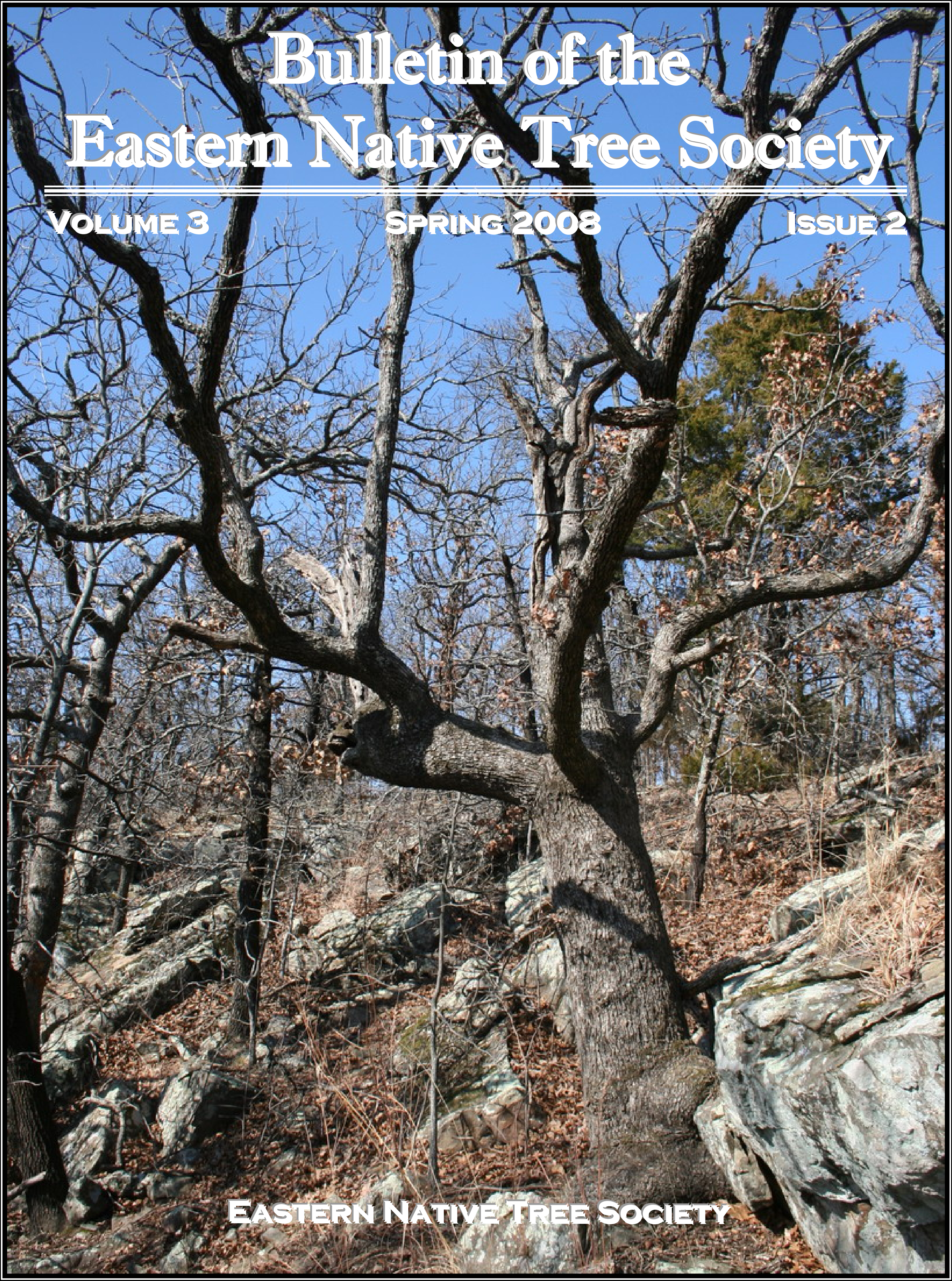
Bulletin of the Eastern Native Tree Society

Volume 3 Spring 2008 Issue 2



Eastern Native Tree Society

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Mission Statement:

The Eastern Native Tree Society (ENTS) is a cyberspace interest group devoted to the celebration of trees of eastern North America through art, poetry, music, mythology, science, medicine, and woodcrafts. ENTS is also intended as an archive for information on specific trees and stands of trees, and ENTS will store data on accurately measured trees for historical documentation, scientific research, and to resolve big tree disputes.

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Membership and Website Submissions:

Membership is free when you sign up for our discussion group, ENTSTrees, at: http://groups.google.com/group/entstrees?hl=en. Submissions to the ENTS website in terms of information, art, etc., should be made to Edward Frank at: ed_frank@hotmail.com

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COVER: Old-growth Cross Timber forests of post oak, blackjack oak, and scattered eastern redcedar dominate many of the steep, rocky, almost inaccessible bluff lines along the Canadian River near Henryetta, Oklahoma. These relicts contain many ancient trees, some of which exceed 500 years old, which are considerable scientific value. Photo by Don C. Bragg.

TABLE OF CONTENTS

AHHH, SPRINGTIME!

This issue of the *Bulletin* is, unfortunately, late. To that, I assign the blame solely to myself—I let the business of this time of the year, coupled with some nice weather, get the best of me. However, given how so much of the eastern US was (until recently) languishing through what has undoubtedly been one of the longest and harshest winters in recent memory, I can assuage myself of some of the guilt knowing that many of you have just begun to experience your spring, so this Spring Issue is still timely.

Springtime in the South is the most volatile time of the year, with beautiful, clear, low-humidity days often punctuated by extended periods of severe weather and heavy rain. Last year, during early April, we had a hard frost all the way across the state of Arkansas—an unremarkable event in my home state of Wisconsin during that month, but highly unusual for Arkansas. This particular frost event wiped out virtually the entire fruit crop in the state. A heavy March snowstorm this year damaged young pine plantations across much of the state, tornadoes in February, April, and May flattening timber and destroyed homes, while lengthy bouts of heavy rain have led to extensive flooding in the river bottoms across much of the Mississippi River Valley. Undoubtedly, baldcypress and tupelo gum stands that we easily explored as late as last winter due to their lack of moisture are now filled with many feet of floodwater. Fortunately, our natural ecosystems are far more robust in severe weather than we are—thank goodness!

Don C. Bragg
Editor-in-Chief

*This large, old stand of yellow-barked ponderosa pines in the background overlooks the early "responders" to a wildfire creating this opening. Such openings with sunny southern exposures are thought to be ideal for incubating future regenerating pine seedlings and saplings. As the older stand passes with time, the opening will likely fill with another even-aged island of yellow-barked giants. At increasing spatial scales, the structural diversity trends toward multi-aged, reflecting the variation due to fire mosaics***. Photo by Don Bertolette.**

ANNOUNCEMENTS AND SOCIETY ACTIONS

2008 Tri-State Forest Stewardship Conference

I left St. Louis on March 7, 2008, to drive up to the Tri-State Forest Stewardship Conference. Along the way I saw a few trees that I noted of good size. I also saw several trees that seemed to "welcome me" to the state of Iowa. Unfortunately, I did not have time to stop as I need to get to Iowa City to meet my niece who is a student at the University of Iowa. She mentioned to me that she was sick and tired of the snow and how the wind blows in town—I thought that was a little odd coming from someone who grew up in Chicago. After taking my niece out to dinner, I drove on to Dubuque to spend the night.

This year's Tri-State Forest Stewardship Conference was held March 8, 2008, at Sinsinawa Mound Center in Sinsinawa, Wisconsin. The conference opened up at 8:00 a.m. with breakfast and a chance to mingle with the exhibitors and other conference-goers. At 9:00 a.m., all 200 to 300 people attending went to the auditorium for a welcome and conference orientation by Peggy Compton. Door prizes were also handed out at this time, ranging from coffee mug to a pound of hazelnuts to 25 Jump Start Treeshelters to a chainsaw, to mention a few.

Around 9:30 a.m. the keynote speaker, Amy Yambor (operations manager for The American Forest Foundation's Tree Farm System), talked about what they were doing to ensure the future of private forests. After the keynote speech we broke up into smaller groups for the four one-hour sessions. Each session had five choices of topics. I elected to go to "GPS on the Back 40" by Steve Jungst, Harmon Family Professor, Department of Natural Resource Ecology and Management at Iowa State University during the first session. I found this to be interesting as Mr. Jungst not only talked about GPS but also GIS. He explained how GPS works and the difference between "recreational grade" and "mapping grade" units (quotation marks are his emphasis). He also had a handout of websites for hardware and software. I had started to map our farm with my GPS receiver that I had bought and now after attending this session I found out that I need to buy another GPS receiver to make my project easier. Just my luck! The topics that I did not go to were tree planting basics, control measures for woodland invasive plants, protecting working forests through local public policy, chainsaw use: directional tree felling, and forest management practices to improve wildlife habitat.

For the second session I attended basic tree identification. I figured a review couldn't hurt and I still don't know everything. This session was given by Mark Vitosh, District Forester, Iowa DNR, Iowa City. He had three handouts and even if they were designed with Iowa in mind, they did cover the two states involved with the conference, Illinois and Wisconsin. He also dealt with broadleaf trees and did not cover evergreens. I did find this to a nice review. The other topics offered were tree diseases, saving the American chestnut and butternut trees, forestry and the farm bill, chainsaw use and storm damage removal, and the potential for wood waste in the bio-economy craze.

Lunch followed this second session, and since this conference site was out in the countryside, the sisters that own the place served us lunch. We had a choice of turkey or vegetable lasagna—it was served buffet style and was absolutely the best turkey and dressing that I have had in a long time.

The third session began about 2:30 p.m. and I went to Illinois forestry development act given by Wade Conn, Forest Stewardship Program Manager, Illinois DNR. There were three handouts here, too. I got the least amount from this session as I did from any other session. I didn't realize at the time I signed up for this talk that it was about a program that has already turned down our farm because we pasture cows in the only area that we want to harvest any trees from. This program requires a landowner to have "at least 5 ac of land on which timber is produced." We do own an area of about 7 ac of woods but they have never been harvested as far as we can tell and do not want to harvest any from there. The other subjects this session were quality hunting ecology-landowners and hunters working together, forest and woodland cost share opportunities in Iowa, Wisconsin's private forest landowner programs and incentives, Lyme disease: a physician's perspective, and restoration and management of habitat for reptiles and amphibians.

The last session choices were marketing your timber to meet your goals, management of pests, bugs and the emerald ash borer for the tri-state area, forest carbon basics: a simplified look at a complex process, management considerations for quail, safe and effective use of herbicides, and the one I choose, deer damage and tree protection aids. Steve Bertjens, coordinator, Southwest Badger Resource Conservation & Development, USDA-NRCS, Lancaster, Wisconsin, covered the status of the deer population in Wisconsin, tree shelters/shrub shelters, bud caps, repellents, and fencing. He told us that the deer population in Wisconsin has gone up by roughly 400% since 1960. He then proceeded to go over the pros and cons and prices for tree shelters, including "bud caps." I was surprised that just placing an envelope over the bud cap of an evergreen would stop the deer from browsing.

