

Dendrochronology in National Parks: A Mammoth Cave Case Study

By Paul R. Sheppard, Edward R. Cook, and Gordon C. Jacoby

The science called dendrochronology – the study of the past using tree rings – depends on old trees for data. Variation in annual tree-rings represents information about the past that is otherwise difficult to obtain. Rising concern about global environmental changes makes tree-ring information even more valuable. In view of tendencies to cut large, old trees and in view of the significant information they contain, we support the designation of natural areas (such as in National Parks) that specifically mandate the preservation of old-growth forests.

Dendrochronologists are interested in the patterns of relatively wide and narrow rings (or other varying ring features), which result mostly from the influence of yearly climatic variation. Analysis begins with the crossdating of tree rings, wherein the goal is to assign an exact year date to every ring of every tree sampled within a site. By matching patterns across several trees, we can account for growth anomalies (missing or false rings). Each series is then measured to the nearest 0.01 mm. The ring-width series, which exhibit both standwide and individual variation, are detrended into relative index series by any of various standardization techniques. All index series thus have a stationary mean and variance and are finally merged into a single mean-value index chronology.

For dendroclimatology, the indices are then correlated with meteorological data – a process called climate modelling – which discovers what monthly climate indicators (total precipitation and average temperature) account for the most tree-ring variation. Once a model is developed and verified, it is extrapolated back through the entire length of the tree-ring data, which may span several hundred years. This provides information about long-term variations that aids our understanding of general climate trends.

An important dendrochronological tree species in North America is white oak (*Quercus alba*). Though growing in mesic, closed-canopy stands, oak still displays yearly tree-ring variation (enabling crossdating), and correlation of that variation to meteorological data is sufficiently high for successful climate modelling. Because of its large range, oak provides the added attraction of climate modelling by region as well as through time. Wisconsin's oak probably responds to its climate differently than does Georgia's oak; spatially differing climate responses offer insights into how and when oak expanded to its large range throughout the Holocene.

Among the many oak chronologies constructed at the Tree-Ring Laboratory of Lamont-Doherty Geological Observatory is one from Mammoth Cave National Park, Kentucky. While this park's main resource is underground, it also has a substantial old-growth forest resource. After coring trees, crossdating cores, measuring rings, and constructing the standardized chronology (Fig. 1, top), we correlated the indices to Bowling Green, KY, meteorological data from 1889 to 1985. This analysis used a 17-month "dendroclimatic year," including the previous May through December and the current January through September. This incorporated the biological persistence phenomenon in trees, whereby one year's ring width is determined partly from the previous year's climate in addition to that of the current year. A result of this particular analysis is that Mammoth Cave oak grows best with

a strong June rainfall and a cool summer (June through August) (Fig. 2). In such years, early season water availability is high and seasonal evapotranspiration is low.

Continuing the climate modelling, the Mammoth Cave chronology was merged with six other oak chronologies from the central states. Meteorological data from pertinent locations were also merged and then converted into a single series of Palmer Drought Severity Index (PDSI), which integrates recent past climatic trends plus soil characteristics into values of moisture deficiency or excess (Palmer, W.C., "Meteorological Drought," U.S. Dept. Commerce Res. Pap. 45 [1965]). After constructing, calibrating, and verifying the relationship of tree-ring indices to PDSI, a long series was reconstructed for the region (Fig. 1, bottom); periodicity of severe droughts can be estimated from this reconstruction.

Another interesting species is northern white-cedar (*Thuja occidentalis*). Unlike oak, little of the white-cedar range has been sampled; nonetheless, this lab's only white-cedar chronology, from Gaspe' Peninsula, Canada, shows a peculiar "ramp" of increasing growth for the last 140 years (Fig. 3). Short-term departures from the mean of 1 and from a homogeneous variance, such as from about 1850 to present, warrant special attention. Does that "ramp" of increasing indices indicate climate change lasting 140 years? Or is it that something non-climatic is affecting white-cedar growth in Gaspe' Peninsula? Hypotheses exist about possible causes of such a trend, but since only one white-cedar chronology exists, other basic questions remain. Do stands of white-cedar from other areas show similar growth increases? Are their climate response models similar? Also, do other species in Gaspe' Peninsula show similar trends? Because we have no other white-cedar chronologies (we are currently analyzing cores from two other sites), these basic questions cannot be answered yet.

In addition to climatology, tree-ring analysis has many other scientific applications. Biological (fire or insect) and physical (earthquake or volcano) distur-

bance histories have been developed from tree rings. Even trace metal chronologies have been developed from tree-ring analysis to study air quality trends. Furthermore, many ancient structures of the southwestern archaeological parks have been precisely dated using dendrochronology.

Managers of some natural areas deny permission to sample old trees because of concern about the effects of coring. Such concern is valid, and we attempt to demonstrate that the effects of coring on tree vigor are negligible. First, Alex Shigo ("Wounded Forests, Starving Trees," *Journal of Forestry* 83(11):668-73 [1985]) showed that trees defend themselves by compartmentalizing, or isolating, a wound, thereby preventing pathogens from attacking healthy tissue. As long as a tree is not girdled (we usually extract just two cores per tree), the tree loses only a small proportion of its storage and translocation tissue around the wound. Long-lived species appear to compartmentalize better than others, and while there is some dendroecological interest in short-lived species, we depend mostly on long-lived species.

