the explanatory variables performed slightly better for the first flowering dataset (AIC = 2,024.6) than the reduced model (AIC = 2,025.1).

Table 1 Simple linear regression coefficient results for individual variables showing significant (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) and non-significant changes in flowering day over the years 1895-2014. Significant results in **bold**.

Phenophase Dataset	Year	Latitude (DD)	Longitude (DD)	Precipitation (in)	Minimum Temperature (°F)	Mean Temperature (°F)	Maximum Temperature (°F)	Elevation (ft)
All Flowering	-0.009	**6.00*****	**4.35*****	**1.17*****	**2.03*****	**2.09*****	**1.34*****	**-0.01*****
	$R^2 = 0.0001$	**$R^2 = 0.09$**	**$R^2 = 0.13$**	**$R^2 = 0.03$**	**$R^2 = 0.41$**	**$R^2 = 0.39$**	**$R^2 = 0.24$**	**$R^2 = 0.06$**
First Flowering	-0.04	**7.11*****	**5.90*****	**1.61*****	**2.30*****	**2.43*****	**2.28*****	**-0.01*****
	$R^2 = 0.002$	**$R^2 = 0.09$**	**$R^2 = 0.15$**	**$R^2 = 0.04$**	**$R^2 = 0.47$**	**$R^2 = 0.46$**	**$R^2 = 0.39$**	**$R^2 = 0.06$**
Peak Flowering	-0.03	**4.43*****	**2.59*****	**0.47***	**0.90*****	**0.83*****	**0.35*****	**-0.006*****
	$R^2 = 0.005$	**$R^2 = 0.13$**	**$R^2 = 0.15$**	**$R^2 = 0.02$**	**$R^2 = 0.14$**	**$R^2 = 0.11$**	**$R^2 = 0.05$**	**$R^2 = 0.09$**

Table 2 Multiple linear regression coefficients results showing significant (*p < 0.05, **p < 0.01, ***p < 0.001) and non-significant changes in flowering day over the years 1895-2014 and with various geographic and climatic variables; significant results in **bold**.

	Phenophase Dataset	Adjusted R^2	Latitude (DD)	Longitude (DD)	Precipitation (in)	Minimum Temperature (°F)	Mean Temperature (°F)	Maximum Temperature (°F)	Elevation (ft)	AIC (weights)
Full Models	All Flowering	**0.49*****	**3.27***** **t = 4.40**	**3.18***** **t = 4.66**	-0.13 t = -0.49	0.86 t = 1.82	0.82 t = 1.48	0.26 t = 1.63	0.002 t = 1.08	3894.0 (<0.001)
	First Flowering	**0.55*****	**2.75*** **t = 2.34**	**4.91***** **t = 4.52**	-0.79 t = -1.82	**-28.84*** **t = -2.30**	**60.17*** **t = 2.41**	**-29.12*** **t = -2.34**	0.003 t = 1.01	2024.6 (<0.001)
	Peak Flowering	**0.32*****	**3.81***** **t = 5.27**	**1.42*** **t = 2.10**	0.07 t = 0.29	0.26 t = 0.65	0.38 t = 0.85	**0.21*** **t = 2.01**	-0.001 t = -0.49	1734.1 (<0.001)

	Phenophase Dataset	Adjusted R^2	Latitude (DD)	Longitude (DD)	Precipitation (in)	Minimum Temperature (°F)	Mean Temperature (°F)	Maximum Temperature (°F)	Elevation (ft)	AIC (weights)
Reduced Models	All Flowering	**0.49*****	**3.73***** **t = 5.38**	**2.57***** **t = 5.81**	0.07 t = 0.31		**1.94***** **t = 17.83**			3893.5 (<0.001)
	First Flowering	**0.54*****	**2.85**** **t = 2.63**	**4.13***** **t = 5.45**	-0.51 t = -1.35		**2.24***** **t = 14.16**			2025.1 (<0.001)
	Peak Flowering	**0.31*****	**3.8***** **t = 5.55**	**1.62***** **t = 4.09**	0.11 t = 0.57		**0.86***** **t = 6.37**			1732.6 (<0.001)

Seventeen Illinois *Collinsia violacea* herbarium specimen images were examined, all collected within Shelby County. The dataset did not provide a good representation of the species, as the range of collection dates was very limited. The species was only collected in May, and it is unknown whether it only flowers in May at this location. We examined linear regression as well as multiple linear regression of the dataset; however, because the sample size was small, we did not obtain valid results.

DISCUSSION

Many studies have hypothesized that climate change would cause some species of plants to start flowering at an earlier date. This prediction has been supported by various studies, but others have indicated that flowering times of plants can be delayed (Calinger et al. 2013; Gallagher and Leishman 2009; Pearson 2019; Sherry et al. 2011). Species' distributions are based on biotic and abiotic factors. *Collinsia violacea* is commonly found across the central US (Missouri, Arkansas, Oklahoma, and Kansas). Habitats in which the plant was collected include shady banks, sandy soils, wet soils, loam, and wooded hills. Previous studies found that habitats can affect plant phenology (Croat 1975, Bazzaz 1979, Wallace and Painter 2002).

Collinsia violacea specimens collected in Oklahoma were from throughout the eastern region, with a few collected in the western region. This distribution is due to the habitats and the climate in the different regions of Oklahoma. In the far western region, shortgrass prairie is present. In the middle region, tallgrass and mixed grass prairie are present and the forest type habitats dominate the eastern region (Tyrl et al. 2017). The distribution of *C. violacea* was expected as the species prefers to grow in wooded areas. The eastern region normally experiences more precipitation than the west, resulting in a humid climate (Tyrl et al. 2017). However, upon closer analysis, a majority of the collected specimens were found in drier microhabitats of the wet eastern region. Although there were very few specimens collected in the west, there was a cluster of collections of the species in Comanche County (Hoagland et al. 2022). Although it is part of the drier western area, the specimens were collected near creeks and wet microhabitats.