--Report submitted by Beth Koebel

MODELING TREE TRUNKS: APPROACHES AND FORMULAE

Robert T. Leverett,[1] Will Blozan,[2] and Gary A. Beluzo[3]

[1] Executive Director, Eastern Native Tree Society; [2] President, Eastern Native Tree Society; and [3] Professor of Environmental Science, Holyoke Community College, Holyoke, MA

INTRODUCTION

One of the most numerically intensive activities that ENTS engages in is the volumetric modeling of the trunks and limbs of trees. On the surface, trunk modeling sounds duplicative of forest mensuration, but on closer examination, we will see that it is not. Forest mensuration deals with calculating, in board feet, the commercial portion of tree trunks. Trunks are typically divided by foresters into log lengths of 8 and 16 ft and the logs are modeled using well-behaved geometric solids such as cylinders, cones, paraboloids, and neiloids. Forestry has long known how to model the trunks of conifers and hardwoods that are grown in close proximity to one another so that the trunks are limb-free. Forestry is generally unconcerned with the non-trunk parts of trees, the part of the bole that threads its way through the upper limb structure, and of open-grown tree forms that branch low to the ground. Consequently, as applied to tree trunks, forest mensuration is highly specialized. In contrast, the whole tree is the domain of ENTS and the new discipline of dendromorphometry, the art and science of measuring trees in the field is being developed around unconventional tree measurements.

One of the key missions that ENTS has defined for itself is the modeling of trunks and limb structures of trees for three important purposes. Those purposes are: (1) to fill in a piece of the historical record on how large different species of trees can grow, (2) to gain a better understanding of how trees organize the wood held in their trunks and limbs, and (3) obtain detailed information on specific trees. Purposes (1) and (3) occupy our time now. Gaining insights into how trees apportion their volume between trunk and limbs and which geometric shapes best mirror portions of the trunk from base to top increasingly will occupy our time. We currently have a wealth of observational experience. For example, we recognize that old-growth eastern hemlocks develop paraboloid-like shapes more than do old-growth eastern white pines, and the paraboloid form of hemlocks increases with age. We notice that tuliptrees retain a main trunk with their highest point over the base well into maturity. However, the tips of the highest twigs of the northern red oak can easily be offset 10 to 30 ft from the vertical projection of the trunk above the base. In actuality, there will likely always be a list of specialized species structures that we will need to examine.

With the ENTS modeling mission noted, we will now turn our attention to the mechanics of modeling trunks. Limb modeling will be the subject of a future article. How do we go about measuring the amount of space that a tree trunk takes up? What level of accuracy can we achieve in our measurements and how can we know that a postulated level of accuracy is real? These are but two of the questions that concern us. Answers to the accuracy questions are still forth-coming. We are currently operating more on faith than a statistical probability. Short of cutting a tree down, sectioning it, and measuring the water displace-ment volume of the sections, we can only approximate the true volume of a tree trunk. Nonetheless, there are methods to us to calculate volume to what we believe is acceptable degree of accuracy. We will now turn our attention to the computation of trunk volume by the use of common geometric models.

APPROACHES TO TRUNK MODELING

There is no single best method or protocol for measuring the volume of the trunk of a tree. There are tools which if applied carefully should give us good, acceptable estimates of the water displacement volume of the trunks of trees. The challenge of the measurer is to understand each tool and to judiciously apply it. The simplest way is to approach modeling by using a well-behaved geometric solid such as a cylinder, cone, paraboloid, or neiloid and attempt to fit the entire trunk or most of it. This approach needs only one or two formulae to calculate the volume of the entire trunk. How good is this simplest of approaches? Not very. Actual experience teaches us that tree trunks change shape, or more appropriately, curvature multiple times from base to top. It is not uncommon to see the base of a tree as neiloid in shape for 3 to 10 ft. This neiloid shape then changes to a cylinder or paraboloid for perhaps several tens of feet and then to a cone for the remaining distance. This approach to modeling requires the application of no less than three separate geometric solids (Figure 1).

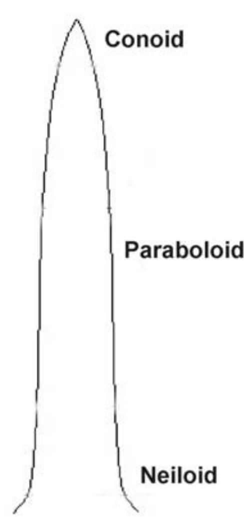

Figure 1. An idealized tree trunk comprised of three geometric solids.

If the above profile represents a typical tree trunk, to do an acceptable job of modeling we would need at least three forms, the neiloid, going to cylinder or paraboloid, and finally to a cone. However, many trunks do not exhibit this idealized form, so we need not feel wedded to it. For many conifers, we can start simply by applying a single solid to establish maximum and minimum volumes. This max-min approach seeks to “box” in the trunk volume. If the lower and upper limits are sufficiently close together, we might then average them as an acceptable approximation. But, we must accept that the one form approach is an approximation. For real accuracy, we need to divide the trunk into a number of sections, with each section not exceeding 10 ft. The individual sections are treated as the frustums of geometric solids. If the sections are no more than a yard or meter in height, then the frustums can all be conical.

Whether one section or many, calculating actual volume requires that we measure length and cross-sectional area. Length is straightforward—linear distance between top and bottom of section. However, the cross-sectional area provides us with more of a challenge. For simplicity’s sake, we usually assume cross-section to be circular, even though there is almost always a deviation from the round. Going with the circle virtually guarantees that we overstate the actual volume by a little and in some cases a substantial amount. We can accept the former, but need to be on the lookout for the latter. In a past experiment of ours, taking measurements on stumps, we calculated a difference in cross-sectional area from circular by 1 to 2% for even trees that were the closest to round. At this point, we believe that trees more out of round likely lead to a 3 to 6% error.

On occasion we assume elliptical cross-sections. The elliptical cross-sectional form has great potential, but does require an extra measurement. Two trunk widths at 90-degree separations are taken. This can be done with calipers at the base of the trunk, but the caliper method leads to challenges when modeling the trunk above normal reach unless the tree is climbed. To obtain the measurements from the ground, we use a class of instruments that allow us to measure width at a distance. With an instrument called a Macroscope, we can be very accurate—generally within a half inch. However, even use of the Macroscope has its challenges. One must keep note of where one is on the trunk as one moves to a second vantage point 90 degrees removed. Visibility is often a problem—losing the spot on the trunk is very easy when viewing in a forest. To be 90 degrees removed, a compass can eliminate the guesswork provided we can track the point as we move around the tree.

We now turn our attention to the required mathematics. Treating cross-sectional area as circular is simple. If we take circumference, we can directly apply the formula:

$$A = \frac{C^2}{4\pi} \qquad [1]$$

Or if we measured diameter, we can apply the more familiar formula:

$$A = \pi r^2 = \pi \frac{D^2}{4} \qquad [2]$$

If we are going to model with the ellipse, we need to know the mathematics of the ellipse, principally the area. Thus, if a = semi-major axis, b = semi-minor axis, A_p = area of ellipse, A_c = area of circle, and R_{pc}=ratio of area of ellipse to circle, then:

$$A_p = \pi ab \qquad [3]$$

How does this area compare with that of the circle? If we use a as the radius, A_p above can be compared to the area of the circle A_c through the following method:

$$A_c = \pi a^2 \qquad [4]$$

Because by definition $b < a$, we can express the difference between b and a as a proportion of a. Thus, if f = a proportion, that b is less than a, then:

$$b = (1 - f)a \qquad [5]$$

and

$$R_{pc} = \frac{A_p}{A_c} \qquad [6]$$

By substitution,

$$R_{pc} = \frac{\pi ab}{\pi a^2} \qquad [7]$$

$$R_{pc} = \frac{\pi a(1-f)a}{\pi a^2} \qquad [8]$$

$$R_{pc} = 1 - f \qquad [9]$$

For this result, if f = 0.01 or 1%, then the ratio of the area of the ellipse to circle is (1 - f) or 0.99 or 99%. Thus, we can see the impact of being elliptical as opposed to circular.

With this introduction, the remainder of this article has three objectives: (1) to examine the cone, paraboloid, and neiloid as canonical forms, (2) to develop strategies for applying these models in the field, and (3) look at form in a more generalized sense. Most of our analysis is mathematical and includes what will be unfamiliar formulae. We include three appendices devoted to derivation of some of the most important formulae. We now turn to the cone.

THE CONE

Full Cone Modeling

Figure 2 below shows the two most important geometric solids we use along with one often used for comparison purposes, the cylinder. The right circular cone is an extremely valuable geometric solid in tree trunk modeling—probably our most useful. The cone has many direct applications. For example, it fits the profile of young conifers remarkably well. The basic shape of a right circular cone is shown below.

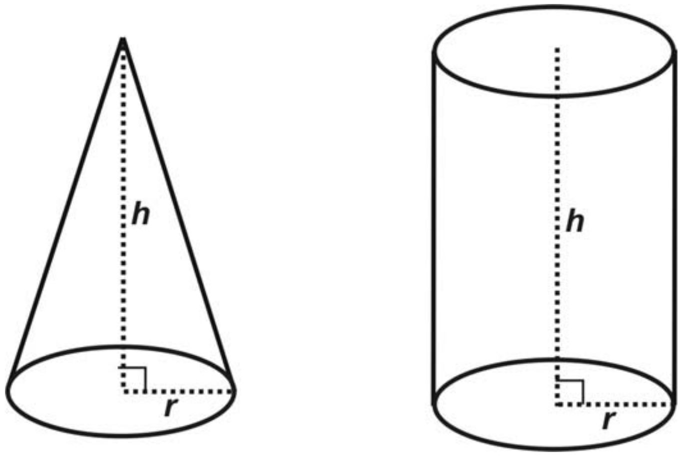

Figure 2. Right circular cone (left) and right circular cylinder (right) of height **h** *and radius* **r.**

The right circular cone is the figure on the left, with its base being a circle. It is sometimes instructive to visualize the cone in relation to the right circular cylinder—the object on the right. We visualize the cylinder as encompassing the cone. The formula for the volume of a right circular cylinder is:

$$V = \pi r^2 h \qquad [10]$$

The volume of the right circular cone has 1/3 the volume of a cylinder with the same base and height, or:

$$V = \frac{1}{3}\pi r^2 h \qquad [11]$$

where h = height of cone and r = radius of base. As can be seen in Figure 2, the cone comes to a point called the apex, which is directly above the center of the circular base. The sides of the cone are straight so the taper from base to apex is linear.

The question for ENTS is how can the cone be used in modeling the trunks of trees? In terms of volume, the right circular cone almost always understates the volume of a straight-trunk conifer if the cone's base is taken as a circle with diameter equal to the DBH of the trunk being modeled. If the base of the cone is taken as the circle with the diameter of the trunk at just above the root flare, the volume almost always overstates the volume of the trunk of a young to early mature conifer. These two cone constructions can be put together to produce the following formula:

$$V = H\left(\frac{C_1^2 + C_2^2}{75.4}\right) \qquad [12]$$

where C_1 is girth at the root collar and C_2 is the girth at breast height; H is total tree height; and 75.4 is a constant. The formula represents the average of the two cones. The primary strength of this formula is that it is simple, requiring only three measurements, two of which would be taken in routine tree measurements, since height and CBH are almost always taken. To these two measurements, we need only add circumference at the root collar and apply the above formula. We have found the formula fits young to mature eastern spruce, eastern hemlock, eastern white pine, and red pine quite well, but fails for conifers that have achieved old-growth status. The formula understates the volume of old-growth specimens. Note that we speak of circumference since we generally treat the trunk as circular. A more realistic approach is to speak of girth and use terms like GBH (girth at breast height). However, as pointed out, we treat the cross-sectional area as circular, so we will stick with circumference and CBH.

