

An Introduction to the Vegetation and Ecology of the Eastern Edwards Plateau (Hill Country) of Texas

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Geology

Geology rules - or at least it's pretty important

The Edwards Plateau is a very large, roughly oblong region in central Texas defined by its bedrock: very thick, mostly flat layers of rock composed primarily of hard early Cretaceous limestone. Its eastern and southeastern boundaries are defined by an old fault zone (now inactive), the Balcones Escarpment. The rocks, soils, and plants east of the Edwards Plateau are quite different from those of the Plateau.

Go to http://www.tpwd.state.tx.us/landwater/land/maps/gis/map_downloads/ and choose any of the maps labeled 'natural regions' to see the location of the Edwards Plateau.

In north-central Austin, MoPac (Loop 1) runs along the edge of the Plateau; the land to the west of MoPac is on the Plateau. Loop 360 has some large road cuts through the Cretaceous limestone of the Plateau. In a few of these road cuts you can see some folding of the rock layers due to the faulting that occurred there. San Antonio and San Marcos also lie on the eastern edge of the Edwards Plateau.

The Plateau extends west to the Pecos River, about 250 miles (or about 400 km) west of Austin. Its northern and southwestern boundaries are not sharply defined. The Plateau is about 100 miles (or about 150 km) north to south.

Northwest of Austin is a region of exposed granite centered in Llano (pronounced lannoe, as in lanolin) and Mason counties. Around the granite are uplifted Paleozoic rocks. Properly speaking, the Llano Uplift is not part of the Edwards Plateau.

The eastern Edwards Plateau is often called the Hill Country, a reference to its many steep hillsides and valleys. This topography has been created by erosion: the flat layers of rock have been cut through by the many streams and rivers in the region. The Glen Rose formation tends to have limestone layers that are alternatively hard and soft, creating a characteristic 'stair-stepped' appearance.

As a result of the presence of thick layers of limestone, the region has creeks that lose water down into the ground, caves, and springs. The Edwards Aquifer underlies the eastern Edwards Plateau. Its recharge zone (the zone where water travels from the surface of the ground down into the aquifer) lies along the eastern edge of the aquifer. Its watershed is much larger. The segment of the Edwards Aquifer that provides the water that comes to the surface at Barton Springs (in Zilker Park, which is in downtown Austin just south of Town Lake) receives water from Barton Creek and Onion Creek, so its watershed includes much of southwestern Travis County and northwestern Hays County. A good site for more information about the Edwards Aquifer is <http://www.edwardsaquifer.net/>.

There are no natural lakes in central Texas, mostly because it was not glaciated. The Colorado River has been dammed to produce a series of reservoirs: Town Lake (created by Longhorn Dam in east Austin), then Lake Austin (created by the Tom Miller Dam near Brackenridge Field Laboratory), Lake Travis (created by Mansfield Dam), and so on. Lake Travis and Lake Buchanan are flood control lakes; their levels rise and fall as the water in them

is stored and released. The LCRA (Lower Colorado River Authority, <http://www.lcra.org/index.html>) administers these dams and reservoirs and some parks located on their shores. Before the dams were built Austin and other river towns flooded frequently.

For more information about the geology of the Austin area, see <http://www.lib.utexas.edu/geo/ggct/toc.html>. A useful book that covers all of Texas is Roadside Geology of Texas, by Darwin Spearing. For a simplified geological map of Texas, see http://www.lib.utexas.edu/maps/atlas_texas/surface_geology_tx.jpg.

Soils

Topography and geology, and maybe land use history, determine the soils

Soil maps are available for each county from the Natural Resources Conservation Service (NRCS), a federal agency (<http://www.tx.nrcs.usda.gov/>). Inspection of these maps reveals that topography (slope or flat, ridge or valley) tends to be closely related to soil type. Soils are often very shallow, and exposed bedrock is common. The Plateau may have had deeper soils before settlement than it does now. In many places no A horizon is now evident.

Soils in this region tend to have relatively high clay contents, due to their origin from limestone. If the soil is more than a few inches thick, it is likely to have a caliche layer. (Caliche is redeposited calcium carbonate, i.e., the same chemical substance as limestone). In practice it is often hard to distinguish caliche from marl, a softer limestone with some clay in it, in the field; both are crumbly white substances.

