LANDOWNER REPORT

Ten Years of Ecological Restoration on a Texas Hill Country Site

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ABSTRACT

We describe ten years of restoration work on a 56-ha tract of former ranchland. The historical characterization of this area at the time of the displacement of indigenous people by settlers initially formed the basis for our restoration decisions. Today, a higher human population density and a change in climate preclude a return to the presettlement state, necessitating the formulation of other restoration goals and methods. The methods employed, metrics to determine the results of restoration, and the results of bird, butterfly, and plant surveys are listed. Changes in vegetation due to the restoration are illustrated and future plans are discussed.

Keywords: Ashe juniper (*Juniperus ashei*), ranchland restoration, Texas Hill Country

Overpopulation in the world, including in the United States, has severely impacted ecosystem health and native fauna and flora. We have been concerned about this issue for the past 60 years and for many years have been active environmentalists working with national and local groups to prevent habitat destruction. Our acquisition of a 56-ha parcel of former ranchland in Texas has allowed us to move into the realm of habitat conservation and restoration, and to carry out our personal commitment to countering the destruction that we witness daily. We supplied the majority of the labor required for this restoration effort. Restoration requires hard work and constant learning from other landowners, books, conferences, academic researchers, experimentation, and failures, as well as financial resources and persistence. This paper summarizes some of the effort we have expended and some of what we have learned in the past 10 years to understand the natural systems and restore to better ecosystem functioning a small part of the Texas Hill Country. We have found it highly satisfying.

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The Texas Hill Country consists of the southern and eastern parts of the Edwards ecoregion, defined roughly by the Austin to San Antonio line along the Balcones fault zone on the east, and from San Antonio west along US 90 to Bracketville. The Edwards ecoregion is unique because it sits at the convergence of several ecological regions: Texas blackland prairie on the east, central and southern mixed grasslands and central forest/grasslands transition zone on the north, the Chihuahuan desert and Tamaulipan mezquital on the south and west (Ricketts et al. 1999). As a consequence, the fauna and flora in this region combine species from each of these neighboring ecoregions, in addition to many endemics.

Recent History of the Texas Hill Country

Since the initiation of large scale European-American immigration in about 1830, the economy of the Hill Country has been based mostly on ranching, with some farming. Rainfall changes from about 914 mm on the eastern edge of the Hill Country to 380 mm per year in the west. Critically, rainfall varies greatly from month to month and year to year (Bomar 1995). In fact, the Blanco River, which flows east out of the Hill Country south of Austin, is the most dynamic river within the United States owing to this large rainfall variability. The Hill Country has been said to be in a permanent drought punctuated by occasional floods. The underlying geology of the Hill Country is layers of limestone, with large variations in hardness and porosity between strata.

Early travelers described huge fires that burned throughout the Hill Country and west Texas, filling the sky with dense smoke and having lines of flames up to 100 km long. Fires were initiated both by lightening strikes, particularly in late summer, and by indigenous people. Settlers mostly arrived through east Texas where rainfall was higher, and they did not have a history of rainfall behavior on which to base their ranching and farming decisions. Much of their migration coincided with a 10–30 year wet period (circa 1880–1910). As a consequence, the relatively fragile ecosystems of the Hill Country were quickly overexploited, especially when more normal rainfall returned. The Hill

Country as described by early travelers may be found in Weniger (1984), and Caro (1982) has an excellent description of the impact of settlers on the Hill Country in his first book on Lyndon Johnson. Caro also explains the relation between the fortunes of the Johnson family and their lack of knowledge of Hill Country ecology, which impacted former President Johnson during his formative years, and through his politics, influenced environmental policies throughout the United States.

The combination of latitude, topography, rainfall, and fire resulted in large parts of the Hill Country being what is classified today as savanna—mostly grassland but with dispersed heavily forested areas. Since periodic fires were an important factor, the ecosystem of the Hill Country was dynamic, rarely reaching a climax condition at any location. Fire suppressed the growth of woody plants, specifically Ashe juniper (*Juniperus ashei*), except on steeply sloped areas. The "cedar barrens" seen throughout the Hill Country today are the result of fire suppression due to changing cultural practices (the growth of cities, suburbs, weekend and retirement homes, etc.), population growth, and overgrazing. County and school district taxing authorities have historically exacerbated the problem by requiring stocking rates that are unrelated to ecological knowledge and climatic conditions. Global warming is also implicated in exacerbating the dominance of Ashe juniper in the Hill Country (Van Auken 2000). In addition, poor coverage by native grasses as the result of excessive herbivory has resulted in severe erosion of the region's relatively thin top soil during drought-breaking floods. Whereas early travelers on horseback reported that their steeds rarely kicked a rock during their traverse of the Hill Country, large areas today exhibit extensive surface rock with only some topsoil remaining.