Collectors may have a bias as to which phenophase the species is in when collecting it, seeking out only one specific phenophase of the plant (Willis et al. 2017). As we were concerned about the potential bias present, we resolved this problem by dividing the dataset by phenophase and separately analyzing each subset with the same method used to analyze the entire dataset. In each subset, although the results of the regressions for year and DOY were not significant, we found the same trend toward earlier flowering times, indicating that the bias toward collection of a specific phenophase did not affect the results.

In this study of Oklahoma *C. violacea*, the year and DOY linear regression analyses for both the first flowering and peak flowering dates showed a non-significant trend toward earlier flowering. We conclude that early and peak flowering times have not significantly changed over the approximately 120 years represented by the analyzed specimens. Simple linear regressions showed significant relationships between day of year for first and peak flowering phenophases and all geographic and climatic variables. A full multiple linear regression model with all variables showed that first flowering was significantly delayed (positive regression coefficients) with increases in latitude, longitude, and monthly mean temperature, and it was significantly earlier (negative regression coefficients) with increases in monthly minimum and maximum temperatures. Peak flowering was significantly delayed with increases in latitude, longitude, and monthly maximum temperature. Our reduced multiple linear regression model, with highly correlated variables removed, showed significant delays in flowering time for both first flowering and peak flowering phenophases with increases in latitude, longitude, and mean monthly temperature. Global average temperatures as well as Oklahoma temperatures are expected to increase (IPCC 2014; Frankson et al. 2022). If minimum and maximum temperatures are the best predictors of first flowering for *C. violacea*, then in the future we expect that flowering will begin earlier. However, if mean temperature is the best predictor of first flowering for *C. violacea*, then we would expect a delay in the future. Although precipitation might also vary in the future with climate change, our multiple linear regressions showed no significant relationships between day of year of first or peak flowering and monthly precipitation.

Regarding this specific study, in the future, we could incorporate soil factors, or factors such as precipitation and temperatures one to three months prior to collection (Calinger et al. 2013; Rawal et al. 2015; Matthews and Mazer 2016) that were not considered in this study to determine whether they would have an influence on the species' flowering dates. Expanding the study to include herbarium specimens from the rest of this species' range would allow assessment of flowering over the entire range.

The contradictory results for some of the climate variables may be because we used averaged climate variables for the month the specimen was collected or because we tested only the possibility of linear responses to our selected variables. Non-linear plant responses have been found in other studies of phenological responses to climatic variables (Hudson et al. 2009; Iler et al. 2013). Additional non-linear testing using generalized additive modeling (Hudson et al. 2009) or piece-wise regression (Iler et al. 2013) approaches could assess the possibility of non-linear responses to our selected variables.

Many plant species may face extinction as climate change progresses. The population of *C. violacea* in Illinois is declining (Taft et al. 2009; Taft and Smith 2012) and is on the state endangered species list (Illinois Natural Heritage 2023). The population is separated from the established populations found throughout Missouri, Arkansas, Oklahoma, and Kansas, being about 200 km from the nearest population found in Jefferson County, Missouri (Taft and Smith 2012). It is unknown whether animals or humans were involved in the dispersal of the species resulting in an isolated population in Illinois, or whether populations of the species that were linked from Illinois to Missouri could have gone extinct due to disturbances in their environment. We were not able to analyze the linear regression and multiple linear regression results for the Illinois dataset as there was not a large enough sample size for a reliable regression summary. Future studies could specifically investigate the Illinois *C. violacea* phenology patterns, as well as look at the species across its entire range and compare the results based on each state to compare and contrast whether there is a delay in flowering or earlier flowering.

As climate change continues to be a driving force in affecting our environment, plants will be forced to continue to adapt to these changes. We have seen that some plants have continued to evolve to cope with the changes by altering their flowering time, allowing us to document the changes. But there is a limit to how much plants can adapt to the changes to their environment. Hamann et al. (2018) documented some species of plants that had altered their flowering times but experienced a decrease in seed production and plant fitness due to climate change. Species that cannot keep up with the changes and adapt will be at risk for extinction. Therefore, it is important that we continue to research the phenology of plants to predict how they may respond in the future.

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POST-BURN, POST-FLOOD EFFECTS IN A DEGRADED GRASSLAND, LAKE TEXOMA, BRYAN COUNTY, OKLAHOMA

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ABSTRACT

Plant communities change over time, sometimes leading to an increase or decrease in biological diversity. Often, absence of active management of a site leads to its degradation including loss of native species and invasion by non-native weeds. Lake Texoma, Texas and Oklahoma, represents an area where extensive landscape change has happened over the course of almost a century. The Denison Dam was completed in 1938, forming the lake, which over time has altered conditions in the forested and formerly-grazed locations surrounding it. The location studied in this paper is a 186-ha tract of land situated between Johnson Creek and the Roosevelt Bridge in Bryan County, Oklahoma. In summer 2000, a species list was compiled for a grassland located at the lake site as part of a larger study. This grassland comprised ~10% of the total site area. Following two major floods and an extended drought, the site was resampled in 2018. Results indicated it had suffered a serious decline in species richness and an increase in abundance of invasive or encroaching species. Species richness was reduced by approximately 50% between 2000 and 2018. Fewer transects were sampled in 2018 because of woody encroachment on the original site. In spring 2021, following an extensive prescribed burn, the site was resampled to see if burning led to any reduction in undesirable species. The most frequent species in 2000 included *Panicum philadelphicum*, *Lespedeza virginica, Rudbeckia hirta* and *Ambrosia psilostachya* and in 2018 they were *Lespedeza cuneata, Ambrosia psilostachya,* and *Dichanthelium oligosanthes.* It is possible that the invasive *Lespedeza cuneata* (sericea lespedeza) spread after a 2007 flood because of some combination of reduced competition and transport of seed in floodwater. In 2021, the most frequent species were the same as in 2018, showing little effect of the burn. However, the Shannon diversity and evenness in both early and late summer sampling periods after the burn were higher than those for the 2018 data, suggesting that the burn may have had some effect. To attempt to restore the site to more "native" conditions would probably require some combination of regular burning, flash grazing, and possibly herbicide use. Once sericea lespedeza establishes, it is very difficult to eradicate from a location.