Soils tend to be neutral to alkaline with a high calcium carbonate content. Alkaline soils tend to make iron unavailable to plants. Plants adapted to sandy soils therefore tend to develop iron deficiency in Austin, easily seen as green veins on yellow leaves on the magnolia trees on campus, and as green-and-yellow longitudinal stripes in the leaves of St. Augustine grass in Austin lawns. This, in addition to the lower rainfall, may be why few east Texas plant species grow on the Plateau.

Climate

The climate is challenging

Californians think Austin is humid, Houstonians think it's pleasantly dry, but everyone agrees that it is hot. Not surprisingly, perhaps, as Austin is at the same latitude as Cairo, Egypt. The climate tends to be 'continental' rather than 'oceanic', despite the presence of the Gulf of Mexico about 200 miles (125 km) away: temperature changes are often large and rapid, especially when a 'norther' arrives. The climate falls on the boundary between sub-humid and semi-arid.

Austin's average daily high temperature in August is about 97° F (36° C) and the average low temperature in January is 40° F (4° C). Every couple of years there is a freeze in Austin, which prevents truly tropical species from living here. Freezes are more common further west on the Edwards Plateau. The ground does not freeze, and snow is rare and ephemeral. Winter temperatures fluctuate widely. Winter cold spells are usually due to the arrival of a 'norther'

coming down the Great Plains, when temperatures really can drop 50° F (28° C) in a day.

Austin receives about 34 inches (860 mm) of rainfall per year, which seems like a lot to those from cooler regions, but is only about half of the potential evapo-transpiration (i.e., the amount that would evaporate from a continuously wet surface in a year). For monthly rainfall and temperatures in Austin, see <http://www.srh.noaa.gov/ewx/html/cli/ausnorm.htm>.

There is a strong gradient of rainfall from east to west across Texas. For example, Fredricksburg, 120 miles (75 km) west of Austin, receives an average of only 27.5 inches (700 mm) per year.

In most of the drier parts of the world, precipitation is seasonal and therefore somewhat predictable. There is NO predictably wet month in this region, and NO day in which the plants may not have to survive one or even two subsequent months without rain. Only in May is the mean rainfall greater than one standard deviation of the rainfall. Rainfall also varies greatly from year to year. The hot temperatures, unpredictable rainfall, and thin soils make the eastern Edwards Plateau ecosystems much more subject to water limitation than the rainfall along might make you expect.

The shallow soils, steep topography, and often intense rainfall make the area one of the most flood-prone in the world. **DO NOT DRIVE INTO LOW WATER CROSSINGS IF THEY HAVE WATER IN THEM. BE CAUTIOUS ALONG CREEKS** even if the sky is blue and cloudless; there could have been rain upstream. Every year there are flood-related deaths.

Seasons and phenology

Plant in October (or January), harvest in June, bake in August

Spring begins in central Texas at the beginning of February, when the first buds open on the trees, although most people don't notice it then.

The roadside wildflowers are usually at their best in late March.

Really hot weather usually begins some time in May. May is the month with the greatest average rainfall, although there have been rainless Mays.

You can 'watch' the soil dry out during the summer by watching the native grass species die back. As the soil dries out, these plants turn brown from their leaf tips towards the base of the tiller. At the same time the depth at which detectable soil moisture is no longer present is increasing. The appearance of the vegetation in the city is deceptive; almost all of it is irrigated.

Rainfall in late August and in September is often due to a hurricane in the western Gulf of Mexico, so it is especially variable.

It WILL cool down, but probably not until October.

Except in the driest years, there will come a time when there is significant rainfall AND

the temperatures are cool enough for the soil to remain moist. That is when almost all native plants germinate. (If they waited for the spring, their roots would not be deep enough to survive the summer.) Plant seeds then.

Transplants are MUCH more likely to survive if transplanted sometime between then and February. March is often too late. December or January are best, unless you are prepared to irrigate.

