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## Abstract

The glory of the caves has long overshadowed other features of the park but the neglected upland landscape has its own extraordinary tale to tell. The park occupies a naturally fire sheltered setting in a historically vast fire landscape of barrens and woodlands once populated by Native Americans, bison and elk. The events aboveground, spanning several thousand years before the arrival of Europeans and the subsequent explosive transformation of the land add rich layers of natural and human history, sadly neglected in development and interpretation of the park. This is the tale of the Barrens region itself.

We constructed maps of historical fire frequency and vegetation, using 2,681 witness trees compiled from original land surveys beginning in 1781. Original fire frequency was interpreted using tree species and the degree of fire exposure of each tree in the landscape, e.g. fire exposed ridgetops, slopes or grassy barrens versus fire sheltered lower slopes, hollows and bottoms. The topographical setting was examined for characteristics related to fire spread such as pathways for fire flow, natural firebreaks and the size of fire compartments. The natural fire relations of each tree species and its distribution on the land were used to assign fire frequency to each site and region. Original fire regimes were complex and extreme: fire frequency ranged from nearly annual fire in the true prairies and grassy woodlands on the limestone karst plain to the south – and on the plain between the Dripping Springs Escarpment and the Green River – to strongly fire sheltered hollows and bottoms within the park. The most fire sheltered sites were defined by the deep limestone bowls developed by karst topography – formed by millennia of dissolution of limestone by subterranean waters – and the rugged relief provided by the deeply entrenched Green and Nolin Rivers.

## Introduction

The distribution and fire relations of trees found on the earliest surveys provide a new view of the Mammoth Cave landscape with tantalizing evidence concerning the return of bison to Kentucky in pre-Columbian times and circumstantial evidence for earlier introduction of European disease before DeSoto.

With postglacial warming, the large Pleistocene mammals of Kentucky, documented as fossils in the mires of Big Bone Lick, either migrated north, as with moose and caribou, or became extinct. Seven of the extinct species, however (American mastodon, Columbian mammoth, Jefferson's ground sloth, Harlan's ground sloth, complex-toothed horse, elk-moose and helmeted musk ox), should have had no trouble following the sub-boreal habitat as it moved north with the melting ice. All, however, vanished between 10,000 and 12,000 years ago, coinciding somewhat precisely with arrival of the earliest Clovis hunters in the region around 10,000-11,500 years ago and Clovis spear points occur in sediments of that age at Big Bone Lick (Hedeen 2008). Never in their evolutionary history had any of these animals experienced humans and the slow-moving ground sloths must have been easy pickings for well-armed, smart

hunters. No other plausible reason has been advanced for the sudden disappearance of these mobile animals who had evolved in this landscape for hundreds of thousands to millions of years.

Other native species such as *Bison bison* antiquus, were also extirpated during this era but persisted in the sparsely populated West to give rise to the modern species. The reason for return of their descendants, *Bison bison*, to Kentucky, after a hiatus of nearly 10,000 years, and before the supposed date of introduction of european diseases is an unanswered question that looms large.

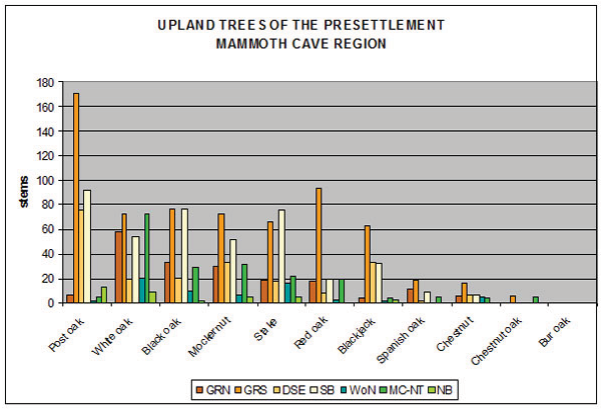


**Figure 1:** Upland Trees in the Presettlement Mammoth Cave Region. The most abundant tree of 2,681 original surveyors' witness trees found in and around Mammoth Cave National Park was post oak. This seems startling in view of the sparse distribution of the tree today, but post oak is a fire dependent species; it was once dominant on the side slopes and edges of the nearly treeless prairies to the south and north of the park – the "Barrens" – and on the more fire exposed ridges within the park, especially on the south side of the Green River. Region codes: GRN – Green River North side, GRS – Green River South side, DSE – Dripping Springs Escarpment zone, SB – Southern Barrens, WoN – West of Nolin River, MC-NT – Mammoth Cave-Northern Transition (between central MACA and the Nolin River north of the park), NB – the Northern Barrens north of the northern, west to east-trending section of the Nolin.