INTRODUCTION

Throughout the southern United States, the U.S. Army Corps of Engineers (USACE) has constructed lakes for flood control, power generation, recreation, and to supply water for homes, agriculture, and industry. These lakes have altered the terrestrial habitat in their vicinity, including hydrologic changes and longer spring inundation periods, and have accelerated erosion (Baxter 1977; Tallent et al. 2011).

In south-central Oklahoma, Lake Texoma resulted from the construction of the Denison Dam, which was built for flood control on the Red River. Dam construction began in 1938 (USACE 2019b) and by 1942 the lake was filled to 188 m above sea level, the "typical" elevation of the lake for hydropower generation, with flood stage at 195 m above sea level (Sublette 1955). The lake has experienced three flood events in recent years: a large flood in 2007, and less extensive floods in 2015 and 2017. The site described in the current study is located between Johnson Creek Campground and the Roosevelt Bridge (33°59'58.7"N 96°35'20.1"W or UTM 33.999636, -96.588920). The entire area is approximately 186 ha in size; the area sampled in this study is perhaps 10-15% of that area, spread across three locations within the site. This location was also formerly known as the Bioscience Area because it was jointly maintained by the USACE and the Department of Biological Sciences at Southeastern Oklahoma State University. The three areas sampled were named (for convenience) in 2000: Big Meadow, Ravine, and Lakeside. Big Meadow and Ravine are about 210 meters apart, with Ravine to the northeast of Big Meadow. Big Meadow and Lakeside are about 785 meters apart, with Lakeside again being to the northeast of Big Meadow. Ravine and Lakeside are about 570 meters apart.

The specific location researched in this study supports a mixture of forest and grassland vegetation. Forest types include those described by Corbett et al. (2013) and Corbett et al. (2002). Most of the forests in the general location were dominated by a mixture of post oak (*Quercus stellata* Wangenh.), blackjack oak (*Quercus marilandica* Munchh.), and black hickory (*Carya texana* Buckley), with some elm (*Ulmus americana* L. and *Ulmus alata* Michx.). One stand at the site was heavily dominated by winged elm (*Ulmus alata*; Corbett et al. 2002), suggesting recent disturbance. In recent years, cutting and burning have opened up much of the forest area and given it a more savanna-like appearance.

Grasslands in south-central Oklahoma tend to be dominated by warm-season grasses. Rice (1952) listed Indian grass [*Sorghastrum nutans* (L.) Nash], switchgrass (*Panicum virgatum* L.), and big bluestem (*Andropogon gerardii* Vitman) as the dominant species in south-central Oklahoma prairie sites. Collins and Adams (1983) reported that in McClain County, Oklahoma, the dominant species were little bluestem [*Schizachyrium scoparium* (Michx.) Nash] as well as switchgrass and Indian grass. A variety of forbs, including legumes and members of the Asteraceae, are found throughout grasslands in Oklahoma. Tarr et al. (1980) report that sedge species, Indian grass, and switchgrass were dominant species in a south-central Oklahoma prairie.

However, much grassland in Oklahoma has been degraded or converted for other land-use practices. Rice and Stritzke (1989) describe this problem, listing many forbs that become more common with overgrazing, including ragweed (*Ambrosia psilostachya* DC.) and heath aster [*Symphyotrichum ericoides* L. (G.L. Nesom) = *Aster ericoides*]. Agriculture (either plowing or pasturage) has altered grasslands within the state, and the location in the current study was grazed prior to the lake's construction. In addition, non-native species and encroaching native species like eastern redcedar, *Juniperus virginiana* L., have invaded grasslands throughout Oklahoma. There is evidence that disturbances caused by lake construction and flooding can contribute to the invasion of non-native species (Hill et al. 1998). Parks and Barclay (1966), in a study at the University of Oklahoma Biological Station on the lake, noted that numerous vine species were abundant, and seemed to be increasing.

A major invasive species in grassland communities of the Great Plains is the non-native sericea lespedeza [*Lespedeza cuneata* (Dum. Cours.) G. Don]. This species was introduced in 1896 as a potential forage species, but it is aggressive in its growth and forms a persistent seedbank (Cummings et al. 2007). This species seems to benefit from periods of disturbance where bare ground may be exposed (Smith and Knapp 2001; Young et al 2009). It forms dense stands and competes with native species for light and space (Brandon et al. 2004). This species also produces a variety of exudates, some of which are allelopathic to other plant species or may alter the belowground microbial community (Ringelberg et al. 2017). Once established on a site, it can tolerate drought because of its deep taproot and can rapidly establish large populations by spreading through rhizomes and by high rates of seed production (Walder 2017). Even fire may not reduce sericea lespedeza; Tompkins and Bridges (2013) suggest that in North Carolina, burning benefited it by leaving the belowground organs to resprout and clearing the area of other species, and that repeated clipping seems to be the best control. Sericea lespedeza is considered a noxious weed in Wisconsin, Kansas, Nebraska, Colorado, and Oklahoma (Center for Invasive Species and Ecosystem Health 2019).

The original sampling of three areas of the site (Big Meadow, Ravine, and Lakeside) occurred in the early summer of 2000. The research site has experienced several disturbances since the original (2000) sampling. Three prescribed burns of the site in general were conducted by the USACE in 2012, 2014, and 2016 (R. Butler, Lead Natural Resource Specialist, Lake Texoma USACE, personal communication, 2019). These burns usually took place in March. The 2012 burn, at least, did not completely burn the Big Meadow location, based on aerial photographs from that time. A more extensive burn of the Big Meadow location took place in March 2021. Additionally, Lake Texoma flooded in 2007 and again in 2015, with lesser inundation (i.e., for a shorter period and covering less area) in 2017 and 2019. Because the sampling site, at roughly 630 feet elevation (194 m) is below the 640 foot (195 m) elevation of the emergency spillway, the site was inundated with at least 0.5 m of water during the most severe flood periods. In 2007, the site first experienced flooding above 630 feet in early July and was flooded until mid-August. In 2015, the site was flooded at 630 feet or deeper from mid-May to early August (USACE 2019a). The flooding was likely the largest disturbance the site has experienced in recent years. The USACE has also periodically cut paths/firebreaks in the area. Most of these are no wider than 2.5 meters, though it is still possible they could serve as corridors for invasive species. Based on Google Earth aerial photographs, the most extensive path-cutting happened in 2012, 2014, and 2016, with considerable loss of trees near the Ravine location after the 2014 burn. There has recently been increased clearing of trees, though not near the sampled locations. Some locations at the site were planted as food plots for deer including species like partridge pea [*Chamaecrista fasciculata* (Michx.) Greene] and wheat (*Triticum aestivum* L.). The current study does not cover any locations used as food plots. Additionally, heavy winter storms in 2020 and 2021 may have affected vegetation.

