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

**Erica A. Corbett**
Department of Biological Sciences
Southeastern Oklahoma State University
Durant, OK 74701
ecorbett@se.edu

*Keywords:* **Lespedeza cuneata***, species diversity*

## 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.

## ACKNOWLEDGMENTS

I thank Amber McCabe, who assisted heavily in collection of the 2018 data, as well as Chris Chambliss, Kyle Collins, and Zachary Justice who provided field assistance in late summer 2018. I also thank Luke Bell, Diana Bannister-Cox, and Caroll Richards for their assistance in summer 2000, particularly Diana Bannister-Cox for work on plant identification.

## LITERATURE CITED

Barnewitz, E., A. Klinkenborg, and J. Scheibel. 2009. Effects of goat grazing and mowing on seed density and seed mass of *Lespedeza cuneata*. *Tillers* 6:21-25.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. *Annual Reviews of Ecology and Systematics* 8:255-283.

Brandon, A.L., D.J. Gibson, and B.A. Middleton. 2004. Mechanisms for dominance in an early successional old field by the invasive non-native *Lespedeza cuneata* (Dum. Cours.) G. Don. *Biological Invasives* 6:483-493.

Center for Invasive Species and Ecosystem Health. 2019. *Sericea lespedeza*. https://www.invasive.org/browse/subinfo.cfm?sub=3033 (18 June 2019).

Collins, S. L. and D. E. Adams. 1983. Succession in grasslands: thirty-two years of change in a Central Oklahoma tallgrass prairie. *Vegetatio* 51:181-190.

Corbett, E.A., D.L. Bannister, L. Bell, and C. Richards. 2002. Vegetational ecology of a disturbed woodland on the shore of Lake Texoma, Oklahoma. *Proceedings of the Oklahoma Academy of Science* 82:15-23.

Corbett, E.A., P. Blanton, and K. Talbot. 2013. Forest diversity around Lake Texoma, Oklahoma and Texas. *Proceedings of the Oklahoma Academy of Science* 93:41-54.

Cummings, D.C., S.D. Fuhlendorf, and D.M. Engle. 2007. Is altering grazing selectivity of invasive forage species with patch burning more effective than herbicide treatments? *Rangeland Ecology and Management* 60:253-260.

Hill, N.M., P.A. Keddy, and I.C. Wisheu. 1998. A hydrological model for predicting the effects of dams on the shoreline vegetation of lakes and reservoirs. *Environmental Management* 22: 723-736.

Integrated Taxonomic Information System. 2022. https://www.itis.gov/ (22 June 2022).

Koger, C.H., J.F. Stritzke, and D.C. Cummings. 2002. Control of sericea lespedeza (*Lespedeza cuneata*) with Triclopyr, Fluroxypur, and Metsulfuron. *Weed Technology* 16:893-900.

Magurran, A. 1988. *Ecological Diversity and Its Measurement*. Princeton (NJ): Princeton University Press.

National Climate Data Center. 2019. https://www.ncdc.noaa.gov/cdo-web/datatools/lcd (17 June 2019).

Parks, J.M. and H.G. Barclay. 1966. The increasing importance of vines in southern Oklahoma. *Proceedings of the Oklahoma Academy of Science* 46:9-16.

Rice, C.K. and J.F. Stritzke. (1989). Effects of 2, 4-D and atrazine on degraded Oklahoma grasslands. *Journal of Range Management* 42:217-222.

Rice, E. 1952. Phytosociologial analysis of a tallgrass prairie in Marshall County, Oklahoma. *Ecology* 33:112-116.

Ringelberg D.B., A.M. Beck, R.R. Busby, I.G. Smith, and A.C. Yannarell. 2017. Exudate chemical profiles derived from *Lespedeza* and other tallgrass prairie plant species. US Army Corps of Engineers publication (ERDC TN-17-1) http://acwc.sdp.sirsi.net/client/en_US/default/search/detailnonmodal/ent:$002f$002fSD_ILS$002f0$002fSD_ILS:296385/one?qu=lespedeza+exudates&te=ILS (18 June 2019).

Silliman, S. and A.D. Maccarone. 2005. Distribution, infestation, and habits of sericea lespedeza (*Lespedeza cuneata*) in Cowley County, Kansas. *Transactions of the Kansas Academy of Science* 108:83-92.

Smith, M.D. and A.K. Knapp. 2001. Physiological and morphological traits of exotic, invasive exotic, and native plant species in tallgrass prairie. *International Journal of Plant Sciences* 162: 785-792.

Sublette J.E. 1955. The physico-chemical and biological features of Lake Texoma (Denison reservoir), Oklahoma and Texas: a preliminary study. *The Texas Journal of Science* 7:164-182.

Sutherland, W.J. 1996. *Ecological Census Techniques: A Handbook*. Cambridge (UK): Cambridge University Press.

Tallent, N., M. Nash, C.L. Cross, and L.R. Walker. 2011. Patterns in shoreline vegetation and soils around Lake Mohave, Nevada and Arizona: implications for management. *Western North American Naturalist* 71:374-387.

Tarr, J., G. Botkin, E.L. Rice, E. Carpenter, and M. Hart. 1980. A broad analysis of fifteen sites in the tall-grass prairie of Oklahoma. *Proceedings of the Oklahoma Academy of Science* 60:39-42.

Tompkins, R.D. and W.C. Bridges, Jr. 2013. Restoration and plant species diversity of an Eastern prairie. *Native Plants Journal* 14:101-113.

U.S. Army Corps of Engineers. 2019a. Lake Texoma Flood History. http://www.swt-wc.usace.army.mil/DENI.lakepage.html (26 June 2019).

U.S. Army Corps of Engineers. 2019b. History of Lake Texoma. https://www.swt.usace.army.mil/Locations/Tulsa-District-Lakes/Oklahoma/Lake-Texoma/History/ (17 June 2019).

USDA, NRCS. 2022. The PLANTS Database. https://plants.usda.gov (22 June 2022).

Walder M.R. 2017. Takeover on the tallgrass prairie: How *Lespedeza cuneata* establishes dominance [Master's thesis]. Normal (IL): Illinois State University. https://ir.library.illinoisstate.edu/etd/815

Young, C.C., L.W. Morrison, and J.L. Haack. 2009. Factors affecting transformer plant species distribution in Tallgrass Prairie National Preserve. *Transactions of the Kansas Academy of Sciences* 112:57-66.