The beginnings of farming around 3000-6000 B.C. and development of a more complex tool kit including the bow and arrow in the Late Woodland Period (400-1000 A.D.) would have allowed the land to support increasing numbers of native peoples. With 10,000 years for equilibration, at each stage of evolving technology the land probably supported all the Indians that it could at that time. By around 400 A.D, at the end of the Late Woodland there were fully agricultural communities across Kentucky (Lewis 2006) and U.S. populations peaked at a still debated 1.8 to 18 million. The lower estimates may not take into account possible higher densities even before first extensive European contact through the Desoto expedition. DeSoto, who had "a privileged glimpse of an Indian world", described areas of the Southeast "thickly

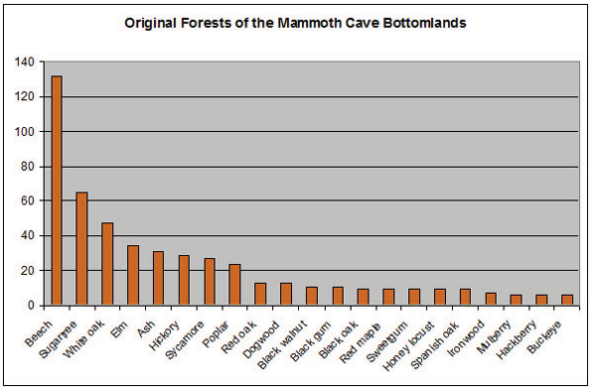


**Figure 2:** Original Forests of the Mammoth Cave Bottomlands. Fire-refugial beech and sugar maple – universally called "the sugartree" by early surveyors – dominated the deep hollows and bottomlands. Sugar maple supported a thriving cottage industry of maple sugar production for the first century, peaking at 34,000 pounds in the census year of 1840 (U.S. Censuses of Agriculture). Production thereafter declined decade by decade as bottomlands were cleared for farming and pasture and all of the old trees were eventually consumed by production of lumber and another cottage industry, sawed railroad ties that were shipped downstream (Warnell 2006).

**Table 1:** Presettlement Fire Regimes of the Mammoth Cave Region. Based on evidence from witness trees, topography and historical data, nine fire frequency classes could be distinguished at Mammoth Cave. These ranged from nearly annual fires in the vast flammable grasslands of the barrens, where a fire ignited several counties upwind to the southwest could potentially reach the Green River, to nearly fire-free pockets in deep hollows and on north facing slopes above the Green River firebreak. The last two columns show the calculated acreage in each fire frequency class in the park and an approximation of the mean annual acreage burned historically in each class.

| Fire Freq. Class | Mean Fire Interval Years | Historic Range of Variation | Description | Acres | Acres Burned Annually |
|---|---|---|---|---|---|
| A | 3 | 1-5 | Karst plain & other barrens | 1,226 | 408 |
| B | 4 | 2-6 | Prairie-woodland mosaic | 12,223 | 3,055 |
| C | 5 | 3-9 | Pyrophytic woodland & karst depression communities | 13,569 | 2,713 |
| D | 6 | 4-12 | Oak-hickory woodland | 11,128 | 1,854 |
| E | 8 | 5-20 | Understory fires in forest | 6,656 | 832 |
| F | 25 | 18-35+ | Light fires in hardwood litter, to almost no fire in sheltered mesophytic forest | 850 | 34 |
| G | Infrequent | Variable | Steep, variably sheltered hardwood slopes | 3,011 | n.a. |
| H | Sheltered | Variable | Rare light fires in hardwood litter in alluvial bottoms | 673 | n.a |
| I | 1-10 | Variable -Anthropogenic | Heavily influenced by nearby resident Indians | 1,158 | variable |
| | | | Total acres | 50,494 | 8,896 |

set with great towns". In 1682, more than a century later, LaSalle found the same areas deserted.