I hypothesized there would be increased species diversity as a result of the spring 2021 burn, and that possibly some native species absent in the 2018 sampling would resurface.

MATERIALS AND METHODS

In 2000, we sampled three locations: the Big Meadow site, the largest expanse of grassland on the site; the Ravine site, a much smaller location adjacent to a stand of winged elm and near a post-oak dominated forested area; and the Lakeside location, a smaller area north and east of the other two and close to the lake shore (Figure 1). Data were collected using a stratified random

Figure 1 Map of the field site showing the three sampling location. Site is located just east of the Roosevelt Bridge. The coordinates of the waypoint on the Big Meadow area are 33°59'59"N 96°35'20"W, those of the Ravine area are 34°00'00"N 96°35'11"W, and those of the Lakeside area are 34°00'08"N 96°34'50"W. The Big Meadow waypoint and that of the Ravine area are approximately 250 m apart, and the Ravine area waypoint and the Lakeside waypoint are approximately 580 m apart. Map generated using Google Earth.

sampling method. The initial sampling was done in early summer, May through June. Fifty-meter transects running north-south were laid out roughly every 12 m. The GPS location (latitude, longitude) of each of the 24 transects was recorded, using a handheld device. Each transect was split into 5-m segments for stratified random sampling (Sutherland 1996). Within the five-meter segments, a single sample point was located using a random numbers table. Ten samples were collected per transect. A 25 cm by 25 cm sampling frame was used to collect presence-absence data for species. Because of difficulties in identifying some species, I am only reporting a partial species list, and not frequency data, for comparison with species lists from later sampling times. We did calculate diversity indices for these data; however, they are not entirely valid because of identification difficulties.

The three locations (Big Meadow, Ravine, and Lakeside) were resampled in late summer, August and September, 2018. The same sampling method (transects and quadrats) was used, and an effort was made to relocate the origin points of the original transects from the GPS coordinates recorded in summer 2000. A different GPS unit (Magellan Explorist 500) was used for this data collection; that could have led to some inaccuracies in relocating the transects. In some cases, woody plants, predominantly honey-locust (*Gleditsia triacanthos* L.) and persimmon (*Diospyros virginiana* L.) but also some woody vines such as peppervine [*Ampelopsis arborea* (L.) Koehne] and trumpet-creeper [*Campsis radicans* (L.) Seem. ex Bureau] formed dense thickets on the area. This made sampling some of the same transects difficult or impossible, and we were able to resample only eight of the 18 transects from the Big Meadow that were sampled in 2000. Also, the Lakeside location was under water in the earlier part of the 2018 sampling time and had to be sampled later. This location was also the most difficult to relocate; erosion during floods may have altered its topography. We recognize that sampling at different times in the summer is not ideal and we may have missed the presence of some early-summer species in our late-summer sampling, but general trends in species diversity and dominant species probably hold.

In summer 2021, following the March burn of the Big Meadow location, I resampled the site. A first round of sampling was done in early summer (mid to late June); a second round was done in late summer to early fall (September and October). The same sampling method as in 2018 was used; the 12 transects from that sample period were relocated using GPS coordinates and "landmarks" that were noted in 2018. The early sampling time is roughly the same season as the 2000 sampling; the late sampling is similar to the time of the 2018 sampling.

I compiled species lists from the data, which allows an estimate of species richness, and calculated relative-frequency measures for the 2018 and 2021 sampling times. To further analyze the data, I calculated the Shannon diversity index (as $-\Sigma p_i \ln p_i$) for each transect (Magurran 1988). The p_i values were calculated by dividing the occurrences of a species per transect by the total occurrences of all species in that transect. Additionally, I calculated evenness (H'/H'max *100) where H'max is calculated as the natural logarithm of the number of species present. Abundance data (calculated as relative frequencies) are available upon request from the author.

RESULTS AND DISCUSSION

In the 2000 sampling, 75 species/genera could be identified (Table 1). Nomenclature follows the Integrated Taxonomic Information System (2022) and nativity status (native vs. non-native to the United States) was determined using the PLANTS Database (USDA, NRCS 2022). There were an additional 87 plants that were unidentified, most of which were in an early vegetative state, complicating identification. Most of the unidentified species were only found once in the sampling, although some plants were similar and might represent the same species. We did not collect voucher specimens. Of the plants that could be identified to the species level, 13% (9) were non-native to the US and 87% (61) were native to the US.

In the 2018 sampling, there were 30 taxa identified to genus or species and two unknowns (Table 1). Among species that could be identified to species, 22% (6) were non-native to the U.S., and 78% (21) were native to the U.S. In addition to a decline in richness, a decline in percentage of native species present has taken place. Three of the taxa could only be identified to genus (*Carex, Quercus* seedling, *Ulmus* seedling) but these are most likely native as well.

In the early summer 2021 sampling, taken at a comparable time of year to the 2000 sampling, there were a total of 46 taxa identified to genus or species (Table 1). Of the 43 taxa that could be identified to species, 36 (84%) were native and seven (16%) were non-native. Three taxa (elm seedling, sedge, and wheat/barley) were not identified to species and so were not included in the nativity calculations. The nativity percentage is more similar to that of the 2000 sampling than it is to the 2018. This could be coincidental, or it could be that many of the non-native species found at this site are warm-season species that do not experience high growth until later in the year.

