Rediscovering Aldo Leopold's Big Woods

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While much of Aldo Leopold's life is associated with Wisconsin, where he wrote A Sand County Almanac, his observations and letters as a high school student in Lawrenceville, New Jersey document his maturing insights into natural history and his eventual land ethic. This article frames Leopold's experiences at the Lawrenceville School within the context of its surrounding environment in 1904-1905 by rediscovering the locations of forests he drew on a map in a letter to his mother. Notably, Leopold referred to the forest west of Rider University today as the Big Woods. Tree-ring data recently collected by Rider University students and other historical evidence (including an oral interview, photographs, 1899 state government report, and 1849 herbarium sample) confirm the location of this forest and reveal that it has been present since at least the mid-nineteenth century. Knowing the locations of these forests, like Leopold's Big Woods, not only enables a greater appreciation for the landscape that he wrote extensively about in letters home, but also provides an opportunity to document the long-term environmental changes that have occurred over the past 110 years in central New Jersey.

In January 1904, just before turning seventeen, Aldo Leopold boarded a train from Iowa to Lawrenceville, New Jersey.[1] Growing up in Burlington, Iowa, Leopold's father had hoped that Aldo would stay close to home; however, Leopold had always possessed a strong interest in the natural world, cultivated by his parents, and longed for a career in conservation.[2] Such a career at that time was only possible with a degree from Yale's School of Forestry, and attending the

[1] Curt Meine, *Aldo Leopold: His Life and Work* (Madison, Wisconsin: University of Wisconsin Press, 1988), 34.
[2] Meine, 16-17, 27.

Lawrenceville School increased his likelihood of entering Yale.[3] After passing through Midwest farm fields, Leopold wrote home about the mountains, fog, and coal-dust covered towns of Pennsylvania as he headed to the Lawrenceville School, starting on a path that would ultimately lead him not only to establish the new academic discipline of wildlife management in the US and advocate for its first wilderness areas, but also to author *A Sand County Almanac*.[4]

Aldo Leopold's Observations of Lawrenceville

During his year and a half in Lawrenceville, Leopold wrote frequently to his family with 175 known letters.[5] At the Lawrenceville School, Aldo Leopold seemed initially out of place, but the surrounding fields and forests provided Leopold with a great opportunity to develop his skills in ecological observation outside of the formal classroom.[6] Two days after his arrival, Leopold set forth across the foot-deep January snow to explore nearby marshland and within his first three weeks he had explored the "big woods" west of the school.[7] He referred to his frequent long walks around Lawrenceville as "tramps" and soon earned the nickname "the naturalist" on campus.[8] While great attention has been appropriately given to Leopold's philosophical insights later in life after shooting a wolf and watching the green fire in its eyes slowly fade (foreshadowing ensuing ecological changes to Southwest environments with wolf extirpation), foundations of Leopold's eventual land ethic are evident even in his letters from Lawrenceville.[9]

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[3] Stephen Laubach, *When My Turn Comes: Selections from Aldo Leopold's Lawrenceville Letters and Journals* (Madison: University of Wisconsin-Madison, 2007), 4.
[4] Aldo Leopold to Clara Leopold, January 6, 1904, *Aldo Leopold Papers* (Madison: University of Wisconsin-Madison), http://digital.library.wisc.edu/1711.dl/AldoLeopold; Aldo Leopold, *A Sand County Almanac, and Sketches Here and There* (New York: Oxford University Press, 1949).
[5] Laubach, 4.
[6] Meine, 34,53; Matt Low, "The Lawrenceville Letters: Tracking the Origins of Aldo Leopold's Environmental Education," *Interdisciplinary Studies in Literature and Environment* 4, no. 18 (2011): 801-819.
[7] Aldo Leopold to Clara Leopold, January 9, 1904 and January 27, 1904.
[8] Aldo Leopold to Clara Leopold, January 9, 1904; Meine, 35.
[9] Leopold, *Sand County Almanac*, 129-133; Low, 811.