What can we do besides apply either equations [10] or [11] directly in volume analysis? On occasion, we want to know what the radius of a cone is at a particular height from either the apex or base. This desire often follows when we have direct diameter measurements of the trunk at points along the trunk and we want to see how our measurements compare with the standard right circular cone, as a check on fit.

So, let R = radius of the cone at its base, H = height of the cone, h_1 = height at point of cone measured from the apex where radius is sought, h_2 = height at point of cone measured from the base where radius is sought, and r = radius at height h_i. Then:

$$r = R\left(\frac{h_1}{H}\right) \qquad [12]$$

or

$$r = R\left(\frac{H - h_2}{H}\right) \qquad [13]$$

The above formulae reflect the fact that the taper of the cone is linear. At one half the full height of the cone, the radius is one-half of the basal radius. When we are able to take periodic diameter measurements with instruments or by climbing, we can compare actual diameter or radial measurements with those from the cone and ascertain the degree of fit. It has been through this type of analysis that we have been able to conclude that young conifers are often fairly conical in form. But, while full cone modeling does fit a limited class of trees and does give us a useful tool to obtain approximations and making comparisons, the real workhorse of the conical form is the frustum.

Cone Frustum Modeling

If two parallel planes at right angles to the axis of the cone are passed through the cone, the result is a section or slice of the cone called a frustum. The following formula gives the volume of a frustum of height h, bottom radius r_1 and top radius r_2:

$$V = \frac{\pi h}{3}\left(r_1^2 + r_2^2 + r_1 r_2^2\right) \qquad [14]$$

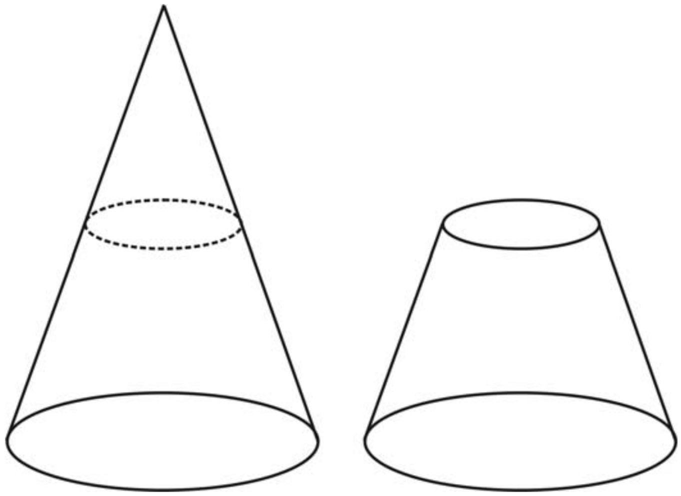

Figure 3. Cone (left) and a frustum of that cone (right).

Note that, in these formulae, the radius is being used, but the equivalent diameter or circumference (girth) can be easily substituted since diameter is twice the radius and circumference is given by the familiar formula:

$$c = 2\pi r \qquad [15]$$

Note that equation [15] does not require information about the total height or base area of the parent cone. This is an extremely convenient fact with an extremely important implication. Simply put, it means that we do not have to force fit the trunk to one encompassing cone. Each frustum can be part of a different cone that is appropriate to the trunk at the particular point. Consequently, it is this formula that we use most when modeling a trunk.

If we specify the height and radius of the parent cone, we may want to know the volume of the frustum that lies between two points say between heights h_1 and h_2 of a cone of height H and basal radius R. In equation [16] below, h_1 and h_2 are measured from the apex, while in [17] they come from the base:

$$V = \frac{\pi}{3}\left(\frac{R}{H}\right)^2\left[h_2^3 - h_1^3\right] \qquad [16]$$

$$V = \frac{\pi}{3}\left(\frac{R}{H}\right)^2\left[(H-h_2)^3 - (H-h_1)^3\right] \qquad [17]$$

These formulae allow us to calculate the predicted volume between one point on the trunk and another. There are times when we wish to interpolate the radius of an intermediate point of a frustum with upper radius r_1, lower radius r_2, frustum height h_0 and height from base to point of interpolation h_1. Our reason for interpolating may be to check the interpolated value against an actual measured one to ascertain the degree of fit of the frustum.

The interpolation formula is:

$$r = r_1 - \left(\frac{r_1 - r_2}{h_0}\right)h_1 \qquad [18]$$

Our final two formulae for the cone provide us with a means of calculating the volume of a portion of a cone representing some percent of total height as measured either from the apex or base. For example, suppose we want to know what the volume is of the first 50% of the cone based on height. The formula needed for the determination is:

$$V = \frac{1}{3}\pi R^2 H f^3 \qquad [19]$$

where f is the proportion of total height as measured from the apex. If height is measured from the base, then the formula is:

$$V = \frac{1}{3}\pi R^2 H\left[(1-f)^3 - 1\right] \qquad [20]$$

These formulae applicable to the cone provide us with a broad range of capabilities. However, the trunk may not be conical in shape. We will now turn our attention to the paraboloid.

THE PARABOLOID

The second most important geometric solid in ENTS tree volume modeling is the paraboloid. The paraboloid as conceived in forest mensuration is shown above. If a vertical plane from apex to the base cuts the sides of the solid in a parabola, then the solid is a paraboloid. Horizontal planes intersect the edge of the paraboloid as circles. The formula for the volume of a paraboloid of height h and r as the radius of the base is:

$$V = \frac{1}{2}\pi r^2 h \qquad [21]$$

The ½ factor means that the parabola fills 50% of the space of a cylinder of the same height and basal radius. We recall that the comparable percentage for the cone is 33%. As with the cone, we may want to know what the radius of a paraboloid is at a particular height from either the apex or base. If we have a direct measurement of the trunk at a particular height, we may want to see how that measurement compares with what a paraboloid would give us at that point. The following formulae provide us with the means of making comparisons.

If we let R = radius of the paraboloid at its base, H = height of the paraboloid, h_1 = height at point of paraboloid measured from the apex where radius is sought, h_2 = height at point of paraboloid measured from the base where radius is sought, r_1 = radius at height h_1, and r_2 = radius at height h_2, then:

$$r_1 = R\sqrt{\frac{h_1}{H}} \qquad [22]$$

$$r_2 = R\sqrt{\frac{H-h_2}{H}} \quad [23]$$

These equations, when solved for h_1 and h_2, respectively yield:

$$h_1 = H\frac{r_1^2}{R^2} \quad [24]$$

$$h_2 = H\left(1-\frac{r_2^2}{R^2}\right) \quad [25]$$

As with the cone, full paraboloid modeling gives us a useful tool to obtain approximations, but the workhorse of form for ENTS is the frustum.

If h_1 and h_2 are points at the base and top of the frustum respectively as measured from the apex and toward the base of a paraboloid with radius R and height H, then the volume of the frustum is given by:

$$V = \frac{\pi R^2}{2H}\left(h_2^2 - h_1^2\right) \quad [26]$$

If the radii at h_1 and h_2 are known, then the volume of the frustum with respect to the radii is:

$$V = \frac{\pi H}{2R^2}\left(r_2^4 - r_1^4\right) \quad [27]$$

If we measure from the base toward the apex, then the formula for the volume of a frustum for h_1, h_2, R, and H is given by:

$$V = \frac{\pi R^2}{H}\left[\left(h_2 - h_1\right)\left(H - \frac{h_1+h_2}{2}\right)\right] \quad [28]$$

In keeping with our treatment of the cone, our final two formulae for the paraboloid provide us with a means of calculating the volume of a portion of a paraboloid representing some percent of total height as measured either from the apex or base. For example, suppose we want to know what the volume is of the first 50% of the paraboloid based on height. The formula needed for the determination is:

$$V = \frac{1}{2}\pi R^2 H f^2 \quad [29]$$

where f is the proportion of total height as measured from the apex. If height is measured from the base, then the formula is:

$$V = \frac{1}{2}\pi R^2 H f\left(2 - f\right) \quad [30]$$

THE NEILOID

In our modeling, the neiloid form has been the least used. This will likely change as we model more trees that have prominent basal flares. The sides of the neiloid are concave, so its volume is less than that of the cone. The neiloid form applies near the base of tree trunks exhibiting root flare, but it also applies to the section just below a limb bulge. Formulae for the volume and frustum of a neiloid as used in forest mensuration are shown in the diagram below.

We repackage the formulae for the neiloid shape by presenting a taper, whole volume, and alternative frustum formula below.

$$r = R\left(\frac{h}{H}\right)^{3/2} \quad [31]$$

$$V = \frac{1}{4}\pi r^2 h \quad [32]$$

where r = radius of the base and h = height of neiloid. The formula for the frustum is given by:

$$V = -\pi\frac{R^2}{4H^3}\left[\left(H-h_2\right)^4 - \left(H-h_1\right)^4\right] \quad [33]$$

Note that forest mensuration has given rise to a general equation for the shape of a regular solid with a taper:

$$y^2 = kx^b \quad [34]$$

where y = radius, k = rate of taper, x = distance from the apex of the shape, and b = related to the shape of taper. For the solid forms considered in developing the above equation, b values will produce the associated shapes (in parentheses):

b = 0.25 (neiloid)
b = 0.33 (conoid)
b = 0.50 (quadratic paraboloid)
b = 0.60 (cubic paraboloid)
b = 1.00 (cylinder)

STRATEGIES FOR APPLICATION

The formulae provided in the preceding sections give us a set of tools to tackle the modeling of a tree trunk. However, at first glance, it is seldom clear where or when we should choose the paraboloid form over the cone since the form of the trunk, especially the lower trunk, usually falls somewhere between the two solids for many trees. Near the base of the trunk, the neiloid form is more obvious; so its applicability is usually not in question. Large basal flares suggest a neiloid form up to between 4.5 and 10 ft. Above that is where the challenge begins. It is our experience that as applied to the entire trunk, the paraboloid usually overshoots the volume of the trunk and the cone undershoots. Table 1 illustrates how our two geometric solids accumulate volume with increasing height. In the table, the starting point for each solid is its apex.

Table 1. Comparison of percentage of volume achieved at different percentages of height (assuming a trunk radius of 2.0 ft, a height of 120.0 ft, a cone volume of 502.65 ft³ and a parabolic volume of 753.98 ft³).

