Post Oak & Prairie Journal

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Contents

Managing Wild Pigs at Fort Worth Nature Center & Refuge

POST OAK & PRAIRIE JOURNAL

A Quarterly Journal of the Cross Timbers and Blackland Prairies Ecosystems

Rob Denkhaus – Editor / Michael Smith – Layout Editor

The *Post Oak & Prairie Journal* is published by Crosstimbers Connection, a 501(c)(3) nonprofit organization whose goal is to connect people with nature in north Texas.

Submissions:

We welcome articles that report observations, research and descriptions of the cross timbers and prairies, as well as articles pertaining to wildlife, plant communities, conservation, and land management within these ecoregions. Articles are peer-edited prior to acceptance.

Manuscripts may be sent in Microsoft Word, Apple Pages, or as documents that can be opened in Word or Pages. The article may also be sent in the body of an email. We regret that we cannot accept handwritten manuscripts.

Photos may be sent by email as JPEG, TIFF, or PNG images. Please send at the highest resolution available and we will compress them as needed. Please do not send photographs to be scanned.

Please contact us regarding submissions by emailing *journal@crosstimbersconnection.org*

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EDITORIAL

In This Issue

Michael Smith, President, Crosstimbers Connection

I remember them well - their twin-spiked heads held high as they darted from one clump of grass to the next, stopping and blending in like just another clump of sandy gravel in the shadow of prairie grasses and prickly pear. The Texas horned lizard was common in the fields and behind the back yards of Fort Worth in the 1960s, and we could hardly have imagined that they would ever disappear. But they dwindled during the following twenty years, as the harvester ant mounds no longer dotted most of the landscape, suburban growth claimed more and more acres of the Fort Worth prairie, and ranchers planted sudangrass and coastal bermuda where native prairie grasses once grew. And, as pointed out in this issue by Rachel Granberg, Gad Perry, and Robin Verble, woody plants encroached into open prairie areas, changing the habitat in ways that do not work as well for species such as the Texas horned lizard.

Granberg and her colleagues describe a post-glacial climate that became drier and more conducive to a southward spread of grasslands down through Texas, with mixed-grass prairie and oak savannah extending into central Texas. Thus, the habitats these authors describe have much in common with a good part of the cross timbers and prairies that are the focus of this journal. When they describe how bison grazing and periodic fire maintained grassland ecosystems in central Texas, the discussion pertains to our region as well. If the Texas horned lizard was ever able to make a comeback in suitable patches of habitat in our area, the land management regimes that Granberg, *et al.* discuss would surely be part of their road to recovery.

Habitat loss and degradation are not the only threats to the wildlife that traditionally lived in our ecoregion. An ever-growing catalog of invasive species shares the landscape with those that evolved here. They range from the apparently innocuous, such as the little Rio Grande chirping frog, to the harmful and destructive, like imported fire ants or salt cedar. Or the wild pig, that ploughs up large areas of river banks and other areas to satisfy its insatiable desire to eat everything in its path. It used to be that a walk through the Fort Worth Nature Center & Refuge would reveal many areas where it looked like a huge roto-tiller had chewed through the area, leaving nothing but churned mud behind. One evening years ago I stood at the boardwalk and watched one of these hogs swim across the marsh toward me. I thought about what Rob Denkhaus had told me about the potential dangerousness of these powerful animals if surprised or cornered. In the years since, Denkhaus and his co-workers at the refuge have implemented effective strategies to reduce the population of wild pigs, so that they and the damage they cause are not so often seen. In the process, they have learned a great deal about these animals, and in this issue Denkhaus shares findings about their reproductive patterns that have clear implications for managing wild pigs.

It is hard for some people to imagine that they live in urban environments in such close proximity to animals such as wild pigs. A number of species are surprisingly able to survive and even thrive in urban areas. In this issue, Derek Broman discusses a monitoring project for urban carnivores, with the bobcat as an example. It involves another great use for iNaturalist, the web- and smartphone-based program that allows any and all of us to report sightings that can contribute to scientific understanding of wildlife. As Broman notes, the benefits are two-way: biologists and agencies can get citizen scientist data, and those of us who report sightings can get help identifying what we see. As such, iNaturalist can be a training tool for us while serving as a research tool for biologists. And in the process, we find that the bobcat is seen surprisingly often in the DFW area, even as a poolside visitor!

This issue also includes a description of plant species characteristic of the headwaters and seeps of the Fort Worth prairie. In these places where water begins to be channeled into ever-larger streams and tributaries, plants have to cope with what Shannon Jones describes as a hyperseasonal moisture regime – saturation in the spring and fall alternating with drying in the summer and winter. Jones takes us to headwater locations near Benbrook lake, where prairie vegetation gives way to other species

EDITORIAL: In This Issue *(continued)*

as we progress down the hillslope to the bottom of the stream channel. She shows us how the species composition as well as species diversity changes in these different locations. Her data provide a welcome addition to our knowledge of the ecology of these unique places in north Texas prairies.

We are excited to bring you this second issue of our journal and look forward to seeing how the *Post Oak & Prairie Journal* evolves with future issues. And that will depend on you, as readers and contributors. We hope that you will share your knowledge with us, by contributing significant sightings, descriptions of time in the field, or articles that explore natural history issues. We look forward to providing a forum for observation, discussion, and celebration of this unique ecoregion in north Texas.

Michael Smith is an amateur naturalist with a lifelong interest in field herpetology. He is Layout Editor for POPJ, and currently serves as President of Crosstimbers Connection. He can be reached at:
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Fort Worth Prairie Headwater and Seep Ecology

Shannon L. Jones, Ecologist, Integrated Environmental Solutions

1. Introduction

In North Central Texas, the Fort Worth Prairie is a grassland unit that extends between the Eastern and Western Cross Timber ecoregions and is bounded to the north by the Red River and to the south by the Brazos River (U.S. Army Corps of Engineers [USACE] 2010). The Fort Worth Prairie is part of the tallgrass prairie, a critically endangered ecosystem. Today, only several thousand acres of the original 1.3 million acres still remains intact (Great Plains Restoration Council 2014). Formed over interbedded hard limestone and soft marl, the Fort Worth Prairie ranges from gently sloping valleys to narrow cuts. Geology, being a broad-scale control, influences topography and stream channel characteristics (U.S. Geological Survey [USGS] 2006). Both topography and impermeable subsurface layers tend to favor the accumulation of soil water, and can create major sources of subsurface runoff (Burt and Butcher 1985; Anderson and Burt 1978).

The riparian headwaters of the Fort Worth Prairie support hyperseasonal environments found in North Texas. Although the Fort Worth Prairie is typically described as a tall-grass prairie (TPWD 2013; USGS 2013; Diamond and Smeins 1993), the riparian headwater communities are unique since ephemeral and intermittent headwater streams are often dominated by species adapted to fluctuation between seasonal saturation and drying; a hyperseasonal moisture regime. This term was first used by Sarmiento (1984) to describe the moisture regime of tropical savannas of Venezuela, but has been adapted for this study due to a similar moisture regime found in North Texas. During the spring and fall rainy seasons, headwater areas become completely saturated, but they go dry in the summer and winter. Due to the ephemeral and intermittent nature of Fort Worth Prairie headwater streams, the high variation of soil moisture restricts perennial tall-grasses from dominating riparian headwaters.

Little research has been conducted about the ecologic functioning of these native headwaters; however, data suggest that these communities are well adapted to change. In 2012, a study of the soil-vegetation relationship along headwater streams and seeps was conducted along reaches that flow into the West Fork of the Trinity River Watershed. These relatively undisturbed reaches contain native tall- and mid-grass prairie species, and capture the variability in topography, soils, and underlying geology of the Fort Worth Prairie. A better understanding of these hyperseasonal communities could create a foundation for improved habitat management, protection, and restoration of riparian headwaters in North Central Texas. Thus describing and characterizing seeps and headwater streams within the study areas, are the focus of this paper.

2. Muhly Seeps

A seep, defined by the USGS (2009), is a "hydrogeologic formation that collects water from upslope or underground." Seeps exist in many environments; however, in the Fort Worth Prairie, seeps dominated by seep muhly (*Muhlenbergia reverchonii*) are common features and can exist in several

Figure 1: Picture of *Muhlenbergia reverchonii* in bloom at the USACE site (fall 2012) (left). Mounted specimen of seep muhly (right).

topographic positions, such as seeps or along ephemeral stream channels. The vegetation forms over alternating layers of erosion-resistant limestone and soft marl. These two types of bedrock are found in the Fort Worth Prairie landscape. The marl layer is less permeable than the limestone, which slows infiltration and forms seeps (Llado 2011).

The dominant vegetation of these seeps is seep muhly. Seep muhly is a perennial grass with "dense tufts of slender stems and foliage" (Lady Bird Johnson Wildflower Center 2012). The old basal sheaths form a matted base along the ground and the seed heads are purplish colored (**Figure 1**). The only known locations of seep muhly are in central Oklahoma and in parts of Texas (USDA 2014). According to NatureServe's (2014) comprehensive report on seep muhly, little is known about the ecology and life history, the economic attributes, or management. Seep muhly is found in Oklahoma and Texas (**Figure 2**) in rocky soils over limestone formations.

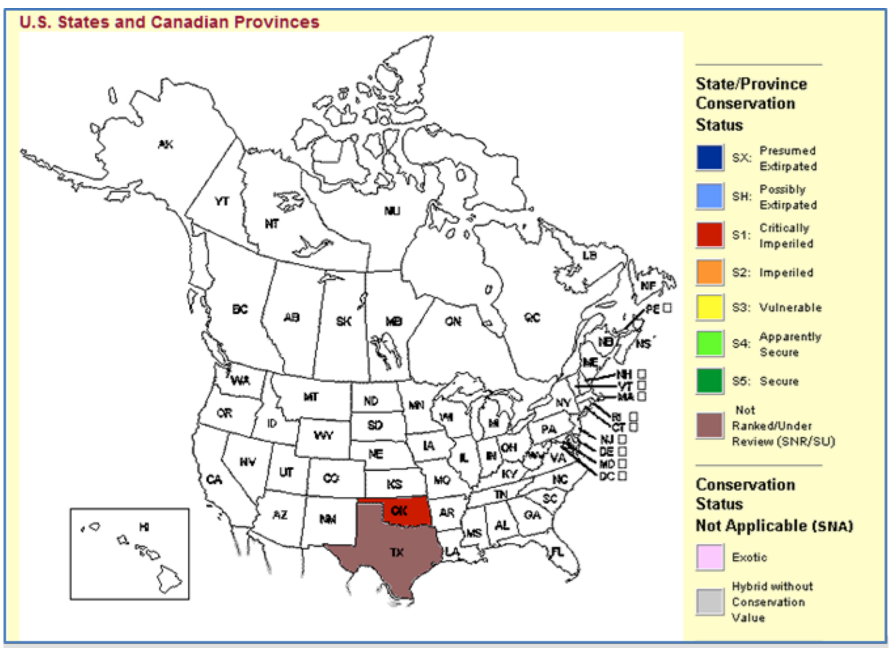

Figure 2: Map of *Muhlenbergia reverchonii*'s habitat. In Oklahoma it is critically imperiled, but in Texas, seep muhly does not have a conservation status and is under review (NatureServe 2014)

Depending on where the seep is, other vegetation, like little-tooth sedge (*Carex microdonta*), and limestone spikerush (*Eliocharis occulta*), are found in the wettest portion of the seep. However, whether these plant communities exist or not is dependent upon the time of year. These wetland communities have two growing seasons: the cool-season grasses and forbs grow from late fall to spring and warm-season annuals grow from late spring to fall. Hyperseasonal hydrology is one of the driving limitations of Muhly seeps since these seeps may not be noticeable during the dry portions of the years. Very few perennials that can tolerate spring waterlogging and summer drought also grow in these habitats.