As an example of these earlier philosophical insights into the value of the ecological community, Meine and Low both discuss Leopold's ethical change in hunting wildlife in January 1905 when he returned to the Lawrenceville School with a shotgun.[10] That spring, Leopold began to hunt crows, or "rascals" as he referred to them and their impact on the rabbit population.[11] While killing dozens of crows, almost for sport, seems antithetical to one who would later argue for the inherent value of the ecological community, Leopold's attitudes developed in a manner foreshadowing his later views when he wrote home in March saying he "no longer enjoyed killing crows and left his gun behind."[12] Yet, an earlier event during his first spring at Lawrenceville in April 1904, mentioned briefly by Meine but deserving more attention in the context of this paper, shows an even greater emotional response as written in a letter to his mother:

> About two weeks ago I had an experience there which I did not write about. I saw a muskrat swimming about as if unable to get away, and an examination disclosed a trap. After some difficulty I released the animal and took the trap. I then looked over the rest of the swamp, and found another, which contained a drowned muskrat apparently several weeks dead. I took this one also. Today I found another, in which the muskrat must have lain half the winter by the looks of the body. This trap I merely concealed in a nearby thicket. So you see I have the three traps on my hands, which of course I will by no means give back to the person who traps in the breeding season, and much less if he leaves the carcases [sic] to rot. At the same time I hesitate to keep the traps myself, so I guess I will take the two former ones back to the swamp, and put them all three away out of doing harm and harm's way… This affair is rather an unpleasant subject but I thought I had better tell you about it.[13]

Leopold's emotions and decision-making reflects how he wrestles with an ethical solution to this situation and how he eventually acts with confidence on his decision. There is no mention of any discussion of this ethical quandary with his classmates or teachers, which seems unlikely given

[10] Meine, 39-42; Low, 812.
[11] Meine, 42.
[12] Meine, 40; Aldo Leopold to Clara Leopold, March 5, 1905 (cited in Meine, 41).
[13] Meine, 37; Aldo Leopold to Clara Leopold, April 2, 1904.

that he refrained from even mentioning it in his letters until after making his decision to hide the traps back in the swamp. As Leopold would later write in his famous essay on *The Land Ethic*:

> A land ethic cannot prevent the alteration, management, and use of these 'resources,' but it does affirm their right to continued existence, and, at least in spots, their continued existence in a natural state. In short, a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such.[14]

One cannot be certain if Leopold was responding to ideas that he would later formalize through his land ethic or if he was acting in response to hunting practices imparted from his father, but his actions are in keeping with his later land ethic.[15] Leopold is not inherently outraged that someone was trapping muskrats, but that they were doing so without any regard to their inherent value as part of a larger ecological community. If Leopold had not already begun to develop a sense of value in the ecological community by the time he arrived in Lawrenceville, situations like this at the very least challenged him to decide the ethical course of action on his own. As he writes later in this essay: "[n]o important change in ethics was ever accomplished without an internal change in our intellectual emphasis, loyalties, affections and convictions."[16]

The Forests of Central New Jersey in 1904 - 1905

When Leopold arrived in Lawrenceville he found himself "well pleased" with his new setting.[17] Likely concerned about finding less opportunities to observe nature than at his Iowa home, Leopold wrote enthusiastically that "[t]here is much timber, almost as much as we have at home" as well as a "good many birds."[18] He further observed:

> Here every farm has a timber lot, sometimes of fifteen or twenty acres, so it is as fine country for birds. It is about like Iowa high prairie, but the timber is more like the Michigan hardwood, the commonest trees being Oak, beech, ash, hickory, chesnut [sic], red cedar,

[14] Leopold, *Sand County Almanac*, 204.
[15] Meine, 18-19.
[16] Leopold, *Sand County Almanac*, 209-210.
[17] Aldo Leopold to Clara Leopold, January 8, 1904.
[18] Aldo Leopold to Clara Leopold, January 8, 1904.