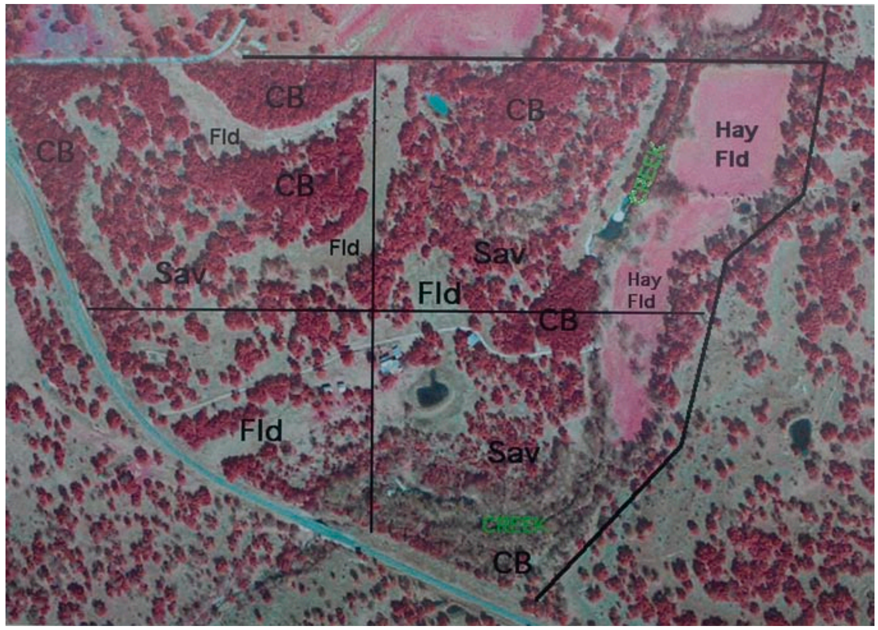

Figure 1. Restoration site in Kendall County, Texas, in approximately 2000, showing quadrants, the creek, cedar breaks (CB), fields (Fld) and hay field (Hay Fld), and savanna (Sav).

Site Description

We acquired our property, at latitude 29° 58' 48" N, longitude 98° 32' 36" W, in 1996 after searching for over two years for a site having some soil and water and within an hour's travel from San Antonio. Soil loss from abusive agricultural practices has exposed the underlying limestone strata in many places, so locating a site with soil greatly facilitates restoration. Erratic and sparse rainfall limits the presence of wildlife unless surface water is available. A portion of Ross Creek, a stream that flows only when rainfall is steady and sufficient, crosses the property from north to south on the east side (Figure 1). This stream is fed now by springs that have started owing to our removal of ash juniper, and by a spring that has never been known to cease flowing, although it is located near the southern border of the property. The area has been mapped using global positioning (GPS) technology that has also been used to locate sites where we have taken periodic photographs of habitat change.

Elevation of this area ranges from 450 m in the northwest quadrant to 408 m where the creek leaves the property in the southeast quadrant, and there are only a few rapid elevation changes. The riparian area soil type is listed as Oakalla-Boerne-Uvalde association, "deep, nearly level to gently sloping, loamy and clayey soils; on flood and stream terraces" (USDA-SCS 1981). The remainder of the property is of a soil type described as "shallow, undulating, loamy and clayey soils; on uplands," known as the Doss-Bracket association (USDA-SCS 1981). These soils, both limestone derivatives, are alkaline.

Steps to Restoration

A law passed by the Texas Legislature in 1998 created the category "wildlife exemption," which is property tax neutral with the existing "agricultural exemption." This new category allows a landowner to manage for some aspect of natural habitat protection and enhanced use by wildlife rather than for economic production (crops or cattle). Without this method for limiting taxation and broadening the goals for land management, restoration would be much more difficult because it would not be possible, in most cases, to completely remove cattle or significantly alter historic grazing practices, as driven by the rules and customs of the taxing authorities.

