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"Science affects the way we think together."
Lewis Thomas

Restoring a Disappearing Ecosystem: the Longleaf Pine Savanna

Tim Harrington

Field crew collect data from a study site in a longleaf pine plantation in South Carolina.

"In 'pine barrens' most of the day. Low, level, sandy tracts; the pines wide apart; the sunny spaces between full of beautiful abounding grasses, liatris, long, wand-like solidago, saw palmettos, etc., covering the ground in garden style. Here I sauntered in delightful freedom..."
—John Muir, 1867

The longleaf pine (*Pinus palustris*) was once one of the most abundant trees in the United States. Its realm—vast savannas shaped by thousands of years of frequent fires set by lightning and Native Americans—stretched across some 90 million acres of the American South, from the Carolinas to Texas. But when John Muir made his southeastern trek in 1867, the longleaf pine-wiregrass ecosystem he saw was already slipping away.

At least a century before, European settlement had gradually transformed the natural landscape. Land was cleared for cotton and other crops. As well, livestock grazing, urban development, fire suppression, and the naval stores industry which harvested pine resin to maintain the wooden ships of the day—took an ever-growing toll on the airy longleaf pine forests. Commercial logging, which began in the early 1700s, also drove the steep decline. So prized was *Pinus palustris* for its straight, honey-hued timber and its superior pitch and resin that forest botanist Roland Harper in 1928 claimed the longleaf had "probably more

IN SUMMARY

*Longleaf pine (*Pinus palustris*) savannas of the southeastern United States contain some of the world's most diverse plant communities, along with a unique complement of wildlife. Their traditionally open canopy structure and rich understory of grasses and herbs were critical to their vigor. However, a long history of land-use practices such as logging, farming, and fire exclusion have reduced this once-widespread ecosystem to only 3 percent of its original range.*

At six longleaf pine plantations in South Carolina, Tim Harrington with the Pacific Northwest Research Station and collaborators with the Southern Research Station used various treatments (including prescribed burns, tree thinning, and herbicide applications) to alter the forest structure and tracked how successful each one was in advancing savanna restoration over a 14-year period. They found that typical planting densities for wood production in plantations create dense understory shade that excludes many native herbaceous species important to savannas and associated wildlife. The scientists found that although tree thinning alone did not result in sustained gains, a combination of controlled burning, thinning, and herbicide treatments to reduce woody plants was an effective strategy for recovering the savanna ecosystem. The scientists also found that these efforts must be repeated periodically for enduring benefits.

uses than any other tree in North America, if not in the whole world."

When the Great Southern Lumber Company ran out of longleaf pine logs and shut down in 1938, foresters had already turned to cultivating other, faster growing types of trees. Today fewer than 2 million acres of longleaf pine savanna and their associated habitats (about 3 percent of the original expanse) survive. About half of this exists on public lands, mainly in southeastern coastal areas. These patches harbor nearly 200 types of birds (including listed species such as the red-cockaded woodpecker) and hundreds of other animal species. Mature longleaf pine savannas also contain some of the most diverse plant communities worldwide, with up to 40 species per square yard. "That's richer than most places in the American West," notes Tim Harrington, a research forester with the Pacific Northwest Research Station in Olympia, Washington.

In 1993, when Harrington was a professor at the University of Georgia, he began long-term research on strategies for restoring this unique ecosystem. His continuing work, with multiple collaborators, has led to significant insights about how a waning biological system might be brought back from decline, but also about its remarkable complexity.

BEGINNINGS IN A PLANTED FOREST SETTING

Restoring any ecosystem requires understanding the elements and structure that enable it to function and remain healthy. Historically, longleaf pine savannas had widely spaced trees of varying ages, from seedlings to centuries-old trees. The understory included a rich variety of herbs and grasses dominated by wiregrass and bluestem. These species depend on regular burning to stimulate flowering and seed production. They provide important food and cover for many birds, reptiles, and small mammals.

"Native grasses and longleaf pine perpetuated each other with the help of fire," Harrington explains. "Longleaf pine needles, up to 18 inches in length, fall as they mature and accumulate as a drape over the understory vegetation. Along with the native grasses, these 'flashy' fuels supported frequent, fast-moving fires that reduced woody vegetation and kept growing space open for wiregrass and new longleaf pine seedlings."