> and some elm. In some places, notably old orchards, young red cedars cover the ground. Nearly all the undergrowth in the woods is saplings and briars. There is little indiscriminate chopping of timber here.[19]

An 1899 New Jersey report is remarkably consistent with Leopold's accounts of the forests in central New Jersey at that time and notes that the amount of agriculture increased dramatically towards Lawrenceville from the terminal moraine across northern New Jersey:

> Passing southwest of the moraine, which crosses from Fanwood through Metuchen to Perth Amboy, we enter immediately an agricultural district. The change is sudden and striking. The forest area suddenly drops from about 30 to 10 percent of the total area, this consisting almost exclusively of small woodlots attached to farms and husbanded for fuel, fencing and other domestic uses. Much of this is fine timber – as good as any in northern New Jersey.[20]

This description included the area around Lawrenceville, located in Mercer County. Only 11% of Mercer County was within forest cover in 1899, the least amount of forest cover recorded in any county in the state at that time.[21] The lack of forests in central New Jersey resulted from land use trends that had likely reached a peak extent of deforestation in 1850-1860.[22] By the time of Leopold's arrival in Lawrenceville, forests were uncommon, but those that remained were used to support farm life.

Locating Leopold's Big Woods

Within a month of arriving at the Lawrenceville School, Aldo included a hand-drawn map of destinations he was visiting on his tramps in a letter to his mother, writing: "I have attempted a map of this vicinity, which, although of course inaccurate, may help you to understand the various

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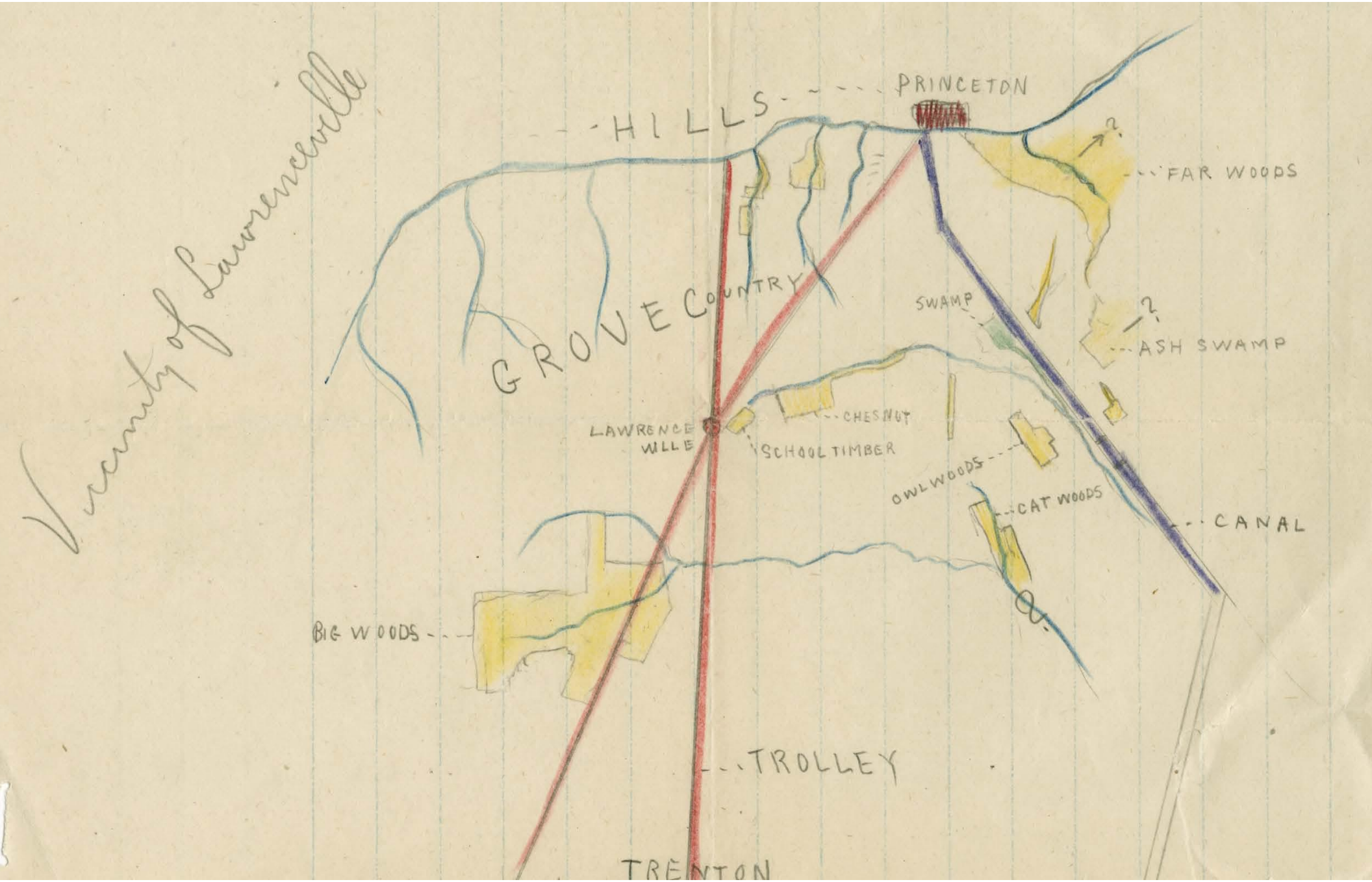
[19] Aldo Leopold to Clara Leopold, January 9, 1904.
[20] C.C. Vermeule, "The Forests of New Jersey," in *Annual Report of the State Geologist for the Year 1899: Report on Forests*, edited by Geological Survey of New Jersey (Trenton: MacCrellish & Quigley, State Printers, 1900) 89. See Plate I of Vermeule for a map overlaying physiographic regions and terminal moraine referenced in the quotation above; see Plate III for a map of percent forest cover showing the region surrounding Lawrenceville as among the areas least forested in New Jersey at that time.
[21] Vermeule, 16.
[22] Vermeule, 23; cited in Beryl Robichaud and Fife Buell Murrary, *Vegetation of New Jersey: A Study of Landscape Diversity* (New Brunswick: Rutgers University Press, 1973), 70-71.