3. Headwater Riparia

Prairie streams occur mainly along the Great Plains region of North America and "represent key interface[s] between terrestrial habitats and downstream areas" (Dodds et al. 2004, 205). These streams do not usually have large tree canopies sustained by abundant rainfall, such as in the Southeastern region of the US, and instead they "exist in a precarious balance between flood and drying" (205). In regions where precipitation is limited, ephemeral and intermittent headwaters rely significantly on precipitation and/or runoff since water tables are usually deep or absent.

In North Central Texas, Fort Worth Prairie headwater streams are the main source of water supply of the northern part of the Trinity River Watershed. These headwater streams seem to function similarly to other grassland streams in the Great Plains Ecoregion, and usually have steady flow in the spring but dry out completely by late summer. Within the stream channel, pools host a variety of plants including hydrophytes that meet obligate wetland criteria (Lichvar et al. 2014). However, these species only remain apparent during the spring rainy season. Once these pools dry, plants either die completely or die back to their root systems until the next growing season (**Figure 3**).

Riparian wetlands are less diverse than the uplands and are usually dominated in late summer by one or two annual species, such as common ragweed (*Ambrosia artemisiifolia*), or narrowleaf marsh elder (*Iva angustifolia*), neither of which are obligate hydrophytes. These warm-season annuals are able to survive in unstable, hyperseasonal environments because they become established on open ground when the soil moisture regime switches from hydric to mesic (Swadek and Burgess 2012).

Fort Worth Prairie Headwater and Seep Ecology *(continued)*

Figure 3: Prairie headwater stream channel with flowing water in the spring (left). Same stream channel completely dry in the late summer (right).

Related to the hydrologic control of the riparian communities is the soil moisture availability, which is dependent upon soil texture and properties. In the Fort Worth Prairie upland clay soils found along the top of the hillslopes support tall grasses, such as Indian Grass (*Sorghastrum nutans*) and Big-Bluestem (*Andropogon gerardii*), and most commonly Little Bluestem (*Schizachyrium scoparium*) (Diggs, Libscomb, and O'Kennon 2001). These tall grasses are unable to become established in most of the headwater riparian areas, since a large abundance of annual grasses and herbs outcompete them. Hyperseasonal vernal seeps and headwater stream habitats are neither typical wetlands, nor are they truly prairie grasslands.

4. Methods

The study site included two streams found at the USACE Property along the east shore of Benbrook Lake (**Figure 4**). One stream is found on a gently rolling landscape over deep clay soils, and the other on steeper hillslope with shallow soils. There were three 50 meter transects chosen for vegetation surveying prior to field work using aerial imagery and the *Soil Survey of Tarrant County* (Ressel 1984) to determine where soil/geology transitions occur.

Transect 1 is along the southern end of the USACE site and has thin gravelly soils common to the Aledo-Bolar complex (1984). A hydrology study was conducted by Llado in 2010 along the same transect further up the hillslope to study the soil moisture characteristics of a muhly seep present along the midslope where a hard limestone layer intersects a clay marl. The transect was adjusted for this study to extended just above the seep all the way into the channel and continued up the west bank.

Transect 2 is located at the beginning of a headwater stream along the northern part of the USACE property. The transect starts southeast of the headwaters and continues down into a gently rolling valley into a shallow, broad floodplain with a marginally defined channel and then continues upslope north of the channel. The soils along this transect are deep, clayey Sanger soils above a gently weathered marl layer, creating a wide valley floodplain.

Transect 3 is located further downstream from Transect 2 in Sanger soil as well, however, the channel and the valley cuts deeper into the hillslope. Transect 3 starts south of the channel at the midslope where there is distinct upland vegetation and continues into the valley, and across the hillslope on the other side of the valley. The soils here are very similar to the soils found near Transect 2 but the stream channel is more defined and the hillslopes are steeper due to the collective flow of water downstream. Topographically, Transect 3 is in a similar location as Transect 1, since they both contain a distinct prairie headwater channel approximately 1,000 feet upstream from the forested portion of the stream channel.

Vegetation Characterization

Vegetation is an important feature in interactive, diverse riparian ecosystems. According to Gregory et al. (1991), the

Fort Worth Prairie Headwater and Seep Ecology *(continued)*

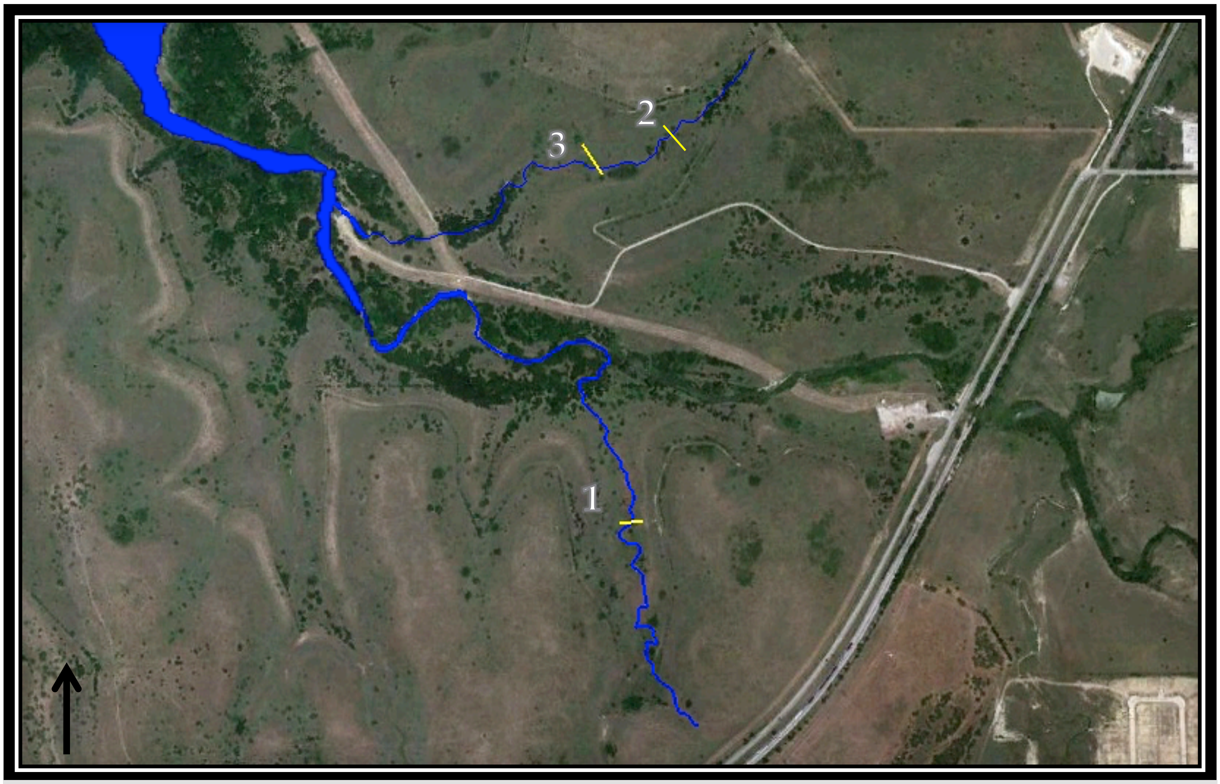

Figure 4: USACE property along the east shore of Lake Benbrook. Image taken from 2011 Google Earth Aerial Imagery. Three linear transects, shown in yellow (2 along the north stream 1 along the south stream), were delineated and vegetation community characteristics were recorded

composition of vegetation is affected by hydrologic and geomorphic processes which provide an array of habitats along the stream corridor. Soil properties and topography affect the structure and composition of both riparian and upland plant communities (Gregory et al. 1991). Vegetative variation not only changes spatially, but also temporally since they fluctuate with disturbances. The relevé method is a sampling method widely used by government agencies, nonprofit organizations, and academic vegetation sciences (Barbour et al. 1999). Sampling sites that "best [represent] the [plant] community" (Barbour et al. 1999) are chosen, and cover classes are estimated based on visual assessment.

Vegetation sampling was conducted during the fall season, when seep muhly flowers. The plant communities were surveyed across the hillslope using an adaptation of the relevé method. This method required a delineation along a transect to find distinct changes in vegetative communities. Each transect was measured across the hillslope using a tape measure. Wire flags were placed where a noticeable transition in vegetation occurred, and the GPS locations were recorded using a Tremble GeoHX unit. The communities within each flagged zone were rapidly surveyed for dominant species. The species in each plot along with their height, density, cover class, physiognomy, habitat characteristics, and changes in microtopography were recorded.

Species richness is the quantitative measurement of different species within an ecological community. Alpha diversity (α diversity) is a single vegetative sample with a uniform vegetative community and beta diversity (β diversity) is "the extent of change in community composition, or degree of community differentiation, in relation to a complex-gradient of environment, or a pattern of environments" (Whittaker 1960). The species richness, as used by Whittaker, was calculated for each plot was based on the total number of species present (α diversity) and across the transect was calculated based on the amount of different species that occurred between two adjacent plots (β diversity). All plant vouchers collected during field research were keyed out to species using the *Shinner's & Mahler's Illustrated Flora of North Central Texas* dichotomous key (Diggs, Libscomb, and O'Kennon 2001), and are mounted and stored in the Botanical Research Institute of Texas's Herbarium and digitally cataloged into their online database, Atrium.

5. Results

Vegetation was recorded along all transects between August 10 and September 12, 2012. Due to time constraints the transects did not get resurveyed in the spring. **Figure 5** shows all three transect elevation changes. Each transect starts at the top of the hillslope and extends downward towards the stream channel, which is the lowest part of the transect, and across the other side of the bank. Transect 1 had a total of 52 different species delineated across 8 vegetative plots. Transect 2 had a total of 35 species delineated across 15 plots, and 49 species across 13 plots were recorded along Transect 3. The species richness across each vegetative plots were recorded and the diversity between adjacent plots was compared (**Figure 6**).

Transect 1 (a) starts at the top of the hill in deep clay soils with upland tall- and mid-grass species such as, big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), composite dropseed (*Sporobolus compositus*) and sideoats gramma (*Bouteloua ciurtipendula*). It then extends down to the stream channel and flattens out at approximately 1.90 meters below the start of the transect and transitions into a seepy area containing seep muhly and little-tooth sedge (*Carex microdonta*) species. The lowest point of the transect, the channel, was at approximately 2.85 meters below the start of the transect and contained caraphytes and algae and Texas rush (*Juncus texanas*); however, there was no hydrology present during the time of the vegetation survey. The western bank is less steep and immediately transitions from bank vegetation into a co-dominant plot of western ragweed (*Ambrosia psilostachya*) and prairie tea (*Croton monanthogynus*).