Pre-settlement vegetation

We don't know much about what the vegetation 'should' be

This region was not settled by people of European and African descent until the mid 1800's or later. Between 1492 and settlement are 350 years in which the original inhabitants disappeared, horses and cattle formed large feral populations and the Apaches and Comanches developed a horse- and bison-based culture. We do not know to what extent these events affected the frequency of fires, the intensity of grazing, and so forth.

Because of the lack of natural lakes and other wetlands, there are no pollen cores to help us reconstruct past vegetation.

Most textbooks include this region either with the eastern deciduous forest or with the grasslands of the Great Plains. Nevertheless, it seems most likely that it has never been either forest or grassland. It also seems likely that it has always been a mosaic of woodlands (defined as vegetation dominated by trees of lower stature than true forests, with a more open canopy) and savannas (defined as areas with scattered woody plants in an herbaceous matrix). It is not known what the ratio of woodland to savanna was, the scale of this mosaic, or how permanent the spatial arrangement of woodland and savanna was. Likewise we do not know the scale or persistence of woody patches within the savannas. We assume that the species common today were also common in the past, but even this may not be true (see below). We assume that fire played a role in maintaining the savannas. The woodlands may also have experienced either surface or crown fires, or both.

We don't even know these things about the vegetation at the time of settlement in the mid to late 1800's. Here a study of old survey records, photographs, etc. might be very useful.

In some ways we are fortunate, however. Very little of the Plateau was ever plowed, in contrast to the Blackland Prairie to the east of the Plateau, whose vegetation is nothing like its original tallgrass grassland. There is a long history of cutting *Juniperus ashei*, first for fence posts and to improve grazing. The Edwards Plateau has been, and continues to be, heavily grazed, but it had bison, so the native grasses are relatively grazing tolerant, unlike those of the Great Basin and central California. Other than *Bothriochloa ischaemum* (King Ranch bluestem) and *Solenopsis invicta* (fire ants), all the common species are still natives. Compared to much of the rest of the United States, the vegetation of this region is probably relatively unaltered.

Plant communities

A brief overview of present vegetation

We can identify several different plant communities that grade into one another on the eastern Edwards Plateau, while remembering that there are many sites whose vegetation is intermediate between two or more of these.

- **mixed woodland**, dominated by *Quercus buckleyi* (Texas oak, Spanish oak), especially on slopes just below hilltops, *Juniperus ashei* (Ashe juniper, cedar), *Ulmus crassifolia* (cedar elm), *Celtis spp.* (hackberry), etc. This is the habitat of the endangered golden-cheeked warbler.

- **tree savanna**, dominated by *Quercus fusiformis* (live oak), *Juniperus ashei* (Ashe juniper), *Berberis trifoliolata* (agarita), *Diospyros texana* (persimmon), etc. Mesquite (*Prosopis glandulosa*) is occasionally present where the soil is deep enough. The herbaceous layer may be dominated by shortgrasses, especially *Bouteloua rigidisetata* (Texas grama grass), *Aristida longisetata* (three-awn grass), *Hilaria belangeri* (mesquite grass), and/or *Buchloe dactyloides* (buffalo grass), or by midgrasses, especially *Schizachyrium scoparium* (*Andropogon scoparius*) (little bluestem grass), *Nassella (Stipa) leucotricha* (Texas winter grass), *Bouteloua hirsuta* (hairy grama grass), *Aristida glauca/purpurea* complex (three-awn grasses), and/or *Muhlenbergia reverchonii* (muhly grass). Taller grasses are more common on hillsides and shorter grasses in flatter areas because grazing pressure is usually less on hillsides than in flatter areas.

- **shrub savanna or shrubland**, dominated by *Rhus spp.* (sumac), *Quercus sinuata* (shin oak), and other shrubby species, with or without small individuals of the larger woody species. This is the habitat of the endangered black-capped vireo.

- **cedar brake**, dominated by *Juniperus ashei* (Ashe juniper), often with a few remaining tall *Quercus spp.* trees (oaks).

- **bottomland forest**, dominated by *Carya illinoensis* (pecan). Rare, since the few bottomland sites are now mostly cultivated or under reservoirs.

- **riparian forest**, dominated by *Taxodium distichum* (bald cypress), *Platanus occidentalis* (sycamore), and/or *Salix nigra* (willow). Grows as a 'gallery forest' along some creeks and rivers.