In the late summer 2021 sampling, taken at a comparable time of year to the 2018 sampling, there were a total of 27 taxa sampled. Of those, 24 could be assigned to a species, and 21 of those (87.5%) were native; three [*Convolvulus arvense* L. (field bindweed), *Lespedeza cuneata*, and *Sorghum halepense* (L.) Pers. (Johnsongrass] were non-native, for a percentage of 12.5%. Once again, a few species (seedlings of an *Ulmus* species, *Carex,* and what is most likely *Triticum* from food-plot planting) were not identified to species and not included in the calculations of nativity percentage. There does seem to be an increase in the proportion of native to non-native species as compared to the late-summer 2018 sampling; several non-native grasses present in the 2018 sampling were not resampled in 2021.

I computed the Shannon diversity index for each transect at each sampling (Table 2). There is a trend for higher diversity in the June 2021 sampling than either the 2018 or the September 2021 sampling times. However, in Oklahoma, early summer is often the time of highest plant species diversity detected in samples. In general, the 2021 transects have higher Shannon diversity, though not necessarily higher evenness, than the 2018 transects. Interestingly, this holds not just for the Big Meadow location (which experienced the most intensive burning) but also for the Ravine location and for the Lakeside location – which was not burned. The numbers from 2000 are not entirely valid given the high number of species that could not be identified, but the Shannon diversity values computed from those data ranged from a low of 1.01 to a high of 3.035. The average, across the 18 transects sampled in the Big Meadow, was an H' of 2.52. The H' value for the single transect next to the Ravine location was 2.93, and the average for the five Lakeside transects sampled in 2000 was 2.79. It does seem likely following the floods of 2007 and 2015, and the invasion of *Lespedeza cuneata*, that the diversity of the site has declined. Anecdotally, the Big Meadow site had a very different appearance in 2018 and 2021 as compared to 2000; the main species seen across the site is *Lespedeza cuneata*, which showed no evidence of being present in 2000.

Table 1 List of species identified from each of the three sites (Big Meadow, Ravine, Lakeside) sampled in 2000/2018/spring 2021/fall 2021. Scientific name given, followed by authority and common name (if available). In some cases, the names have changed according to www.itis.gov; the previous name is listed in brackets. A few species were identified to genus only; no further information is provided for them. Nativity status is denoted with an N for native to continental US and an asterisk (*) for non-native species. The four final columns represent each sampling time and a P species presence.

Name	2000	2018	2021S	2021F
Acalypha virginica L. (three-seeded mercury) N			P	P
Achillea millefolium L. (common yarrow) [*Achillea lanulosa*]*	P			
Acmispon americanus var. *americanus* (Nutt) Ryd. (American bird's foot trefoil) [*Lotus purshianus]* N	P			
Agrostis elliottiana Schult. (Elliott's bentgrass) N	P			
Amaranthus retroflexus L. (red-root amaranth) N	P			
Ambrosia artemisiifolia L. (common ragweed) *	P	P		
Ambrosia psilostachya (DC.) (western ragweed) N			P	P
Ampelopsis arborea (L.) Koehne. (peppervine) N	P	P	P	
Amphiachyris dracunculoides (DC.) Nutt. (broomweed) N		P		
Andropogon gerardii Vitman (big bluestem) N	P	P		
Asclepias viridis Waller (green milkweed) N	P			
Astragalus nuttallianus DC. (Nuttall milkvetch) N	P			
Bothriochloa ischaemum (L.)Keng (yellow bluestem)*			P	
Bothriochloa laguroides (DC.) Herter (silver beardgrass) N	P			
Bradburia pilosa (Nutt.) Semple (soft goldenaster) [*Chrysopsis pilosa*] N	P	P		
Bromus catharticus Vahl. (rescuegrass) *	P			
Bromus japonicus Thunb. ex Murray (Japanese bromegrass) *	P	P	P	

Name	2000	2018	2021S	2021F
Campsis radicans (L.) Seem. ex Bureau (trumpet creeper) N	P			
Carex sp. (sedges)	P	P	P	P
Castilleja indivisa Engelm. (Texas paintbrush) N	P			
Cephalanthus occidentalis L. (common buttonbush) N			P	
Chaerophyllum procumbens (L.) Crantz (spreading chervil) N			P	
Chamaecrista fasciculata (Michx.) Greene (partridgepea) N		P	P	
Cirsium altissimum (L.) Hill (tall thistle) N	P		P	
Convolvulus arvensis L. (field bindweed)*				P
Conyza canadensis (L.) Cronquist (Canadian horseweed) N			P	P
Coreopsis tripteris L. (tall tickseed) N	P			
Croton capitatus Michx. (doveweed) N			P	P
Croton monanthogynus Michx. (prairietea) N		P		
Cynodon dactylon (L.) Pers. (Bermudagrass) *		P		
Dactylis glomerata L. (orchardgrass) *	P		P	
Danthonia spicata (L.) P. Beav. Ex. Roem. & Schut. (poverty wild oat grass) N	P			
Desmodium sessilifolium (Torr) Torr. & A. Gray (sessileleaf tick trefoil) N	P			
Dichanthelium dichotomum (L.) Gould (cypress panicgrass) [*Panicum dichotomum*] N	P			
Dichanthelium oligosanthes (Schult.) Gould (Heller's rosette grass) N		P	P	P
Dichondra micrantha (Urb.) (Asian ponysfoot) *	P			
Diospyros virginiana L. (eastern persimmon) N	P	P	P	P

Name	2000	2018	2021S	2021F
Eragrostis curvula (Schrad.) Nees (weeping lovegrass) *		P		
Eragrostis trichodes (Nutt.) Alph. Wood (sand lovegrass) N	P	P	P	
Erigeron philadelphicus L. (Philadelphia fleabane) N	P			
Erigeron strigosus Muhl. ex Willd. (prairie fleabane) N	P			
Eupatorium serotinum Michx. (late eupatorium) N		P	P	P
Euthamia gymnospermoides Greene (Texas goldentop) N	P	P		
Galactia regularis (L.) Britton, Sterns & Poggenb. (eastern milkpea) N	P			
Galium tinctorium L. (dye bedstraw) N			P	
Geranium carolinianum L. (Carolina crane's bill) N	P			
Gleditsia triacanthos L. (honey-locust) N			P	P
Grindelia ciliata (Nutt.) Spreng (wax goldenweed) [*Grindelia papposa*] N	P		P	
Lactuca serriola L. (prickly lettuce) *			P	
Lathyrus hirsutus L. (singletary pea)*	P	P		
Lespedeza cuneata (Dum. Cours.) G. Don (sericea lespedeza) *		P	P	P
Lespedeza violacea (L.) Pers. (intermediate lespedeza) (sometimes recorded as *Lespedeza intermedia)* N	P			
Lespedeza virginica (L.) Britton (slender lespedeza) N	P	P	P	P
Lindernia dubia (L.) Pennell (moistbank pimpernel) N	P			
Linum sulcatum Riddell (grooved yellow flax) N	P			
Lithospermum incisum Lehm. (fringed gromwell) N	P			
Lolium perenne L. (perennial ryegrass) *	P			