Transect 2 (b) starts at the top of the hill in deep clay soils with upland tall- and mid-grass species, big bluestem, little bluestem,

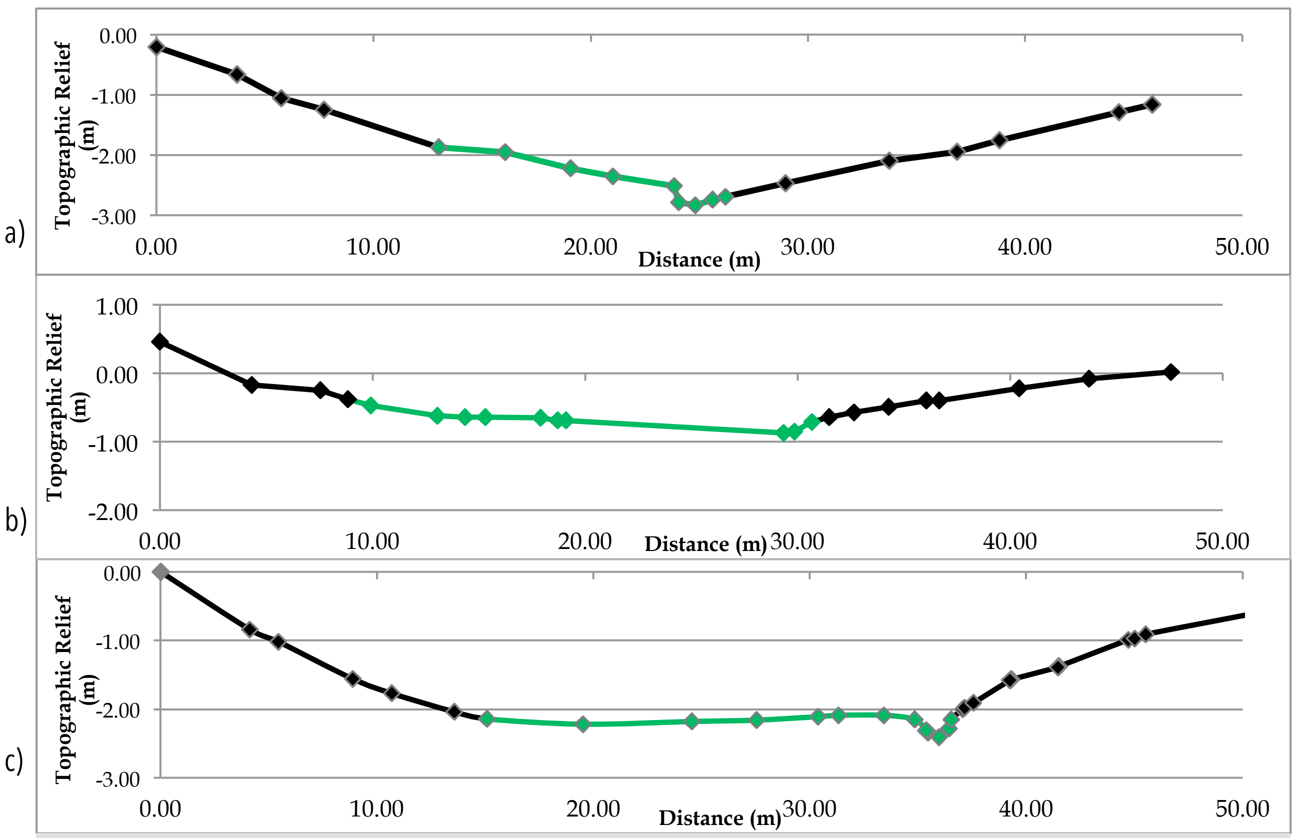

Figure 5: Topographic relief, in meters, of Transect 1(a) Transect 2(b) and Transect 3(c): All transects are 50 meters long and have less than 3 meters of elevation change. The green line shows where the riparian zone is along the transects. The stream channel occurs at the lowest elevation along the transect.

eryngo (*Eryngium leavenworhii*), prairie rose (*Rosa foliosa*), and composite dropseed. It then extends down to the stream channel approximately 2.41 meters below the start of the transect, where there was western ragweed, seep muhly, and narrowleaf marsh elder (*Iva angusifolia*). A distinct seepy area containing seep muhly and western ragweed occurs at approximately 2.14 meters below the start of the transect at the base of the hillslope. The bottom of the channel was primarily bare with seep muhly and western ragweed interspersed throughout the channel. Similar to Transect 1, there was no hydrology present during the time of the vegetation survey. The northern bank immediately transitioned into the same upland prairie species found at the start of the transect.

Transect 3 (c) had the least microtopographic change (0.87) and starts at the beginning of the northern stream near the northeast border of the property. The transect begins along the midslope where tall-grass prairie species, such as snow-on-the-prairie (*Euphorbia bicolor*), big bluestem, and broomweed (*Guiterrezia dracunculoides*) are dominant. The transect gently slopes down and flattens to a broad toe slope seep 0.47 meters below the start of the transect containing remnant limestone quillwort (*Isoetes buteri*) and limestone spikerush (*Eleocharis occulta*) from the spring vegetation. The transect reaches the stream channel at approximately 30 meters north and is 0.87 meters below the start of the transect. The dominant channel species were Maximillian sunflower (*Helianthus maximilliani*), Canada germander (*Teucrium canadense*), and narrowleaf marsh elder were prevalent along the bank and no stream flow was present during the time of the vegetation survey. North of the bank, is a relatively steeper slope and immediately transitions from bank vegetation into the same upland prairie species found at the beginning of the transect.

6. Discussion and Conclusion

The total diversity of all three transects was 65 species across 38 plots. Transect 1, along the southern stream, had the highest species richness across the entire transect. This could be, in part, due to this transect having the steepest slope of all three transects and due to the soil composition. Approximately halfway down the hillslope, there was a distinct seep coupled with a barrens layer (Llado 2011) which hydrologically influenced the vegetative communities downslope. The western bank of Transect 1 and northern banks of Transects 2 and 3 were less steep but immediately transitioned from bank vegetation into a co-dominant plots of western ragweed (*Ambrosia psilostachya*) and prairie tea (*Croton monanthogynus*). This shows that although this side of the stream channel gets

a) b) c)

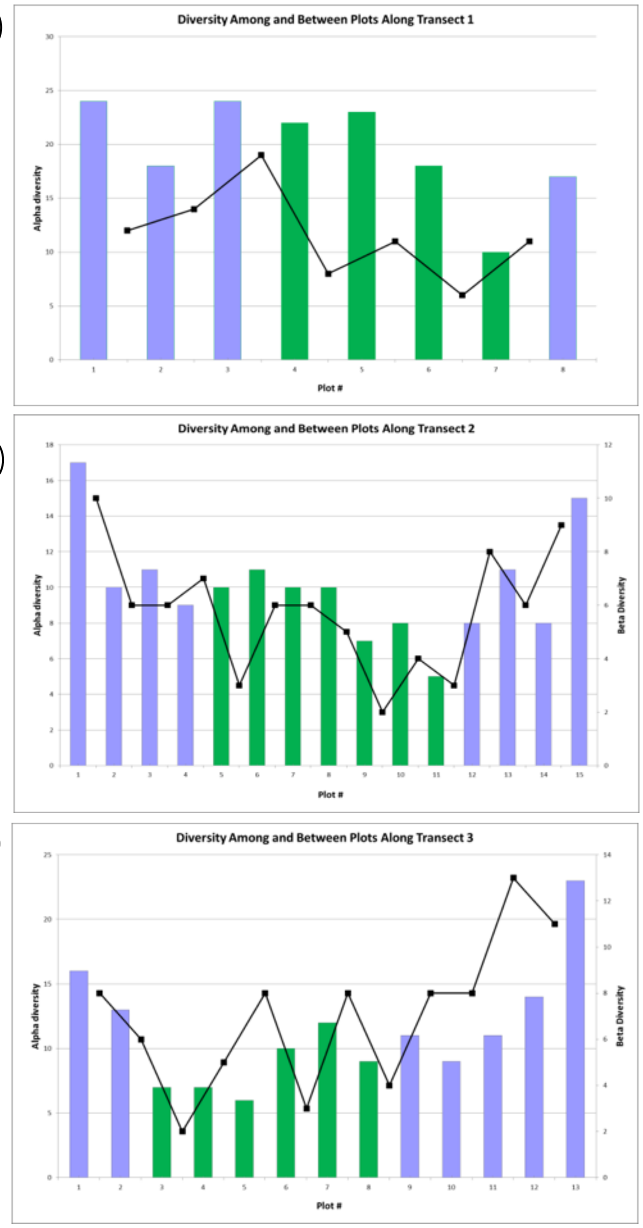

Figure 6: These graphs show the species richness along each transect (a, b, and c). The bars represent the total number of species found within each plot (alpha diversity). The purple bars represent upland and transition plots, while the green plots represent the seep and channel plots. The line represents the number of species shared between two adjacent plots (beta diversity).

wet, it drains better than the other side that contains seep species. There is likely no geologic contact between a limestone and marl layer on this part of the hillslope to form a perched water table. Instead, deep clay soils allow water to infiltrate and flow into the channel.

Both headwater streams had noticeable transitions from upland prairie species near the crest of the hillslopes to wetland areas along the stream channel and seep areas. Although there are different soil types found along the northern stream and southern stream and the vegetative communities along each transect vary, all three transects show a clear connection between the soil, vegetation, landscape, and underlying geology.

Although muhly seeps are recognized by the ecological community, they may or may not meet regulatory wetland criteria set forth by the U.S. Army Corps of Engineers, depending on where they are found in the landscape. The riparian and seep zones found along the two intermittent headwater streams varied depending on soil types, moisture availability, and topography. Although seep areas are influenced by precipitation infiltration into the stream channel, the plant communities, themselves, may or may not meet wetland indicator status because wetland plants may not be dominant and are often found with upland species.

To the untrained eye, the Fort Worth Prairie headwater landscapes may seem like a non-diverse monoculture, uniform in composition, however, these ecological systems are very complex and unique. Although there has been relatively little research on the importance of ephemeral and intermittent headwater streams in North Central Texas, continued research can determine the ecological and economic importance of these natural systems. Because the Trinity River is the main source of water supply in the North Central Texas region, seep and headwater stream environments can be used for biomimicry designs, such as bioswales and other storm water management features. Thus, a better understanding of these hyperseasonal communities will create a foundation for improved habitat management, protection and restoration of riparian headwaters in the Fort Worth Prairie.

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Shannon Jones is an ecologist with Integrated Environmental Solutions in McKinney, Texas. She obtained her M.S. (2013) in Environmental Science from Texas Christian University. Being a Texas native, her goal is to obtain her PhD and teach young adults about management, protection, and restoration of water resources in North Texas.

SIGHTINGS:

Things seen and heard, especially the first and last sightings of the season, or sightings in unusual places or significant situations

Week in 2015	Sighting
Week 4: January 18-24	January 18, between 3:30-5:00pm. Diamond-backed watersnake (*Nerodia rhombifer rhombifer*), approx. 30 in. length, under flat piece of wood at the edge of dry pond. When exposed, the snake was fully active. Rough earthsnake (*Virginia striatula*) under 3-foot log on open hillside. 3 southern/broad-banded copperheads (*Agkistrodon contortrix* ssp.), two adults and one subadult, in densely wooded floodplain under a car wheel and logs. Dallas County, TX, Trinity River bottomland, SE Dallas near Loop 12. Maximum reported temperature 70°F. Observation: Shaun Hayes January 20, 3:45pm. Western diamond-backed rattlesnakes (*Crotalus atrox*), one adult and one juvenile observed basking, two additional individuals heard rattling, and a fifth one noted by observing the tail disappearing into rock crevice. Seen on an artificial, south-facing slope formed by large stacked rocks. Dallas County, TX, Grand Prairie. Maximum reported temperature 70°F. Observation: Shaun Hayes
Week 6: February 1-7	February 1, 1:43pm. Red-eared slider (*Trachemys scripta elegans*), adult, half submerged at edge of a pond. Tarrant County, TX, Southwest Nature Preserve. NWS reported maximum temperature 58°F. Observation: Michael Smith, michael@crosstimbersconnection.org
Week 12: March 15-21	March 19, 9:15-10:00pm. Woodhouse's toads (*Anaxyrus woodhousii*) on the road and calling, spotted chorus frogs (*Pseudacris clarkii*) Wise County, TX, County Road 3424, prairie/agricultural mix. Also southern leopard frog (*Lithobates sphenocephala*) on Trinity River Rd. west of Decatur, in floodplain/woodland. Temperature 66°F. Observation: Clint King, massasaugaville@gmail.com

To submit a sighting, please send the relevant information to: journal@crosstimbersconnection.org. Please include the date, location, identification, and the significance of the sighting (unusual location or habitat, early or late season sighting, etc.). If possible, include a photo in jpg or similar format to confirm identification. We publish selected sightings but regretfully cannot always publish all of them. Thank you for contributing!

