

13830

Edwards Plateau Limestone Savanna and Woodland

BpS Model/Description Version: Aug. 2020

Modelers		Reviewers	
Lee Elliott	lelliott@tnc.org	None	None
Delbert Bassett	dmbassett@neo.tamu.edu	None	None
Douglas Zollner	dzollner@tnc.org	None	None

Reviewers: Tim Christiansen, Charlotte Reemts

Vegetation Type

Forest and Woodland

Map Zones

32, 35, 36

Geographic Range

This system is best characterized on limestone uplands of the Edwards Plateau Ecological Region in central Texas. It may also occur on limestone (particularly Cretaceous limestone) exposures in portions of map zone (MZ) 32, though the vegetation composition may differ.

Biophysical Site Description

This system includes limestone uplands of central Texas. Geologic strata are primarily Cretaceous-aged limestone. Members within these geologic strata vary in their susceptibility to erosion and soil development. Hard-bedded limestone of the Edwards Formation forms a resistant cap over much of the plateau and isolated buttes or hills. Less resistant limestones form the side slopes and lower divides (Hill and Vaughn 1898). Soils vary from calcareous clays and clay loams over limestone and vary from shallow and rocky to deep. Topography is primarily level to rolling.

Different site conditions lead to a mosaic of vegetation physiognomies and composition, even on level uplands that are believed to have existed in the region prior to European settlement (Beuchner 1944; Bray 1904; Smeins 1982; Riskind and Diamond 1988; Weniger 1988). Rainfall is generally associated with severe thunderstorms, and amounts peak in spring and fall. There is a marked difference in precipitation from the eastern portions of this system (85cm/yr) to the western portions (35cm/yr) (Bomar 1983 in Riskind and Diamond 1988). This gradual drying from east to west across the region results in vegetation transitions from woodlands and tallgrasses to shrublands and shortgrasses. This model does not incorporate large rock outcrops, steeper slopes, canyons, and floodplains.

Vegetation Description

Historical accounts are inconsistent in the reporting of woody cover on the Edwards Plateau (Beuchner 1944; Bray 1904; Smeins 1982; Riskind and Diamond 1988; Weniger 1988). But it is generally accepted that grassland, shrubland, and woodland areas all were present in the pre-settlement upland landscape (Smeins 1982; Riskind and Diamond 1988; Weniger 1988). This model addresses the vegetation mosaic that includes dense shrublands, dense forests, open woodlands, and grasslands. An important aspect of this model is the variable site conditions

(substrate, landscape position, weather conditions, and others) that lead to these different states and hence the mosaic of physiognomies that are believed to have coexisted in the region. Under certain fire regimes, a certain portion of the landscape is considered to be predisposed to have a dense cover of shrubs, open woodland, grassland, or dense forest, depending on site conditions.

In many parts of this region, Texas live oak (*Quercus fusiformis*) is the predominant tree in the woodland and forest class where it typically occurs with Ashe's juniper (*Juniperus ashei*), Buckley's oak (*Q. buckleyi*), netleaf hackberry (*Celtis laevigata* var. *reticulata*), cedar elm (*Ulmus crassifolia*), and Texas ash (*Fraxinus texensis*). In areas with soils derived from a siliceous limestone or granite, blackjack oak (*Q. marilandica*) and post oak (*Q. stellata*) may dominate the forest and woodland areas (Beuchner 1944; Tharp 1939; Walters and Wyatt 1982; Whitehouse 1933), and these sites generally represent separate Biophysical Settings (BpSs). Bigelow oak (*Q. sinuata* var. *breviloba*) is the diagnostic shrub in the shrublands and occurs along with Texas mountain laurel (*Sophora secundiflora*), Texas kidney wood (*Eysenhardtia texana*), Texas persimmon (*Diospyros texana*), evergreen sumac (*Rhus virens*), lotebush (*Ziziphus obtusifolia*), Brazilian bluewood (*Condalia hookeri*), Texas colubrina (*Colubrina texana*), Mexican buckeye (*Ungnadia speciosa*), algerita (*Mahonia trifoliata*), and stretchberry (*Forestiera pubescens*). The grasslands vary from primarily tallgrasses (dominated by little bluestem [*Schizachyrium scoparium*], Indiangrass [*Sorghastrum nutans*], switchgrass [*Panicum virgatum*], muhly grass [*Muhlenbergia lindheimeri*], sideoats grama [*Bouteloua curtipendula*], Texas wintergrass [*Nassella leucotricha* = *Stipa leucotricha*], Texas cupgrass [*Eriochloa sericea*], silver bluestem [*Bothriochloa saccharoides*], cane bluestem [*B. barbinoides*], lovegrass [*Eragrostis* spp.], and big bluestem [*Andropogon gerardii*]) to midgrasses (dominated by sideoats grama [*Bouteloua curtipendula*], blue grama [*B. gracilis*], hairy tridens [*Erioneuron pilosum*], threeawn [*Aristida* spp.], and sand dropseed [*Sporobolus cryptandrus*]), but shortgrass areas (dominated by curly-mesquite [*Hilaria belangeri*], buffalograss [*Buchloe dactyloides*], and tobosa [*Hilaria mutica*]) persist on very droughty or shallow soils throughout and dominate in the far western parts of the region.