- **highly disturbed sites, especially roadsides**. *Baccharis neglecta* (Roosevelt weed) is found almost exclusively in dry sites where the soil has been intensively disturbed. *Yucca rupicola* (twist leaf yucca) is often found growing with it on roadside banks. Roadside areas that receive road runoff water are often significantly wetter than the rest of the landscape and often have tall grasses, including *Sorghum halapense* (Johnson grass).

For a generalized vegetation map of Texas, see

<http://www.csd.tamu.edu/FLORA/taes/tracy/regecoNF.htm>

For a more detailed vegetation map of Texas, go to http://www.tpwd.state.tx.us/landwater/land/maps/gis/map_downloads/ and click on one of the maps labeled 'vegetation types'. The actual link to the smallest pdf file is http://www.tpwd.state.tx.us/landwater/land/maps/gis/map_downloads/media/pwd_mp_e0100_1070n_08.pdf.

Vegetation dynamics and management

Under present conditions, *Juniperus ashei* (Ashe juniper, cedar) rapidly increases in number and cover in every kind of site in this region except bottomland and riparian sites. *J. ashei* and other woody species are cleared by land managers to maintain or increase forage for cattle and other stock, for aesthetic or recreational reasons, and to maintain savanna vegetation. Savanna sites in which this species is not removed usually become cedar brakes.

Shrub savannas and shrublands are also not stable vegetation types under present conditions. They tend to become cedar brakes or perhaps mixed woodlands.

The potential relationship between cedar brakes and mixed woodlands is not clear. Under present conditions there is little or no regeneration of oaks due to deer browsing. Casual observations suggest that other woody angiosperm species are also not regenerating.

Herbicides are not sufficiently effective on *Juniperus ashei*, so brush clearing is done mechanically. Sometimes all woody plants are cleared; sometimes the oaks are left. *J. ashei* does not re-sprout if cut close to the ground or uprooted. After clearing, the brush is usually piled up and burned.

Fire is beginning to be used for *J. ashei* control in savannas in some areas. However grazing must be reduced or eliminated long enough to allow sufficient fine fuel to accumulate, and the mortality rate of small *J. ashei* plants in winter fires was found to be only about 40%, so the usefulness of fire is limited. Presumably summer fires would be more effective, but most counties have a burn ban in place all summer.

Under present conditions fires are uncommon. Lack of fine fuel, fire suppression, and the firebreaks created by roads all probably help make surface fires uncommon. Cedar brakes and mixed woodlands can support crown fires, although they are rare. These fires are very intense and very dangerous. The possibility of a crown fire in western Austin and in the urban/rural interface west of Austin is a serious safety concern.

Deer

Deer, or why murder Bambi

The density of white-tailed deer (*Odocoileus virginianus*) in the region is very high. Once you know what to look for, evidence of browsing is very common. Deer densities in some suburban areas of Austin are as high or higher than in 'the country'. The effects on native plants and plant communities are probably profound, but almost unknown (but see Vegetation dynamics and management). Because of their effects on gardens and landscape planting, and because of car-deer collisions, there is some public sentiment for controlling deer numbers.

However, many people feed deer and deer feed is sold at most grocery stores in west Austin. Experiments are being conducted in other parts of the country with contraceptives, but it is not a viable control option yet. Hunting is too dangerous in built-up areas, and is not necessarily effective in more rural areas. Killing does is legal during hunting season, but large numbers of does have to be killed to affect population growth rates. Many hunters prefer to kill bucks, which does not reduce population growth rates.

Fire ants

Fire ants, a species with no redeeming value

Newcomers to the region, watch where you step and sit! After a rain, fire ant (*Solenopsis invicta*) mounds are often visible, but the absence of visible mounds does not mean an absence of fire ants. If you kick a mound and ants come boiling out in large numbers, that's a fire ant mound. If an ant bite hurts immediately, and then forms a small itching bump filled with what looks like pus, that's a fire ant bite.

If you find a large (0.5 to 1.0 m diameter) flat cleared area with large ants going in and out, that is NOT a fire ant mound. It is a harvester (*Pogonomyrmex*) ant nest. Harvester ants are important native seed dispersers and are becoming uncommon due to fire ants.