Our goal for restoration is to increase biodiversity in the context of what is known about the historic landscape and native fauna and flora. Our time horizon for this restoration was originally set at ten years on the basis of our age and health. Although this article summarizes these ten years, the restoration is currently ongoing with many projects. The steps we have followed were originally formulated as a result of a workshop on land stewardship presented at "Selah," a 2,025-ha former ranch about 64 km away, owned and managed by David Bamberger, who has been carrying out restoration there for 30 years. An approximate quantification of habitat types on our property at the time of acquisition, and 10 years later in 2006, is given in Table 1.

Table 1. Classification of habitat types on the 56-ha restoration site in the Texas Hill Country. The entire floodplain has been defined as riparian, even though creek flow is intermittent. "Fields" designate once badly overgrazed pastures that have grown back in predominantly non-native grass species.

Year	Habitat Type			
	Nonriparian			Riparian
	Savanna	Field	Cedar Barrens	
1996	7%	28%	65%	26%
2006	51%	28%	21%	26%

Cedar Barrens

From a restoration perspective, Ashe juniper is an invasive species. It forms dense thickets that transpire large amounts of groundwater, with canopies that deny smaller plants access to light. Fallen juniper needles form dense, crusty carpets, shielding the ground from rainfall penetration (thus promoting runoff and erosion) and preventing the emergence of new plants. When we acquired our property approximately 36 ha (about 65% of the land) was covered with a dense growth of secondary Ashe juniper, known locally as "cedar." This density of cedar, much higher than historical estimates, is typical of most of the Hill Country today. The diameters of the trees, often with multiple trunks, ranged from 50 to 250 mm. A count of growth rings from these junipers indicates that 50% of these trees are less than 20 years old and 90% are less than 30 years old. Counting growth rings cannot be reliably used to age this species so these ages are only approximations (Grissino-Mayer 2008), but it does establish that most of the cedar started growing in the last half of the 20th century.

Our first management decision was to reduce the area dominated by cedar barrens. This is a common practice for recent land acquisitions in the Hill Country and is recommended by Bamberger. We removed juniper from different areas on the property in a manner intended to promote site heterogeneity and restore the landscape to a savanna-like composition. Cedar thinning was accomplished using rubber-tired tractor-like machines equipped with hydraulic shears. The blades of the shear are placed on each side of the trunk at ground level and the tree is cut by closing the blades. This method of tree removal leaves the ground almost undisturbed, relative to the use of a bulldozer, but it does not reduce the tree to small pieces as would occur with the use of hydromulching machinery.

Owing to the density of the cedar stands, the shear operators (we used three different contractors) originally stacked many of the downed trees into large piles to make room for maneuvering the tractor. Some piles were 15 to 30 m in diameter and 6 to 9 m high. In some places, mainly in the southeast quadrant, trees were left where they fell. In the early years of restoration, grass coverage was sparse, which minimized the risks of out-of-control burning, and we burned about 30% of the sheared cedar in this manner. After about 5 years, grass coverage had increased enough to make burning a much more hazardous effort, and during that time, the climate became dryer and hotter, so that there have been fewer times when the conditions suitable for burning (high humidity and no wind) were satisfied; thus, it has been necessary to phase out brush removal by burning.

Where large piles of cedar were burned, soil temperatures were very high, which destroyed soil organisms, thus preventing rapid revegetation. To prevent erosion, we spread leaves collected from urban neighborhoods in these areas, and spread small brush atop the leaves to prevent wind from removing the leaves. Rain falling on the leaves produced "compost tea," which replaced some of the soil organisms and stimulated plant growth. In some areas, we spread commercially purchased mycorrhizae. Grass cover returned within two years in up to 80% of the areas we treated this way.

Upon completion of this phase of the restoration, approximately 12 ha in cedar barrens in 8 parcels remained and were left uncleared as cover for wildlife, mainly white-tailed deer (*Odocoileus virginianus*), and partially because continued efforts to prevent regrowth in the cleared areas have priority over further reduction in the area dominated by cedar. Smaller diameter cedars in some of these parcels have been selectively removed. After a few years a variety of plants began to appear in areas where sheared cedar was left as it was cut or arranged in small brush piles. This led us to conclude that the downed cedars were acting as nurseries for the return of native vegetation by protecting these areas from browsing by deer (Figure 2). This realization encouraged us to rearrange remaining piles of sheared cedar to form natural barriers to deer herbivory.