BpS Dominant and Indicator Species

Symbol	Scientific Name	Common Name
QUFU	<i>Quercus fusiformis</i>	Plateau oak
QUSIB	<i>Quercus sinuata</i> var. <i>breviloba</i>	Bastard oak
JUAS	<i>Juniperus ashei</i>	Ashe's juniper
ULCR	<i>Ulmus crassifolia</i>	Cedar elm
BOCU	<i>Bouteloua curtipendula</i>	Sideoats grama
SCSC	<i>Schizachyrium scoparium</i>	Little bluestem
BOSA	<i>Bothriochloa saccharoides</i>	Silver bluestem
HIBE	<i>Hilaria belangeri</i>	Curly-mesquite

Species names are from the NRCS PLANTS database. Check species codes at <http://plants.usda.gov>.

Disturbance Description

Fire is the primary natural disturbance that is preventing all classes from becoming closed forests and shrublands. Mixed-intensity fires are thought to be the predominant fire type in this landscape and are used in the model to exemplify the variability in fuel caused in part by the variability in fine fuels (grasses), both spatially and physiognomically (shortgrass, mixedgrass, and tallgrass), and the abiotic variability in site conditions. Current conditions and historical

accounts suggest that fine fuels varied from mid/tallgrasses to mid/shortgrasses in part due to a decrease in rainfall and increase in evapotranspiration from east to west on the plateau but also related to soil depth and grazing (Beuchner 1944; Fowler 1988; Riskind and Diamond 1988). Site conditions, patchy and variable fuels, drought, and grazing by native ungulates may act synergistically to promote the establishment of woody species. Once woody plants are established in the grassland, they may act as “nurse” plants to facilitate the establishment of other woody plants, increasing the movement toward a closed canopy system (Fowler 1988).

Frequent fires are thought to have occurred during all seasons (Diamond 1997; Smeins 1980) with winter and summer fires having different effects on the vegetation. Seasonality of fire in combination with drought years, normal years, or wet years will produce varying results. Replacement fires (classes D and E) were more likely during the summer droughts where preceding years allowed for sufficient fuel buildup.

While native grazing also acts to maintain the system in a grassland state, disturbances such as grazing and fire can act synergistically during droughts to reduce the cover of fine fuels and promote woody invasion into grasslands. The frequency of fire required to prevent woody invasion of the grassland may be longer in midgrass systems as opposed to shortgrass systems (Fuhlendorf and Smeins 1997).

In areas with sparse fine fuels, the fires may have been wind-driven shrub fires. In areas with heavier fine fuels, the fires may have been mosaics of mixed severity. Fractures and fissures in rock outcrop areas with sparse fuels are places where fire-sensitive trees and shrubs could maintain a presence and provide a constant seed source.