The ecosystem was well-adapted to the underlying soils, which evolved from ancient ocean beaches. "Grasses and nitrogen-fixing legumes kept the system in a relatively fertile state; without them longleaf pine growth can be stunted," he continues. "But tillage farming and fire suppression upset this balance and opened the way for hardwoods such as oaks, hickories, and black cherry to move in, along with the fire-intolerant loblolly pine." These changes led to closed-canopy stands intermingled with hardwoods and a tangled understory of woody shrubs and vines. The dense shade and deep accumulation of forest litter choked out plant species critical to the longleaf pine community. So, where to start in rebuilding a savanna composed of scattered trees and a rich herbaceous understory?

Harrington turned to the 200,000-acre Savannah River Site, a U.S. Department of Energy defense facility near Aiken, South Carolina, that also serves as a National Environmental Research Park and a setting for ecological research. "We set up study sites in longleaf pine plantations on former native savanna lands where loblolly pine had seeded in naturally and was harvested in the 1980s," Harrington says.

"Plantations such as these have successfully produced fiber and wood, but restoring the savanna demands different practices," he explains. For example, tree-farming operations use machines to prepare the soil and plant straight rows of seedlings at densities often exceeding 600 trees per acre. "In the past,

Tim Harrington

Hardwoods and shrubs often crowd the understory of young longleaf pine plantations.

KEY FINDINGS

- Thinning 8- to 11-year-old pine plantations to about 250 trees per acre (half their original planting density) increased the diversity of herbaceous plants by six to eight species and expanded their coverage by 13 to 22 percent for up to 8 years. However, these increases were nearly undetectable by year 14 because of increasing shade and root competition from overstory pines and understory shrubs and hardwoods.
- When hardwood and shrub densities were reduced with herbicide treatments, increases in herbaceous plant diversity and cover were still evident 14 years after treatment.
- A combined treatment of pine thinning and herbicides to control woody plants led to the largest and most prolonged increases in the abundance and diversity of birds. Small mammal populations increased with either pine thinning or woody plant control; the beneficial effects from thinning lasted 5 to 7 years after treatment.

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mortality of newly planted pine seedlings could approach 50 percent, but today's survival rates are much higher, leading to tree densities up to 500 per acre. That's about 10 times the levels on historical longleaf pine savannas," he continues. This crowding hastens the canopy closure that deprives savanna understory species of sun and gives a competitive edge to shade-tolerating woody shrubs and hardwoods.

Harrington and his colleagues wanted to better understand the key processes limiting the abundance and diversity of herbaceous understory plants important to the savanna community and how management techniques could intervene to restore the ecosystem. Between 1994 and 2008, the researchers experimented with methods for manipulating the canopy layers of the forest and tracked how successful each one was in advancing restoration.

Robert Simmons

For this study, prescribed fire was applied every 3 to 5 years to control growth of woody vegetation other than pine and reduce accumulations of needlefall, which prevents growth of herbaceous vegetation.

THE STANDS, THE PLANTS, AND THE STRATEGIES

"We had three basic research questions," Harrington explains. "Given periodic applications of prescribed fire, first, how did pine thinning influence the abundances of hardwoods and shrubs? Second, to what degree did herbicide treatments reduce these target plant groups, and how long did the effect last? And, third, how did these changes in the plant community impact the diversity and numbers of herbaceous species?"

The six selected study sites had dense stands of 8- to 11-year-old longleaf pines interspersed with many hardwoods. To set the stage for the experiments, a prescribed burn took place in 1994 (and again in 1998 and 2003) to reduce woody plants and encourage the fire-dependent germination of seeds from desirable herbaceous species.

Each site was divided into four treatment plots of roughly 7 to 17 acres to enable tracking of the responses of plant and animal species. In one-fourth (6) of the plots, no other interventions besides burning occurred. In a second group, about half of the longleaf pines were thinned manually, to achieve uniform spacing of about 250 trees per acre. In the third group of plots, workers applied several herbicide treatments to eliminate (as much as possible) nonpine woody vegetation such as vines, shrubs, and hardwoods. The fourth set of the plots received a combination of thinning and herbicide treatments.

At the outset of the study, the researchers carried out baseline surveys of the plants present on the plots. "The understory included about 265 herb and woody species, with the coverage of each group being roughly equal," Harrington says. "Surprisingly, many of the most common savanna species were still there—but often at surprisingly low abundances."