Height from apex (ft)	Radius of parabola (ft)	Radius of cone (ft)	Difference (parabola - cone, in ft)	Difference (in percent)	Percent of Height	Volume for % height of cone	Volume for % height of parabola
5	0.41	0.08	0.32	389.9	4.2	0.0	0.2
10	0.58	0.17	0.41	246.4	8.3	0.1	0.7
15	0.71	0.25	0.46	182.8	12.5	0.2	1.6
20	0.82	0.33	0.48	144.9	16.7	0.5	2.8
25	0.91	0.42	0.50	119.1	20.8	0.9	4.3
30	1.00	0.50	0.50	100.0	25.0	1.6	6.3
35	1.08	0.58	0.50	85.2	29.2	2.5	8.5
40	1.15	0.67	0.49	73.2	33.3	3.7	11.1
45	1.22	0.75	0.47	63.3	37.5	5.3	14.1
50	1.29	0.83	0.46	54.9	41.7	7.2	17.4
55	1.35	0.92	0.44	47.7	45.8	9.6	21.0
60	1.41	1.00	0.41	41.4	50.0	12.5	25.0
65	1.47	1.08	0.39	35.9	54.2	15.9	29.3
70	1.53	1.17	0.36	30.9	58.3	19.8	34.0
75	1.58	1.25	0.33	26.5	62.5	24.4	39.1
80	1.63	1.33	0.30	22.5	66.7	29.6	44.4
85	1.68	1.42	0.27	18.8	70.8	35.5	50.2
90	1.73	1.50	0.23	15.5	75.0	42.2	56.3
95	1.78	1.58	0.20	12.4	79.2	49.6	62.7
100	1.83	1.67	0.16	9.5	83.3	57.9	69.4
105	1.87	1.75	0.12	6.9	87.5	67.0	76.6
110	1.91	1.83	0.08	4.4	91.7	77.0	84.0
115	1.96	1.92	0.04	2.2	95.8	88.0	91.8
120	2.00	2.00	0.00	0.0	100.0	100.0	100.0

We see that at 50% of its full height, the cone has accumulated only 12.5% of its total volume—a surprising result. By comparison, the paraboloid has accumulated 25%. Let's now look at the same height percentage, but approached from the base end of each solid. The cone has accumulated 87.5% of its total volume and the paraboloid has accumulated 75% at 50% of height. The volume of an actual tree with a basal radius of 2 ft and a height of 120 ft will likely fall somewhere between these two extremes. Consequently, we may want to try intermediate forms, i.e. intermediate between paraboloid and cone. Equation [35] below allows us to mix the paraboloid form with the cone for the purposes of predicting radius, diameter, or circumference at specified heights. In the formula, c is the predicted circumference (just to illustrate our independence of radius), f is the weight given the paraboloid form.

$$c = \frac{C}{H}\left[f\sqrt{\frac{H-h}{H}} + (1-f)\left(\frac{H-h}{H}\right)\right] \quad [35]$$

Let's now look at some actual trees. Table 2 shows a comparison of actual circumference measurements taken at 100 ft up the trunk (or close to it) of 38 old-growth hemlocks documented in the Tsuga Search project with what can be expected from paraboloid and conical forms. Actual measurements were taken by Will Blozan, who climbed all the trees listed below.

The lessons from this exercise show that the paraboloid over-estimates the circumferences at 100 ft by an average of 18.8% and the cone understates the circumference by 32.5%. Because the cone underestimates and the paraboloid overestimates, we are led toward intermediate forms. Table 3 shows forms that are hybrids-part paraboloid and part cone. The first is 50% paraboloid and 50% is cone. The second hybrid is a 67%-33% mix. As we can see, it comes closest to predicting circumference at 100 ft above base or 95.5 ft above the breast-high circumference measurement.

The 14.4% difference clearly shows the influence of the paraboloid for old-growth forms. In fact, it carries a weight of 67% versus the cone at 33%. For short trunk sections modeled as frustums, how do we test for a convex or concave curvature and if we find it, what do we do? The following exercise examines the Caldwell Colossus, an eastern hemlock climbed and modeled by Blozan and Jess Riddle using frustums of cones. In Table 4 we combine the cone and the paraboloid to arrive at a slightly higher volume than was calculated in Tsuga Search.

Table 2. Eastern hemlock taper analysis (field data from Tsuga Search Project).

Tree name	Full height (ft)	Above BH BH (ft)	Circum. at BH (ft)	Height near 100 ft	Less 4.5 ft	Circum. at height (ft)	Predicted parabolic vol. (ft^3)	Absolute difference (%)	Predicted conic vol. (ft^3)	Absolute difference (%)
BFR Trail hemlock	154.30	149.80	16.39	100.00	95.50	9.60	9.87	2.7	5.94	38.1
Big Fork Tower	169.40	164.90	14.24	100.00	95.50	9.46	9.24	2.3	5.99	36.6
Buck Creek HM	148.80	144.30	15.56	99.90	95.40	8.76	9.06	3.4	5.27	39.8
Caldwell Colossus	159.58	155.08	16.82	100.58	96.08	8.40	10.37	23.5	6.40	23.8
Caldwell Giant	152.10	147.60	18.80	100.00	95.50	10.00	11.17	11.7	6.64	33.6
Cannon Creek Falls	154.67	150.17	14.61	97.20	92.70	8.67	9.04	4.2	5.59	35.5
Chapman Prong HM	125.80	121.30	18.38	102.93	98.43	4.45	7.98	79.3	3.47	22.1
Cheoh Hemlock	157.95	153.45	16.00	103.45	98.95	5.79	9.54	64.7	5.68	1.9
Crows Nest	167.30	162.80	13.18	100.00	95.50	8.62	8.47	1.7	5.45	36.8
Double Gap HM	164.80	160.30	14.92	99.80	95.30	10.49	9.50	9.4	6.05	42.3
Dunn Creek HM	143.25	138.75	18.07	100.25	95.75	5.92	10.06	69.9	5.60	5.4
East Fork Spire	168.76	164.26	11.22	100.88	96.38	5.68	7.21	27.0	4.64	18.4
Ellicott's Rock	168.84	164.34	11.83	99.08	94.58	6.78	7.71	13.7	5.02	25.9
Fat Nellie	160.80	156.30	14.50	100.00	95.50	9.32	9.04	3.0	5.64	39.5
Forge Creek HM	144.00	139.50	14.48	99.00	94.50	8.92	8.22	7.8	4.67	47.6
Gabes Mtn HM	117.85	113.35	15.64	99.80	95.30	7.25	6.24	13.9	2.49	65.6
Headless Giant	120.30	115.80	15.80	100.00	95.50	7.68	6.62	13.9	2.77	63.9
Hurricane Creek #1	162.30	157.80	14.89	99.19	94.69	8.33	9.42	13.0	5.96	28.5
Hurricane Creek #2	167.30	162.80	16.22	100.00	95.50	9.20	10.43	13.4	6.71	27.1
Jim Branch	166.70	162.20	12.88	99.70	95.20	9.17	8.28	9.7	5.32	42.0
Laurel Branch L	156.30	151.80	18.30	100.00	95.50	9.29	11.14	20.0	6.79	26.9
Leconte Creek	140.40	135.90	18.80	100.30	95.80	6.62	10.21	54.3	5.55	16.2
Long Branch	143.60	139.10	16.00	100.60	96.10	7.63	8.90	16.6	4.95	35.2
Lowes Creek	163.70	159.20	14.33	97.70	93.20	7.86	9.23	17.4	5.94	24.4
Medlin Mtn Mon	161.83	157.33	13.48	99.25	94.75	6.99	8.50	21.6	5.36	23.3
Nellie's Needle	168.40	163.90	10.63	100.00	95.50	5.91	6.87	16.2	4.44	24.9
Nolan Mtn HM	171.50	167.00	13.71	101.00	96.50	8.88	8.91	0.3	5.79	34.8
Pole Creek	150.10	145.60	15.93	100.10	95.60	7.79	9.34	19.8	5.47	29.8
Seneca HM	145.40	140.90	11.94	100.00	95.50	5.45	6.78	24.4	3.85	29.4
Shanty Branch	166.10	161.60	12.37	100.00	95.50	6.75	7.91	17.2	5.06	25.0
Survivor Tree	172.10	167.60	11.60	100.00	95.50	8.17	7.61	6.9	4.99	38.9
The Beast	151.50	147.00	15.86	100.00	95.50	8.59	9.39	9.3	5.56	35.3
The Colleague	167.20	162.70	15.60	100.00	95.50	9.67	10.03	3.7	6.44	33.4
Usis	173.10	168.60	15.43	99.70	95.20	9.63	10.18	5.7	6.72	30.2
Valley Vista	164.70	160.20	13.88	100.00	95.50	6.65	8.82	32.6	5.61	15.7
Yughi	171.70	167.20	9.29	100.00	95.50	5.06	6.08	20.2	3.98	21.3
Dunbar Brook	115.50	111.00	12.50	99.65	95.15	6.04	4.72	21.8	1.78	70.4
Tionesta	135.00	130.50	11.80	90.73	86.23	7.38	6.87	6.9	4.00	45.8
								18.5		32.5
							Average difference (%):	18.8		14.2

The Caldwell Colossus is 159.63 ft tall and has a radius of 2.68 ft at breast height. The Colossus was modeled using frustums of cones and that led to a calculated 1,384.6 ft^3 in the main trunk. Reiterations added 26.4 ft^3 more, for a total of 1,411 ft^3. Following our above development, suppose we impose a cone on the form of the Colossus and check its fit at each measurement point, noting the difference and averaging those differences for the entire trunk. We do the same for the paraboloid. We then hunt for a mix of cone and paraboloid that minimizes the average difference between the actual and the modeled measurements as a composite of cone and paraboloid. We apply the resulting composite and calculate its volume. Table 4 shows the result, modeling from 3.08 ft to 159.63 ft. The first 3.08 ft are left as is since they include the root collar and probably can best be described with the neiloid shape. The original modeling produced 83.07 ft^3. It is used below as an add-on.

Table 3. Eastern hemlock taper analysis.