Name	2000	2018	2021S	2021F
Medicago lupulina L. (black medick) *	P			
Mnesithea cylindrica (Michx.) de Koning & Sosef (jointgrass)[*Manisuris cylindrica*] N	P			
Monarda citriodora Cerv. ex Lag. (lemon beebalm) N		P		
Nassella leucotricha (Trin. & Rupr.) R.W. Pohl (Texas wintergrass) [*Stipa leucotricha*] N	P			
Oenothera filiformis (Small) W.L. Wagner & Hoch (longflower beeblossom) N				P
Oenothera glaucifolia W. L. Wagner & Hoch (false gaura) [*Stenosiphon linifolius*] N	P			
Oenothera linifolia Nutt. (threadleaf sundrop) N	P			
Oxalis stricta L. (common yellow oxalis) N	P	P	P	P
Panicum brachyanthum Steud. (prairie panicgrass) N	P			
Panicum capillare L. (panicgrass) N	P			
Panicum hillmanii Chase (Hillman's panicgrass) N	P			
Panicum philadelphicum Bernh. Ex Trin. (Philadelphia panicgrass) N	P			
Panicum virgatum L. (switchgrass) N	P			
Pascopyrum smithii (Rydb.) Á. Löve (western wheatgrass) N			P	
Paspalum setaceum var. *ciliatifolium* (Michx.) Vasey (sand paspalum) [*Paspalum ciliatifolium*] N	P			
Passiflora incarnata L. (purple passionflower) N			P	P
Persicaria hydropiperoides (Michx.) Small (swamp smartweed) N			P	P
Phlox sp.	P			
Phyla nodiflora (L.) Greene (frogfruit) [*Phyla incisa*] N	P			
Plantago aristata Michx. (bottlebrush Indianwheat) N	P			

Name	2000	2018	2021S	2021F
Plantago virginica L. (paleseed Indianwheat) N	P			
Ptilimnium capillaceum (Michx.) Raf. (threadleaf mockbishopweed) N			P	
Ptilimnium nuttallii (DC.) Britton (Nuttall's mock bishopweed) N	P		P	
Pyrrhopappus pauciflorus (D. Don) DC. (smallflower desert chickory) [*Pyrrhopappus geiseri*] N	P		P	
Quercus seedling		P		
Rhus glabra L. (smooth sumac) N	P	P	P	P
Rhynchosia latifolia Nutt. ex. Torr. & A. Gray (broadleaf snoutbean) N	P			
Rubus trivialis Michx. (southern dewberry) N	P	P	P	P
Rudbeckia hirta L. (blackeyed Susan) N	P		P	
Rumex altissimus Alph. Wood (smooth dock) N	P			
Rumex crispus L. (curly dock) *			P	
Sabatia campestris Nutt. (meadow-pink) N	P		P	
Schizachyrium scoparium (Michx.) Nash (little bluestem) N	P			
Setaria pumila (Poir.) Roem. & Schult, (yellow bristlegrass) [*Setaria lutescens*]*	P			
Setaria parviflora (Poir.) Kerguélen (knotroot bristlegrass) N			P	P
Smilax bona-nox L. (saw greenbriar) N	P	P	P	
Smilax tamnoides L. (bristly greenbriar) N		P		
Solanum carolinense L. (horsenettle) N	P			
Solidago cf. missouriensis Nutt. (Missouri goldenrod) N				P
Solidago nemoralis Aiton (grey goldenrod) N			P	P

Name	2000	2018	2021S	2021F
Sorghastrum nutans (L.) Nash (Indiangrass) N	P		P	
Sorghum halepense (L.) Pers. (Johnsongrass)*				P
Steinchisma hians (Elliott) Nash (gaping grass) N		P		
Stellaria sp.	P			
Stellaria media (L.) Vill. (common chickweed)*			P	
Strophostyles leiosperma (Torr. And A. Gray) Piper (slickseed fuzzybean) N			P	
Symphyotrichum ericoides (L.) G.L. Nesom (heath aster) [*Aster ericoides*] N	P			
Teucrium canadense L. (hairy germander) N	P	P	P	P
Toxicodendron radicans (L.) Kuntze (poison ivy) N		P	P	P
Triodanis perfoliata (L.) Nieuwl. (clasping bellwort) N	P			
Tridens flavus (L.) Hitch. (purpletop) N	P		P	P
Tripsacum dactyloides (L.) L. (eastern gamagrass) N	P			
Triticum sp.			P	P
Ulmus seedling	P	P	P	P
Verbena halei Small (slender verbena) N	P			

Table 2 Summary of species-diversity data by transect for 2018, early-summer 2021, and late-summer 2021 sampling, by transect.