“Areas with flat or rolling uplands and fairly deep soils tend to have larger scale fires at higher frequency, while areas with significant topographic relief and/or shallow soils over massive limestone tend to have smaller scale fires at lower frequency” (Diamond et al. 1995). Natural breaks such as rivers and moist canyons served to limit the spread of fire. The scale of fires probably increased from east to west with fires in the Balcones Canyonlands (ECOMAP subsection 315Da) being smaller than those of the remainder of the ecoregion. Fires on the scale of 20,000ac (~8,000ha) may be a reasonable estimate for the system away from the Canyonlands. Fires probably occurred on a much smaller scale, perhaps on the order of 2,000ac (~800ha) for large occurrences within ECOMAP subsection 315Da. Likewise, bison were known from the ecoregion historically (Weniger 1997). However, herd size may have been greater on the western plateau than within the Canyonlands, where topography may have made movement difficult and dangerous. These disturbances also lead to patch dynamics, which may differ with differing topographic, edaphic, and geologic context. In different situations, disturbance patches may revert to shallow alkaline soil shrublands, mixedgrass prairie, or savanna (Lee Elliott 2001).

Fire Frequency

Severity	Avg FI	Percent of All Fires	Min FI	Max FI
Replacement	15	38		
Moderate (Mixed)	24	23		
Low (Surface)	14	39		
All Fires	6	100		

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is the central tendency modeled. Percent of all fires is the percent of all fires modeled in that severity class. Minimum and Maximum FIs show the relative range of fire intervals as estimated by model contributors, if known.

Scale Description

The components of this system once covered the majority of the Edwards Plateau in central Texas, an area of ~16 million acres. "Areas with flat or rolling uplands and fairly deep soils tend to have larger scale fires at higher frequency, while areas with significant topographic relief and/or shallow soils over massive limestone tend to have smaller scale fires at lower frequency" (Diamond et al. 1995). Natural breaks such as rivers and moist canyons served to limit the spread of fire. The scale of fires probably increased from east to west with fires in the Balcones Canyonlands (ECOMAP subsection 315Da) being smaller than those of the remainder of the ecoregion. Fires on the scale of 20,000ac (~8,000ha) may be a reasonable estimate for the system away from the Canyonlands. Fires probably occurred on a much smaller scale, perhaps on the order of 2,000ac (~800ha) for large occurrences within the Canyonlands (Elliott 2001).

Adjacency or Identification Concerns

For mapping, this system is on the plateau portion of the Edwards Plateau, occurring on 0-15% slopes at the higher topographic position. The shrubland on very shallow soils (exposed bedrock) is a separate system (BpS 1393). The savanna and woodland occur in areas with >10cm soil depth.

Embedded within this system, but modeled separately, are hardwood/juniper slope forests, canyons, and floodplain forests, many of which would act as firebreaks on the landscape. Current conditions are very different from what has been described here. In particular, the present-day landscape is occupied by large areas of forest dominated by a mixed juniper-oak forest, and many areas that once supported tall- to midgrass savannas have been converted into shortgrass grasslands and barrens due to overgrazing. This existing vegetation is not directly addressed here, though closed canopy forests are included in the model (Class E).

Issues or Problems

A dense shrubland, forest, woodland, and grassland mosaic all persisted and were controlled by site conditions, fire, and grazing. Also, the grassland component transitioned from tall to mid to short, partly as a result of a decrease in rainfall from east to west but also as a result of site conditions. Within this landscape, bare rock, thin soils, and deeper soils exist. Information from some publications is not included here, and it would be good to conduct a thorough literature review and consult with other experts and reassess this model.

Drought has changed forest conditions to a large increase of dead junipers and very stressed oaks and an increase in both standing dead and woody debris. This situation has decreased canopy cover, increased insect activity, decreased tree seedlings, and decreased the grass layer under shrubs. All of these conditions are increasing erosion and changing the fire conditions to be more extreme and to occur more often.

Native Uncharacteristic Conditions

Throughout this system, there has been an increase in juniper species, to the point of dominating large parts of the plant community. In the western portions of the range, it is Pinchot's juniper (*J. pinchottii*), and in the central and eastern portions, it is Ashe's juniper (*J. ashei*).

Climate change predictions and analysis of the weather data from the last 45 years indicate that there will be more severe rain storms and that there is an increase by 2wks of degree growing days. But pollinators have not yet changed their growth development time. Succession classes may be changed by the differing of the lessened canopy cover and the increase of growing degree days of understory plants. There may be a shift from closed canopies in many areas to shrublands or more open woodlands.

