Tracking the Seasonal Rhythms of Boston Common Trees

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New England's deciduous forests undergo dramatic seasonal changes. New leaves emerge from protective buds as winter gives way to spring, green trees conceal the landscape and cast deep shade during the height of summer, and glorious fall foliage senesces as autumn yields to the snows and bitter cold of winter. But how much do these seasonal transitions vary from year to year? We are exploring this phenological question through detailed observation of a setting familiar to many New Englanders and visitors alike—the Common in downtown Boston. Since mid May of 2010, a digital camera mounted on the roof of the ten-story Walker Building, overlooking the Boston Common from the campus of Emerson College, has taken photos at thirty-minute intervals of a tree-covered area on the east side of this historic park.

The images generated by digital cameras represent colors using the RGB (red, green, blue) additive color model, which proposes that any color perceived by the human eye can be represented by some combination of these three primary colors. Each digital image is actually composed of three separate layers, one each for red, green, and blue. We characterize the "greenness" of the tree canopy by using image analysis software to measure how bright the green layer is relative to the total brightness of the red, green, and blue layers together. The color of the canopy is related to the color of individual leaves, as well as to the number of layers of leaves in the canopy. Individual leaf color is largely determined by pigments—green

Photos of the Boston Common in spring (April 30, 2011), summer (July 1, 2011), fall (November 11, 2011), and winter (February 5, 2012).

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chlorophylls, orange carotenoids, and red anthocyanins—but is also an indicator of photosynthetic capacity (Richardson et al. 2007; Sonnentag et al. 2012).

When we use this approach to quantify the greenness of all of these photos of the Common we can visualize the seasonal shifts. Following budburst, leaves expand rapidly and the springtime green-up happens quickly. Over a span of just four weeks, the leaf-out of deciduous elms, basswoods, cherries, and maples transforms the Common from a late winter landscape of browns and grays to its maximum greenness, which generally occurs during the first half of May. Peak green lasts only a couple of weeks, though, because as leaves mature they actually darken somewhat (Keenan et al., 2014). This causes a gradual reduction in our greenness index over the course of the summer. Then fall arrives: day lengths get shorter, temperatures become colder, and chlorophyll production gradually slows down. Greenness fades with the onset of senescence, leaf coloration, and leaf fall. The timing of these autumnal changes varies from species to species, and thus the de-greening of the Boston Common landscape happens somewhat more slowly than spring leaf-out, taking about six weeks from start to finish.

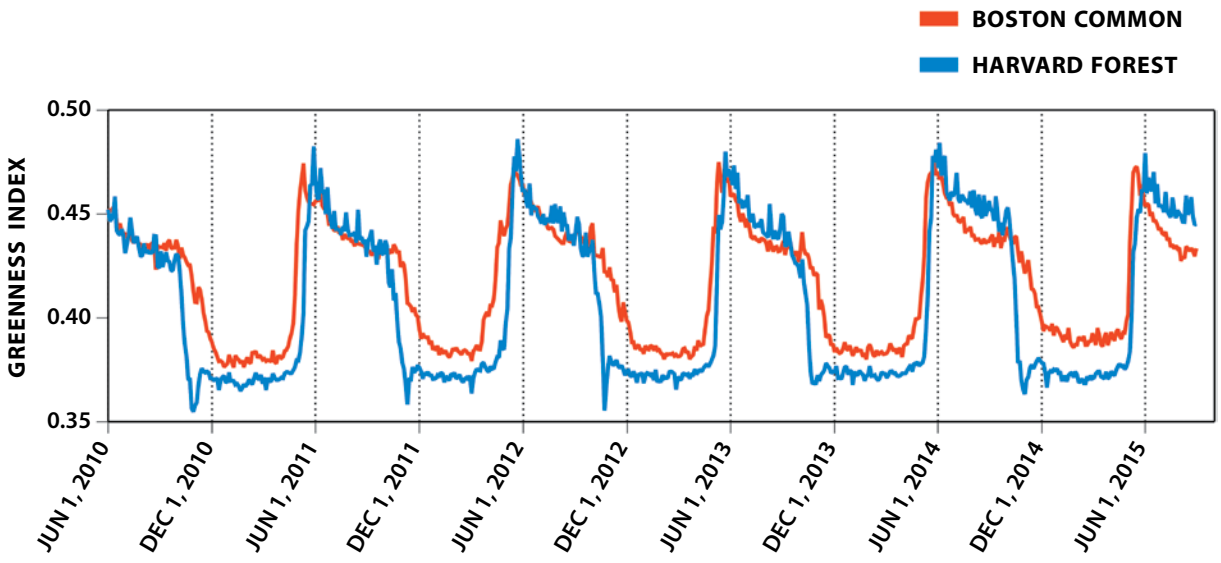
Comparison of the Boston Common data with those from a similar camera at Harvard Forest, located in the north-central Massachusetts town of Petersham, illustrates the general similarity of vegetation phenology in deciduous forests across southern New England. Despite differences in species composition between the native flora of Harvard Forest and the human-constructed mixture of native and nonnative tree species that we find in the Boston Common, both landscapes feature rapid spring green-up and maximum greenness at the beginning of the growing season. However, since Harvard Forest is situated more than 300 meters (984 feet) higher than Boston, nearly 100 kilometers (62 miles) inland, and well outside the urban heat island (Zhang et al. 2004), it is cooler than the Common and thus has a shorter growing