DeSoto visited the southern Cherokee villages and traveled west along a route to the south of the Cumberland River, as shown on the De L'Isle map of 1718, which includes Kentucky & Tennessee. The epic expedition provided opportunity to spread diseases throughout the region and it may be no coincidence that the Indians resident in Kentucky at the time, the Mississippian and Fort Ancient cultures, died out within the next century, 1540 to 1600, or 60 years in the case of the Mississippians, and 1540 to 1650, or 110 years for the Fort Ancient Indians).

Archeological knowledge of the Late Woodland period is still very sparse but sites from the Mississippian (the last culture in the Mammoth Cave region) and Fort Ancient and all earlier periods are scattered all across Kentucky (Lewis 1996). There is no reason why the second wave of explorers – French, then English – should have found an empty land other than it had been depopulated by diseases introduced 60 to 110 years before the last native cultures died out.

If elimination of the large food species was accomplished by the first wave of thinly distributed Paleoindian Clovis hunters, the increase in population density of later cultures with more highly evolved tools such as the bow and arrow, should have prevented the return of any large animals other than fast-breeding deer and small game. And yet bison returned from the

west. One explanation suggests that relief from hunting pressure occasioned by decimation of modern Indian populations by European diseases allowed expansion of bison into the East. And yet the radiocarbon dates of modern bison bones at Big Bone Lick indicate their return to Kentucky by at least 1450, nearly a century before the presumed plagues introduced by DeSoto (Tankersley 1985).

The return of bison before Columbus suggests the possibility of an earlier introduction of disease than usually supposed. This may not be unreasonable since there had been temporary settlements along the northeast coast in the 1300s by northern European fishermen and there has been speculation of undocumented early exploration of the lower Mississippi. Other fishing boats may have been carried away by storms to introduce disease to the New World but never to return. Any such incursion could have introduced an earlier wave of disease, reducing Indian populations in at least some areas, bringing about sufficient release of bison from hunting to allow some to expand into the East. This is speculation, but offers a reasonable explanation and should prompt further research into early contact with the western world.

Though little studied, the barrens of Kentucky and Tennessee likely formed at the same time as the "prairie peninsula", a woodland-forest-prairie mosaic that extended from Iowa east into Illinois, Indiana and Ohio (Transeau 1935). in the eastern U.S., peak post-glacial temperatures appear to have been reached during the Holocene Climatic Optimium or Hypsithermal period, some 4000-6000 years ago with temperatures perhaps 1 or 2 degrees C higher than at present. The warm peak should have occurred early in this period in the barrens area and moved to the Northeast with recession of the Laurentide ice sheet into Canada. Warmer temperature would have been accompanied by increased thunderstorm activity associated with the swirl of moisture that flows up from the Gulf of Mexico, the driver of lightning ignition regimes in the South and Midwest.

While Indian ignitions were dominant in specific regions (Frost 1998), they always occurred against a background of lightning ignitions and lightning is the ancient driver of fire regimes as well as the evolution of fire-dependent species, extending back hundreds of millions of years to the first evolution of land plants.

In the 1960s ecologists discovered fire, as E.V. Komarek published a pioneering series of articles in the Proceedings of the Tall Timbers Fire Ecology Conferences documenting the role of lightning in maintaining fire regimes in the South. In Florida in 1962 he tabulated 1146 lightning ignitions and 1048 in 1963 and that was only for some 2/3 of the counties reporting data (Komarek 1964). That rate should have been sufficient to fund a high fire frequency even with no contribution by Indians. Lightning alone, millions of years before North America saw its first human, would have accounted for evolution of the many fire dependent species of the South, including post oak and prairie coneflower found at Mammoth Cave.

Indian uses of fire have been well documented and some have theorized that since Indians used fire, Native American burning accounts for the presettlement fire regimes of the U.S. Others have extrapolated this idea far enough out on a limb to claim that the barrens and other eastern grasslands were created immediately before settlement in the 1700s, driven by Indian use of fire to promote habitat for buffalo so they could be hunted for skins to trade to the Europeans! Even rudimentary knowledge of the role of lightning ignitions, original fuels and the role of topography in regulating fire frequency renders this supposition insupportable.

1) Fire compartment size drives fire frequency regardless of whether Indians or lightning did the igniting. The barrens to the north and south of Mammoth Cave are comprised of thousand square mile compartments, originally covered with a mosaic of mid-grass and eastern tallgrass prairie, as well as grassy post oak savannas, all with flashy fuels, the ignitibility, flammability and fuel connectivity of which have no counterpart today. This explains why the thunderstorms of today rarely ignite wildfires and those that do rarely burn more than an acre, instead of tens of thousands of acres. The probability of ignition in a natural grass landscape is many times higher than in the modern mosaic of forest leaf litter, tilled fields and overgrazed pasture.