Tree name	Full height (ft)	Above BH (ft)	Circum. (ft)	Height near 100 ft (ft)	Less 4.5 ft (ft)	Circum. height height (ft)	*f*	Circum. at 50% (ft)	Abs. diff. (%)	*f*	Circum. at 67% (ft)	Abs. diff. (%)
BFR Trail hemlock	154.30	149.80	16.39	100.00	95.50	9.60	0.5	7.90	17.7	0.67	8.56	10.9
Big Fork Tower	169.40	164.90	14.24	100.00	95.50	9.46	0.5	7.62	19.5	0.67	8.16	13.8
Buck Creek HM	148.80	144.30	15.56	99.90	95.40	8.76	0.5	7.17	18.2	0.67	7.80	11.0
Caldwell Colossus	159.58	155.08	16.82	100.58	96.08	8.40	0.5	8.39	0.2	0.67	9.05	7.7
Caldwell Giant	152.10	147.60	18.80	100.00	95.50	10.00	0.5	8.90	11.0	0.67	9.66	3.4
Cannon Creek Falls	154.67	150.17	14.61	97.20	92.70	8.67	0.5	7.31	15.6	0.67	7.89	9.0
Chapman Prong HM	125.80	121.30	18.38	102.93	98.43	4.45	0.5	5.72	28.6	0.67	6.48	45.6
Cheoh Hemlock	157.95	153.45	16.00	103.45	98.95	5.79	0.5	7.61	31.4	0.67	8.25	42.5
Crows Nest	167.30	162.80	13.18	100.00	95.50	8.62	0.5	6.96	19.2	0.67	7.47	13.4
Double Gap HM	164.80	160.30	14.92	99.80	95.30	10.49	0.5	7.78	25.9	0.67	8.35	20.4
Dunn Creek HM	143.25	138.75	18.07	100.25	95.75	5.92	0.5	7.83	32.3	0.67	8.57	44.8
East Fork Spire	168.76	164.26	11.22	100.88	96.38	5.68	0.5	5.92	4.3	0.67	6.35	11.9
Ellicott's Rock	168.84	164.34	11.83	99.08	94.58	6.78	0.5	6.36	6.1	0.67	6.81	0.5
Fat Nellie	160.80	156.30	14.50	100.00	95.50	9.32	0.5	7.34	21.2	0.67	7.91	15.1
Forge Creek HM	144.00	139.50	14.48	99.00	94.50	8.92	0.5	6.45	27.7	0.67	7.04	21.1
Gabes Mtn HM	117.85	113.35	15.64	99.80	95.30	7.25	0.5	4.37	39.8	0.67	4.99	31.1
Headless Giant	120.30	115.80	15.80	100.00	95.50	7.68	0.5	4.69	38.9	0.67	5.33	30.5
Hurricane Creek #1	162.30	157.80	14.89	99.19	94.69	8.33	0.5	7.69	7.7	0.67	8.26	0.8
Hurricane Creek #2	167.30	162.80	16.22	100.00	95.50	9.20	0.5	8.57	6.9	0.67	9.19	0.1
Jim Branch	166.70	162.20	12.88	99.70	95.20	9.17	0.5	6.80	25.9	0.67	7.29	20.5
Laurel Branch L	156.30	151.80	18.30	100.00	95.50	9.29	0.5	8.97	3.5	0.67	9.69	4.3
Leconte Creek	140.40	135.90	18.80	100.30	95.80	6.62	0.5	7.88	19.0	0.67	8.66	30.8
Long Branch	143.60	139.10	16.00	100.60	96.10	7.63	0.5	6.92	9.3	0.67	7.58	0.6
Lowes Creek	163.70	159.20	14.33	97.70	93.20	7.86	0.5	7.58	3.5	0.67	8.13	3.5
Medlin Mtn Mon	161.83	157.33	13.48	99.25	94.75	6.99	0.5	6.93	0.8	0.67	7.46	6.7
Nellie's Needle	168.40	163.90	10.63	100.00	95.50	5.91	0.5	5.65	4.4	0.67	6.06	2.5
Nolan Mtn HM	171.50	167.00	13.71	101.00	96.50	8.88	0.5	7.35	17.3	0.67	7.87	11.4
Pole Creek	150.10	145.60	15.93	100.10	95.60	7.79	0.5	7.40	5.0	0.67	8.05	3.3
Seneca HM	145.40	140.90	11.94	100.00	95.50	5.45	0.5	5.31	2.5	0.67	5.80	6.5
Shanty Branch	166.10	161.60	12.37	100.00	95.50	6.75	0.5	6.49	3.9	0.67	6.96	3.1
Survivor Tree	172.10	167.60	11.60	100.00	95.50	8.17	0.5	6.30	22.9	0.67	6.74	17.5
The Beast	151.50	147.00	15.86	100.00	95.50	8.59	0.5	7.47	13.0	0.67	8.11	5.6
The Colleague	167.20	162.70	15.60	100.00	95.50	9.67	0.5	8.23	14.8	0.67	8.83	8.7
Usis	173.10	168.60	15.43	99.70	95.20	9.63	0.5	8.45	12.3	0.67	9.03	6.3
Valley Vista	164.70	160.20	13.88	100.00	95.50	6.65	0.5	7.21	8.5	0.67	7.75	16.5
Yughi	171.70	167.20	9.29	100.00	95.50	5.06	0.5	5.03	0.5	0.67	5.38	6.4
Dunbar Brook	115.50	111.00	12.50	99.65	95.15	6.04	0.5	3.25	46.1	0.67	3.74	38.0
Tionesta	135.00	130.50	11.80	90.73	86.23	7.38	0.5	5.44	26.3	0.67	5.92	19.8
									16.1			14.4
									12.0			12.9

This first 3.08 ft are not subjected to the modeling since that form is best captured by considering the neiloid or cone. We leave it as modeled by Will and Jess. The remainder of the trunk adds 19.49 ft^3. While not a large increase, it does reflect the pattern of actual measurements.

The actual formula that we use to calculate volume for mixed forms is:

$$V = \left(\frac{\pi R^2}{3H^2}\right)\left[(H-h_2)^3 - (H-h_1)^3\right](1-f) + \left(\frac{\pi R^2}{H}\right)\left[(h_2-h_1)\left(H-\frac{h_2+h_1}{2}\right)\right]f \qquad [36]$$

The above equation is complicated, but can be built into an Excel spreadsheet. The f factor is the weight given to the paraboloid. In Table 4, f = 0.32.

Table 4. An example volume distribution for the Caldwell Colossus, an eastern hemlock 159.6 ft tall, with a radius of 2.68 (and assuming an f = 0.32).

									Volume, in ft³			
Height (ft)	Diameter (ft)	Radius (ft)	Parabolic radius (ft)	Diff. (ft)	Cone radius (ft)	Diff. (ft)	Comp.	Diff.	Cone volume	Cone portion	Parabolic portion	Total
159.58	0.00	0.00	0.03	0.03	0.00	0.00	0.01	0.01				
150.28	0.33	0.16	0.65	0.48	0.16	-0.01	0.31	0.15	0.26	0.16	1.96	2.12
146.58	0.53	0.26	0.76	0.50	0.22	-0.04	0.39	0.13	0.54	0.28	1.87	2.14
138.38	0.95	0.48	0.98	0.50	0.36	-0.12	0.55	0.08	3.60	1.47	6.34	7.81
132.78	1.20	0.60	1.10	0.50	0.45	-0.15	0.66	0.06	5.11	1.95	6.07	8.02
122.18	1.71	0.85	1.30	0.44	0.63	-0.23	0.84	-0.01	17.78	6.63	15.37	22.00
112.58	2.21	1.10	1.45	0.35	0.79	-0.32	1.00	-0.10	29.07	10.33	18.29	28.62
100.58	2.68	1.34	1.63	0.29	0.99	-0.35	1.19	-0.14	56.36	20.36	28.72	49.08
94.18	2.92	1.46	1.71	0.26	1.10	-0.36	1.29	-0.16	39.32	14.90	17.97	32.88
82.58	3.43	1.71	1.86	0.15	1.29	-0.42	1.47	-0.24	91.80	35.44	37.29	72.73
68.58	3.70	1.85	2.02	0.17	1.53	-0.32	1.69	-0.16	139.62	59.53	53.10	112.63
58.08	3.89	1.95	2.14	0.19	1.70	-0.24	1.84	-0.10	118.85	58.54	45.63	104.17
46.58	4.12	2.06	2.25	0.19	1.90	-0.16	2.01	-0.05	144.85	79.60	55.68	135.29
37.58	4.03	2.01	2.34	0.33	2.05	0.03	2.14	0.13	117.14	74.74	47.74	122.48
22.58	4.37	2.18	2.48	0.30	2.30	0.11	2.36	0.17	207.52	151.40	87.70	239.09
20.08	4.18	2.09	2.50	0.42	2.34	0.25	2.39	0.30	35.82	28.73	15.60	44.33
9.58	4.62	2.31	2.60	0.29	2.52	0.21	2.54	0.23	159.49	132.31	68.62	200.93
7.08	4.97	2.48	2.62	0.13	2.56	0.07	2.58	0.09	45.10	34.38	17.07	51.45
4.58	5.35	2.68	2.64	-0.04	2.60	-0.08	2.61	-0.06	52.31	35.53	17.35	52.88
3.08	5.86	2.93	2.65	-0.28	2.63	-0.30	2.63	-0.29	37.04	21.87	10.55	32.42
Average				0.26		-0.12		0.00	1301.58	768.16	552.91	1321.07
					neiloid form			83.07			83.07	
					Grand Total			1384.65			1404.14	

DIRECTION FOR FUTURE MODELING

The chief weakness in the above approach that mixes the cone and paraboloid is that each solid encompasses the entire trunk based on cross-sectional area at 4.5 ft above base and full tree height. As indicated in the preceding sections, the better way would be to use a number of frustums and to make a decision about the form of each frustum. Each frustum should be free to represent a different parent cone or paraboloid. This is essentially what we do when we apply the cone formula:

$$V = \frac{\pi(h_2 - h_1)}{3}\left(r_2^2 + r_1^2 + r_1^2 r_2^2\right) \quad [37]$$

The quantities r_1, r_2, h_1, and h_2 for each frustum determine a cone unique to the frustum. As long as we model with frustums of cones, we need not impose a single cone onto the trunk. However, we need to be able to do the same thing with the paraboloid, but we have no formula comparable to [31]. We will derive such a formula.

To do this, we shall begin with a frustum that we want to treat as paraboloid and consider the base of the frustum to be the base of the paraboloid. With this constraint, we can determine the height H and then derive a formula for volume of a paraboloid frustum that is not forced to treat the height of the parent paraboloid as the height of the tree. Therefore, let $r = R\sqrt{(H-h)/H}$ and impose the conditions $R = r_1$, and $h = h_2 - h_1$. Substituting and solving for H, we get:

$$r_2 = r_1\sqrt{\frac{H-(h_2-h_1)}{H}} \quad [38]$$

$$r_2^2 = r_1^2\left[\frac{H-(h_2-h_1)}{H}\right] \quad [39]$$

$$Hr_2^2 = Hr_1^2 - r_1^2(h_2 - h_1) \quad [40]$$

However, when $h_1 = 0$, $Hr_2^2 = Hr_1^2 - r_1^2 h_2$. Solving for H yields:

$$H = \frac{r_1^2 h_2}{r_1^2 - r_2^2} \quad [41]$$

Thus,

$$V = \frac{\pi R^2}{H}\left[(h_2 - h_1)\left(H - \frac{h_1 + h_2}{2}\right)\right] \quad [42]$$

So the specialized frustum formula becomes:

$$V = \left[\frac{\pi r_1^2\left(r_1^2 - r_2^2\right)}{r_1^2 h_2}\right]\left(\frac{r_1^2 h_2}{r_1^2 - r_2^2} - \frac{h_2}{2}\right) \qquad [43]$$

which simplifies to:

$$V = \frac{\pi h}{2}\left(r_1^2 + r_2^2\right) \qquad [44]$$

This latter formula allows us to compute the volume of a paraboloid frustum based on the assumptions made. It does not require the frustum to be part of a single paraboloid that encompasses the entire tree. As an extension of this approach, a parent frustum can be defined by taking a longer section of trunk instead of taking each section defined by the actual measurements. The choice of section to be treated as a frustum can be dictated by visual inspection. A section that appears convex is a prime candidate for a paraboloid frustum.

To see how long and short frustums work, let's first model by defining a frustum around each set of measurements and comparing them (Table 5). As can be seen in the table, the difference between the two forms is minor when the paraboloid frustums are defined analogous to how the conical frustums are defined. As a final modeling exercise, let us consider the possibility that the paraboloid form constitutes a larger portion of the trunk than each adjacent pair of measurements. We will construct two scenarios (Table 6).

Table 5. Comparison of different frustum volumes for the Caldwell Colossus.

Height (ft)	Diameter (ft)	Radius (ft)	Cone (ft^3)	Paraboloid (ft^3)	Diff. (ft^3)
159.583	0.000	0.000			
150.283	0.329	0.165	0.264	0.396	0.132
146.583	0.525	0.263	0.539	0.558	0.019
138.383	0.950	0.475	3.600	3.794	0.194
132.783	1.200	0.600	5.106	5.151	0.046
122.183	1.708	0.854	17.784	18.142	0.359
112.583	2.208	1.104	29.073	29.387	0.314
100.583	2.675	1.338	56.359	56.701	0.342
94.183	2.917	1.458	39.315	39.364	0.049
82.583	3.425	1.713	91.796	92.188	0.392
68.583	3.700	1.850	139.619	139.757	0.139
58.083	3.892	1.946	118.846	118.897	0.050
46.583	4.117	2.058	144.853	144.929	0.076
37.583	4.025	2.013	117.143	117.153	0.010
22.583	4.367	2.183	207.519	207.748	0.229
20.083	4.175	2.088	35.820	35.832	0.012
9.583	4.617	2.308	159.488	159.756	0.268
7.083	4.967	2.483	45.102	45.142	0.040
4.583	5.354	2.677	52.312	52.361	0.049
3.083	5.857	2.928	37.043	37.093	0.050
Total			1301.580	1304.350	2.770

Table 6. Different conic frustum volume predictions for the Caldwell Colossus based on type of geometric solid assumed. For types, P = paraboloid, C = cone.