Fire ants are recent invaders of this region. They are known to have a devastating effect on native ants. Their effect on other invertebrates has not been studied but is probably very large. They are known to eat the nestlings of vireos, quail, and other birds that nest close to the ground. They may be reducing the tick and chigger populations (personal observation).

Poisoning a mound often just makes the fire ant colony move.

Dr. Larry Gilbert has studied this species for many years and been instrumental in the testing and release of phorid flies, a potential biocontrol agent (<http://uts.cc.utexas.edu/~gilbert/research/fireants/>).

Reading the landscape

Reading the landscape: grazing

A quick way to determine if the land is still being grazed is to look at the condition of the fencing.

Species that are abundant where grazing has been very intense include *Opuntia spp.* (prickly pear, tasajillo), *Stillingia texana* (Queen's delight), *Asclepias asperula* (antelope horns), *Cnidoscolus texanus* (bull nettle) and thistles *Cirsium* and *Carduus* species). Rocks on the soil surface may be much more conspicuous in overgrazed sites.

Technically, goats don't graze; they are browsers, like deer. That is, they eat primarily woody plants and forbs, but little grass. Where goat densities have been very high you may see a 'browse line' at 1.5-2 m above the ground surface, with little vegetation other than tree trunks

below it.

Reading the landscape: soil disturbance

Look for *Baccharis neglecta* (Roosevelt weed) as a sign of past quarrying, road bank grading, plowing, and similar soil disturbances.

Reading the landscape: soil type

Where the soil is sandy, rather than formed from the breakdown of limestone, you may find *Quercus stellata* (post oak) in place of *Q. fusiformis* and *Q. buckleyi*. *Prosopis glandulosa* (honey mesquite) is a sign of relatively deep soil.

Canyons

A special kind of place: canyons

Steep sunny canyon walls may support hanging plants of *Nolina spp.* (beargrass). Shaded canyon walls, especially those with seeps, may have maiden-hair fern (*Adiantum capillus-veneris*) and columbine (*Aquilegia canadensis*). Travertine, a type of rock which looks a bit like small dirty cave stalactites, forms on some seeping canyon walls. *Salvia roemeriana* (cedar sage) is a conspicuous and beautiful canyon wildflower when it is blooming. In a few places we find palmetto in wet places on canyon floors. A beautiful local canyon accessible to the public (by guided tour) is Westcave Preserve (<http://www.westcave.org/>). The difference in temperature, light, and humidity between a canyon and the neighboring upland on a sunny summer day is dramatic.

Ball moss

A popular myth: ball moss

Ball moss (*Tillandsia recurvata*) is common in Austin but rare outside of Austin. It may be that the city 'heat island effect' allows it to grow in Austin. This is a member of the bromeliad family, closely related to Spanish moss.

It is an epiphyte, not a parasite. There is no evidence at all that it harms trees, contrary to local myth. Indeed, since it is an epiphyte, it is difficult to see how it would harm trees. The myth probably arises from the tendency of sick and dying trees to have conspicuously large ball moss populations. This is likely due to the lack of new (hence ball moss-free) growth and also to increased light levels within the canopy of an unhealthy tree.

Armadillos

Comic relief: armadillos

That loud scuffling you hear when you are out doing fieldwork, that sounds like a herd of elephants, is one armadillo (*Dasypus novemcinctus*) under the trees. Armadillos dig large holes under the trees, to which they retreat when scared. They make smaller holes, often just scrapes, wherever the soil is not too rocky or dry, as they forage.

If you make too much noise, however, you won't see a live armadillo. You will be

restricted to seeing dead armadillos in the road and the many armadillo knickknacks for sale all over Austin. Jim Hightower, a local liberal Democrat, once said - in the context of politics - that the only thing in the middle of the road is yellow lines and dead armadillos

Armadillos eat invertebrates in the soil, and are also strongly attracted to buried peatpots. They will dig up an entire experiment, only to discard every peatpot and the plant in it (personal experience - and it wasn't funny at the time!).