We love getting significant sightings here, but remember to also report sightings to www.inaturalist.org! Sightings of herpetofauna in Texas should be contributed to the Herps of Texas project, http://www.inaturalist.org/projects/herps-of-texas. Additionally, Crosstimbers Connection has a project at iNaturalist: http://www.inaturalist.org/projects/crosstimbers-connection.

Winter herp sighting: red-eared slider observed February 1

Notes on the Reproductive Potential of a North Texas Urban Wild Pig (*Sus scrofa*) Population

Rob Denkhaus, Natural Resource Manager, Fort Worth Nature Center & Refuge

Introduction

Wild pigs (*Sus scrofa*) were first introduced to the continental United States by the Coronado and de Soto expeditions in 1540 and 1541, respectively (Towne and Wentworth 1950) but only in the past few decades have they become a problem in north Texas and only in recent years have they become a problem within urban areas. Little research has been conducted on wild pig ecology and management within the Cross Timbers and Blackland Prairie Ecoregions leaving resource managers forced to interpret findings from other regions. Even less published research exists on urban wild pig populations leading urban wildlife managers to rely on information gleaned from non-urban studies. In addition, wild pigs are the subject of much conjecture amongst people which often leads to extreme hyperbole when describing the animals and their attributes. Many of these attributes are centered on the species reproductive potential and, because of the feral nature of the species in Texas, are based at least partially upon the species under domestication.

In general, domestic swine have been selectively bred for maximum reproductive potential but basic physiological characteristics remained relatively stable as the domestic pig evolved from the wild stock. Wild sows are polyestrous and, if not successfully bred, will come into estrus every 18 – 24 days (Barrett 1978) with a mean period between cycles of approximately 21 days (Sweeney et al. 2003). The first cycle lasts approximately 24 hours while subsequent cycles last 48 – 72 hours. Gestation periods in wild and domestic pigs are similar, averaging 112-120 days. Henry (1968) identified a mean of 115 days while Mauget (1982) reported 119 days for two populations of wild pigs.

Reported wild pig reproductive potential is highly variable. Non-scientific publications frequently report typical wild pig litter sizes of up to 12 piglets (Ferman 2009, McPhate 2014, Texas Hunt Lodge 2014). Lay-articles also report that wild pigs frequently give birth to $\geq$2 litters annually (Anonymous 2010, Texas Hunt Lodge 2014). Domestic pigs exhibit an average litter size of 6.6 – 11.2 piglets depending upon the domestic breed (Nalbandhov 1976) with a maximum of 24 young per litter (Barrett 1978).

Wild pigs, which, in the United States, consist of Eurasian wild boar (ancestral stock for domestic pigs), escaped domestic, i.e. feral, pigs, and so-called hybrids between the two (Mayer 2009), are reported to exhibit lower fecundity than domestic breeds or the mythical pigs of the lay-literature. Comer and Mayer (2009) reviewed 81 published international studies and reported a mean litter size range of 3 – 8.4 based on live fetal counts. Individual litter size within the 81 studies ranged from 1 – 14 live fetuses. Hanson and Karstad (1959) reported a wild sow with a fetal litter of 16 but only 6 were viable at the time of examination. In Texas, Springer (1977), working at the Aransas National Wildlife Refuge, reported an average fetal litter size of 4.2. Taylor et al. (1998), working in the Gulf Coast prairie region and the south Texas plains, reported mean fetal litter sizes of 4.4 – 6.3 and 4.7 – 5.6, respectively, over a multi-year period. None of the reviewed studies referred to urban or exurban wild pig populations.

The number of litters per year is reported to be related to times of abundant food resources (Barrett 1978) and the age of the sow (Taylor et al. 1998) with better nutrition and adult age class producing more litters. In general, only a relatively small proportion of wild sows produce multiple litters annually but specific sows provided with adequate nutrition can, and do, produce multiple litters (Baber and Coblentz 1986, Johnson et al. 1982, Springer 1977). Taylor et al. (1998) reported sows $\geq$ 21 months of age produced a mean of 1.57 litters/year while yearlings produced a mean of 0.85 litters/year. In New South Wales, Australia, Giles (1980) found that sows produced 1.93 litters/year.

Wild pigs were first found on the Fort Worth Nature Center & Refuge (FWNC&R) in the summer of 1999. The pigs' origins are unknown but are believed to have been the result of immigration from outlying ranch lands along the West Fork of

Reproductive Potential of a North Texas Urban Pig Population *(continued)*

the Trinity River or possibly intentional, but illegal, planting by poachers. FWNC&R staff developed a set of control protocols that were accepted by the City of Fort Worth and implemented in January 2003 (Denkhaus 2006). Lethal control was ongoing during the period from 2003-2013 with 261 wild pigs removed (Denkhaus Unpublished).

Study Area

The Fort Worth Nature Center & Refuge is a 3,621 acres (1,465 ha) urban green space owned and operated by the City of Fort Worth's Parks and Community Services Department. The FWNC&R straddles the West Fork of the Trinity River extending from Wells Burnett and Ten Mile Bridge Roads, just south of Eagle Mountain Lake, to the northern extent of Lake Worth at Jacksboro Highway.

FWNC&R vegetation communities form a landscape mosaic of Cross Timbers forest, Fort Worth prairie, and bottomland hardwoods and other wetlands associated with the West Fork of the Trinity River. The vegetation is predominantly native although significant stands of exotic, invasive species including, but not limited to, privet (*Ligustrum spp.*), Chinaberry (*Melia azedarach*), Johnson grass (*Sorghum halepense*), King Ranch bluestem (*Bothriochloa ischaemum*), etc. are present.

All of north Texas has suffered from a long-term drought which peaked in 2011. Water levels in the West Fork of the Trinity River through the FWNC&R have been approximately 3 ft. (0.92 m) low annually. Wetlands within the FWNC&R have been dry during much of the time.

Methods

Wild pig control was accomplished through live-trapping and euthanasia. Euthanized pigs were weighed and measured in the field immediately upon removal from the trap site. External examination was used to determine a sow's lactation status. Data from camera traps and the number of piglets trapped with the sow were used to determine the number of live young.

Adult sows were examined internally for the presence of fetuses to determine total number, number of viable, and number of aborted fetuses. Viable fetuses were aged according to Henry (1968) and dates of conception calculated through back-dating.

Game camera photo of wild pigs trapped in the study area

Results

Control efforts resulted in the removal of 261 wild pigs of both sexes and representing all age groups. One hundred forty eight (148) female pigs of all ages were removed. Reproductively active sows (pregnant or lactating) were removed in all years that had active control except for 2003 (Table 1). Sows determined to be either lactating or pregnant through external and internal examination respectively, totaled 31 (21.8%) of all females removed. Lactating sows (N = 22) accounted for 14.9% of the total. Pregnant sows (N=9) accounted for 6.1% of total females.

Control efforts were conducted during all months with pigs removed during all months other than November. Reproductively active sows were removed during all months that resulted in removed pigs (Table 2). Sows removed from January – June accounted for 75% of all females removed and 83.9% of all reproductively active sows removed (77.3% of lactating sows; 100.0% of pregnant sows) indicating that most farrowing occurs during the first six months of the year.

Game cameras used in the control process provided data on surviving litter size. Of the 22 lactating sows removed, 17 were

Reproductive Potential of a North Texas Urban Pig Population *(continued)*

Control Year	Total Sows Removed (% Reproductive)	Lactating Sows (% Total)	Pregnant Sows (% Total)
2003	19 (0.0%)	0 (0.0%)	0 (0.0%)
2004	26 (19.2%)	5 (19.2%)	0 (0.0%)
2005	16 (25.0%)	2 (12.5%)	2 (12.5%)
2006	14 (35.7%)	4 (28.6%)	1 (7.1%)
2007	13 (23.1%)	3 (23.1%)	0 (0.0%)
2008	24 (16.7%)	0 (0.0%)	4 (16.7%)
2009	17 (29.4%)	5 (29.4%)	0 (0.0%)
2010	No Control Activities		
2011	4 (25.0%)	1 (25.0%)	0 (0.0%)
2012	No Control Activities		
2013	15 (26.7%)	2 (13.3%)	2 (13.3%)

Table 1. Annual take of reproductively active sows.

accompanied by a litter ranging in number from 1 to 7 piglets. Mean live piglet litter size was 3.71. Piglets weighing up to 49 lbs. (22.25 kg) were observed nursing from known lactating sows. A total of 85 piglets weighing ≤ 49 lbs. were removed during control operations. Sixty-three (74.1%) were associated with one of the lactating sows. Table 3 summarizes live piglet data and yields an average piglet sex ratio of 1 male:1.5 females.

Pregnant sows (*N*=9) examined contained 64 total fetuses, providing a mean fetal litter size of 7.11 (Table 4). Individual fetal litter size ranged from 5 – 11. Nonviable fetuses totaled 34 (53.1%) and ranged from 0 – 6 (mean = 3.78). Viable fetuses totaled 30 (46.9%) and ranged from 0 – 7 (mean = 3.33).

Pregnant sows were removed during 4 years (Table 5). The mean fetal litter size/year ranged from 5.75 – 9.5. Mean viable fetal litter size was 3.33. Eleven fetuses from 3 litters were sexed providing a fetal sex ratio of 1 male:1.75 females.

Fetal litters of 6 pregnant sows removed in 2006 (1 litter), 2008 (3 litters) and 2013 (2 litters) were able to be aged by crown-rump length (Henry 1968). The average crown-rump length of all fetuses in the litter was used to backdate to conception. Predicted farrowing date uses a 115 day gestation period (Henry 1968). Table 6 summarizes fetal age and predicted conception and farrowing data for 26 fetuses.

Discussion

A small sample size precludes making substantial statements regarding wild pig reproductive potential in north central Texas but does provide an opportunity to make comparisons to the existing literature and form a base for additional data to build upon.

Reproductive Activity Periods

Reproductively active sows were removed during all seasons of the year although pregnant sows were only removed during January, February and June. Fetal litters from examined pregnant sows indicate projected breeding dates in March and November with projected farrowing dates in July and March, respectively.

Month	Total Sows Removed (% Reproductive)	Lactating Sows Removed (% Total)	Pregnant Sows Removed (% Total)
January	57 (19.3%)	5 (8.8%)	6 (10.5%)
February	4 (50.0%)	1 (25.0%)	1 (25.0%)
March	7 (28.6%)	2 (28.6%)	0 (0.0%)
April	18 (22.2%)	4 (22.2%)	0 (0.0%)
May	10 (20.0%)	2 (20.0%)	0 (0.0%)
June	15 (33.3%)	3 (20.0%)	2 (13.3%)
July	4 (25.0%)	1 (25.0%)	0 (0.0%)
August	7 (14.3%)	1 (14.3%)	0 (0.0%)
September	4 (25.0%)	1 (25.0%)	0 (0.0%)
October	6 (16.7%)	1 (16.7%)	0 (0.0%)
November	0 (0.0%)	0 (0.0%)	0 (0.0%)
December	16 (6.3%)	1 (6.3%)	0 (0.0%)

Table 2. Reproductive sows removed / month (2003-20013).