Managing Cedar Regrowth

In all areas where cedar was cleared, many small junipers began to grow within one to three years. There were probably several origins of this "secondary growth." If small (a few centimeters tall) cedars were missed during

Figure 2. Soapberry (*Sapindus* sp.) growing within a pile of sheared cedar (*Juniperus ashei*) as a result of protection from browsing by white-tailed deer (*Odocoileus virginiana*), 2006. All photos by D. Davidson

the clearing process, then growth could regenerate from these, but there were a number of areas where no small plants were evident and regrowth must have resulted from the germination of seeds already in the soil. Several small cedars we extracted displayed singular roots 4 to 10 times the length of the aboveground growth. In a few areas, we have removed this secondary growth every year for most of the ten-year span of this restoration. During this time, the grass has become very thick and high, and yet new cedar growth occurs each year.

In the absence of fire, which was the historic disturbance that killed such secondary growth, it is necessary to use mechanical methods for control. The hand cutting of secondary growth using loppers has occupied large amounts of time and effort. It is estimated that 163 hours were spent controlling secondary growth (we kept records only for the past four years). Our measured rate of tree removal is at least 400 trees per hour. Thus, in the past four years only, approximately 65,200 secondary cedar plants have been removed by hand. Over the entire 10-year period, it is estimated that about 140,000 secondary cedars were removed. Even in the northwest quadrant area, cleared ten years ago, it is still necessary to remove secondary growth at least once a year even though the undergrowth is now extensive and the grass cover is dense. Our conclusion from this experience is that it is not possible to ever grow grass thick or high enough to prevent cedar regrowth.

Savanna Areas

Higher parts of the property that were cleared of cedar are reverting to savanna, 7 ha in one area and 10 ha in another. Most of the northwest quadrant was cleared in 1996, leaving mainly Texas live oaks (*Quercus fusiformis*) (Figure 1). Since then, a dense understory has grown of mostly Texas persimmon (*Diospyros texana*), which may develop into black-capped vireo (*Vireo atricapilla*) habitat as its density increases. There are 55 species of native trees, in addition to Ashe juniper, on the property. The most abundant trees are cedar elm (*Ulmus crassifolia*) and several species of oaks, although an inventory by numbers for each species has not been made (see online appendix for a list of plant and animal species at http://www.wisc.edu/wisconsinpress/journals/journals/er_suppl.html). In the northeast quadrant area, cleared of cedar in 1999, we found more tree species diversity, including shin (wavyleaf) oaks (*Quercus sinuata*), Texas oaks (*Quercus texana*), and post oaks (*Quercus stellata*) in addition to live oaks. Grass has been partially reestablished, although it is still sparse where the canopy is more complete. Undergrowth development has been much slower in this area.

Fields

Eight open fields on our property have remained in grass for many years. Predominant grass species are little bluestem (*Schizachyrium scoparium*) and the non-native King Ranch (KR) bluestem (*Bothriochloa ischaemum*) (see online appendix for full grass species list at www.wisc.edu/wisconsinpress/journals/journals/er_suppl.html). One 7-ha field in "coastal" bermudagrass (*Cynodon dactylon*) is cut and bailed as cattle feed by a local resident. This field has not been restored to native grasses, partially because of the positive relationship it maintains with land owners and managers in the surrounding area.

Riparian Area

About 15 ha are within the riparian zone of Ross Creek. The northern property boundary coincides with the confluence of two branches of this creek, whose upper watershed is about 300 ha. Thus, only about 20% of the watershed is under our management. Heavy rainfall within the watershed results in flooding that carries a substantial load of erosion products into the riparian area (limestone gravel and rocks up to basketball size—0.35 m in diameter), causing inundation of most of the floodplain in the lower part of the property. Four flooding incidents have occurred during the past 10 years. Cedar cleared from this area in 1997 and arranged into piles dampens this flooding, but the stream remains very dynamic before reaching the southern boundary, having shifted its course several times. Grasses have been established in the floodplain since the removal of the cedar, and further stabilization will be undertaken by planting cypress and cottonwood trees at points along the creek path.