"After 3 years, the canopy had expanded significantly over the plots where only moderate thinning had occurred, and the developing shade gradually reduced the understory plant cover. In general, the abundance of herbs corresponded to the level of thinning around any given plot," Harrington says.

Further investigations on the effects of canopy shading and root competition revealed more detailed impacts on plant processes of about 20 different understory species, such as flowering, seed production, and seed viability. "In one case, an herbaceous species produced more seeds where all pines had been removed, but the seeds had reduced viability," Harrington notes. "More than anything else, our studies demonstrated just how dynamic the system was, with all the different life histories of the different species playing out and interacting within the changing environment."

Tim Harrington

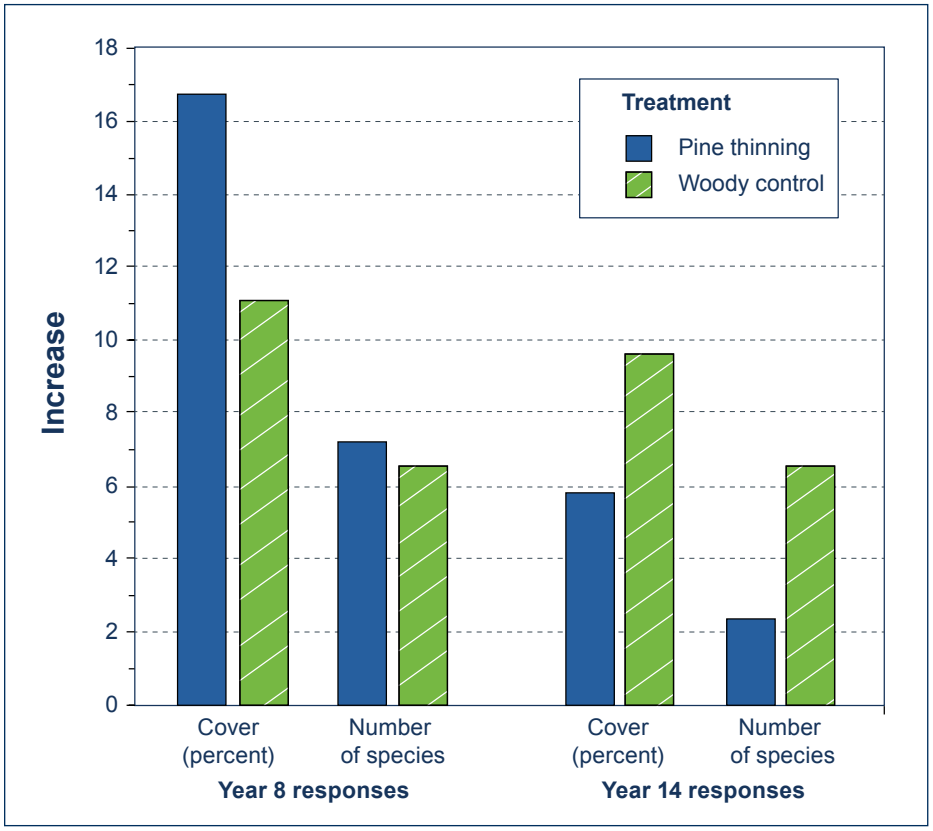
A forestry technician estimates cover and species composition of the understory vegetation.

MORE SUN ISN'T ENOUGH

The vegetation measurements following years 5, 8, and 14 showed that in plots that were thinned, the diversity of herbaceous plants increased by six to eight species and overall herbaceous cover rose by 13 to 22 percent. Although these gains lasted up to 8 years, by year 14, they were nearly undetectable, and by the study's end, there was little difference between these once-thinned plots and the nonthinned ones.

"Reducing the density of the pines without using herbicides gives the woody shrubs and hardwoods a big advantage; opening up the canopy provides more sun exposure and allows them to explode in growth, so the understory herbs eventually lose out," Harrington says. "In fact, herb species on these plots actually dipped below their starting numbers by year 14, underscoring how detrimental shade is for them." However, in plots that were thinned and treated with herbicides, the diversity and total area covered by herbs increased and held throughout the 14-year period because of sustained cutbacks in woody encroachment.