places to which I refer" (Figure 1A).[23] While the map included the towns of Lawrenceville and Princeton as well as the trolley lines connecting them, it was largely a map of the ecological landscape surrounding the Lawrenceville School highlighting its streams and forests. Although this map has been mentioned previously in biographical sources, the locations and ecological histories of these forests deserve further attention in understanding Leopold's development as a naturalist and the ecological change that has occurred in Lawrenceville during this last century.[24]

(Please scroll for graphics.)

[23] Aldo Leopold to Clara Leopold, February 6, 1904.
[24] Meine, 35; Laubach, 11-12.


Vicinity of Lawrenceville
HILLS
PRINCETON
FAR WOODS
GROVE
COUNTRY
SWAMP
ASH SWAMP
LAWRENCE
VILLE
CHESNUT
SCHOOL TIMBER
OWL WOODS
CAT WOODS
CANAL
BIG WOODS
TROLLEY
TRENTON


LAWRENCEVILLE
PRINCESVILLE
FRANKLIN CORNER
BAKER'S BASIN
Canal
Ewingville
0 250 500 1,000 Meters
N


Chesnut
Lawrenceville School
School Timber
Canal
Owl Woods
Cat Woods
Big Woods
Little Shabakunk Creek
0 250 500 1,000 Meters
N


Chesnut
Lawrenceville School
School Timber
Canal
Owl Woods
Cat Woods
Rider University
Big Woods
Little Shabakunk Creek
0 250 500 1,000 Meters
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 1. Locations of forests visited and mapped by Aldo Leopold as a student at the Lawrenceville School in 1904 and re-located using georeferenced maps and imagery. (A) Map from a letter by Leopold showing forests (yellow), streams (blue), and two trolley lines (red). (B) Topographic map by the State of New Jersey ca. 1880. Dashed lines marking forests on the original map are highlighted in yellow. (C) 1930 aerial photograph showing forest as dark gray patches and fields as lighter gray patches and (D) 2015 aerial photograph. Yellow lines marking circa 1880 forests are overlaid along with stream locations and trolley lines. Green dots indicate locations of trees sampled within Leopold's Big Woods that date back at least to 1905, the year Leopold graduated. Leopold's map courtesy of the Aldo Leopold Foundation.