Climate changes can be for all the models and BpS in MZ35.

Comments

Models and descriptions for MZs 32, 35, and 36 were identified as duplicates during the BpS review process. With only minor additions, the description from MZ32 was used for all three MZs.

For MZs 32 and 35, Lee Elliot took the MZs 34 and 26 model for this same BpS and expanded it to represent conditions in these MZs. The models for MZs 34 and 26 were retained.

For MZs 34 and 26, Douglas Zollner, Lee Elliott, and Delbert Bassett adapted BpS 1383 from the Rapid Assessment (RA) model R5LOSapa -- Oak Woodland/Shrubland/Grassland Mosaic (RA contributors to that original model were Judy Teague and Lee Elliott; RA reviewers were Douglas Zollner and Maria Melnechuck).

Succession Classes

Mapping Rules

Upper Layer Lifeform	Height (m)	Canopy Cover (%)									
		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Herb	0-0.5	A	A	A	A	A	A	A	A	A	A
Herb	0.5-1.0	A	A	A	A	A	A	A	A	A	A
Herb	>1.0	A	A	A	A	A	A	A	A	A	A
Shrub	0-0.5	C	C	C	C	C	B	B	B	B	B
Shrub	0.5-1.0	C	C	C	C	C	B	B	B	B	B
Shrub	1.0-3.0	C	C	C	C	C	B	B	B	B	B
Shrub	>3.0	C	C	C	C	C	B	B	B	B	B
Tree	0-5	C	C	B	B	B	B	B	B	B	B
Tree	5-10	C	C	D	D	D	E	E	E	E	E
Tree	10-25	D	D	D	D	D	E	E	E	E	E
Tree	25-50	D	D	D	D	D	E	E	E	E	E
Tree	>50	D	D	D	D	D	E	E	E	E	E

Succession class letters A-E are described in the Succession Class Description section. Some classes use a leafform distinction where a qualifier is added to the class letter: Brdl (broadleaf), Con (conifer), or Mix (mixed conifer and broadleaf). UN refers to uncharacteristic native or a combination of height and cover that would not be expected under the reference condition. NP refers to not possible or a combination of height and cover which is not physiologically possible for the species in the BpS.

Description

Class A 29 Early Development 1 - All Structures

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
SCSC	Schizachyrium scoparium	Little bluestem	Upper
NALE3	Nassella leucotricha	Texas tussockgrass	Upper
BOCU	Bouteloua curtipendula	Sideoats grama	Upper
HIBE	Hilaria belangeri	Curly-mesquite	Upper

Description

Even though there are trees and shrubs in this class, their cover is <10%, and therefore the herb layer is considered the upper-layer lifeform here.

Class A includes the first few years after a burn, and fine fuels are expected to green up within one growing season and be attractive to grazers. By the end of Class A, in normal years, fine fuels would be well developed but little thatch would have built up. Replacement fire is a frequent disturbance in this type. This condition includes sparse to moderate cover of mid- to tallgrasses and forbs with a scattered canopy of trees and shrubs resprouting. Woody cover of resprouting shrubs and trees is sparse. This class would also have some cover that is comprised of bare rock. The mosaic on the landscape would have open areas of bare rock, thin soil areas with some bare ground, and discontinuous grass cover and then other areas with more continuous grass cover. Grass cover varies from primarily tallgrasses (dominated by little bluestem, Indiangrass, switchgrass, Texas wintergrass, Texas cupgrass, silver bluestem, cane blustem, lovegrass, and big bluestem) to midgrasses (dominated by sideoats grama, blue grama, hairy tridens, threeawns, and sand dropseed), but shortgrass areas (dominated by curly-mesquite, buffalograss, and tobosa) persist on very droughty or shallow soils and in the western parts of the region. Grasses grade from taller grasses in the eastern part of the region to shortgrasses in the western part of the region. Also, some evidence suggests that taller grasses are present on the slopes where more water is available in the cracks than on the upland flats where more soil is developed but the soils are more droughty (Fowler 1988). The combination of severe drought and grazing will reduce fine fuels and therefore fire frequency.