Harvester ants

An interesting insect: harvester ants

The nests of harvester ants (*Pogonomyrmex*) are conspicuous because of the flat bare area that they clear. Their nests typically have a central bare area covered with coarse sand or gravel, surrounded by a ring in which the only plant species are species of three-awn grass, *Aristida spp.* It is not known whether this is the result merely of selective weeding, or differential discarding of germinated seed, or something else. You can also see their trails running off for long distances. They are not aggressive and can be picked up by letting them run up a stick or even your hand. Their sting is painful, however, so don't antagonize them!

They are seed eaters but also eat dead insects (personal observation). They are now absent from areas (including Brackenridge Field Laboratory where they used to be abundant) because the fire ants have eliminated them. 'Pogos' are seed eaters, especially grass seeds. They were the principal food of the horned lizard (*Phrynosoma cornutum*), which was common in this region 50 years ago but is now extinct in the Austin area.

King Ranch bluestem

An invasive grass

Bothriochloa ischaemum (King Ranch bluestem) is native to Eurasia. It is a perennial bunchgrass. It is extremely common along roadsides, in part because it has been widely planted by the highway department for erosion control. It is found in savannas throughout the eastern Edwards Plateau. It was once widely recommended to ranchers, but was then found to be of low forage value.

It is unusually plastic. When heavily grazed or mowed, the tillers grow horizontally and the stand may resemble a golf course in height. Unmown and ungrazed, it grows upright and is often 20 or 30 cm tall. In some sites it forms pure stands that replace the native plant species. It can successfully invade and dominate ungrazed sites as well as grazed sites, and burned as well as unburned sites. However it, like most of the native grass species, does not tolerate heavy shade.

Texas winter grass and its parasite

A native grass and its parasite

Nassella (formerly *Stipa*) *leucotricha* (Texas winter grass) is our only common perennial

C₃ grass. It has both chasmogamous seeds (on the conspicuous inflorescences) and cleistogamous seeds (down among in the leaf bases). It is often infected by *Atkinsonella texensis*, an epiphytic fungus. This fungus sterilizes the plant, preventing it from forming both chasmogamous and cleistogamous seeds. Instead, an infected plant forms a fungal fruiting body at the end of what would have been the flowering stalk (culm). This fungal fruiting body looks exactly like a bird dropping.

Some conservation biology and environmental issues in the eastern Edwards Plateau region

Welcome to the front lines of conservation! many endangered species, rapid population growth, an extensive urban/rural interface, a private land state, a challenging political environment....

Endangered species

- The federally listed threatened and endangered species in this region include
- **black-capped vireo** (*Vireo atricapillus*). habitat: shrub savanna and shrubland (see above). threats: development (habitat loss); cowbird (lays eggs in nest; associated with cattle and with lawns, suburbs); fire ant (eats nestlings)
 - **golden-cheeked warbler** (*Dendroica chrysoparia*). habitat: mixed woodlands (see above). threats: development (habitat loss); blue jay (a non-native predator of nestlings found in suburbanized areas)
 - various **karst invertebrates**, for example, the Tooth Cave pseudoscorpion (*Microcreagris texana*) and the Kretschmarr Cave mold beetle (*Texamaurops redelli*). habitat: caves, subterranean fractures in limestone. threats: pesticide runoff from lawns; silt from soil erosion; other pollutants from developed areas; fire ants; filling in of caves by buildings, parking lots, and trash
 - various **salamanders**, including the Barton Springs salamander (*Eurycea sosorum*), Texas blind salamander (*Eurycea rathbuni*) and San Marcos salamander (*Eurycea nana*). habitat: various springs and water-filled fractures in the aquifer. threats: pollutants in the aquifer, including silt, road runoff, and pesticides; reduction in flows due to pumping and drought.
 - **San Marcos gambusia** (*Gambusia georgei*). habitat: springs in the San Marcos river. threats: reduction in flow; pollution.
 - **Texas wild rice** (*Zizania texana*). habitat: San Marcos River. threats: recreational use of the river; pollution; invasive non-native species; changes in river flow.