Prior to Leopold's arrival in Lawrenceville, C.C. Vermeule produced the first set of topographic maps for the state of New Jersey between 1870 and 1887, including hand-drawn depictions of areas in forest cover (Figure 1B above).[25] Using geographical information systems software, Vermeule's map of the Lawrenceville area was digitally georeferenced and polygons of forest cover were overlain on the first aerial photograph in 1930 (Figure 1C above).[26] While there are spatial offsets between the yellow Vermeule forest polygons and the dark patches of forests on the 1930 aerial, these are largely the result of location errors from both georeferencing the topographic map and the 1930 photograph in addition to potential cartographic errors in the hand-drawn topographic maps. Even with these errors, the locations of forest stands over this half-century clearly serve as bookends, anchoring the forest landscape on either side of Leopold's time in 1904-1905. The stand of "School Timber" and "Chesnut" [sic] are present near the Lawrenceville School buildings while "Owl Woods" is present further east towards the Delaware and Raritan Canal. Upstream of "Cat Woods" along the Little Shabakunk Creek, one can also discern the location where two of its tributaries merge in between the trolley lines. These tributaries originate further west near the area Leopold labelled as the "Big Woods."

Overlaying these features on a 2015 aerial shows that this landscape has undergone much development since 1930 (Figure 1D above). Surprisingly, most of the forests depicted by Leopold

[25] Vermeule, *Historical Topographic Manuscript Maps by C. C. Vermeule Around 1870-1887* (New Jersey Division of Water Supply and Geoscience, 1870-1887), accessed July 25, 2016, available from http://www.state.nj.us/dep/njgs/enviroed/vermeulemaps.htm.
[26] ArcGIS 10.3 for Desktop. ESRI, Redlands.

and some even earlier by Vermeule remain on this landscape including School Timber, Chesnut, a portion of Cat Woods and most of Leopold's Big Woods. Part of the development includes the construction of Rider University in Lawrenceville beginning in 1957 after re-locating from Trenton. Rider University and Lawrence Township now own the eastern half of the Big Woods. While former agricultural fields have been converted into athletic fields and campus grounds (Figure 2 below), these maps reveal forests present over much of the same area as was historically within the eastern half of the Big Woods.

To independently verify the location and to investigate the ecological history of the Big Woods, forest survey data and tree-ring data were collected within its eastern half. Tree cores were sanded and crossdated following standard dendrochronological procedures.[27] While much of the forest has young trees, 19 remnant white oak (*Quercus alba*) and American beech (*Fagus grandifolia*) trees were located with rings extending back to at least 1905, with the oldest tree dating to 1816 (Figure 1C and 1D above). The distribution of these trees across the eastern half further support the identification of this site as Leopold's Big Woods.

Independent documentary data also support this interpretation of Leopold's map, these historical maps, and tree-ring data. Perhaps signifying the importance of the Big Woods to others living in Lawrenceville prior to Leopold, the 1899 *Report on Forests* specifically refers to a

[27] James H. Speer, *Fundamentals of Tree-Ring Research* (Tucson: University of Arizona Press, 2010).

Figure 2. Photograph of farmland that would become Rider University in Lawrenceville, New Jersey. The forests in the background are the eastern side of Aldo Leopold's Big Woods. Photo courtesy of the Rider University Archives.

forest that matches the location and description of the Big Woods a few years prior to Leopold's observations:

> East of Ewingville is a tract comprising some 400 acres [160 ha], principally oak and chestnut, with some hickory, beech, and maple. A part of this is fine timber, 6 to 36 inches diameter and 55 to 70 feet high. The chestnuts run up to a good height without branching. A count gave 255 of these trees to the acre.[28]

While the area of the woods at that time as drawn on the topographic map was closer to 550 acres (220 ha), this forest was clearly the largest in between Lawrenceville and Ewingville. As early as 1849, these woods were also known locally as Five Mile Woods because of its distance

[28] Vermeule, 92.

from Trenton and because it was the source of Five Mile Run, now known as the Little Shabakunk Creek.[29]

Changes in Forests around Lawrenceville over the Past Century

The development evident around Lawrenceville since 1930 represents a larger statewide trend as New Jersey now has the highest population density, is the most urbanized state, and since 2007 has a greater amount of urban land than forest cover.[30] Within Mercer County specifically, 48% of its land use/land cover is now classified as Urban, 15% Agricultural, 16% Wetlands, and 18% Forest.[31] While the amount of forests may have increased slightly since the late nineteenth century, the most significant change is the transition from predominately agricultural to urban land use.