Height	Diameter (ft)	Radius (ft)	Cone (ft^3)	Paraboloid (ft^3)	Difference (ft^3)	Comb 1	Type 1	Comb 2	Type 2
159.583	0.000	0.000							
150.283	0.329	0.165	0.264	0.396	0.132	0.264	C	0.264	C
146.583	0.525	0.263	0.539	0.558	0.019	0.539	C	0.539	C
138.383	0.950	0.475	3.600	3.794	0.194	3.600	C	3.600	C
132.783	1.200	0.600	5.106	5.151	0.046	5.106	C	5.106	C
122.183	1.708	0.854	17.784	18.142	0.359		P	17.784	C
112.583	2.208	1.104	29.073	29.387	0.314		P	29.073	C
100.583	2.675	1.338	56.359	56.701	0.342		P		P
94.183	2.917	1.458	39.315	39.364	0.049		P		P
82.583	3.425	1.713	91.796	92.188	0.392		P		P
68.583	3.700	1.850	139.619	139.757	0.139		P		P
58.083	3.892	1.946	118.846	118.897	0.050		P		P
46.583	4.117	2.058	144.853	144.929	0.076		P		P
37.583	4.025	2.013	117.143	117.153	0.010		P		P
22.583	4.367	2.183	207.519	207.748	0.229		P		P
20.083	4.175	2.088	35.820	35.832	0.012		P		P
9.583	4.617	2.308	159.488	159.756	0.268	1100.832	P		P
7.083	4.967	2.483	45.102	45.142	0.040	45.102	C	1224.022	P
4.583	5.354	2.677	52.312	52.361	0.049	52.312	C	52.312	C
3.083	5.857	2.928	37.043	37.093	0.050	37.043	C	37.043	C
Total			1301.580	1304.350	2.770	1244.798		1369.742	

The combination columns illustrate how quixotic the totals can be based upon what part of the trunk we choose as being under the influence of a single paraboloid form. At this point in the development of our modeling methodology, the modeler chooses the parts of a trunk to be treated as frustums of a paraboloid based on visual cues. Our plan is to devise more sophisticated numeric methods for defining trunk areas that fit a chosen scenario.

CONCLUSIONS

This article has presented a number of formulae useful in modeling tree trunks and limbs. These formulae utilize three prominent geometric solids: the cone, paraboloid, and the neiloid. The simplest method for applying a solid is to model the entire trunk with one application of a solid. Application of one form to the whole tree has been discussed as a way to get a quick volume approximation. But, the method is unlikely to produce an accurate result. The best method for modeling that we have found is to divide the trunk into adjacent segments no more than 3 to 5 ft in height/length and then apply either the cone, paraboloid, or neiloid frustum form to each. However, this approach is labor intensive. A 160-ft trunk requires 40 circumference-diameter-radius measurements for 4-ft frustums. We do model trunks at this level of detail, but seek more efficient methods.

To gain efficiency, longer sections are chosen that appear to the eye to have uniform curvature. However, the longer the segment, the more important it is to choose the optimum solid. Over longer frustums, the greater volume contribution of the paraboloid or the lesser volume of the neiloid becomes apparent. Consequently, it behooves the measurer to perform independent checks to insure that the right solid has been chosen. One way to check is to take a diameter measurement at an intermediate point and then project what the diameter would be for the chosen model at the point. If the projected diameter is substantially greater or lesser than the measured diameter, then the selected solid is not the right choice. In this case, an intermediate form that combines the two forms through weighting may be appropriate. The measurer selects weights and applies them to each solid formula to arrive at an intermediate result.

As we move forward in our volume modeling and development of dendromorphometry, we will add processes and some formulae that are general in their application and others that are highly specialized. It is always important to understand the underlying assumptions that a model or formula incorporates and use only where applicable.

An unusual outlier of mature American beech in Beech Creek Natural Area of the Overflow National Wildlife Refuge in Ashley County, Arkansas. Photo by Don C. Bragg.

FIRE, STONE, AND FOREST

Don Bertolette

Restoration Forester (retired), Grand Canyon National Park

The National Park System encompasses a wide array of our country's diversity of cultural and natural resources. From small parks capturing historical "eventscapes" to large parks with multiple large watersheds, the managers of our country's special places have a mandate to "protect and preserve" them for generations into the future. Efforts to stay current with the latest scientific understanding of natural and cultural phenomena are continuous. Even so, the National Park Service's (NPS) understanding of complex ecosystems can always be improved. A pertinent example familiar to this author is the forested ecosystems of Grand Canyon National Park (GCNP) in northern Arizona.

Natural Range of Variation (NROV)

Prior to European settlement in the southwest United States, the natural range of environmental variability graphed would show a range (amplitude) of vegetation response to environmental variables. While one frame of reference for Grand Canyon could start from its origin as a large featureless seabed as it began to drain with geologic uplift, a more recent and useful period of time would be that elapsing since the last ice age to affect this area. This time continuum would start about 15,000 years ago and continue to present. The average response of vegetative communities that developed from this glacially scoured landscape to that of today would constitute the timeline continuum. As climatic changes occurred over this time period, the vegetative community responses to changes in temperature and precipitation would vary.

For the southwestern United States, records of vegetation began occurring as pollen and other particles accumulated in ephemeral ponds, bogs, and lakes. Approximately 12,000 years ago the initial plants that first took hold on the scoured landscapes began depositing pollen that is still layered in those water bodies. Pollen analyses indicate that 8,000 years ago many of today's vegetation types already occurred on the Kaibab Plateau. Around 4,000 years ago, the Younger Dryas brought about changes in vegetation and the approximate location of current communities. In ensuing millennia, the ranges for forest, woodland, and grassland communities shifted kilometers north and south, with range extents of individual plant species moving along elevation, latitude, and moisture gradients, reflecting changes in regional climate.

Historical Range of Variation (HROV)

It has only been in this last period of time (Younger Dryas) that significant change in vegetative communities has borne the impact of human presence, and then only in the last five hundred years of recorded history. Along the NROV timeline continuum referred to above, the HROV begins at about 500 years ago, with the arrival of European settlers and their propensity towards recording observations of their explorations. Prior to 500 years ago, it was generally thought that the effects of prior indigenous cultures were temporary and seasonal, and of small groups or tribes. While their accumulated effect across regional landscapes was significant, at local scales their impacts have been described as minor to negligible.

Prior indigenous cultures were primarily hunters and gatherers. According to paleoecologists, Native American cultures didn't significantly impact the vegetation prior to European settlement. In a region experiencing very severe and frequent lightning storms, the impact of Native American fire use is thought to be relatively minor. It is thought that the introduction of maize from southern-based cultures (Central and South American) hastened the establishment of year-round cultures in the southwestern United States, yet human impact on forested ecosystem at regional scales remained minimal. At local scales, the impact of prior indigenous cultures may be more variable.

Extending back into the last thousand years, dendrological records (from analysis of tree-rings) provide a credible account of some of the climatological change occurring within this region. The tree rings provide a record of a tree's growth in response to environmental influences. Years of higher than average moisture led to tree rings of higher than average width, thereby recording patterns of abundant moisture and drought. Cross-dating live trees and well-preserved timbers (still present in many of the ruins across the Southwest) permitted extension of climate analysis well beyond the oldest living trees in the region.

One of the more data-rich features of dendroecology has been the frequency and patterns of wildfire. The forests of the Southwest and the Grand Canyon in particular have recorded in tree-rings the presence of small and frequent wildfires, their ignition due to some of the highest incidences of lightning ground-strikes of any location in North America. This natural wildfire regime presented the post-European settlers with open, park-like stands of ponderosa pines (Figure 1), forming the largest contiguous ponderosa pine forest in the North American continent.

Within the context of Grand Canyon National Park lands, the vegetative communities ranging from the northern boundary to south along fairly parallel topographic contours went from a Spruce-Fir Forested Ecosystem (S-FFE) to a Mixed Conifer Forested Ecosystem (MCFE) to an intermediate ecotone between the MCFE and the Ponderosa Pine Forested

Ecosystem (PPFE) on the North Rim. The South Rim, even though split by the Colorado River and the Grand Canyon, continued in a PPFE that gradually changed to a Pinyon-Juniper Forested Ecosystem (P-JFE).

Post-European settlement of the Kaibab Plateau has generally been considered to have begun in the mid to late 1800s, with the arrival of sheepherders, cattle ranchers, and to some extent miners. Even though the area had been the focus of heavy lightning-based wildfire ignitions for more than a millennia, the overgrazing of "fine" fuels (small, easy to ignite) by the new settlers' livestock most significantly changed long-established vegetation patterns. The foraging of early settlers (1870s), in concert with the advent of a Park-wide policy of fire suppression (1920s) by well meaning NPS land managers, resulted in almost a century of forest growth left unchecked by the once natural fire regime.

Figure 1. A relatively undisturbed **Pinus ponderosa** *ecosystem found on Rainbow Plateau, with classic array of structural diversity. Note native grasses, pine seedlings and saplings in the wildfire-created opening (mosaic), and mature stand of 'yellowbark' pines.*

Forests had grown dense with young trees that otherwise would have been thinned by the natural fire regime, now known to have been small in area but frequent (4 to 36 years for 10 to 25% scarring in ponderosa pine forest) (Figure 2). The mixed conifer ecosystem (white fir/Douglas-fir/ponderosa pine) began invading the pure ponderosa pine ecosystem. Lightning fires occurring in this ecotone went from ground fires in the fine grassy fuels into young volatile white firs, which served as a "ladder fuel" permitting generally once "safe" ground fires to climb into the crowns of old yellow-barked ponderosa.

Today, crown fires have higher burn severity and travel much more quickly from crown to crown, injuring or killing old pines that had survived centuries of untended (unsuppressed, prior to Park-established suppression policies) wildfires. These conflagrations were the unintended consequences of well-intended policy.

Of the nation's land management agencies, the NPS has traditionally been at the forefront of fire ecology and its inclusion in resource management, initially with the foresight of Starker Leopold (son of Aldo Leopold) in the 1950s and even more pragmatically in the 1980s. The relatively early recognition of the negative consequences of the misguided fire suppression policies of the earlier years and subsequent change of standard ecosystem management practice are examples of perhaps tardy but important insights of this federal agency. This contrasts with the past and finally changing policies of some of its resource management peers.

Current Frame of Reference

Lessons learned from the catastrophic wildfires in Yellowstone National Park (1988) were soon applied at GCNP on the ground. While Grand Canyon had been experimenting with controlled burns with some success (and notable failures), it was after a series of its own "learning experiences" the Park's fire management branch (Fire and Aviation) began implementing a "fire restoration" strategy that currently re-introduces wildfire into 1200 to 1500 forested acres per year.

Some of these acres are those that were planned in advance to be WFURBS (WildFire Use for Resource Benefit) and had "not-to-exceed boundaries, acreages" (primarily lightning-caused ignitions that would be allowed to let burn, under specified circumstances); others were planned in advance and ignited by hand or from specially equipped helicopters) with pre-determined boundaries. Both fire use programs were required to document NEPA (National Environmental Protection Act) compliance.