Maximum Tree Size Class

None

Class B 15 Mid Development 1 - Closed

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
QUSIB	Quercus sinuata var. breviloba	Bastard oak	Upper
DITE3	Diospyros texana	Texas persimmon	Upper
RHVI3	Rhus virens	Evergreen sumac	Upper
SCSC	Schizachyrium scoparium	Little bluestem	Lower

Description

Fire and grazing are the dominant disturbance types.

None

Class C	15	Mid Development 1 - Open
----------------	-----------	---------------------------------

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
QUFU	<i>Quercus fusiformis</i>	Plateau oak	Upper
QUSIB	<i>Quercus sinuata</i> var. <i>breviloba</i>	Bastard oak	Middle
SCSC	<i>Schizachyrium scoparium</i>	Little bluestem	Lower
NALE3	<i>Nassella leucotricha</i>	Texas tussockgrass	Lower

Description

Class C is the young to mid-aged savanna. It is expected to have a moderate to dense cover of mid- to tallgrasses and forbs with an open canopy of trees and shrubs along with small clumps of trees (mottes). This class would also have some cover (low) that is comprised of bare rock. The grassland and woodland components of this class are maintained by mixed fire intensities. Canopy species include *Quercus fusiformis* and *Juniperus ashei*. (LFE-*Q. stellata*-*Q. marilandica* woodlands typically occur on distinct sites, BpS 1308.) Fire and grazing are the dominant disturbance types. Herbaceous composition is similar to Class A. Native grazing (and browsing) keep resprouting low.

Maximum Tree Size Class

Medium 9-21" DBH

Class D	35	Late Development 1 - Open
----------------	-----------	----------------------------------

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
QUFU	Quercus fusiformis	Plateau oak	Upper
OUBU2	Quercus laceyi	Lacey oak	Upper

SCSC	Schizachyrium scoparium	Little bluestem	Upper
------	-------------------------	-----------------	-------

Description

Class D is the mature, open canopy oak savanna with trees and shrubs >6ft tall and a dense herbaceous understory of mid- to tallgrasses and forbs. It is maintained by fires of mixed intensity. Surface fires keep the wooded patches from expanding. Trees, present as scattered individuals and larger clumps (oak mottes), cover a moderate area. This class could also have low cover of bare rock. Species composition is similar to Class C, with a greater diversity of trees (*U. crassifolia*, *C. laevigata* var. *reticulata*, *J. ashei*) occupying the mottes due to the lowered fire effect in the mottes. Herbaceous composition is similar to classes A and C. Fire and grazing are the dominant disturbance types. Native grazing (and browsing) and resource competition keep resprouting low.

Maximum Tree Size Class

Very Large >33" DBH

Class E 6 Late Development 1 - Closed

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
QUFU	Quercus fusiformis	Plateau oak	Upper
QUSIB	Quercus sinuata var. breviloba	Bastard oak	Upper
JUAS	Juniperus ashei	Ashe's juniper	Upper

Description

Class E is the closed canopy oak forest with trees and shrubs and a sparse herbaceous understory. This class may also have low cover of bare rock. The highest richness of woody species occurs in this class, including *Q. fusiformis*, *J. ashei*, *Q. buckleyi*, *C. laevigata* var. *reticulata*, *U. crassifolia*, *F. texensis*, *Q. sinuata* var. *breviloba*, *Cercis canadensis* (redbud), Texas mountain laurel, Texas kidney wood, Texas persimmon, evergreen sumac, lotebush, Brazilian bluewood, Texas colubrina, Mexican buckeye, algerita, and stretchberry, among others. Studies have shown that fuel moisture is higher under live oak (*Q. virginiana*) canopies than post oak canopies or open grassland (Fonteyn et al. 1988). In a landscape subjected to fire, *J. ashei* is more likely to occur in combination with other trees, especially live oak, where it will be protected from fire, than individually. Replacement fires in Class E would only be expected during extreme drought years and possibly with summer fires (Fonteyn et al. 1988).

Fire will occur rarely in this class.