2) The natural fire flow stopped around 1830 as numbers of domestic livestock on open range approached saturation, eliminating grass fuel connectivity.

3) The historical dominance of the tree flora by fire dependent species such as post oak and blackjack, and the fire refugial distribution of fire sensitive trees such as beech and sugar maple on the original surveys refute any idea of recent creation. The distribution of dominant trees reported by the early surveyors could not have been produced by introducing fire 50, 100 or even 500 years before English settlement. None of the dominants were weedy species and even if planted by hand, carefully placing the beech seedlings in the hollows and the post oak, blackjack and mockernut hickory on the fire exposed upper slopes and ridges, it would take 300 years for the hypothetical forest to develop to the sizes reported at first settlement. Without meticulous human control a fire-mediated tree distribution should take thousands of years to develop under a natural fire regime whether Indians or lightning provided the ignition. Similarly, the species richness of the grass-forb layer, including many species endemic to southeastern prairies and savannas found in small remnants today would have required thousands of years for assembly.

The first French explorers and later Virginian and Carolinian long hunters found extensive grassland in the barrens and in the bluegrass region. It is striking that, even without Indians, the barrens were maintained in grass and largely free of trees for 240 years, from the time of DeSoto's passage and depopulation of Indians, until the land was opened for settlement in 1780. The Mississippian Indians were wiped out by 1600, within 60 years of the passage, removing any influence of resident Indians for at least 180 years before opening of the barrens to settlement. Indians undoubtedly added to fire frequency before their decimation but the fire regime that persisted follows a pattern compatible with lightning ignition, undisturbed grassy fuels and large fire compartment size, not dependent upon Indian ignition.

After depopulation the barrens were far removed from remnant bands of Indians—the Cherokee in the mountains of NC, the Shawnee in southern Ohio and the Chickasaw to the south in Tennessee and Alabama. Before the tribes obtained horses, just a short time before settlement, any long distance travel was by foot and there was no convenient way for overland transport of hundreds of pounds of meat from even a single buffalo. The Green River, called the Buffalo River by the French, provided the only route for canoe transport, leading west only to the towns of the Iroquois across the Ohio river from its mouth where buffalo were already conveniently located.

The maintenance for at least 180 years of vast areas of grassy barrens described by the first settlers cannot be ascribed to a small number of Indians on raiding expeditions or hypothetical seasonal hunters who traveled on foot to hunt big game that they could not transport and there is no evidence to support widespread

burning after extirpation of the resident tribes. That leaves the ancient lightning fire regime to explain the landscape found by the first explorers.

The settlers also used fire widely but the barrens fire regime collapsed with a few decades after settlement in spite of that.

### Lightning

Our ignorance of historical lightning ignition rates and of fire-maintained grasslands in the Southeast has been underscored by Reed Noss in his new book "Forgotten Grasslands" (2013). The Mammoth Cave region has a lightning strike density of 4-8 strikes per square kilometers per year (NOAA/National Weather Service). For Mammoth Cave, which occupies some 50,494 acres or 205 square kilometers, that gives 820-1640 lighting strikes per year. In the grassy landscape that surrounded and interpenetrated the park along the ridges south of the river, that should have been enough to produce abundant fire. The conditions that perpetuated the barrens after 1540 finally came to an end some 180 years ago, within five decades of settlement, when the original fire regimes died around 1830.

### Transformation

After 1779 the Virginia legislature appointed commissioners to determine the validity of claims for land on the frontier and by April 1780, the commissioners approved more than 1,300 settlements and preemption claims in Kentucky. This opened the door for the largest land rush in Kentucky history, the state was flooded by settlers, investors and land speculators. Henderson was the entry point for settlers coming up the Green River into the Mammoth Cave area and by November 1780 over 5000 claims had been entered in the surveyor's office at Wilson Station near what is now Henderson at the mouth of the Green River on the Ohio.

