Deriving Hemlock Crown Density Measures from Digital Photographs

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My objective is to develop and evaluate an objective strategy for deriving numerical measures of hemlock crown density (HCD) using digital photographs. For the present, my focus is on a special type of photograph, one that silhouettes the hemlock crown against an open sky. The goal is to develop a measurement procedure that will provide an accurate and reliable numerical measures of hemlock crown density, as well as allowing accurate measurement of changes in HCD for use in over-time comparisons of trees.

I now have collected several before/after photographs of trees that can be used with this measurement protocol and this is a report on some preliminary results for one site. In the photographs to be utilized, the hemlock trunk, branches and foliage (i.e., density) are represented by darker pixels, while the background (transparency) is represented by lighter pixels. The procedure that I propose utilizes histograms for digital photos generated by Photoshop Elements. The first operation utilizes the Histogram procedure to chart the percentage dark/light content of the pixels in a digital photo from darkest to lightest. The second operation uses the histogram to calculate the cumulative density at a darkness level representing hemlock foliage. This density level can be used to measure hemlock density for that digital photo and can be compared with corresponding measures for other photos to measure change in one tree or make numerical comparisons between different trees.

The photos and data below illustrate the use of this measurement strategy on a 2007 *Sasjiscymnus tsugae* release sites on hemlocks near the Horsepasture River in Sapphire, NC. The two photos were taken in mid-April and mid-July, approximately 3 months apart. (The planned application for this procedure will be comparisons over a 7-8 month period, but the shorter-term comparisons utilized here will provide a good test for the sensitivity of the measurement procedure.) Below are the "before" and "after" photos for a site containing a pair of adjacent hemlocks. These photos have the same general orientation, but will need cropping in order to focus the measurement procedure on the same crown areas for comparison.

Mid-April

Mid-July

Below are the cropped photos of these trees that will be used in the measurement process. The goal of this cropping is to get approximately the same crown area in both pictures. Differences in the background light or color (blue & white on the left and gray on the right) should not be a problem for the proposed procedure, because the focus will be on the dark end of the spectrum – the frequency of pixels at the darkest levels. Because variations in light conditions involve the other (lighter) end of the spectrum, such variations will not influence the results under the proposed measurement strategy.