Restoration Results

Native Plant Establishment

A significant increase in biodiversity should result from removal of the cedar and suppression of secondary growth, but only if plants native to this area supplant the invasive trees. Native plant inventories by two botanists each located approximately 175 species. While this list is extensive, biodiversity is not uniform throughout our property, and for many species, only one or a few plants were found. We have established both a photographic and a physical herbarium to help in future identification of plants. Also, growth of native plants has been agonizingly slow, exacerbated by low rainfall. Irrigation is necessary for plant establishment, and plantings near our well were drip irrigated (once per week for 5 years) from April to December.

Exacerbating the problem of reestablishing native plants has been the too high density of white-tailed deer, and during the time of this restoration, chital "axis" deer (*Cervus axis*) invaded the property, even though it is high fenced (2.7 m). Browsing by deer has been evidenced by a lack of regeneration beneath live oaks and shin oaks. Also, saw greenbrier (*Smilax bona-nox*) and twistedleaf yucca (*Yucca rupicola*), good indicator species, have been heavily browsed.

Between 2003 and 2005 we used sheared and chainsaw-cut cedar to construct deer exclosures; the first around a 120-m^2 area, and the second around a 520-m^2 area (Figure 3, see online appendix for planted species). Both these exclosures are located in the southeast quadrant within 60 m of the creek, from which water was carried to the plantings. When the creek ceases flowing, we carry water by hand from the well (we are currently constructing a rainwater collection and drip irrigation system). We are also constructing a third ring of brush in the northeast quadrant that will enclose an area about 5 times that of the second exclosure, although native plants will be more difficult to establish at this location because sources of water are remote.

Figure 3. A large pile of sheared cedar arranged to exclude deer browsing, 2006.

From 2000 to 2004, we purchased native plants from nurseries, when we could find them. This proved frustrating and expensive, and we now propagate plants for establishment in the exclosures from existing stock on the property using techniques described in Nokes (2001) and other sources. Most plants are placed in the ground in October or November so that expected rains during the winter will induce root growth, making them more drought tolerant the next summer. When an exclosure is distant from a water source, plants are irrigated about once per week until they are established (up to 5 years); this is necessary even for drought-resistant native species.

Deer Management

According to Texas Parks and Wildlife Department biologists, the density of white-tailed deer in this county exceeds carrying capacity, and it became evident in about 2001 that the number of deer exceeded the long-term carrying capacity of our property. About this same time, axis deer found their way onto our property from the surrounding area. Our peripheral high fence offers some control of deer density on the restoration site, but only if sufficient hunting pressure can be exerted over an extended period. We commenced efforts to hunt and kill white-tailed and axis deer, hoping to eliminate axis entirely and greatly diminish the population of white-tailed deer. However, axis deer are smart and difficult to hunt, so that only five deer have been killed, mainly by hunting at night. Axis deer are also capable of jumping the 2.7 m-high fence, and it is possible that many of these animals escaped in response to hunting pressure. Deer (probably axis) are also breaking holes in the fence, which we have to periodically repair. We have had better success hunting white-tailed deer (12), but their numbers are still excessive, and continued

Figure 4. Savanna in the northwest quadrant of the property in June 1996 (top) and April 2006 (bottom).

Figure 5. Savanna in the southeast quadrant in November 2002 (top) and April 2006 (bottom).

hunting will be necessary. Hunting pressure has had a very positive effect on the level of browsing, which has noticeably diminished in most areas. Browse monitoring began about 2000, and is used in lieu of making an annual deer census, which is time consuming and results in only an approximate measurement.

King Ranch Bluestem Replacement Project

One of the largest current efforts is experimentation to find a method for replacing invasive KR bluestem with native prairie grasses. Imported into south Texas from the Middle East for the King Ranch in the 1940s, it has spread to most parts of Texas and northern Mexico and dominates our site. KR outcompetes native grasses in disturbed soils, so it has been used extensively for erosion control, but is now regarded as a threat to the long-term survival of many native species, including insects, birds, butterflies, and perhaps rodents, that depend on native grasses.