Game camera data associated with trapping efforts showed that piglets as large as 49 lbs (22.25 kg) were observed nursing. Eighty-five pigs weighing ≤49 lbs were removed during control efforts and these were all assumed to be nursing to provide additional data on farrowing and breeding dates. Piglets are weaned at 3-4 months (Nowak 1991). In an attempt to deduce breeding and farrowing dates, pigs weighing 49 lbs were considered to be at the end

Reproductive Potential of a North Texas Urban Pig Population *(continued)*

	Males	Females	Total	Sex Ratio M:F
2003	3	5	8	1:1.67
2004	6	6	12	1:1.00
2005	5	9	14	1:1.80
2006	3	5	8	1:1.67
2007	0	2	2	~
2008	2	5	7	1:2.50
2009	6	9	15	1:1.50
2010				
2011	3	2	5	1:0.67
2012				
2013	6	8	14	1:1.33
Totals	34	51	85	1:1.50

Table 3. Sex ratio of piglets (≤ 49 lbs.) removed in control operations.

Sow ID	Viable Fetuses	Aborted Fetuses	Fetal Litter Size
05-05	2	4	6
05-06	2	6	8
06-03	3	5	8
08-01	0	5	5
08-05	4	2	6
08-06	7	0	7
08-28	1	4	5
13-03	5	3	8
13-04	6	5	11

Table 4. Viable and aborted fetuses and total fetal litter size for pregnant sows (N=9).

of the nursing period, designated as 3.5 months or 105 days. The live weight of each pig weighing ≤ 49 lbs was divided by 49 lbs to calculate a percentage of weaning weight. This percentage of weaning weight was then multiplied by 105 days, the average length of the weaning period, to determine the approximate number of days since farrowing. This number was subtracted from the date of trapping to approximate a date of birth. The average gestation period, 115 days, was subtracted from the date of birth to provide an approximate date of breeding for each piglet.

Year	Pregnant Sows	Viable Fetuses	Aborted Fetuses	Fetal Litter Size
2005	2	2	5	7
2006	1	3	5	8
2007	0	~	~	~
2008	4	3	2.75	5.75
2009	0	~	~	~
2010	No Control Activities			
2011	0	~	~	~
2012	No Control Activities			
2013	2	5.5	4	9.5

Table 5. Average number of viable and aborted fetuses and fetal litter size per pregnant sow (N=9).

Combining the data approximated from the 85 controlled piglets with that of the 6 fetal litters examined provides 107.2 projected breeding and farrowing dates. Fetal litter calculations were weighted by the observed average litter size of 3.7 piglets/litter (see below). Figure 1 shows the number of projected breeding and farrowing events for each one-half month. A smoothed line was used to indicate the potential variability of the projected dates due to the method of calculation.

Sow ID	Viable Fetuses	Trap Date	Fetal Age (Days)	Conception Date	Farrowing Date
06-03	3	6-Jun-06	74	24-Mar-06	17-Jul-06
08-05	4	9-Jan-08	50	19-Nov-07	13-Mar-08
08-06	7	18-Feb-08	97	13-Nov-07	7-Mar-08
08-28	1	25-Jun-08	90	27-Mar-08	20-Jul-08
13-03	5	9-Jan-13	51	19-Nov-12	14-Mar-13
13-04	6	9-Jan-13	55	15-Nov-12	10-Mar-13

Table 6. Fetal aging data with predicted dates of conception and farrowing.

The combined data indicate a peak of breeding in early November with a secondary peak in late June. This secondary peak is most likely

Reproductive Potential of a North Texas Urban Pig Population *(continued)*

representative of those sows that lose the litter in utero. Farrowing peaks occur throughout the month of February and into early March with a secondary peak throughout October and into early November. These November peaks serve to explain the lack of control success experienced by the FWNC&R since 2003 as pigs are not food driven during these times and therefore less susceptible to trapping. Farrowing peaks coincide with the advent of spring which brings an influx of nutritious foods and mast drop in the fall.

Number of Litters/ Year

Figure 1 also shows that it is unlikely for north central Texas wild pigs to produce an average of 2 or more litters annually. It is possible that in any given year a sow may have 2 litters but this would include only one full breeding-through-farrowing cycle. Although no local data exists to verify the possibility, it is conceptually possible for a sow to farrow a litter, lose the litter to a predator and then go through estrus, be bred and produce a second litter, or possibly even third if the second was also lost. While this would constitute multiple litters within a single year, only one litter would have survived.

Litter Size

Nine fetal litters were examined (Table 4). Total fetal litter size ranged from 5 – 11 piglets with a mean of 7.1. This mean is within the upper range of reported international studies (Mayer 2009) and slightly higher than that previously reported in Texas by Springer (1977) and Taylor et al. (1998). However, the mean number of viable fetuses was 3.3; in the low range of Mayer's (2009) review and 25% less than the Texas reports.

Control efforts provided litter size data on 17 additional litters where personal observations, game camera data, and/or carcass counts indicated an average of 3.7 piglets/litter (Range 1 – 7). This number, like that derived from fetal litters, is in the low range of the international studies and less than the Texas studies. Whether these smaller litter sizes are a factor of the north central Texas wild pig population's fecundity or related to ongoing drought conditions is not known but given the low pig population density observed on the FWNC&R, it is believed unlikely that litter sizes are reduced because of a lack of resources.

Litter Sex Ratio

Insufficient data was collected from fetal litters to determine the fetal sex ratio but using the 85 piglets weighing ≤ 49 lbs., indicates an overall ratio of 1 male:1.5 females (Table 3). Annual sex ratios range from 1M:0.67F in 2011 to 1M:2.5F in 2008. A litter sex ratio weighted towards females is to be expected of a population that is able to expand due to sufficient food resources. The male biased ratio of 2011 is believed to be a result of the extreme drought year.

Management Implications

Wild pig management in the Cross Timbers and Blackland Prairie Ecoregions is primarily focused on population control and damage limitation. While complete, area-wide eradication is not a feasible objective, it is imperative that control efforts maximize the derived benefit through efficient control operations. Knowledge of the local wild pig population's reproductive parameters can assist in maximizing control efficiency.

Figure 1 illustrates the time periods when pig populations are least susceptible to control efforts because breeding age pigs' attention is directed towards reproduction or farrowing. Control efforts, concentrated during the time periods between breeding and farrowing, have proven to be effective at the FWNC&R. Additional efforts focused on the time periods immediately following farrowing peaks also indicate efficiency and serve to remove future breeders from the population. Post-farrowing efforts also benefit from the lack of experience found

Reproductive Potential of a North Texas Urban Pig Population *(continued)*

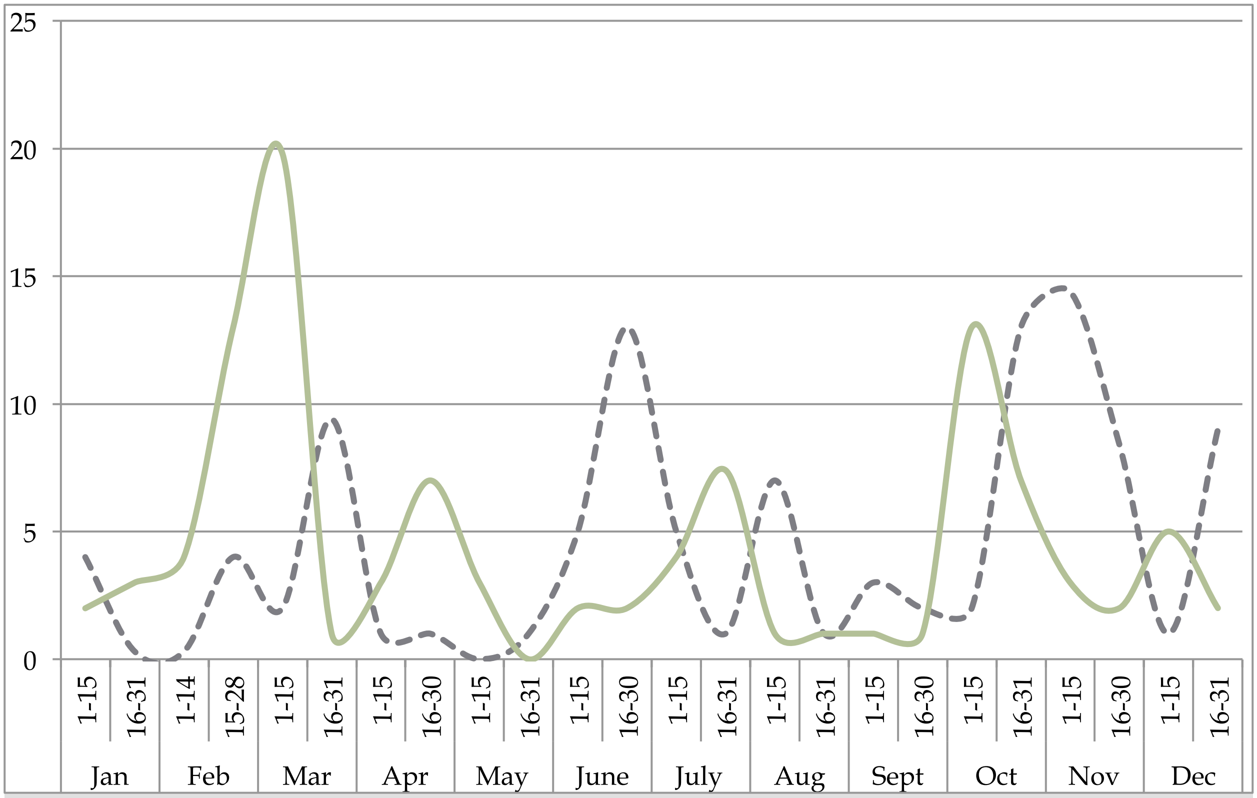

Fig. 1. Calculated breeding (dashed line) and farrowing (solid line) dates within approximately two week periods for 91 piglets removed from the FWNC&R (2003-2013).

in piglets as they enter traps readily.

While local pig populations have not exhibited exceptional population growth abilities such as multiple litters/year or abnormally large litter sizes, it is apparent that the population has the ability to grow at a rapid rate due to other traits of the species' reproductive potential. Therefore, any pig removed from the population should be considered a positive but given the limitations of time and other resources, focusing on specific time periods will lead to increased efficiency in the use of those resources.

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Rob Denkhaus has been with the FWNC&R since 1997, first as a Park Naturalist and since 2005, the Natural Resource Manager. He has been a part of the Refuge's wild pig control program from the beginning. Rob serves on the National Wild Pig Task Force and has presented at International Wild Pig, International Urban Wildlife, and various wildlife damage and nuisance wildlife conferences. He can be reached at Robert.Denkhaus@fortworthtexas.gov

NOTEWORTHY EVENTS

For a Biodiverse Calendar!

May 29, 2015 – 8:00am-5:00pm (*Early registration ends May 8, 2015)*

Addressing Conflict with Deer in Our Communities

Workshop offered this May by Texas Parks & Wildlife Department, Texas Wildlife Association, and Texas State University, to help communities address conflict situations involving overabundant deer.

Texas State University, LBJ Student Center Ballroom, 109 Student Center Drive, San Marcos, TX 78666

More information at: http://www.texas-wildlife.org/resources/events/urban-deer-workshop

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June 1 - 3, 2015

National Bison Association Summer Conference

The Association plans to have a great series of speakers, lots of time to commune with fellow bison ranchers, and some fantastic buffalo meals.

Fort Worth Stockyards, Fort Worth, Texas

More information at: http://bisoncentral.com/nba-conferences

June 4 - 7, 2015

North American Native Fishes Association Convention

Four-day NANFA convention features wading and snorkeling in field trips, as well as a lineup of speakers on June 5.