Figure 2. **Pinus ponderosa** *at the edge of Rainbow Plateau, with increased wildfire activity cycle, and resulting multi-aged "islands." Note passing of large old pine at left in primarily native grass foreground, the incoming pine regeneration in photo center, and the islands of large pines ranging from photo center to right in background. Much of the Rainbow Plateau's periphery could be similarly characterized.*

Fire use is an imperfect science, due to lack of complete control, i.e., wildfire. Several times in recent fire history (the

Park's recorded fire suppression history dates to 1921, the history of active re-introduction of fire dates to 1980s), fires have escaped and burned extensive unplanned acreages (two escaped Park boundaries onto adjacent Forest Service lands, one over 50,000 ac, the other nearly 15,000 ac; and numerous other wildfires of smaller but significant acreages). Unexpected changes in weather were one common denominator between these fires. Unnaturally high levels of highly volatile white fir regeneration invading once pure ponderosa pine forests set the stage for other extensive wildfires escaping planned prescribed burns. Several other wildfires, in the more difficult to control MCFE, due to their adjacency, synergistically combined into larger than planned acreages, with unplanned burn severity classifications.

Figure 3. The* Pinus ponderosa *forest ecosystem as found in Grand Canyon National Park is relatively depauperate. Less so than adjacent, more disturbed forests, this image displays an opening created by a wildfire of medium to high burn severity, slowly returning to forbs, grasses, and shrubs. Pine regeneration in background is returning in less severe burn area mosaics. Mid-ground large pines show the accom-modation that thick bark offers to fast-burning, low-intensity, high-frequency fires expected of this fire-adapted species. The Rainbow Plateau, as well as the nearby Powell Plateau, is characterized by similar wildfire mosaics varying from forests with islands of grasses, to grasslands with islands of the large old yellow-barked pines.

The Park, in its attempt to reintroduce fire into the forested ecosystems, has by several measures exceeded the natural and historical ranges of variation for wildfire extent and burn intensity. As measured in *acreages*, the Park has had more acres burned during the last 50 years than the last 500. Measured in *burn intensity* (how much damage to the vegetative community), the wildfires of the last 50 years have significantly exceeded the historical and natural range of wildfire burn intensities of those found in the preceding 500 years.

Future Frames of Reference

Would the Park's fire managers have been better off with a policy of no action than their current policy to reintroduce fire to re-establish a more natural fire regime? With the advantage of hindsight, that might not have been the case, and the Park's fire-reintroduction strategies were warranted. Without a replicable experimental design to accurately compare the success of existing fire management strategies against a strategy of no action (Control Group), the retrospective rationale is speculative.

The key question that *isn't* being asked at decision-making levels is whether the reintroduction of fire on its own is the only appropriate tool with which to manage the forested ecosystems. Wildfire has been restored into three-fourths of the Park's forests with considerable success in the PPFE, but with some cost to the MCFE and S-FFE. The remaining forested acreages are primarily the more difficult-to-manage mixed conifer and spruce-fir forests of the Grand Canyon's North Rim. Some of the earlier fire re-introduction units (for the most part, pure ponderosa pine types) are already entering their second cycle (Figure 3).

Figure 4. The first visitors to Grand Canyon's unique, little-disturbed ponderosa pine forests (at the time of settlement, part of the largest contiguous assemblage of ponderosa pines in North America) characterized the forests as open park-like stands, such that one could ride on horseback and wagon unimpeded, and see far into the stands ahead.

In partial response to the question above, the Park's Division of Science & Resource Management recently (in 2002, then the Science Center Division) initiated an experiment to assess a combination of wildfire management strategies to augment the "tool chest" that the Fire and Aviation Branch had available. Fire surrogates such as hand-thinning and various levels of mechanical thinning were compared both in combination with prescribed fire, and separate from prescribed fire. With four experimental blocks set up in three different geographic and administrative locations in and adjacent to the Park, the proposed research required NEPA compliance prior to implementation. Initial public input reflected the mistrust of environmental organizations for federal land managers during the late 1990s, and was successful in stopping the research as originally designed.

During this same period, efforts by the Grand Canyon Trust (not associated with the National Park), and the Ecological Restoration Institute (at Northern Arizona University) expanded efforts to provide a heightened awareness of the dangerous conditions of the over-dense forests to the nearby community of Flagstaff and its surrounding natural/cultural resources. The Greater Flagstaff Forest Partnership (overseen by The Grand Canyon Trust) and its collaborating partners (community stakeholders (county, state, and federal), environmental organizations) undertook a concerted effort to educate the public to the dangers of unmanaged wildfire and the means of properly restoring fire in the landscape.

Figure 5. Another stand of yellow-barked pines on Rainbow Plateau, with the charred large coarse woody debris, fire scars on live pines, grassy openings, and relatively open stands leading one's eyes off into the distance.

By 2002, the Park re-proposed the Fire Restoration research in a much-revised version which diminished the impact of the more effective thinning "tools." A more involved and educated public lent their favorable input to the NEPA process and compliance was approved for "Wildfire Hazard Reduction Research" by 2003. This research also investigated several techniques designed to reduce damage to the old yellow-barked ponderosa pines (ranging from 200 to 500 years of age). While fire-managed acreages outside the NROV generally were considered acceptable, the increased incidences of fires with unnaturally high burn severity classifications are in dispute.

One technique to prevent unnaturally high burn severity was to manually remove the dense matting of pine needle detritus (from 0 to 18 in. out from base of tree) which had accumulated (often 12 to 15 in. deep) around the bases of these old pines during the previous century of fire exclusion. Another was to remove young regenerating firs and pines from the immediate vicinity of these old pines (as far out as the height of the old tree being protected), so as to prevent the 'ladder fuels' from escalating surface fires into crown fires (burning more intensely, and consuming more acres faster). An intermediate thinning that removed all regeneration less than five inches diameter at breast height was also part of the experimental design.

With successful results from the Wildfire Hazard Reduction Research and administrative approval, these techniques are currently employed in limited use in Grand Canyon, primarily around structures and resources of value (e.g., threatened and endangered species), and near Park boundaries. Funding was requested to expand these and other applications to a broader forested ecosystem, but as of the date of this brief bulletin note but financial support has yet to be approved, either at park or regional levels. A pro-fire administration, weary of the previous decade of litigation, has taken a conservative approach while operating under the 1995 Fire Management Plan (FMP). For pragmatic reasons, the Park's FMP grew very long in the tooth. Fire management favored operating under the less specific, out-of-date 1995 plan. This plan served as a vague umbrella under which wildfire managers had been allowed to operate, frequently at or outside the boundaries, within NEPA compliance.

The Park is currently revising its 1995 Fire Management Plan, updating content to reflect more current fire management policy and NEPA compliance. An essential part of the NEPA process is public involvement and participation in the management of public lands. Members of the public with concerns about cultural and natural resources and social and economic issues have an opportunity to have their say and are encouraged to participate in the management of their lands, for their own enjoyment and the enjoyment of future visitors to this grand Park and World Heritage Site.

For more information, see the website for NPS fire management program:

http://www.nps.gov/fire/fire/fireprogram.cfm

You may also contact the author at FoRestoration@ak.net.

CURIOSITIES OF THE CROSS TIMBERS, VOLUME 1

Don C. Bragg

Research Forester, USDA Forest Service, Southern Research Station
P.O. Box 3516 UAM, Monticello, AR 71656

In the last issue, Will Blozan provided pictures of a curious "melding" of two different oaks of different species. The natural environment is full of interesting-looking surprises, if we just look for them. Perhaps even more curious than the merger of two living trees is the blending of a live tree with an inanimate object.

Now, I'm sure that most of us have seen how a tree can grow around a small object. Witness the wholly encompassed strand of barbed wire that this oak has grow around in the many decades since it was first affixed to it (Figure 1). The fact that a tree could envelope such a small object is of no great surprise to us.

Figure 1. An oak growing around a strand of ancient barbed wire in the Cross Timbers of Oklahoma. Photo by Don C. Bragg.

Figure 2. Shortleaf pine in a rock crevice of the Oklahoma Cross Timbers. Photo by Don C. Bragg.

We may also witness a tree that grows in the cracks of a rock or cliff face, sometimes wedging itself so firmly into the stone as to split the rock apart. People tend to think almost exclusively of the fragility of nature—which is true, in many instances—yet plants and animals can be imposing agents of change. The splitting of the rock by this shortleaf pine (Figure 2) is the most obvious example of this in this particular photograph, but the organic acids produced by the lichens and pine needles covering these rocks also help to reduce it to rubble.

Figure 3. A curious fusion of oak and sandstone.

Perhaps the most curious tree I spotted on this day was an oak that appears to reach out to embrace a low rock shelf (Figures 3 and 4). Undoubtedly, this tree is producing callous materials to deal with abrasion from the immovable rock, but the extent to which this particular individual has done this is impressive—almost pathological! This series of images show the innate ability of trees to blend with the features of its environment in an often seamless fashion. Such examples can be found in just about any forested setting, if you look closely enough.

Figure 4. A different perspective on the fusion of oak and stone.

Curious about the Cross Timbers? Want to know more about the ancient oaks, cedars, and pines of this ecosystem? Visit the website of the Ancient Cross Timbers Consortium for more information:

http://www.uark.edu/misc/xtimber/

NATIVE AMERICAN VIEWS ON NATURE

Robert T. Leverett

Founder, Eastern Native Tree Society

Part of the ENTS mission is to explore myths and legends about the origins of tree species as a way of acknowledging and honoring the beliefs of all cultures. There are plenty of Native American myths and legends that give us insight into the Native's widow to the natural world and beyond – perhaps what we really seek. Many legends explain natural land features and the origins of species. Large landforms are guaranteed to be included on the list. For example, the Cheyenne, Arapahoe, Lakota, and Shoshone all have myths about the origin of Devil's Tower in Wyoming.

As colorful as are original accounts of land features, what I find of greatest interest is what they say about the underlying belief system in the power of nature. Of course, this quickly invokes notions of polytheism. Certainly, Native peoples have a concept of spirit in nature and how that spirit works that elevates the importance of non-human life forms (including trees). This is especially true when comparing Native beliefs to those of modern Christianity. Without exploring details, I will make a simple observation—their concept of spirit leaves room for a kind of respect that typifies Native beliefs about animals and plants. A popular notion based in liberal quarters of modern European-American society is that the Native concept of spirit predisposes Native peoples to be good environmentalists. There is an element of truth in this view. The subject is complex, but in practice, people are people.

One distinguishing feature of indigenous cultures, especially before the advent of modern Europeans on the North American continent, is that the Natives were supremely utilitarian in their outlook toward nature and individual species. Typically, in Native American religions, each species was given an original assignment by the creator. Consequently, there is a role to be played by each species in supporting all life. Where Native cultures have held to this kind of belief system, some anthropologists believe there is a kind of check and balance created against over-exploitation of species. However, a belief in Native adherence to natural balance is far from being universally held within the societies of anthropology, archeology, ethnology, etc. Societies such as the southwestern Anasazi are believed to have exhausted their natural resources and Native civilizations such as the lordly Mayans of Central America were first-class resource exploiters. So were the Aztecs and any Native civilization that moved toward a division of labor. But, as one moves north from Mexico, with the possible exceptions of the Mississippian and Ohioan cultures, exploitation seems to have occurred on a far more modest scale. One needed deerskin for clothing and venison for food, but the deer and its contribution to human survival were highly respected. Traditional Native belief systems never reduced deer to the status of modern-day cattle or a chicken—animals to be exploited without thought for the spirit of the species, or even if such a thing exists. To Natives, all wild animals had an innate dignity. Large, ferocious animals were respected and feared, and, hence, often made the basis for clan identification. For example, western Natives both feared and revered the grizzly. Bear medicine was very potent—a warrior who killed one could inherit its strength.