In 2004, we began an effort to replace some of the KR with native grasses, the results of which will not be known for many years. We tested a method prescribed by The Nature Conservancy: kill the KR with a commercial herbicide and plant the seeds of the fast-growing and tall grasses blue grama (*Bouteloua gracilis*), green sprangletop (*Leptochloa dubia*), little bluestem, and Indiangrass (*Sorghastrum nutans*) that will eventually shade out the KR. We treated two plots this way using seed purchased from a native seed company about 160 km away. In one plot, about 25% of the KR was not killed by herbiciding and almost none of the native grasses have germinated after 2 years. In another plot, less than half the KR was killed and very few of the seeded grasses have grown. A second experiment, suggested at an invasive species conference held at The Wildflower Center in Austin, Texas, was begun in 2005. All the KR was removed within a plot during November using a grubbing hoe, and seeds from tall grasses growing nearby were collected and planted in the plot (very few non-KR

Figure 6. Southeast quadrant in March 1999 (top) and April 2006 (bottom). The structure is a defunct deer feeder. One day this will be converted into a bird feeder. The top photo is about 2 years after the cedar was sheared and before the area was burned; the bottom photo is some 7 years later revealing improved health of oak trees and established grass cover.

plants were found in this plot). After about a year, there has been no germination of those seeds and most of this area has been reinvaded by KR bluestem. The Wildflower Center has also experimented with summer burning, which has been reported to be successful (Ewing et al. 2005). Controlled burning at our site is not feasible at this time because of climatic conditions and the requirements of manpower and equipment.

Measuring Progress

Considerable thought has been given as to how to measure progress toward our restoration goal of increasing biodiversity. We are constantly recording sightings of birds, butterflies, mammals, and plants and are analyzing this data. Photographs provide a qualitative record of changes. Twenty widely scattered rephotograph locations, or photopoints, have been established. One site covers the entire 10-year period. Figure 4 shows the increase in grass cover, understory (mainly Texas persimmon), and canopy that resulted from cedar removal. The northeast quadrant was not cleared until 1999 and burned sites have not yet fully grassed over (Figure 5). Little bluestem recovered rapidly after cedar clearing in a wet year, but subsequent recovery has been slower (Figure 6). Increase in tree health is more noticeable. Generally, these photographs show that cedar clearing resulted in increased coverage and height of grasses, as well as denser understory vegetation. The amount of revegetation that occurs each year is dependent directly on the magnitude of the rainfall. Annual rainfall for the Kendalia gauging station about 1.6 km east is shown in Figure 7. Only annual rainfall is shown, but the month in which rain falls is an important restoration variable.

The number of bird species identified annually might be one measure of restoration success (Figure 7 and online appendix). Although birds are observed year round, most nonresident species are found from March to July and September to November, mainly in the riparian and adjacent areas. Bird species counts have increased each year because the density of vegetation (excluding cedar) has increased; thus, more bird species are finding food and shelter on the property somewhat independently of annual rainfall because the effect of rain on vegetation has been cumulative (i.e., less dependence on annual rainfall as time has progressed). No attempt has been made to measure vegetation density or canopy coverage quantitatively. However, it is clear that restoration depends on increasing both the amount and diversity of vegetation, and rainfall is the limiting factor in how rapidly restoration progresses.

Another measure of increasing biodiversity would be an increase in plant species. Two plant surveys by botanists in 1999 and 2004 have not indicated much change in the number