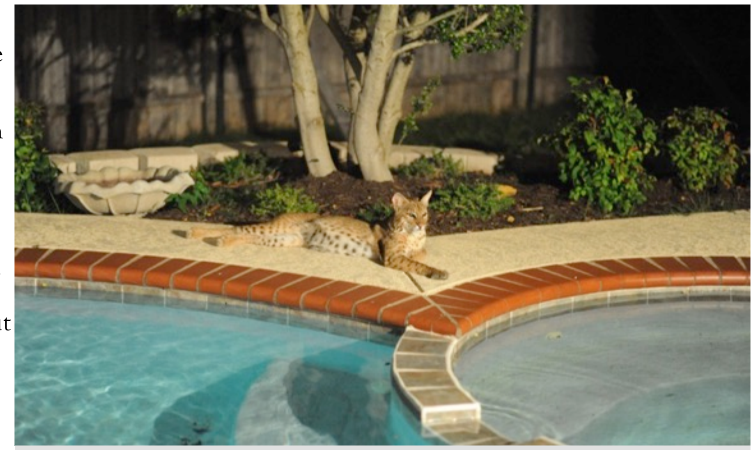
Beavers Bend State Park, Hochatown Oklahoma, approximately 8 mi N of Broken Bow

More information at: www.nanfa.org/convention/2015.shtml

Blackstripe topminnow (*Fundulus notatus*)

The Public's Role in Urban Carnivore Research

Derek Broman, Dallas-Fort Worth Urban Wildlife Biologist, Texas Parks & Wildlife Department

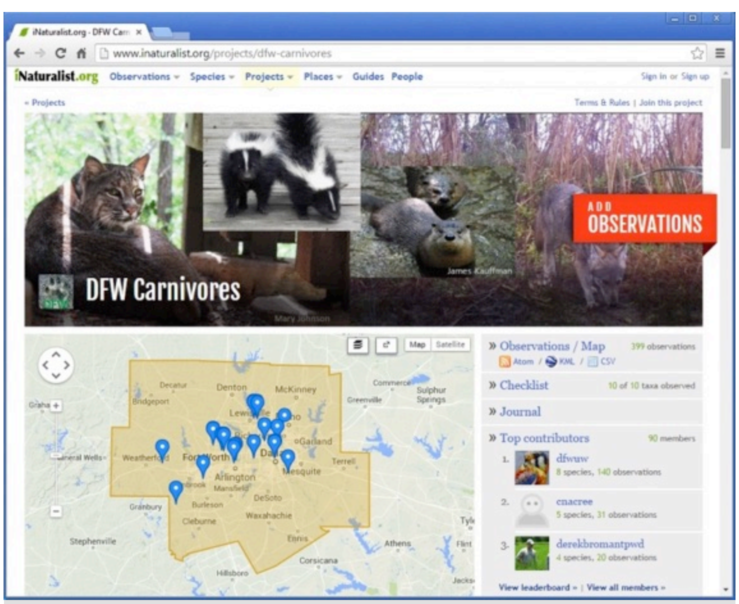


Poolside bobcat observation reported to DFW Carnivores. Photo: Karin Saucedo

In the Dallas–Fort Worth Metroplex (DFW), Texas Parks and Wildlife's Urban Wildlife Office is involved with a collaborative urban bobcat research project that includes Utah State University, USDA Wildlife Service's National Wildlife Research Center, Welder Wildlife Foundation, and Texas Christian University and seeks to provide information on bobcat habitat, diet, and population demographics in an urban landscape. Some of the products from this project will include estimates of bobcat habitat and maps that display suitable habitat throughout DFW. However, testing the quality and validity of these products requires additional information. For example, if a bobcat habitat map indicates large amounts of habitat occur in southwest Dallas County, how could we test that suggestion? A common solution is to see if anyone has viewed bobcats in that area, but where does that information occur? What about sightings in other areas of DFW? No robust repository exists for bobcat sightings across DFW. With 6.7 million people in DFW, surely the public is encountering bobcats or their sign (i.e., tracks, scat).

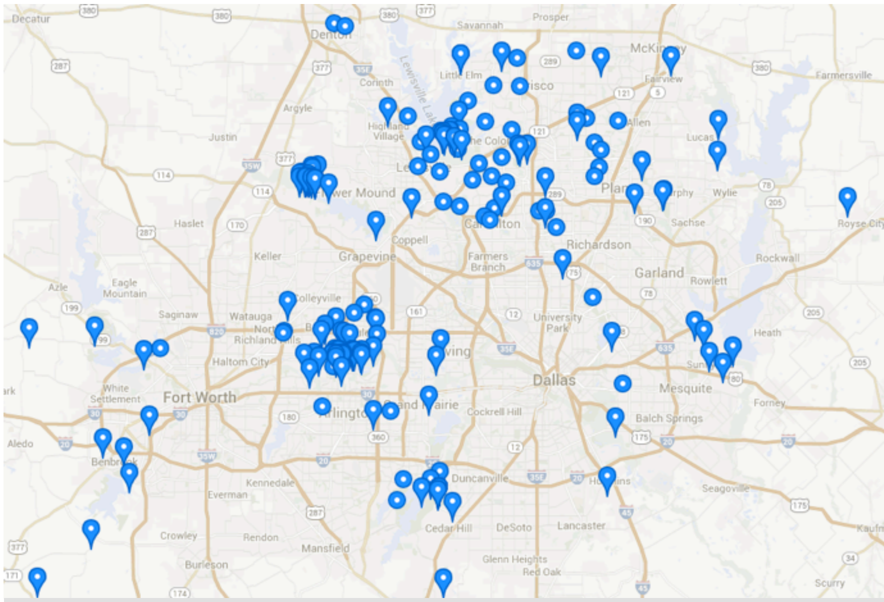
To meet these needs, I created a project on the website iNaturalist.org to collect, store, and manage public reported bobcat sightings in DFW. iNaturalist is a free website and mobile app where one can document and share observations of plants and animals anywhere in the world. It is also an excellent resource for receiving assistance on plant and animal identification as others on iNaturalist provide recommendations on the identity of your observation. Many times these individuals are leading experts in their field. Each observation you make, whether added using the mobile phone app or manually on a computer, is stored to your personal library and includes date, time, and location (derived from the GPS on your phone or an interactive Google Map in the website).

The project I created, called 'DFW Carnivores' (http://www.inaturalist.org/projects/dfw-carnivores), allows anyone to submit observations within the 10 central DFW counties (Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, Tarrant, and Wise). While I am primarily interested in bobcat sightings, the project actually allows the submission of any member of the Order Carnivora in DFW in the hopes that Texas Parks and Wildlife can begin to detect and document the presence and distribution of focal species in a rapidly developing area. Specifically, we are interested in rare or secretive carnivores (e.g., ringtail, mink), especially those listed on the Texas Conservation Action Plan (TCAP) for the region (e.g., river otter, long-tailed weasel, mountain lion, eastern spotted skunk, and American badger).



Landing page for the DFW Carnivores Project on iNaturalist.org

The Public's Role in Urban Carnivore Research *(continued)*



Map showing approximately 200 bobcat observations reported to the DFW Carnivores iNaturalist Project

The project was created in September 2013 and the number of contributions has more than doubled in the past year from around 80 bobcats (250 total carnivore observations) in February 2014 to over 200 bobcats (>600 total carnivore observations) in February 2015. While it can be extremely difficult to capture an image of an elusive, cryptic mammal, most bobcat observations (87%) include a photo for identification. The high occurrence of photographs helps address some of the critiques of citizen science and crowd-sourced information that include inaccuracies and an inability to assess data quality. Some of the photos are of stationary objects such as bones, roadkill, tracks, and scat but many photos have been taken with use of remote-triggered trail cameras (i.e., game cameras). I was quite surprised to learn so many of these cameras were being deployed in urban areas.

A lot of effort has gone into recruiting outdoor enthusiasts, such as Texas Master Naturalists and nature photographers, to contribute to the DFW Carnivores project. Once those individuals have been exposed to iNaturalist, the overwhelming benefits of that website retain those users and keep them coming back. One of the most popular uses of iNaturalist includes assistance with organism I.D. from others on iNaturalist, a feature that has made contributors more inclined to share observations of organisms, tracks, scat, or other sign that can be difficult to identify. The increased willingness to report animal sign has greatly impacted my project as sign is often the only information available for secretive animals that yield few sightings. Project contributors have commented they never gave much thought to reporting scat or tracks, but once they learned that was welcomed information they quickly realized how frequent animal sign is observed in most landscapes. Looking for mammal sign also serves as an outlet for urban wildlife enthusiasts during the time of year when most other plants and animals are dormant.

In addition to indicating species presence and distribution, data reported to iNaturalist may be used for other investigations. For example, should data reach sufficient levels, a future goal is to derive information on habitat use from those reported observations to construct species-specific habitat models and maps (e.g. Broman et al. 2014). Should that technique prove valid, the use of public reported information (i.e., citizen science, crowd sourcing) could reduce the need for intensive field investigations and serve as an immensely valuable tool in wildlife conservation. The presence and distribution of certain animals can also provide insight on habitat health. For example, mink and river otter populations are often associated with high water quality and good riparian areas. Their presence may very well indicate good aquatic health within DFW.

The DFW Carnivores project has also highlighted the commonality of many carnivores throughout all of the Metroplex. Because of that, it has served as a valuable resource for local municipal staff and conservation organizations that encourage coexistence with native wildlife. They use the project maps to educate the public and show that these animals occur almost everywhere, yet conflict is rarely observed nor are such events making 'front page news.' Once the public understands that coexistence is possible, and has likely occurred for some time, the request for relocation or eradication is retracted.

As public awareness increases of iNaturalist and the DFW

The Public's Role in Urban Carnivore Research *(continued)*

Carnivores project, I am optimistic that observations of bobcats and other carnivore species will continue to increase. I strongly encourage you to use iNaturalist to view the organisms being observed in an area, store your personal plant and animal observations, and contribute to research projects that utilize iNaturalist.

Bobcat tracks reported to DFW Carnivores. Photo: Chris Jackson

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Bobcat wearing a GPS collar as part of an urban bobcat research project being conducted with Texas Parks and Wildlife. Photo: Mary Johnson

Using Historic Evidence to Inform Conservation Decisions for the Texas Horned Lizard (*Phrynosoma cornutum*)

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Abstract

The Texas horned lizard is a state-listed threatened species suffering precipitous declines in central Texas, relative to historic abundance. Within this region, habitat characteristics may play a critical role in determining survival of the species. Current rangeland ecology literature describes worldwide encroachment and invasion of woody plants in grass-dominated ecosystems. This literature review evaluates woody plant encroachment on the Edwards Plateau of central Texas and its importance to the Texas horned lizard (*Phrynosoma cornutum*). We evaluate historical climate change and disturbance regimes of the region and contend that woody plants are a natural part of the southern mixed-grass prairie, at least in central Texas, and that shrub encroachment into historically open habitat is avoidable and can be mitigated when land managers appropriately use modern surrogates for historic disturbance regimes.

Introduction

Texas horned lizards (*Phrynosoma cornutum*) are a state-listed threatened species in Texas and experiencing population declines across their geographic range (Donaldson *et al.* 1994, Johnson-Linam 2008). Within Texas, *P. cornutum* have experienced the most precipitous declines in the central region relative to historical populations (Donaldson *et al.* 1994, Johnson-Linam 2008). Researchers and land managers in central Texas are currently exploring options for reintroduction of *P. cornutum* to land parcels that previously supported this species. Recent funding for *P. cornutum* research for multiple projects by Texas Parks and Wildlife Department, Texas Army National Guard, and the Ft. Worth Zoo (among others) demonstrates that there is interest in recovering the species. Reasons for this decline are not clear, but several factors are implicated: the spread of red imported fire ants (*Solenopsis invicta*), agricultural pesticide use, collection of lizards for the pet trade, and habitat degradation. Some of these limiting factors no longer occur, do not occur across the geographic range of the species, or have limited impact on the species. Habitat loss, degradation, and fragmentation are issues that have not been thoroughly evaluated in conservation of *P. cornutum*. This literature review focuses on the role habitat degradation may play in limiting the abundance of the Texas horned lizard in central Texas by evaluating historic habitat characteristics, changes to habitat and habitat maintenance after European settlement, and effective methods to restore habitat for the conservation of *P. cornutum*.