Second, by returning to sites cored in the past, we are collecting evidence about the effects of coring. For example, we recently re-cored a site of eastern hemlock (*Tsuga canadensis*) for the purpose of updating a chronology constructed in 1974. During the re-coring, the original core holes were indistinguishable because they had filled in with sap and healed over with callus tissue and bark. The only trees with rot were two that originally showed it in 1974. Furthermore, ring-width patterns showed no departures from pre-1974 growth rates that might indicate decline as a result of coring.

Third, old trees have proven their vigor by surviving for hundreds of years. Throughout their lives they have probably been mechanically injured by such disturbances as wind, landslide, avalanche, lightning, fire, scraping from other trees, or even self-pruning. Cut stumps of old trees often display many such wounds that apparently did not affect their longevity. Compared to this disturbance history, a 5-mm diameter core hole is probably negligible.

Nonetheless, we still consider the concern about coring to be valid, so we often consult with natural areas managers about which trees may be sampled and which to avoid, about reducing impact on other

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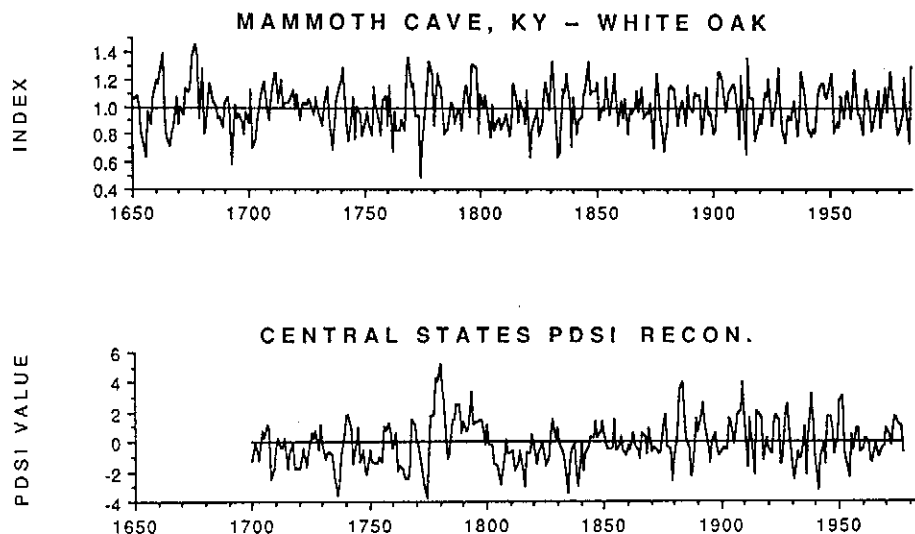


Figure 1. (top) Mammoth Cave NP, KY, white oak tree-ring chronology. (bottom) Central states PDSI reconstruction, based on seven white oak chronologies, including Mammoth Cave.

Relocation Preferred Option to Save Hatteras Lighthouse

By Jim Wood

After a nine month study requested by the National Park Service, an expert committee of the National Research Council has determined that moving the Cape Hatteras Lighthouse about 500 feet southwest of its present location is the best way to save the historic structure.

Relocating the lighthouse away from the shoreline, where erosion threatens to topple the landmark, was deemed to be cheaper in the long run and less likely to damage the century-old beacon than other alternatives, such as building a seawall and revetment around its base or constructing offshore breakwaters and groins in an attempt to halt the erosion.

The 200-foot-tall lighthouse has been standing watch over North Carolina's Outer Banks since 1870, warning ships to steer clear of the treacherous Diamond Shoals — the so-called "Graveyard of the Atlantic," where at least 600 ships have been lost.

Over the years, storms and powerful ocean currents have gradually eroded the eastern shoreline of Hatteras, transporting beach sand to its southern shores in a natural process that's causing the Atlantic barrier islands to migrate westward. At the time of its construction, the lighthouse was approximately a quarter of a mile from the water's edge. Today this cushion has been reduced to a scant 50 yards, and experts say it's only a matter of time before waves undermine the structure and topple it into the sea. A hurricane could wipe it out at any time.

The NPS had asked the Research Council committee in July 1987 to evaluate alternative ways to save the structure. The committee was not asked whether the lighthouse should be saved, but was asked only to determine the best options for preserving it. The Council, an operating arm of the National Academies of Science and Engineering, estimated moving the lighthouse would cost about \$4.6 million and take nearly a year, including planning and site preparation. The actual move will take about three months.

The 2,800-ton tower could be moved safely with proper bracing and engineering techniques, according to the committee. First, the external structure would be strengthened and reinforced as an integral unit by vertical and circumferential prestressing, using concrete tie beams with prestressed rods and tendons. Next, the foundation of the lighthouse would be tun-

neled for insertion of a series of needle beams. The lighthouse (minus part of its below-surface foundation and the timber mat) would then be vertically raised by hydraulic jacks to clear the below-surface foundation that remained.