- Two of the unlisted but endangered plants species in the Austin area are
- **canyon mock-orange** (*Philadelphus ernestii*). habitat: edge of limestone cliffs, often with elbowbush (*Foresteria*), shrubby boneset (*Eupatorium havanense*), silktassel (*Garrya ovata*), etc. threats: development (habitat loss); probably also deer browsing.
 - **bracted twistflower** (*Streptanthus bracteatus*). habitat: uncertain. threats: development (habitat loss); deer herbivory

Non-native invasive species

- Non-native species that reduce native biodiversity include
- *Solenopsis invicta* (fire ants)

- domestic cats, presumably
- *Bothriochloa ischaemum* (King Ranch bluestem)
- cattle, goats, and 'exotic ungulates', when overstocked

In addition, there are a number of non-native plant species that may become problems and should therefore probably not be planted as landscaping any more. All of these have already become problems in other regions.

- nandina (*Nandina domestica*)
- Chinese tallow (*Triadica sebifera*)
- chinaberry (*Melia azedarach*)
- Chinese privet (*Ligustrum sinense*)
- Japanese honeysuckle (*Lonicera japonica*)
- fountain grass (*Pennisetum spp.*)

Since the reservoirs are a novel habitat, it is difficult to say that non-native invasive species are reducing biodiversity, but there are at least two non-native aquatic plants that are causing problems in these 'lakes', Eurasian watermilfoil (*Myriophyllum spicatum*) and hydrilla (*Hydrilla verticillata*).

Development and its consequences

Perhaps the largest single source of environmental issues on the eastern Edwards Plateau is the rapid growth of San Antonio, San Marcos, Austin, Round Rock, and the suburbanizing areas around them. Further west, many formerly rural areas have become retirement communities or vacation resorts. Outside the urban areas large ranches are being replaced by 'ranchettes' of one to twenty acres, similar to what is happening in many Western states. Texas, however, is a private land state, so almost all of the land is available for development.

Habitat is lost as former ranchland is converted to suburbs. The presence of lawns is thought to increase cowbird and bluejay populations. Potentially invasive plants are planted for landscaping, lawns, and gardens.

Development brings with it increases in runoff rates, reduced recharge rates, increased water pollution, and increased pumping from the aquifer, all of which affect aquatic species (see above). As impermeable cover increases, creeks alternate between going dry and flooding, which erodes their banks and alters the environment of aquatic and riparian species.

Fire and hunting becomes less available as management tools as housing density increases.

The increasing population causes more use of recreational areas, which tends to degrade the quality of the habitat for conservation.

Field guide recommendations

- Enquist, M. 1987. Wildflowers of the Texas Hill Country. Lone Star Botanical. *For herbaceous species other than graminoids. It has the most useful photographs (both flowers and leaves perfectly in focus) that I have ever seen. It goes in and out of print.*
- Gould, F. W. 1978. Common Texas grasses: an illustrated guide. Texas A&M Press, College Station, Texas. *Its excellent line drawings make it easy to identify grasses.*
- Lynch, D. 1981. Native and naturalized woody plants of Austin and the Hill Country. Saint Edwards University, Austin, Texas. *Excellent line drawings.*
- Vines, R. A. 1984. Trees of central Texas. University of Texas Press, Austin, Texas. *Line drawings. Many more species than Lynch, but no keys.*
- Wrede, J. 2005. Trees, shrubs, and vines of the Texas Hill Country, a field guide. Texas A&M Press, College Station, Texas. *In addition to photographs of woody species, it has good general information about plants and ecology of the eastern Edwards Plateau.*
- Drees, B. M., and J. A. Jackman, J. A. 1998. A field guide to common Texas insects. Gulf Publishing, Houston, Texas. *No insect field guide can be anywhere close to complete, but this has lots of the commoner arthropod (not just insect) species. Some of the contents of this book are posted online at <http://insects.tamu.edu/fieldguide/>.*
- Not being a bird watcher myself, I hesitate to recommend anything, but there is a Peterson field guide for Texas birds.*

Floras

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An Edwards Plateau bibliography

This bibliography is undoubtedly biased towards my own field of plant ecology. I would be happy to post additional references if you would like to send them to me.

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Links to sources of 'gray literature'

TEXNAT (Texas Natural Resource Server) is a web site of the Texas Cooperative Extension Service and Texas A&M University. Check out 'Plant Identification', a link to a dozen different documents. 'Library' will take you to many more documents, including the proceedings of dozens of symposia. Of particular relevance to the role of **juniper** species in Edwards Plateau vegetation is here is the 1997 Juniper Symposium (<http://texnat.tamu.edu/symposia/juniper/index.htm>, Technical Report 97-1, Texas Agricultural Experiment Station).