Habitat degradation and loss occurs in conjunction with changes in land-use, such as urbanization, conversion of wildlands to agriculture and, we posit, woody plant encroachment into the mixed-grass prairies of central Texas. Though no published species-specific evidence exists establishing a relationship between woody plants and *P. cornutum*, woody plant encroachment in historically open habitat is associated with drastic changes in reptilian community composition (Meik *et al.* 2002), reduced herpetofaunal diversity (Perry *et al.* 2009), reduced lizard dispersal (Templeton *et al.* 2011), reduced lizard thermoregulation opportunities (Brown *et al.* 1997, Angert *et al.* 2002), and reduction of harvester ant abundance (Brown *et al.* 1997), a main prey item of *P. cornutum*, presumably due to suppressed understory seed production that harvester ants rely on.

Worldwide, researchers are concerned about expansion of woody plants into grasslands and related threats to productivity, diversity, and ecosystem function (Bond and Keeley 2005, Scholes and Archer 1997). In central Texas, native honey mesquite (*Propopis glandulosa*), Ashe juniper (*Juniperus ashei*), and redberry juniper (*Juniperus pinchotii*) are all considered problem species when they occur in high densities. These woody plants are native within the communities in which they occur, but high densities are considered undesirable by many because there is a negative correlation between density and diversity of native fauna (Bond and Keeley 2005) as well as productivity of grasses (McPherson and Wright 1990).

Using Historic Evidence to Inform Conservation Decisions for the Texas Horned Lizard *(continued)*

The Edwards Plateau is the southernmost extent of the North American Great Plains and part of the southern mixed-grass prairie (Risser *et al.* 1981). Situated in central Texas, it is bordered by the Balcones Escarpment to the southeast, the Rolling Plains to the North, and merges with the Southern High Plains on its western edge. Once a mosaic of southern mixed-grass prairie and oak savanna the Edwards Plateau has experienced severe alterations of fire and herbivorous disturbance regimes since the colonization of North America by Europeans (Foster 1917) leading to expansion of woody plants into previously open habitat. Factors implicated in woody plant encroachment: climate change, changes in atmospheric, fire suppression, elimination of native herbivores, grazing by domestic livestock, and silvicultural practices (please see Granberg 2014 for an in-depth discussion of these factors). We hypothesize that alterations to historical disturbance regimes have allowed fragmentation, degradation, and loss of suitable *P. cornutum* habitat in central Texas, largely due to range expansion of woody plants.

For many people, the word *prairie* indicates a treeless landscape of North America; however, southern mixed-grass prairie in central Texas was not a treeless system (Bryant and Holloway 1985, Diamond 1997). Although this ecosystem is dominated by graminoids and forbs, trees and shrubs were present in mottes interspersed throughout the landscape and in steep, mesic drainages that escaped frequent fire (Amos and Gehlbach 1988). We use the term *grassland*, to indicate what other authors refer to as *prairie* or *savanna*, in order to maintain continuity with international biome characterizations (UNESCO 1973). While *grassland* may not lend itself to an image of an herbaceous understory dotted with trees, grasslands may occur with up to 40 percent canopy cover by woody plants (UNESCO 1973).

Biome	Percent Cover
Grassland	Woody plant component <40 percent
Woodland	Trees >5m tall and canopy cover >40 percent
Forest	Trees >5m tall, tree crowns interlocking

Table 1. Definitions of biomes adapted from the UNESCO International classification and mapping of vegetation (1973)

Historical Disturbance Regimes

Natural disturbance regimes are important for maintenance of species diversity (Collins and Barber 1986). When disturbances occur throughout a landscape with moderate frequency, species richness is maximized by creating a myriad of microhabitat types and ages in relatively close proximity (Connell 1978, Collins and Barber 1986). This section discusses three large components of the natural disturbance regime in the southern mixed-grass prairie: climate, herbivory, and fire. Although not independent of one another, each of these factors has a different influence on vegetation structure, affecting fuel continuity and fire regime. Atmospheric CO_2 concentration may play a role in woody plant encroachment, but due to a limited understanding of long-term impacts on woody vegetation (Ceulemans and Mousseau 1994), we focus our discussion of historical climate effects on vegetation on precipitation and temperature regimes. By developing a better understanding of historical habitat characteristics and disturbance regimes, land managers can better understand what state to restore habitat to in order to achieve conservation goals for *P. cornutum*.

Climate

Climatic conditions in central Texas historically ranged from cool and humid, to warm and dry (Bryant and Holloway 1985, Heubner 1991, Toomey *et al.* 1993, Nordt *et al.* 1994, Musgrove *et al.* 2001). The present condition is a snapshot of a warming and drying trend along a much larger temperature and precipitation gradient. A combination of climatic factors, topography, soils, and disturbance regimes have formed and maintained grasslands (Haire and McGarigal 2009). In central Texas, grasslands existed prior to the most recent glaciation; however differences in plant communities, megafaunal herbivores, and anthropogenic influences are outside the scope of this study. We limit this review to southern mixed-grass prairie in central Texas that formed during the most recent post-glacial period. The publications we use in this synthesis reconstruct the climatic conditions, historic assemblages of vegetation, and historic presence of bison in central Texas. While some authors look to pollen records for indications of climate (Bryant and Holloway 1985, Nordt *et al.* 1994), others use stalagmite chronology (Musgrove *et al.* 2001) or faunal and/or plant fossil records (Heubner 1991, Toomey *et al.* 1993).

According to most sources, central Texas experienced a transition to a more xeric climate in the late-glacial period (14,000 – 10,000 years BP; Bryant and Holloway 1985, Nordt *et al.* 1994, Musgrove *et al.* 2001, but see Toomey *et al.* 1993). During this time, grasslands expanded southward through the Texas Panhandle into west, central, and south Texas (Bryant and Holloway 1985, Heubner 1991). Pollen records from central Texas suggest that by the end of the late-glacial period, grass-dominated landscapes were gradually replacing forested areas (Bryant and Holloway 1985) and stable isotope analysis of sediment and alluvial deposits support the slow increase of C4 grasses during this period (Nordt *et al.* 1994). Mesic tree species, such as maple, basswood, hazelnut, and spruce also disappeared from the pollen record at this time (Bryant 1977).

The post-glacial period was a terminus for deciduous forests in central Texas (Bryant and Holloway 1985). These forests were replaced with the southern mixed-grass prairie and oak savannas; areas west of the Balcones Escarpment were dominated by juniper and oak woodlands (although the area dominated by juniper has since expanded; Shaw *et al.* 1980, Bryant and Holloway 1985). Where topography is relatively even, fires maintained open grasslands with scattered oak mottes in the uplands (Amos and Gehlbach 1988). In riparian zones, areas of steep topography, or areas with exposed parent material, fire was less frequent and trees (e.g., oak and juniper) were able to persist in greater abundance (Amos and Gehlbach 1988, Diamond 1997).

The most recent trends of the post-glacial period are either described as a general continuation of the drying trend (Bryant and Holloway 1985, Musgrove *et al.* 2001) or are in disagreement about short periods of mesic conditions that persisted prior to European contact. Toomey (*et al.* 1993) proposed more mesic than current conditions existed from ca. 2500 BP to 1000 BP based on changes in faunal assemblages and increased presence of *Pinus* in the pollen record. Similarly, Nordt (*et al.* 1994) suggested that ca. 4000 BP to 2000 BP was slightly more mesic than current trends and C_4 grasses dominated the landscape based on stable isotope analysis of soils and alluvial deposits. These slight discrepancies in timeline may reflect a spatial difference in sampling. Hughes and Diaz (1994) described data with significant variability throughout North America; the observed drying trend was temporally coincidental, but spikes in climatic trends were not. Still, sources agree that the past 1000 years are part of a drought-prone xeric trend under which the southern mixed-grass prairie and the Texas horned lizard flourished.

Herbivory

Both grazing and browsing have contributed to vegetation maintenance in central Texas. American bison (*Bison bison*) provided a large portion of the herbivory that formed and maintained central Texas grasslands (Heubner 1991), although it is likely that ungulate browsers (e.g., pronghorn and white tailed deer) also played important roles in maintaining grasslands by consuming young shrubs (Anderson 1982) and keeping these woody plants within the flame zone (e.g., the hottest part of a fire capable of killing more resilient plants; Scholes and Archer 1997). The presence of bison in central Texas was not constant, but pulsed and ebbed over time, likely due to climatic conditions and resultant vegetation dynamics (Heubner 1991).

Young, tender growth that emerged post-fire was highly palatable; herds of bison shifted grazing patterns to follow this new growth (Coppedge *et al.* 1998, Fuhlendorf *et al.* 2009). The high-intensity, short-duration grazing that occurred, in addition to the physical disturbance caused by massive herds of bison, maintained small stature of arborescent species and resulted in highly-nutritious regrowth that was grazed multiple times in succession (Fuhlendorf and Engle 2001, Fuhlendorf *et al.* 2009). The large scale of this grazing disturbance prevented overutilization of grasses that occurs with modern grazing regimes. In comparison to cattle, bison will forage on upland sites, consume more C_4 grasses, and consume grasses of lower nutrition content, meaning grazing pressure is distributed more evenly among microhabitats (Peden *et al.* 1973, Plumb and Dodd 1993). While bison grazed certain areas heavily, there were also areas within their geographic range that were ungrazed within the same time period (Fuhlendorf *et al.* 2001, Fuhlendorf and Engle 2009), with grazed areas having a reduced fuel load and lower probability of ignition (Scholes and Archer 1997). This unequal use of habitat patches promoted diversity of habitat at a landscape scale (McGranahan *et al.* 2013).

The functional extirpation of bison in North America occurred for many reasons, but is most often attributed to the Plains tribes' adoption of horses, buffalo robe trading, development of railways, development of new leather tanning technologies, and as an attempt to disenfranchise Native Americans (Isenberg 2000). The southern herds in Colorado and Kansas were extirpated by 1875; by the late nineteenth century, hide hunters had nearly extinguished bison populations in Texas and Oklahoma (Leuck 2002). Although the efforts of the American Bison Society, an organization formed in 1905 to protect the species, prevented extinction of bison, the disturbance regime maintained by bison herbivory disappeared from the landscape (Leuck 2002).

During initial settlement of the western parts of the United States, ranchers grazed domestic cattle on unfenced rangelands, often illegally, and shifted to new areas as forage availability waned (Sanderson 2011). With the increased settlement of the west and the invention and improvement of barbed wire, changes in grazing patterns continued (Hayter 1939). Farmers settled and fenced land, parcels became smaller, and cattlemen were pushed outward to higher elevations or less-desirable grazing lands (Hayter 1939).

Currently, many cattle operations in Texas operate under high-intensity, rotational management systems, although some research indicates lower stocking rate is more important in preserving ecological function of rangelands than pasture rotation (Briske *et al.* 2008). Much like bison, grazing of domestic livestock decreases fine fuel loads (Ford and McPherson 2006), which in turn reduces the probability of ignition (Anderson 1990) and increases the length of interval between fires (Gill and Taylor 2009). Unlike bison, domestic livestock are constrained to smaller parcels that do not allow shifts in grazing to new areas as forage is consumed and affect the landscape at a much smaller scale. This allows woody species to persist in areas they would otherwise be set back or eliminated by fire (Bond and Keeley 2005). Besides altering fire regime, grazing may also reduce the ability of grasses to outcompete woody plant seedlings (Miller and Rose 1999) and promote the dominance of less-desirable forbs following the cessation of grazing (Plumb and Dodd 1993, Fuhlendorf and Engle 2001).