Where trees are concerned, I have encountered fewer Native origin legends, although I don't doubt they exist. A lot of ENTS research will be required to compile what is known of Native myths and legends on the origin of tree species. I suspect that will do best concentrating on species that had high utility value, such as white birch, American chestnut, and lodgepole pine. Species used for canoe and dugout building are excellent candidates for legends of origin. The last time I talked to an Algonquin canoe builder near Maniwaki, Canada, he was having trouble finding white birch large enough to serve for his customized canoe building. Forest exploitation in that part of Quebec had decimated the number of large white birch. I could see the frustration in his face. He saw the unmistakable mark of modern society on the Canadian forests. He complained that exploitation, mass conversion of forests, monocultures, etc. all represent the dominant societal view that trees were just a commodity. It wasn't clear what he felt his people should be doing since timber exploitation was also being done by Natives on their tribal lands.

As I find the time, I will begin researching the Jani Leverett library in earnest for examples of to Native views of forests as well as species origin legends. This will be a labor-intensive task. However, an exploration of Native views about the roles of specific tree species is a companion subject. I will likely hop back and forth among the spiritual, the legend, and the utilitarian. I welcome participation by others.

INSTRUCTIONS FOR CONTRIBUTORS

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The *Bulletin of the Eastern Native Tree Society* accepts solicited and unsolicited submissions of many different types, from quasi-technical field reports to poetry, from peer-reviewed scientific papers to digital photographs of trees and forests. This diverse set of offerings also necessitates that (1) contributors specifically identify what type of submission they are providing; (2) all submissions should follow the standards and guidelines for publication in the *Bulletin*; and (3) the submission must be new and original material or be accompanied by all appropriate permissions by the copyright holder. All authors also agree to bear the responsibility of securing any required permissions, and further certify that they have not engaged in any type of plagiarism or illegal activity regarding the material they are submitting.

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Send all materials and related correspondence to:

Don C. Bragg
Editor-in-Chief, *Bulletin of the ENTS*
USDA Forest Service-SRS
P.O. Box 3516 UAM
Monticello, AR 71656

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All submissions must be made to the Editor-in-Chief in digital format. Manuscripts should be written in Word (*.doc), WordPerfect (*.wpd), rich-text format (*.rtf), or ASCII (*.txt) format.

Images can be submitted in any common format like *.jpg, *.bmp, *.tif, *.gif, or *.eps, but not PowerPoint (*.ppt). Images must be of sufficient resolution to be clear and not pixilated if somewhat reduced or enlarged. Make sure pictures are at least 300 dots per inch (dpi) resolution. Pictures can be color, grayscale, or black and white. Photographs or original line drawings must be accompanied by a credit line, and if copyrighted, must also be accompanied by a letter with express written permission to use the image. Likewise, graphs or tables duplicated from published materials must also have expressly written copyright holder permission.

PAPER CONTRIBUTIONS (ALL TYPES)
All manuscripts must follow editorial conventions and styling when submitted. Given that the *Bulletin* is edited, assembled, and distributed by volunteers, the less work needed to get the final product delivered, the better the outcome. Therefore, papers egregiously differing from these formats may be returned for modification before they will be considered for publication.

Title Page
Each manuscript needs a separate title page with the title, author name(s), author affiliation(s), and corresponding author's postal address and e-mail address. Towards the bottom of the page, please include the type of submission (using the categories listed in the table of contents) and the date (including year).

Body of Manuscript
Use papers previously published in the *Bulletin of the Eastern Native Tree Society* as a guide to style formatting. The body of the manuscript will be on a new page. Do not use headers or footers for anything but the page number. Do not hyphenate text or use a multi-column format (this will be done in the final printing). Avoid using footnotes or endnotes in the text, and do not use text boxes. Rather, insert text-box material as a table.

All manuscript submissions should be double-spaced, left-justified, with one-inch margins, and with page and line numbers turned on. Page numbers should be centered on the bottom of each new page, and line numbers should be found in the left margin.

Paragraph Styles. Do not indent new paragraphs. Rather, insert a blank line and start the new paragraph. For feature articles (including peer-reviewed science papers), a brief abstract (100 to 200 words long) must be included at the top of the page. Section headings and subheadings can be used in any type of written submission, and do not have to follow any particular format, so long as they are relatively concise. The following example shows the standard design:

FIRST ORDER HEADING
Second Order Heading
Third Order Heading. The next sentence begins here, and any other levels should be folded into this format.

Science papers are an exception to this format, and must include sections entitled "Introduction," "Methods and Materials," "Results and Discussion," "Conclusions," "Literature Cited," and appendices (if needed) labeled alphabetically. See the ENTS website for a sample layout of a science paper.

Trip reports, descriptions of special big trees or forests, poetry, musings, or other non-technical materials can follow less rigid styling, but will be made by the production editor (if and when accepted for publication) to conform to conventions.

Table and figure formats. Tables can be difficult to insert into journals, so use either the table feature in your word processor, or use tab settings to align columns, but DO NOT use spaces. Each column should have a clear heading, and provide adequate spacing to clearly display information. Do not use extensive formatting within tables, as they will be modified to meet *Bulletin* standards and styles. All tables, figures, and appendices must be referenced in the text.

Numerical and measurement conventions. You can use either English (e.g., inches, feet, yards, acres, pounds) or metric units (e.g., centimeters, meters, kilometers, hectares, kilograms), so long as they are consistently applied throughout the paper. Dates should be provided in month day, year format (June 1, 2006). Abbreviations for units can and should be used under most circumstances.

For any report on sites, heights must be measured using the methodology developed by ENTS (typically the sine method). Tangent heights can be referenced, especially in terms of historical reports of big trees, but these cannot represent new information. Diameters or circumference should be measured at breast height (4.5 ft above the ground), unless some bole distortion (e.g., a burl, branch, fork, or buttress) interferes with measurement. If this is the case, conventional approaches should be used to ensure diameter is measured at a representative location.

Taxonomic conventions. Since common names are not necessarily universal, the use of scientific names is strongly encouraged, and may be required by the editor in some circumstances. For species with multiple common names, use the most specific and conventional reference. For instance, call *Acer saccharum* "sugar maple," not "hard maple" or "rock maple," unless a specific reason can be given (e.g., its use in historical context).

For science papers, scientific names MUST be provided at the first text reference, or a list of scientific names corresponding to the common names consistently used in the text can be provided in a table or appendix. For example, red pine (*Pinus resinosa*) is also known as Norway pine. Naming authorities can also be included, but are not required. Be consistent!

Abbreviations. Use standard abbreviations (with no periods) for units of measure throughout the manuscript. If there are questions about which abbreviation is most appropriate, the editor will determine the best one to use. Here are examples of standardized abbreviations:

inch = in	feet = ft
yard = yd	acre = ac
pound = lb	percent = %
centimeter = cm	meter = m
kilometer = km	hectare = ha
kilogram = kg	day = d

Commonly recognized federal agencies like the USDA (United States Department of Agriculture) can be abbreviated without definition, but spell out state names unless used in mailing address form. Otherwise, spell out the noun first, then provide an abbreviation in parentheses. For example: The Levi Wilcoxon Demonstration Forest (LWDF) is an old-growth remnant in Ashley County, Arkansas.

Citation formats. Literature cited in the text must meet the following conventions: do not use footnotes or endnotes. When paraphrasing or referencing other works, use the standard name date protocol in parentheses. For example, if you cite this issue's Founder's Corner, it would be: "…and the ENTS founder welcomed new members (Leverett 2006)." If used specifically in a sentence, the style would be: "Leverett (2006) welcomed new members…" Finally, if there is a direct quotation, insert the page number into the citation: (Leverett 2006, p. 15) or Leverett (2006, p. 16-17). Longer quotations (those more than three lines long) should be set aside as a separate, double-indented paragraph. Papers by unknown authors should be cited as Anonymous (1950), unless attributable to a group (e.g., ENTS (2006)).

For citations with multiple authors, give both authors' names for two-author citations, and for citations with more than two, use "et al." after the first author's name. An example of a two-author citation would be "Kershner and Leverett (2004)," and an example of a three- (or more) author citation would be "Bragg et al. (2004)." Multiple citations of the same author and year should use letters to distinguish the exact citation: Leverett 2005a, Leverett 2005b, Leverett 2005c, Bragg et al. 2004a, Bragg et al. 2004b, etc.

Personal communication should be identified in the text, and dated as specifically as possible (not in the Literature Cited section). For example, "…the Great Smoky Mountains contain most of the tallest hardwoods in the United States (W. Blozan, personal communication, March 24, 2006)." Examples of personal communications can include statements directly quoted or paraphrased, e-mail content, or unpublished writings not generally available. Personal communications are not included in the Literature Cited section, but websites and unpublished but accessible manuscripts can be.

Literature Cited. The references used in your work must be included in a section titled "Literature Cited." All citations should be alphabetically organized by author and then sorted by date. The following examples illustrate the most common forms of citation expected in the *Bulletin*:

Journal:

Anonymous. 1950. Crossett names giant pine to honor L.L. Morris. Forest Echoes 10(5):2-5.

Bragg, D.C., M.G. Shelton, and B. Zeide. 2003. Impacts and management implications of ice storms on forests in the southern United States. Forest Ecology and Management 186:99-123.

Bragg, D.C. 2004a. Composition, structure, and dynamics of a pine-hardwood old-growth remnant in southern Arkansas. Journal of the Torrey Botanical Society 131:320-336.

Proceedings:

Leverett, R. 1996. Definitions and history. Pages 3-17 *in* Eastern old-growth forests: prospects for rediscovery and recovery, M.B. Davis, editor. Island Press, Washington, DC.

Book:

Kershner, B. and R.T. Leverett. 2004. The Sierra Club guide to the ancient forests of the Northeast. University of California Press, Berkeley, CA. 276 p.

Website:

Blozan, W. 2002. Clingman's Dome, May 14, 2002. ENTS website http://www.uark.edu/misc/ents/fieldtrips/gsmnp/clingmans_dome.htm. Accessed June 13, 2006.

Use the hanging indent feature of your word processor (with a 0.5-in indent). Do not abbreviate any journal titles, book names, or publishers. Use standard abbreviations for states, countries, or federal agencies (e.g., USDA, USDI).

ACCEPTED SUBMISSIONS

Those who have had their submission accepted for publication with the *Bulletin of the Eastern Native Tree Society* will be mailed separate instructions to finalize the publication of their work. For those that have submitted papers, revisions must be addressed to the satisfaction of the editor. The editor reserves the right to accept or reject any paper for any reason deemed appropriate.

Accepted materials will also need to be accompanied by an author contract granting first serial publication rights to the *Bulletin of the Eastern Native Tree Society* and the Eastern Native Tree Society. In addition, if the submission contains copyrighted material, express written permission from the copyright holder must be provided to the editor before publication can proceed. Any delays in receiving these materials (especially the author contract) will delay publication. Failure to resubmit accepted materials with any and all appropriate accompanying permissions and/or forms in a timely fashion may result in the submission being rejected.

Larry Tucei standing next to the Josephine A. Stewart Oak. This colossal live oak has a circumference of 31.2 ft, a crown spread of 150 ft, and is 71 ft tall, and was thought to have been planted by a French settler sometime between 1720 and 1730. Photo courtesy of Larry Tucei.