About Boston Common

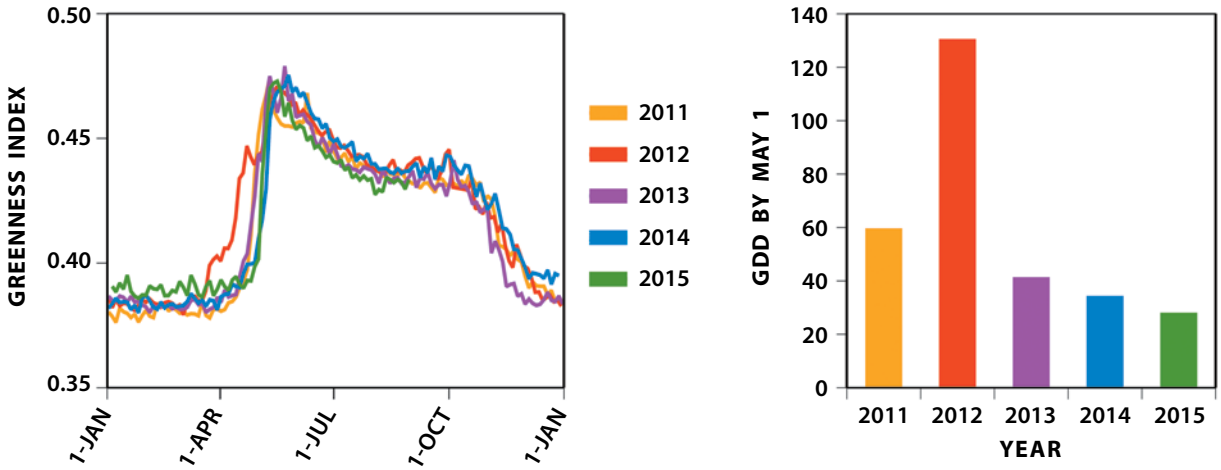
Since its founding in 1634, the fifty-acre Boston Common has served many purposes. In the seventeenth century, the sparsely wooded Common was used as a pasture for cattle. Early maps show only three trees, including the Great Elm, a majestic tree that loomed over the Common until it was blown down in a windstorm in the winter of 1876. The Common began to take on parklike qualities early in the eighteenth century. Bostonians strolled along wide, tree-lined malls, the first of which was established along Tremont Street in 1722. During the American Revolution and War of 1812, however, hundreds of soldiers were based in Boston and large encampments were built on the Common. Cows were eventually banned in 1830, and with subsequent formal landscaping the Boston Common was transformed to the largely forested park that exists today (Friends of the Public Garden 2005).

COURTESY OF HISTORIC NEW ENGLAND

This 1845 engraving by Hammatt Billings shows the Great Elm growing in the Boston Common.



Seasonal shifts in greenness for Boston Common in downtown Boston and Harvard Forest in Petersham, Massachusetts, between June 1, 2010 and September 1, 2015.



Leaf-out in the Boston Common occurred much earlier in 2012 than in the other years between 2011 and 2015. Springtime temperatures were anomalously warm in 2012, as reflected by the high number of growing degree days (GDD) reached by May 1 of that year.

season. With earlier leaf-out and later leaf drop, trees in downtown Boston have green leaves some eight weeks longer than their counterparts in Petersham.

Now that we have captured the vegetation phenology of five springs in the Boston Common photos, we can see how the timing of leaf-out has varied across years with strikingly different weather conditions. All but one of the years have a similar pattern: in 2011, 2013, 2014, and 2015, leaf emergence at the Common started at the beginning of April and greenness increased steadily over the next five weeks or so. In contrast, early spring temperatures in 2012 were significantly warmer than normal (Friedl et al. 2014), with record-breaking heat in Boston during the middle of March. The trees of the Boston Common responded immediately to this unseasonable warmth, leafing out within just a few days. As a result, the 2012 growing season was about a month longer than the other years for which we have photos.

The first five years of data from the Boston Common are consistent with other phenology studies in showing that the green-up of deciduous trees is highly sensitive to climatic variability (Cleland et al. 2007). If the warmth of March 2012 gives us a sense of what the future holds for springtime in Boston, as climate projections suggest (Hayhoe et al. 2007), then we can expect earlier leaf-outs and a substantial lengthening of the growing season. A failure to track these changes could be deleterious to the insect, bird, and mammal species that utilize urban forests as habitat. Such an outcome also has consequences beyond the Boston Common: phenological changes have the potential to shift competitive interactions among tree species and affect the carbon balance of forest ecosystems (Keenan et al. 2014). To better anticipate these dynamics, our research on vegetation phenology and related ecological processes will continue for years to come at the Boston Common, Harvard Forest, and dozens of other sites where this type of study is being carried out as part of the PhenoCam Network (phenocam.sr.unh.edu/webcam). More broadly, as Aldo Leopold put it, "phenology may eventually shed some light on that ultimate enigma, the land's inner workings" (Leopold and Jones 1947).

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