2018			2021 June			2021 Sept		
Big Meadow			Big Meadow			Big Meadow		
Transect	H'	evenness	Transect	H'	evenness	Transect	H'	evenness
1	1.65	80%	1	2.31	90%	1	2.15	90%
2	1.48	80%	2	2.11	87%	2	2.16	87%
3	1.92	87%	3	2.36	89%	3	1.70	72%
4	1.65	79%	4	2.32	88%	4	1.87	81%
5	1.66	72%	5	2.52	89%	5	1.88	82%
6	1.60	76%	6	2.48	88%	6	1.90	86%
7	1.82	83%	7	2.20	89%	7	1.79	81%
8	1.80	87%	8	2.22	87%	8	1.50	84%
Ravine			Ravine			Ravine		
Transect	H'	evenness	Transect	H'	evenness	Transect	H'	evenness
1	1.86	85%	1	2.49	92%	1	2.13	86%
Lakeside			Lakeside			Lakeside		
Transect	H'	evenness	Transect	H'	evenness	Transect	H'	evenness
1	1.84	88%	1	2.45	93%	1	2.10	96%
2	1.17	86%	2	2.30	93%	2	1.67	93%
3	1.95	89%	3	2.22	93%	3	1.91	92%

A comparison of species lists from 2000, 2018, and 2021 shows a number of patterns. Most importantly, *Lespedeza cuneata* was not sampled in 2000 and, if present at the site, was in very low abundance. There were also a number of prairie species identified in 2000, e.g., *Castilleja indivisa* Engelm. (Texas paintbrush) and *Desmodium sessilifolium* (Torr.) Torr. & A. Gray (sessileleaf tick trefoil), that were not sampled or observed at the site in either 2018 or 2021. The general pattern has been the increase of a few species [*Lespedeza cuneata*, *Rubus trivialis*, *Dichanthelium oligosanthes* (Schult.) Gould (Heller's rosette grass)] that have come to dominate the site.

Parks and Barclay (1966) noted that one of the characteristics of "secondary succession" in locations around Lake Texoma was an increasing importance of woody vines to the point where they seemed to "overgrow" some of the other species present. Many of the species they listed as abundant, including *Rubus trivialis* Michx. (southern dewberry), *Ampelopsis arborea* (L.) Koehne. (peppervine), *Smilax bona-nox* L. (saw greenbriar), and *Toxicodendron radicans* (L.) Kuntze. (poison ivy) were present in the 2018 samples, and another species they noted, *Passiflora incarnata* L. (purple passionflower), was collected in the 2021 samples. During the 2018 and 2021 sampling periods, in some locations, the vining species were so abundant that they made walking difficult. This was not the case in 2000 (Corbett, unpublished observation). *Rubus trivialis* was sampled in 2000 but was not abundant, and *Passiflora incarnata* and *Toxicodendron radicans* were observed at the site but were not abundant and were not recorded in samples.

In general, the site has experienced a simplification and homogenization over the past 18 years. In 2000, the Lakeside location had species not found elsewhere on the site, and it had no *Lespedeza* present. In 2018, it was dominated by the same species found in the Big Meadow location, which was arguably the most disturbed location of the site. I have also anecdotally noticed changes in the vegetation over the past 18 years, especially increase in abundance and distribution of *Lespedeza cuneata* on the site. And in the past, *Asclepias viridis* Walter (green milkweed) was common and even *Asclepias tuberosa* L. (butterfly milkweed) was present (a brief, unpublished research study was conducted on these in 2003-2004). These species are now presumably extirpated from the site, crowded out by overgrowth of *L. cuneata.* Plant community diversity has suffered.

It seems likely that the changes that took place in the site over the past 18 years – the loss of low-abundance species and the rise of dominance of a few aggressive species (*L. cuneata*, *R. trivialis, D. oligosanthes*) are caused by a combination of natural and human-caused disturbances that have affected the site. In 2007 and again in 2015, the water level in Lake Texoma was high enough that the sites were underwater, killing most of the vegetation present. This flooding may have been what allowed spread of sericea lespedeza throughout the site. Silliman and Maccarone (2005) note that sericea seeds are readily transported by flowing water. There were other, lesser, periods of high water; in fact, in 2018, the Lakeside location was underwater for the early part of our sampling season, and we had to wait for the lake to recede. Additionally, in summer 2011, an extended period of drought led to the death of much vegetation in the area. June 2011 had the lowest rainfall of the 30-year period starting in 1981, July 2011 was the 4th driest July, and August 2011 was the 3rd driest August (National Climate Data Center, 2018). The burning regime has been limited in recent years by difficulties in finding teams to work the burns, and the site had not been burned since 2016. All these factors contribute to allowing the reduction of the more-sensitive native species and the growth of invasive introduced or encroaching native species.

There has also been encroachment of woody vegetation such as *Rhus glabra* L. (smooth sumac), *Diospyros virginiana* L. (eastern persimmon), and *Gleditsia triacanthos* L. (honey-locust) into both the Big Meadow and the Ravine location, probably because of the lack of burning. Some cutting and burning in a post oak dominated forest area near the Ravine location has opened up the canopy some, but other parts of the site may require more active management.

MANAGEMENT CONCERNS / RECOMMENDATIONS

Literature review suggests that reducing the dominance of sericea lespedeza requires extreme methods. Because it tends to develop an extensive seed bank (Silliman and Maccarone 2005), burning control would require multiple years of precisely-timed early growing-season burns. Burning this area is complicated because of weather challenges, proximity to a major highway (US 70), and difficulties in assembling a burn crew. Additionally, there is a chance that burning – especially if sporadic – could encourage growth of sericea lespedeza (Barnewitz et al. 2009). Many publications suggest that herbicide application can be an effective method (Silliman and Maccarone 2005; Koger et al. 2002); however, Rice and Stritzke (1989) suggest that low-intensity applications of 2,4-D seem to increase sericea lespedeza over time. Some researchers have experimented with flash-grazing by goats (Barnewitz et al. 2009). Goats are one of the relatively few grazing species that tolerate sericea lespedeza's high tannin levels. However, that again presents logistical challenges. Barnewitz et al. (2009) also noted that seasonal mowing could reduce seed density and seed mass over time. Removing the dominant sericea lespedeza (and other aggressive, encroaching species like *Rubus trivialis*) from the site presents a considerable challenge. Any procedure used to restore a site will require regular application of treatment and monitoring of the site over numerous years, representing considerable cost to a landowner (Silliman and Maccarone 2005). As is often the case with invasive species, control in the early stages of the invasion is necessary, and that did not happen here.