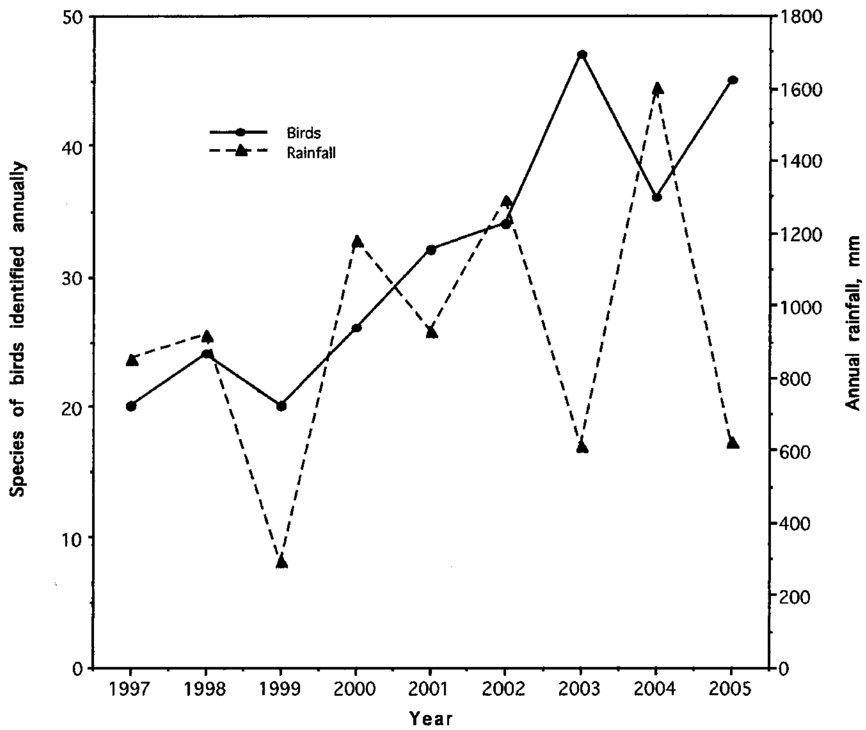

Figure 7. Annual rainfall and bird species richness over time. Note the generally parallel upward trend in both.

of species (about 175). During the visits, the botanists hiked most of the open parts of the site. The rephotographic effort reveals that the amount of nonjuniper vegetation has clearly increased, but there has been little change in the number of species. This result, coupled with the increase in the annual bird species count, appears to indicate that increasing the vegetation density is more important than increasing number of plant species at this site. Increasing the number of species of plants apparently must be done through plantings.

Recently, a published work using butterflies as an indicator species for biodiversity (Mas and Dietsch 2003) appeared to be an applicable metric for restoration work. Butterfly censuses in 2004 and 2005 found most butterflies in the riparian and adjacent areas, as with birds. A butterfly list for Kendall County includes 88 species (Opler et al. 2006). Our first census located 60 species (see online appendix), with most photographed for positive identification; several were not on the list of expected species. In the second year, fewer species were found (40), which was attributed to a very dry autumn and winter the previous year; notably, fewer skippers (Hesperioidea) were found.

A metric using butterflies might be used for biodiversity, but we have not yet established specific indicator species for this location. Possibly, known migratory species such as the monarch (*Danaus plexippus*) and painted lady (*Vanessa cardui*) should be excluded from consideration. Butterfly abundance is influenced by abiotic conditions, but exactly how is still to be determined. In fact, butterflies appear to be a good indicator of how abiotic conditions, mainly rainfall, are affecting ecosystem productivity. Neither birds nor butterflies are ideal indicator species because butterflies are more dependent on fluctuations in rainfall and birds are more dependent on conditions over a wider area.

During the restoration period, many mammals were sighted (see online appendix), but mammal sightings have been too sporadic and they are so mobile that using mammals as a measurement of progress does not seem feasible, or particularly useful, as they can move in and out of the site with ease. A more accurate metric for biodiversity might be through the creation of an index that would weigh certain bird, butterfly, and plant species according to abiotic conditions (rainfall, temperature, and the deviation from "normal" conditions) within at least the previous year. Other factors, such as the dates of data collection, might also be included. The annual census of birds and butterflies, together with periodic plant surveys, appears to offer the best metric for determining the effects of management practices until an index, or some other better metric, can be developed.

Summary, Conclusions, and Future Plans

Restoration of this site has proven to be a complex undertaking, beginning with difficulty in determining what constitutes appropriate goals. Returning the site to pre-European settlement condition was possible in concept only. Highly erratic rainfall, resulting in both floods and droughts, has significantly impacted restoration efforts. Methods for restoration have been limited, especially owing to the infeasibility of using fire. Mechanical removal of cedar barrens has had the most influence on restoration, and the control of secondary growth of juniper has required an ongoing high level of effort. Control of other invasive species, including KR bluestem and deer, has also been required.

During the restoration period, the number of bird species identified annually has doubled, which we believe to be a direct result of the increase in noncedar vegetation density. The number of butterfly species identified reflects the high diversity of native plant species identified in our plant surveys. Wildlife would be distributed more evenly outside the riparian area if water were available elsewhere, and we plan to construct rainwater collection systems outside of the riparian zone for wildlife watering and native plant establishment. Stabilizing the riparian zone against flood damage is another priority item, although the method is currently unclear.

Highly erratic rainfall, resulting in both floods and droughts, has significantly impacted the rate of change in vegetation. Increasing the number of endemic Hill Country plants, especially those that flower, is another desirable goal, as we have noticed that there is a deficit of flowering plants. Increasing the species of native plants will necessitate finding them externally. Scarcity and expense of native plants practically requires creating a nursery. Development of quantitative metrics for determining the effectiveness of restoration methods is continuing, with repeat photography and the census of birds and butterfly species being the current methods employed.

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