Maximum Tree Size Class

Very Large >33" DBH

Model Parameters

Deterministic Transitions

From Class	Begins at (yr)	Succeeds to	After (years)
Early1:ALL	0	Mid1:OPN	10
Mid1:OPN	11	Late1:OPN	50
Mid1:CLS	11	Late1:CLS	50
Late1:OPN	51	Late1:OPN	999
Late1:CLS	51	Late1:CLS	999

Probabilistic Transitions

Disturbance Type	Disturbance occurs In	Moves vegetation to	Disturbance Probability	Return Interval (yrs)	Reset Age to New Class Start Age After Disturbance?	Years Since Last Disturbance
Alternative Succession	Early1:ALL	Mid1:CLS	1	1	Yes	9
Native Grazing	Early1:ALL	Early1:ALL	0.1	10	No	0
Replacement Fire	Early1:ALL	Early1:ALL	0.2	5	Yes	0
Alternative Succession	Mid1:OPN	Mid1:CLS	1	1	Yes	15
Competition or Maintenance	Mid1:OPN	Mid1:OPN	0.02	50	No	0
Replacement Fire	Mid1:OPN	Early1:ALL	0.033	30	Yes	0
Native Grazing	Mid1:OPN	Mid1:OPN	0.1	10	No	0
Mixed Fire	Mid1:OPN	Mid1:OPN	0.2	5	No	0
Replacement Fire	Mid1:CLS	Early1:ALL	0.02	50	Yes	0
Native Grazing	Mid1:CLS	Mid1:CLS	0.04	25	No	0
Mixed Fire	Mid1:CLS	Mid1:OPN	0.05	20	Yes	0
Alternative Succession	Late1:OPN	Late1:CLS	1	1	Yes	25
Replacement Fire	Late1:OPN	Early1:ALL	0.005	200	Yes	0
Mixed Fire	Late1:OPN	Late1:OPN	0.01	100	No	0
Competition or Maintenance	Late1:OPN	Late1:OPN	0.02	50	No	0
Native Grazing	Late1:OPN	Late1:OPN	0.1	10	No	0
Surface Fire	Late1:OPN	Late1:OPN	0.2	5	No	0
Mixed Fire	Late1:CLS	Late1:OPN	0.007	143	Yes	0
Replacement Fire	Late1:CLS	Early1:ALL	0.007	143	Yes	0

References

Amos, B.B. and C.M. Rowell. 1988. Floristic geography of woody and endemic plants. In: Edwards Plateau vegetation. Plant ecological studies in central Texas: Amos, B.B. and F.R. Gehlbach (eds.). Baylor Univ. Press, Waco, TX. 25-42.

- Amos, B.B. and F.R. Gehlbach (eds.). 1988. Edwards Plateau vegetation. Plant ecological studies in central Texas. Baylor Univ. Press, Waco, TX. 144 pp.
- Beuchner, H.K. 1944. The range vegetation of Kerr County, Texas in relation to livestock and white-tailed deer. *Am. Mid. Nat.* 31: 697-713.
- Bray, W.L. 1904. The timber of the Edwards Plateau of Texas, Its relation to climate, water supply, and soil. USDA Bureau of Forestry Bulletin 49. Washington.
- Diamond, D.D., G.A. Rowell and D.P. Keddy-Hector. 1995. Conservation of Ashe Juniper (*Juniperus ashei* Buchholz) woodlands of the central Texas Hill Country. *Natural Areas Journal* 15: 189-197.
- Diamond, D.D. 1997. An old-growth definition for western juniper woodlands: Texas Ashe juniper dominated or codominated communities. Gen. Tech. Rep. SRS-15. Asheville, NC: USDA Forest Service, Southern Research Station. 10 pp.
- Elliott, L. 2001. Matrix Communities of Texas. Matrix Systems of the Southern Shortgrass Prairie and Edwards Plateau and the Scale of Processes. The Nature Conservancy of Texas. Unpubl doc.
- Fonteyn, P.J., M.W. Stone, M.A. Yancy and N.M. Nadkarni. 1988. Determination of community structure by fire. P. 79-90 in Edwards Plateau vegetation. Plant ecological studies in central Texas: Amos, B.B., and F.R. Gehlbach (eds.). Baylor Univ. Press, Waco, TX.
- Fowler, N.L. 1988. Grasslands, nurse trees, and coexistence in Edwards Plateau vegetation. In: Edwards Plateau vegetation. Plant ecological studies in central Texas: Amos, B.B. and F.R. Gehlbach (eds.). Baylor Univ. Press, Waco, TX. 91-100.
- Fuhlendorf, S.D. and F.E. Smeins. 1997. Long-term vegetation dynamics mediated by herbivores, weather and fire in a *Juniperus-Quercus* savanna. *Journal of Vegetation Science* 8: 819-828.
- Gehlbach, F.R. 1988. Forests and woodlands of the northeastern Balcones Escarpment. In: Edwards Plateau vegetation. Plant ecological studies in central Texas: Amos, B. B., and F. R. Gehlbach (eds.). Baylor Univ. Press, Waco, TX. 57-78.
- Hill, R.T. and T.W. Vaughan. 1898, Geology of the Edwards Plateau and Rio Plain adjacent to Austin and San Antonio, Texas, with reference to the occurrence of underground waters: U.S. Geological Survey Annual Report, 18(2): 193-321.
- Keddy-Hector, D.P. 1992. Golden-cheeked warbler recovery plan. U.S. Fish and Wildl. Serv., Austin, TX.