Settlers swarmed in, first establishing homesteads in the barrens, and along both sides of the Green River at Mammoth Cave, a region where Indians were seldom seen. While settlers were infiltrating these lands, colonists in the Bluegrass region to the north were engaged in an all-out, seven-year war for Kentucky, 1775-1782, a struggle with the Ohio Shawnee, the only tribe offering substantial resistance. At its height the Shawnee destroyed the corn crops and settlers faced starvation, whereupon, the native grazers, elk and bison, were extirpated (eaten) during a single decade, 1775-1785, leaving only a few survivors to persist for a few more years. The last confirmed reports of wild buffalo in the state came from Hart County not far from the park, where a few were seen going down to the Green River as late as 1820 (Kleber 1992).

Settlement initiated a cascade of land changes that extinguished the complex natural fire regime throughout Kentucky over a 50 year period 1780-1830. For the first three decades 1780-1810, settlers writing home reported an easy life, subsisting on game and livestock that thrived on huge tracts of open range grassland and woodland, supplemented by small plantations of corn (Loving 1812). After 1810 increasing population density drove the shift to increasing dependence on agriculture; travelers in the 1840s on the way to the "wilderness" of Mammoth Cave were at first disappointed with the thoroughly agricultural nature of the land between Bowling Green and the Dripping Springs.

Domestic livestock proliferated on open range, with sustainable numbers exceeded by around 1930, and severe oversaturation by 1850 (Figure 4). Fire flow was disrupted by roads and plowed fields but especially by saturation of the landscape by hordes of livestock which consumed the grass fuel required for fire spread. With the end of fire, post oak, blackjack, black oak

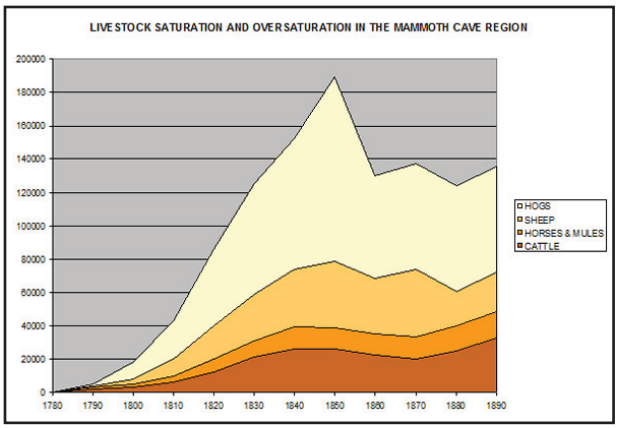


**Figure 3:** Livestock Saturation and Oversaturation at Mammoth Cave. Beginning in 1840 livestock were censused along with people. Prior to that we know that, with exception of an occasional party of long hunters with horses, or the rare backwoodsman who attempted to set up an early homestead in spite of Indians, there were essentially no domestic livestock in the region before 1780. The intervening decades up through 1830 are estimates. The picture is typical of the pattern of livestock introduction: Malthusian increase with unrestrained exploitation of open range, until reaching terminal supersaturation and subsequent dieback to a relatively stable asymptotic plateau. This picture is seen repeatedly throughout the South with the supersaturation peak reached in the 1700's in coastal Virginia, and coastal Alabama, 1840 in central Mississippi, Georgia and Alabama and 1850 in Kentucky and Tennessee. The rolling wave continued westward with the advancing frontier, peaking in the western Great Plains and midgrass prairie of Montana around 1905. At Mammoth Cave the original fire regime died around 1830 upon saturation of the landscape with sheep, hogs, horses, mules and cattle, eliminating grass fuels sufficient to carry fire. By 1847 travelers reported the former barrens becoming overgrown with brush and blackjack.

and other species of slightly fire sheltered side slopes in the barrens spread onto the uplands. Woody succession in the absence of fire was so far advanced by 1847 that one contemporary traveler noted "…the Barrens, formerly an extensive prairie,[are] now overgrown with a scrubby oak called Black Jack."

Over the 166 years since 1847, the landscape has been increasingly fragmented by roads, towns, fields and overgrazed pastures with insufficient grass fuel to carry fire, to the extent that fire will never again reassert itself without human intervention. While the original fire regime has been dead for at least 180 years and some of its component plants and animals such as elk and buffalo extirpated, many fire dependent species are still hanging on, along sunny roadsides and in the few places that have been burned. National Parks are among the few places where this heritage can be preserved, where fire can be reestablished in its natural role where future generations can see windows into the original landscapes, with their diversity of grassy prairies, flowery post oak savannas and all the plant, animal and bird species dependent upon them for survival.

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