There were parallel findings with respect to wildlife. In separate research carried out by University of Georgia professor Karl V. Miller from 1996 to 2003, the diversity of birds, small mammals, amphibians and reptiles on the study sites was tallied and rechecked annually. Preliminary analyses indicate that either thinning or woody control increased the abundance and diversity of songbirds, including several Neotropical migrants, for about 2 years—an effect that quickly waned and disappeared by year 8. When treatments were combined, modest increases in the abundance and diversity of bird populations were prolonged, persisting up to 7 years after the treatments.



Increases in cover and number of herbaceous species 8 and 14 years after pine thinning and non-pine woody control. By year 14, the gains had diminished in thinned plots.

Similar patterns for small mammals such as shrews, mice, and voles also were observed. "The gains were due in part to a higher abundance of coarse woody debris left on the ground, compared to unthinned areas, and to the greater plant species richness in these stands," Miller says. However, benefits due to thinning lasted only 5 to 7 years after treatment because by then the tree cover had returned to pretreatment levels. For amphibians and reptiles, there appeared to be no changes related to the treatments.

Tim Harrington

Different management treatments led to very different understory conditions 17 years into the study. The study site on the left received periodic burning. The study site on the right received periodic burning plus pine thinning and non-pine woody control in years 1 and 2, respectively, of the study.

FACILITATING SAVANNA RESTORATION

The findings point to two possible strategies for managing longleaf pine plantations to facilitate savanna restoration. Thinning pines and hardwoods at an early stage of development and again later when the canopy has expanded to cover more than half the stand area may provide a reasonable compromise between production of wood products and savanna restoration, in Harrington's view.

An alternative approach would employ a combination of treatments. Fewer seedlings would be planted in the first place followed by periodic burning, more aggressive thinning, herbicide control of woody vegetation, and even planting of selected savanna species. "These steps are important to transform a currently fire-resistant ecosystem into one that perpetuates and is perpetuated by frequent, low-intensity fires. But regardless of the management system, the dynamic canopy development of young pine and hardwood stands is likely to necessitate repeated treatments of pine thinning, woody control, and prescribed fire to fully restore and maintain a vigorous herbaceous community," explains Harrington.

John Blake is the assistant manager for Forest Service supported research at the Savannah River Site where Harrington's experiments are installed: "Tim's work has helped to refocus managers and researchers on the critical importance of overstory density management and the impacts of woody plants in the understory as major constraints on restoration of native savanna grasses and forbs. Prior to his studies, the prevailing paradigm was that one just needed to burn these stands periodically. Prescribed fire is just one tool in the tool box for restoration of longleaf pine savannas."

Blake also notes that the study results have prompted significant changes in silvicultural management within areas targeted for savanna restoration, and they have challenged stocking levels in the recovery standard for the endangered red-cockaded woodpecker.

"Longleaf pine seedlings are now generally planted at lower densities (<500 trees per acre), which delays or prevents crown closure and associated loss of herbaceous species. On existing pine plantations, more vigorous thinning to lower densities is occurring to promote establishment of herbaceous plants critical to wildlife habitat. And the value of reducing or eliminating woody shrubs and hardwoods in recovery of the savanna community is recognized," explains Blake.

The next phase of the study is now underway. Another round of thinning (2012) and prescribed burning (2013) was carried out on the six study sites to see if these treatments will re-stimulate increases in the diversity and cover of herbaceous species.

LAND MANAGEMENT IMPLICATIONS

- Planting longleaf pines is essential in savanna restoration, however; typical plantation densities (>600 trees per acre) create excessive shade and root competition for herbaceous plants, reducing their abundance and species diversity. This in turn diminishes wildlife habitat, resulting in fewer birds and small mammals.
- Active management to regulate the density of overstory pines and limit abundance of other woody plants with appropriate use of prescribed fire and herbicides will accelerate development of a savanna community structure composed of widely spaced pines and a vigorous and diverse understory of herbaceous species.
- Woody debris created by the pine thinning provided an important habitat feature for several reptile and amphibian species. The debris facilitated travel by the small vertebrates through the dense thickets of vegetation that developed in the absence of natural or prescribed fire.
- More birds were observed in pine stands that received combined thinning and woody control treatments, creating open canopies similar to those of mature longleaf pine forest maintained by frequent low-intensity fires.

"What thrills me most about the longleaf is how the pine trees sing. Even in the fragments you can hear music. Horizontal limbs of flattened crowns hold the wind as if they are vessels, singing bowls, and stir in them like a whistling kettle. "

—Janisse Ray, "Ecology of a Cracker Childhood"

FOR FURTHER READING

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