Murray, D. B., J. D. White, et al. (2012). "Woody vegetation persistence and disturbance in central Texas grasslands inferred from multidecadal historical aerial photographs." Rangeland Ecology & Management **66**(3): 297-304.

NatureServe. 2007. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA, U.S.A. Data current as of 10 February 2007.

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available <http://www.natureserve.org/explorer>. (Accessed: March 13, 2007).

Riskind, D.H. and D.D. Diamond. 1986. Plant communities of the Edwards Plateau of Texas-an overview emphasizing the Balcones escarpment zone between San Antonio and Austin with special attention to landscape contrasts and natural diversity. In: Abbott, P.L. and Woodruff, C.M., Jr., eds., The Geological Society of America, p. 21-32.

Riskind, D.H. and D.D. Diamond. 1988. An introduction to environments and vegetation. In: Edwards Plateau vegetation. Plant ecological studies in central Texas: Amos, B.B., and F.R. Gehlbach (eds.). Baylor Univ. Press, Waco, TX. 1-16.

Smeins, F.E. 1982. Natural role of fire in Central Texas. In: Prescribed range burning in Central Texas, L.D. White (ed.). Texas Agric. Ext. Serv., College Station, TX. 3-15.

Smeins, F.E. 1980. Natural role of fire on the Edwards Plateau. In: L.D. White (ed) Prescribed burning of the Edwards Plateau of Texas. Texas Agr. Ext. Serv., College Station, Tex. 74 p. 4-16.

Tharp, B.C. 1939. The vegetation of Texas. Texas Academy Publications in Natural History. Texas Academy of Science. Anson Jones Press, Houston.

Walters, T.W. and R. Wyatt. 1982. The Vascular Flora of Granite Outcrops in the Central Mineral Region of Texas. Bulletin of the Torrey Botanical Club, Vol. 109, No. 3 (Jul.-Sep., 1982), pp. 344-364.

Welch, T. 1982. Prescribed Range Burning in Central Texas. Texas Agricultural Extension Service.

Weniger, D. 1988. Vegetation before 1860. In: Edwards Plateau vegetation. Plant ecological studies in central Texas: Amos, B.B., and F.R. Gehlbach (eds.). Baylor Univ. Press, Waco, TX. 17-24.

Weniger, D. 1997. The Explorers Texas, Volume 2, The Animals They Found. Eakins Press, Austin, TX.

Whitehouse, E. 1933. Plant succession on central Texas granite. Ecology 14: 391-405.

Young, K. 1986. The Pleistocene Terra Rossa of Central Texas. In: The Balcones Escarpment. Geology, hydrology, ecology and social development in Central Texas: Abbott, P.L. and C.M. Roodruff (eds.). Geol. Soc. of Am., Dep. of Geol. Sci., San Diego State Univ., San Diego, CA. 63-70.