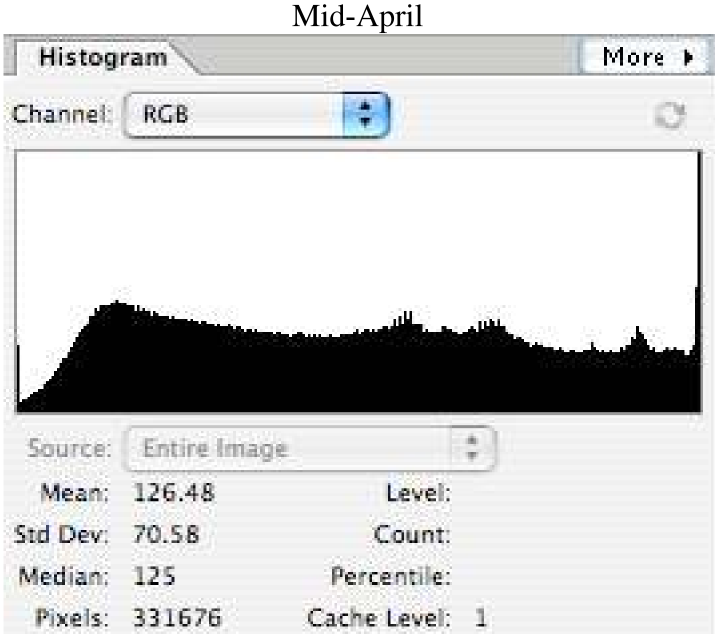
Mid-April

Mid-July

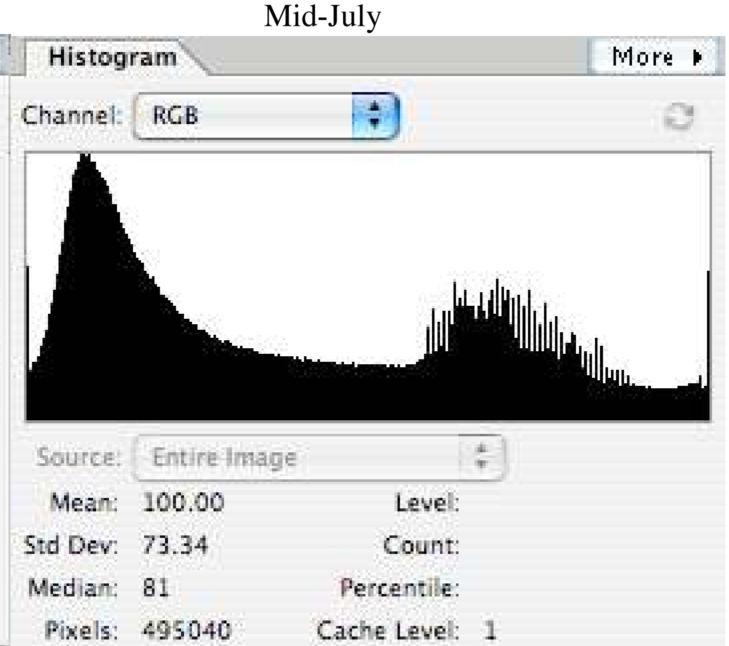
One can see from an "eyeball" test that there appears to be more foliage on the trees in mid-July than mid-April. But the histogram allows us to quantify these density differences in terms of the percentage of pixels in the darker range. The histogram is a plot with pixel darkness on the horizontal axis and pixel frequency/percentile on the vertical axis. It also provides cumulative percentile information - from dark to light - at any specified level that can be used to obtain quantitative measures of HCD.

The corresponding histograms for these two photos (below) illustrate even more clearly the impact of foliage growth on the hemlock crown density in the two pictures. The histogram for the April photo shows a relatively uniform density distribution moving horizontally from dark (left) to light (right) - with a spike at the far right for the white clouds. The histogram for the July photo shows a definite peak for darker pixels in the early part of the distribution, representing new foliage.

Mid-April



Mid-July



We can use these histograms to measure hemlock crown densities by calculating the percentile of darker pixels in a photograph. This is illustrated in the table below, where the mid-April photo had 51.12% of the pixels darker than the midpoint of the spectrum, while by the mid-July photo, the same trees had 61.99% pixels darker than the midpoint, leading to a difference (change) of 10.87%. The proposal here is to use cumulative percentile numbers derived from a photograph's histogram to represent the crown density in the pictured tree(s), as well as to measure changes in that density over time. However, this will require one more step - to select a darkness level that best captures hemlock foliage growth.

Table 1: Comparisons of Hemlock Crown Density Measurement

	Darkest 1/2	Darkest 1/3	Darkest 1/4
mid-April	51.12%	34.75%	25.35%
mid-July	61.99%	51.30%	44.39%
3 Month Change	10.87%	16.55%	19.04%

The histograms illustrate that changes due to new foliage growth appear well down into the darker end of the spectrum. So this will help us to identify the "best" point in the spectrum for measuring these foliage changes. The table above contains readings for 3 different darkness levels – darkest ½, darkest 1/3, and darkest ¼. A review of histograms for these and other photos, suggests that differences due to foliage changes are concentrated in the darkest 20% of the spectrum. And the results in the table indicate that either the 25% or 33% benchmarks would have considerable sensitivity to the 3-month foliage changes represented here. Specifically, the 25% benchmark, representing the darkest 25% of the pixel color spectrum, indicates a 19.04% increase (due to new foliage growth) while the 33% benchmark, representing the darkest 33% of the pixel color levels, indicates a 16.55% increase (due to new foliage growth).

While differences are still visible at the midpoint of the darkness/lightness spectrum, it would appear that use of 50% or higher levels would unnecessarily dilute the information about foliage growth (as well as introduce confounding due to other sources of light variability). And while the 33% level would be acceptable for this purpose, the 25% benchmark would appear to be the most effective for measuring levels and changes in hemlock crown density.