Fire

Fire is key to the maintenance of species composition and structure in many ecosystems (Daubenmire 1968, Risser *et al.* 1981, Bond and Keeley 2005). Frequent fire kills woody plant seedlings or maintains small stature in fire-resilient species, benefitting herbaceous, low-growing plants (Fonteyn *et al.* 1988). Within mixed-grass prairies, research demonstrates a spectrum of vegetative responses to fire, with many pointing to precipitation as an important driver of post-fire recovery and species diversity (reduced species diversity, Collins and Barber 1986; increased species diversity, Wienk *et al.* 2009).

Historically, fires were caused by lightning strikes and occurred during summer months (Komarek 1966). In addition, Native Americans ignited fires for as many as 70 different reasons (Lewis 1985); cited most often are to influence the presence of game species, to increase visibility of game species, and to improve forage quality (Boyd 2002). Higgins (1986) suggests, based on historical fire accounts of the Northern Great Plains, that the seasonality of these anthropogenic fires was frequently different than those of naturally-occurring summer fires based on management goals. Following European settlement, fire was increasingly excluded from the landscape (Courtwright 2007); a sedentary agricultural lifestyle meant resources (homes, crops, livestock) were put at risk when fires occurred.

The interactions between fire, herbivory, and climate are key in understanding creation and maintenance of grassland ecosystems. Woody plant encroachment hinges on these interactions in semi-arid grasslands (Lohmann *et al.* 2014), where fire is limited by fuel availability as dictated by climate and modern grazing regimes. Climate affects both amount of fuel and fuel moisture content with a delicate balance; precipitation is needed for plant (fuel) growth, but low fuel moisture enhances probability of ignition. Because fire reduces plant cover and increases soil temperature (Sharrow and Wright 1977), post-fire recovery is heavily influenced by precipitation. If fire occurs during a wet year, plant cover soon re-establishes, slowing erosion and preventing evaporation of soil moisture (Wink and Wright 1973). When fire occurs during periods of drought, additive stress from moisture limitation results in greater plant mortality coupled with less post-fire regrowth, and increased soil erosion (Wink and Wright 1973). In the Oklahoma Cross Timbers region, DeSantis *et al.* (2011) found that severe drought killed woody plant species. When combined with human suppression of fire, this resulted in an increase in Ashe juniper-analogous *Juniperus virginiana*, a decrease in *Quercus* species fire-induced regeneration and recruitment, and contributed to alterations in local fire regime. Timing prescribed fires to follow wet periods thereby preventing a flush of woody plant recruitment may be beneficial; however, land managers should consider this approach in light of current precipitation patterns.

Fire is also heavily influenced by herbivory; grazing is found to reduce fine fuels, decrease continuity of fuels, and increase length of time between fires, leading to fuel build-up and increased fire severity. In terms of woody plant encroachment, grazing is associated with increasing *Juniperus* species cover, potentially by increasing time between fires or reducing competition for resources with grasses and forbs (Schmidt and Stubbendieck 1993). Furthermore, alterations in the scale and intensity in which grazing occurs means the historic, landscape-scale grazing regime maintained by native megafauna is not sufficiently replaced by modern high-intensity rotational cattle grazing (Briske *et al.* 2008), further affecting the relationship between fire and herbivory.

Current research in central Texas uses radio-telemetry to monitor Texas horned lizard movement in translocation efforts as well as in response to habitat management activities. Photo: Rachel Granberg

Current Trends

Prior to European colonization in North America, climate, herbivory, fire, and their interactions maintained low woody plant establishment and density in grasslands (Fuhlendorf *et al.* 2009). Although climate, topography, and soils cannot be ignored as important factors in the formation and maintenance of grasslands, fire and herbivory are disturbance regimes that have drastically changed since European settlement (Leuck 2002). In many grass-dominated ecosystems, the establishment of trees is not directly related to current climate, but rather the ecological and disturbance history of the site (Staver *et al.* 2011). Post-European suppression of fire and alteration of herbivory regimes severely impact the structure, composition, and conservation of southern mixed-grass prairie. However, alterations of natural disturbance regimes did not halt after initial settlement; continuing change in land-use and land owner demographics in central Texas pose threats to and opportunities for grassland restoration and conservation of the Texas horned lizard.

Land Owner Demographics

Successful restoration of southern mixed-grass prairie in central Texas, for the benefit of *P. cornutum* as well as other native wildlife, is dependent on the introduction of modern surrogates for natural disturbance regimes that have been removed from the ecosystem. Prescribed fire has been introduced to central Texas on a local level due in part to government agencies (Brown and Rollins 2005) and prescribed burn cooperatives (Taylor 2005, Kreuter *et al.* 2008, Twidwell *et al.* 2013).

Changing land-owner demographics in the region; however, complicate education and outreach efforts. Central Texas land ownership is transitioning from large tracts of land devoted to agricultural purposes to smaller parcels owned by "amenity buyers" who prefer to live in a rural environment for recreational purposes (Sorice *et al.* 2012). Small parcels (1-19 ha) have increased 106%; average acreage of farms has decreased 27 %; and overall market value of these properties increased 155% from 1992 - 2007 (Sorice *et al.* 2012). Increased fragmentation of land combined with amenity buyers that are not well-versed in habitat management could result in drastic ecological effects in terms of woody plant encroachment and resulting habitat connectivity, degradation, and loss. Multiple government and non-governmental organizations provide land management services and education to landowners (Texas Parks and Wildlife Department, Natural Resources Conservation Services, The Nature Conservancy, etc.), but because the number of land owners is increasing and parcel size is decreasing, resources spent to educate one land owner in managing southern mixed-grass prairie garner less average acres of habitat managed.

That being said, a large part of the local economy on the Edwards Plateau is dedicated to hunting both native and introduced wildlife species. These natural and recreational amenities attract migrants, both as tourists and permanent residents, and drive development of the area (Marcouiller *et al.* 2002). Newcomers to these natural-amenity rich areas often identify with environmentalism and push for government control of land use in developing areas (Smutny and Takahashi 1999). This interest in protecting the natural resources that attracted them to the area in the first place, combined with tax credits for managing wildlife habitat (Texas Administration Code 9.2001), and support from local agencies has started a grassroots movement to protect and manage wildlife habitat in central Texas.

Outreach and Education

Even with this boon of support from conservation agencies, most amenity landowners do not have the education, experience, or equipment to conduct their own prescribed burns (Taylor 2005, Kreuter *et al.* 2008). Private contractors are available to coordinate burns, but the cost is often prohibitive to landowners. Because of restrictions placed by Texas House Bill 2599 of the 76th Legislative Session in 1999, government employees cannot be bonded and insured to conduct burns, even when adequately trained. They are able to provide assistance as highly trained individuals, but landowners must provide their own bonded and insured burn boss (Brown and Rollins 2005). Furthermore, the wait for state and federal assistance in conducting prescribed burns is long (Brown and Rollins 2005). The Edwards Plateau Prescribed Burning Association (EPPBA) was organized in 1997 as a means to organize, educate, and equip local landowners interested in conducting prescribed burns on their land. From 1997 to 2013, EPPBA members burned over 100,000 hectares with more than 300 burns (Twidwell *et al.* 2013). Although assistance is available through the EPPBA, it is still a challenge to find enough able-bodied and knowledgeable volunteers who can achieve management objectives. Local prescribed burn cooperatives and agencies that provide support and education (e.g., TPWD, NRCS) help increase area burned; however, significant hurdles to landscape-scale fire implementation still exist.

Impacts on the Texas Horned Lizard

Paired with changing land owner demographics in central Texas is the issue of changing land use. Fragmentation, degradation, and loss of habitat are primary reasons for declines in amphibians and reptiles worldwide (Gibbon *et al.* 2000) and are implicated in the decline of *P. cornutum* (Donaldson *et al.* 1994). Habitat loss and degradation have the strongest negative effect on biodiversity, but are often accompanied by fragmentation (Fahrig 2003). Fragmentation occurs when the spatial distribution of habitat within a landscape is disrupted (Fahrig 2003); within the Edwards Plateau, urbanization, agriculture, and woody plant encroachment may have the greatest impact on *P. cornutum* habitat quality and availability.

Woody plant encroachment plays a large role in habitat loss, degradation, and fragmentation, not only in central Texas, but other grass-dominated landscapes (Fischer and Lindenmayer 2007). Habitat that is poorly connected and experiences changes in species composition, such as historically open areas being encroached upon by woody plants, is more susceptible to extinction cascades, a domino effect of loss of species (Fischer and Lindenmayer 2007). Habitat fragmentation caused by woody plant encroachment may also lead to reduced dispersal (Heath *et al.* 2012, Templeton *et al.* 2011), reduced genetic differentiation (Heath *et al.* 2012), and reduced thermoregulatory opportunities (Angert *et al.* 2002) in lizards.

We assert that Texas horned lizard habitat degradation is due, at least in part, to alterations in historical disturbance regimes, which have allowed woody plant encroachment into historically open habitat. While urban sprawl and agriculture have obvious effects on habitat, woody plant encroachment also affects habitat, but in ways less obvious to the lay-person. In an arid shrubland in New Mexico, woody plant encroachment was correlated with reduced abundance of two harvester ant species, which constitute a majority of *P. cornutum* diet (Whitford and Bryant 1979), and several granivorous rodents, owls, and rattlesnakes (Brown *et al.* 1997). Relative to thermoregulation, body temperature in ectotherms influences the physiological reaction time and governs the individual's ability to forage, mate, and avoid predators (Huey and Kingsolver 1989). Although not empirically tested in phrynosomatids, formation of dense forests can negatively impact thermoregulation opportunities for lizards (Angert *et al.* 2002).

Conclusions

Humans managed North American grasslands, including southern mixed-grass prairies, using fire for centuries prior to European contact. Additionally, climate, herbivory, wildland fires, and their interactions helped maintain grasslands by setting back woody plant growth. Land managers must keep this in mind when setting goals for habitat restoration for the Texas horned lizard and other grassland-obligate species. In central Texas, where herbivory and fire regimes have been drastically altered over the past 200 years, ongoing and extensive land management will be required to create and maintain optimal horned lizard habitat.

P. cornutum has declined across most of its range, especially central Texas, for the past 50 years (Donaldson *et al.* 1994, Johnson Linam 2008). Habitat loss, degradation, and fragmentation are implicated in the decline of this species (Henke and Fair 1998), although researchers have yet to include woody plant encroachment as a form of habitat loss and degradation. Land owner education and organization, especially through the use of extension programs and burn cooperatives, can provide an effective means of reaching out to amenity land owners who may not have the education or tools to properly manage these areas. Implementation of regional-scale land management programs will not only benefit *P. cornutum*, but the golden-cheeked warbler (*Setophaga chrysoparia*), black-capped vireo (*Vireo atricapilla*), bobwhite quail (*Colinus virginianus*), and other central Texas species of concern (Texas Parks and Wildlife Department 2013).

Given current climactic conditions, if central Texas is managed without modern surrogates for the historic disturbance regimes, many species that previously occurred in this region may be extirpated or experience severe declines due to the formation of dense stands of *Juniperus* species. While individual species may benefit from woody plant encroachment, we posit that a disturbance regime that is only comprised of modern anthropogenic activities (i.e., fire exclusion, urbanization, recreational activities, agriculture) is more "unnatural" than well-managed surrogates for a disturbance regime, such as prescribed burning and responsible grazing. If landowners and conservation agencies are striving to conserve biodiversity and ecosystem function, a balanced disturbance regime that mimics disturbances that formed and maintained the southern mixed-grass prairie is a necessary component of the process.

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Using Historic Evidence to Inform Conservation Decisions for the Texas Horned Lizard *(continued)*

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Editor's Note: An example of woody plant encroachment in an urban prairie preserve in Fort Worth, Texas (Photo: Michael Smith)