Useful documents from Texas Parks and Wildlife about **deer** include 'White-tailed Deer Management in the Texas Hill Country' by W. E. Armstrong and E. L. Young (http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_rp_w7000_828.pdf) and 'Vegetation of the Kerr Wildlife Management Area and its Preference by White-tailed Deer' by Armstrong et al. (http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_002a.pdf). See also 'The Use and Management of Browse in the Edwards Plateau of Texas, a 1994 NRCS document (<http://texnat.tamu.edu/cmplants/UseMgmtBrowseEPTX.pdf>)

See http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_196.pdf for an introduction to prescribed **fire** in rangelands. The web site of the Edwards Plateau Prescribed Burning Association is <http://www.ranchmanagement.org/eppba/>.

<http://www.texasinvasives.org/Publications/texas1.pdf> is an introduction to **invasive species** in Texas.

Texas Parks and Wildlife Department provides information about each **endangered species** in

Texas via links from <http://www.tpwd.state.tx.us/huntwild/wild/species/?c=endangered> . The list of species is somewhat longer from <http://www.tpwd.state.tx.us/huntwild/wild/species/> . There is a copy of a 127-page book they published, Endangered and Threatened Animals of Texas, at http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_013.pdf

An introduction to ranching in Texas, entitled Reference Guide for Texas Ranchers, by Allan McGinty, is available on line at <http://texnat.tamu.edu/ranchref/guide/index.htm>.

More links

Some Austin area places

Lady Bird Johnson Wildflower Center (<http://www.wildflower.org/>). *Not only a great place to visit to see native plants growing, they also have public talks, programs for undergraduate interns, ongoing research projects, and a web site with many pictures of plants. In southwest Austin.*

City of Austin parks and preserves (<http://www.ci.austin.tx.us/parks/>). The direct link for the Balcones Canyonlands Preserves operated by the City of Austin is <http://www.ci.austin.tx.us/preserves/bcp.htm>.

Travis County parks (<http://www.co.travis.tx.us/tnr/parks/default.asp>)

Wild Basin Wilderness Preserve (<http://www.wildbasin.org/>) *A bit of the Hill Country in the city - in Austin, on Loop 360.*

Balcones Canyonlands National Wildlife Refuge
(<http://www.fws.gov/southwest/refuges/texas/balcones/index.htm>)

Texas State Parks and State Natural Areas on the Edwards Plateau
(http://www.tpwd.state.tx.us/publications/parkguide/irgn_hc.phtml).

Pictures of plants found in this region

<http://www.wildflower2.org/NPIN/Gallery/gallery.html> The LBJ Wildflower Center's extensive picture collection.

http://www.sbs.utexas.edu/bio406d/PlantPics_archive.htm Dr. Bierner's extensive set of pictures for the Native Plants course.

<http://www.noble.org/imagegallery/> The Noble Foundations extensive image collection.

Pictures of grasses, together with some information about them, can also be found at <http://texnat.tamu.edu/cmplants/B-182/main.htm> , <http://www.dkseeds.com/grasses.html> , and <http://www.pogueagri.com/>.

Pictures of animals found in this region

<http://www.tpwd.state.tx.us/huntwild/wild/species/> is a set of fact sheets, with pictures, of many Texas animals, including invertebrates, posted by Texas Parks and Wildlife Department.

<http://wfsc.tamu.edu/TCWC/herps/herps.htm> or <http://wfscnet.tamu.edu/twc/herps/herps.htm>
Texas herps, from Texas A&M University

<http://insects.tamu.edu/fieldguide/> Texas arthropods, from Texas A&M University

Gardening...

Anyone who is suspected of knowing anything about plants will sooner or later be asked questions about garden plants, gardening, landscaping, and so on, especially in Austin, where standard garden books are not very useful. Here are two local web sites that provide starting points.

<http://www.ci.austin.tx.us/growgreen/>
<http://travis-tx.tamu.edu/hort/hortindex.htm>