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NOTE

PAWNEE NATIVE SUMAC/TOBACCO RESURGENCE

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ABSTRACT

Research of historical tobacco changes and continuation in current practices has led to recommendations after thoughtful consideration by the Pawnee Nation Agricultural Committee and the Chiefs' Council. Preparation of a native tobacco mixture taught to the author by Boy Chief is explained. Traditionalists recently allowed the use of a native tobacco/native smooth sumac mixture in tribal ceremonies. Because native tobacco is additive-free and has a lower nicotine content, this mixture is considered healthier than commercially marketed tobacco for use in ceremonies.

INTRODUCTION

The Pawnee lived in portions of Nebraska and Kansas but roamed large areas to the west and south. Earth lodges provided homes and ceremonial places. Farming was done by groups of women, men cultivated a specific native tobacco, and there were two main bison hunts, summer and winter, that led them afield on long trails. All Pawnee were knowledgeable botanists to some degree. Their gardens' produce, native plant harvests, and bison were critical to sustenance and survival of the Tskiri(Skiri), Tsawii(Chawi), Kitkahahki(Kitkaharu') and Pitahawirata bands/divisions. By 1875, most of the Pawnee had been relocated to what is now known as Pawnee, Oklahoma. Cultural destruction had been the practice long before their march to Indian Territory. For a chronological history of the Pawnee, see *The Pawnee Indians* by George E. Hyde (1951).

Many native people regard tobacco as sacred as do the Pawnee. Native species of tobacco were used by many tribes across the United States. However, with the introduction of European commercial trade tobacco, well before the Pawnee left their homelands to Oklahoma, the cultivated traditional native tobacco was abandoned. A substitute tobacco was Cultivated Tobacco, Racakihtu, *Nicotiana tabacum* L., which became mainstream and eventually had chemical additives (Kunitz 2016).

The native tobacco cultivated and used by the Pawnee and other tribes of the Missouri River region is known as Indian Tobacco, Raawikaaru, *Nicotiana quadrivalvis* Pursh. The plant is native to California and some adjacent western regions, but not to the northern or southern plains (Gilmore 1977). As a side note, a wild native perennial tobacco, Desert Tobacco, *Nicotiana obtusifolia* M. Martens & Galeotti has been documented in southwestern Oklahoma (TORCH Data Portal 2023).

I am not a Pawnee tribal member, but I have lived in Pawnee, OK for nearly thirty-three years including time spent as the manager of the Pawnee Bill Buffalo Ranch and Museum. I have been fortunate to observe and at times participate in many native practices and am a member of the Pawnee Nation Agricultural Committee.

FROM SEED TO PLANTING

In 2017, I visited with a Pawnee Skiri elder friend, Tom Evans (Kahike=Leader of Expedition), about the Pawnee tobacco once cultivated and the causes for the plant's cultural disappearance and the popularity of commercial substitutes. I obtained seeds of Indian Tobacco, *Nicotiana quadrivalvis,* from California and before long his family and I worked together to cultivate the native tobacco outdoors.

Soon after, I was fortunate to learn about a Pawnee tobacco mixture using native sumac leaves. In early 2022, I and two other Agricultural Committee members proposed that the committee cultivate the native tobacco and provide the product to the Chiefs' Council. The committee decided to sponsor the cultivation of native tobacco in what was called the Chiefs' Garden. I shared a proposal with the Chiefs' Council at a meeting on September 24, 2022, which was unanimously approved.

THE MIXTURE FROM THE ELDER

Tobacco mixtures are as varied as the personal choice of an individual: native plants used, tobacco type, animal grease or oil, amount, and proportions. A person in the company of the Pawnee noted a "Kinnekinnick (sic) mixture: ...is usually comprised of dried leaves of the shumack (sic) and the inner bark of the red willow...the addition of one fourth proportion of tobacco" (Murray 1839).

An old Pawnee story *The Medicine Child and the Beaver Medicine* mentioned sumac: "The man then reached for his tobacco pouch, which was a skunk skin, and from his bag took out a little pipe, fill it up with sumac leaves and tobacco" (Dorsey 1997).

Also, speaking specifically of *Rhus glabra* L., "In the fall when the leaves turned red, they were gathered and dried for smoking.... (Gillmore 1977).

A friend, Chawi band member, elder and former Chief, Austin Real Rider, Resa'ru' Piiraski (Boy Chief) accepted my request to meet with him. I carried with me a red leaf from a native smooth sumac, Nuppikt=Sour Top, *Rhus glabra*, a common species in Pawnee, OK. He said, "that is the kind I use with tobacco". I shared with him my interest in learning the tobacco mix from him and told him I would be using the healthier traditional native tobacco used by the Pawnee many years ago.

Boy Chief began by saying he obtained the leaves when red - when they are red, they are ready. He allowed the leaflets to dry some and prepared some animal fat to mix with the leaflets. He said he typically used fat from beef kidney as it was most easily available, but went on to say that deer, elk, and especially bison fat was good as it also has a traditional history. The warmed fat is mixed with the leaflets, allowed to dry, and placed outside under full sun if it is a warm day. If that is not possible, heat is applied, but not excessively. Then the chopped tobacco is added, and all ingredients are mixed. I have prepared the mixture numerous times and have found that experience is required for the best results; one must learn by doing. There are some details that I have omitted out of respect.

PROMOTING USE OF HEALTHIER TRADITIONAL TOBACCO

The Pawnee Nation Chiefs' Council, recognized traditionalists, and other tribal members see the benefits of using native tobacco as well as discouraging the personal or ceremonial use of harmful commercial tobacco products that include additives. The leaves of commercial *Nicotiana tabacum* also have a much higher nicotine content than *N. quadrivalvis* (Kaminski et al. 2020). Tobacco is a sacred plant to be respectfully used. Using the native tobacco as described here, linked to Pawnee history, adheres to tradition and the promotion of a healthier smoke. I donated a portion of the traditional Resa'ru' Piiraski mixture for the Young Dog Dance, Asaakipiriiru', and it was used in the pipe ceremony November 20, 2020 and November 19, 2023 at the Pawnee Nation Round House. On Saturday, October 21, 2023, during a Pawnee Native American Church Ceremony, the native tobacco mix was used in what is commonly called "the main smoke"

.

Figure 1 Resa'ru' Piiraski Mixture (Photo by Pam Ledford)

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