The lighthouse would be lowered onto rollers that rest on multiple horizontal steel-rail beams supported by precast concrete piles. The entire lighthouse structure would be moved on the tracks with hydraulic jacks and slowly pulled with winches to its new site, where it would be placed on a newly-constructed foundation, such as a pile-supported concrete mat. The Keeper's Quarters and other buildings in the complex would also be moved (using standard housemoving techniques) and placed in the same proximity to the lighthouse.

Because the lighthouse may have to be moved again in 25 to 100 years to escape additional beach-front erosion, the committee proposed that the lifting beams be left in place to facilitate future relocation. Such "multi-stage" relocation would be a "flexible response to a dynamic problem," the committee said. With this foundation in place, a second move would cost about \$1.6 million in 1988 dollars, the committee projected.

Building a seawall would cost at least \$5.6 million by Army Corps of Engineers estimates. During the year-long construction process, the lighthouse would be particularly vulnerable to risk from storms. The seawall option also conflicts with many national, state, and NPS policies. Moreover, the wall would obscure much of the lighthouse itself, while continued erosion would eventually separate the lighthouse from the mainland and effectively foreclose future preservation options, the report says.

Rebuilding the existing groinfields and providing a protective underground casing or revetment to prevent undermining of the lighthouse would take less than a year and cost from \$4.7 to \$6.7 million. While it would protect the lighthouse for 20-30 years (barring a disastrous storm), the committee said, it would be difficult, if not impossible, to maintain a protective beach in front of the lighthouse indefinitely. The revetment casing would make future relocation difficult and expensive and also conflicts with relevant public policies, it noted.

The committee considered other options, as well, but rejected them after preliminary study showed them to be even more unsuitable than the seawall or groin-field options.

Because of the intense public interest in preserving the lighthouse, a new Park Service document evaluating these options is scheduled to be released for public comment this fall. The alternatives will be (1) moving the lighthouse to one of several possible sites, (2) building the seawall and revetment, or (3) a combination of a smaller revetment and improvements to the existing groins.

(Wood is a Technical Publications Writer/Editor with the NPS Southeast Regional Office, Atlanta, Georgia.)

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projects, and about eliminating impacts on visitor use and esthetic quality. We also report about the dendrochronology of specific sites to area managers; in addition, we provide base-line data, and our reports have been the bases for occasional interpretive features on the history of the trees.

Such interpretation could help visitors realize the scientific value in addition to the esthetic appeal of old trees. Most National Parks are noted for scenic

grandeur and wildlife values; the preservation of old growth forests is an important mandate in many of these same parks. Because of these natural areas of old-growth forests, we have often looked to the National Park System for tree-ring sampling sites; our Mammoth Cave case study encourages us to continue that relationship.

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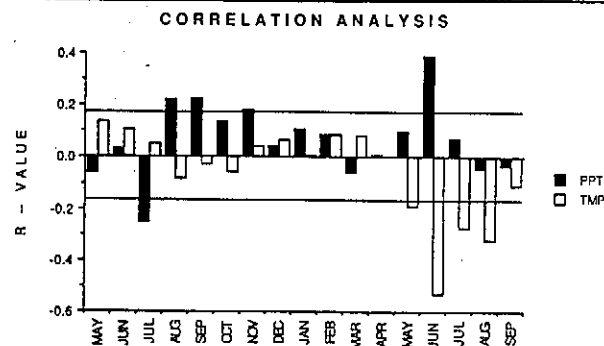


Figure 2. Correlation analysis of Mammoth Cave white oak tree-ring indices and monthly climate variables (dark bars show total precipitation and light bars show average temperature from Bowling Green, KY. All correlations beyond the reference lines are significant to the 0.10 level.

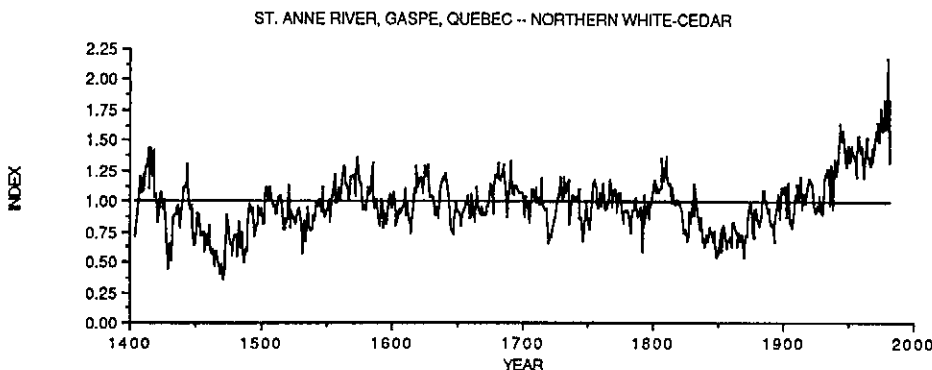


Figure 3. Northern white-cedar tree-ring chronology from Gaspe Peninsula, Canada. Notice the trend of increasing growth since 1850.