Within the Big Woods, Rider University students have been assisting in surveying the relative abundance of tree species within 25 plots (each comprising 400 m^2) since 2009. Considering trees with diameters greater than 10 cm at 1.37 m height, American beech trees are now the most common tree in this woods (37%) followed by red maple (*Acer rubrum*, 17%), oaks (13%, with 10% northern red oak, *Quercus rubra*), sweetgum (*Liquidambar styraciflua*, 10%), and tulip poplar (*Liriodendron tulipifera*, 8%), among other species. In precolonial forests in northern New Jersey, an analysis of preserved lake pollen showed that oak species were the most

[29] Dennis Waters, Lawrence Township Historian, email message to author, August 24, 2014. A lichen sample was also recorded in 5 Mile Woods in Mercer County by a botanist, C.C. Frost, in 1849 and is held in the J.F. Bell Museum of Natural History, University of Minnesota.

[30] "American FactFinder: Table GCT-PH1: Population, Housing Units, Area, and Density: 2010 - United States -- County by State; and for Puerto Rico," *U.S. Census Bureau*, accessed July 27, 2016, available from http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk; "Newsroom Archive: Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports 2012," *U.S. Census Bureau*, accessed July 27, 2016, available from https://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html; John E. Hasse and Richard G. Lathrop, *Changing Landscapes in the Garden State: Urban Growth and Open Space Loss in NJ 1986 thru 2007: Executive Summary* (Glassboro: Rowan University and Rutgers University, 2010), 7.

[31] "Draft 2016 Multi-Jurisdictional Hazard Mitigation Plan, Section 4 - County Profile," *Mercer County*, accessed July 27 2016, available from http://nj.gov/counties/mercer/departments/psem/draftplan.html.

dominant species represented while other tree species including American chestnut (*Castanea dentata*) and American beech were also present.[32] Except for the absence of American chestnut, the species abundance within the Big Woods now broadly corresponds with the regional expectation of a mixed oak forest for mesic, upland forests in New Jersey, although the location of Lawrenceville near the fall line with the coastal plain may contribute to the prevalence of American beech which is sometimes dominant in those forests.[33] While ecologists now recognize that forest succession represents an ongoing response to environmental change and does not achieve a climax community, the regeneration and shade tolerance of beech trees enable them to outcompete other species for light availability under forest canopies in this region.[34] Sweetgum and tulip poplar are also common in New Jersey forests, but only in younger forests since they cannot tolerate the shaded conditions beneath a forest canopy in older forests.[35] This description also fits the Big Woods today as more than 97% of the trees in a recently abandoned field within the Big Woods are sweetgums. After learning how to identify this species, Leopold too wrote home that sweetgums were common in this area.[36] Before following a farm cat to Cat Woods, Leopold also described the Chesnut forest labelled on his map as a managed stand with even-aged chestnuts, yet no American chestnut trees have been found in any of these forests today.[37]

The chestnut blight (*Cryphonectria parasitica*) was first identified at the Bronx Zoo in 1906; however, it had likely been independently introduced to multiple locations within the eastern

[32] Emily W. B. Russell, "Vegetational Change in Northern New Jersey from Precolonization to the Present: A Palynological Interpretation," *Bulletin of the Torrey Botanical Club* 107 no. 3 (1980): 432-446
[33] Robichaud and Buell, 169, 220.
[34] H.S. Horn, "Markovian properties of forest succession," in *Ecology and Evolution of Communities*, edited by M.L. Cody and J.M. Diamond (Cambridge, Massachusetts: Harvard University Press, 1975), 196-211.
[35] Robichaud and Buell, 210-211
[36] Aldo Leopold to Clara Leopold, May 3, 1905.
[37] Aldo Leopold to Clara Leopold, February 3, 1904.

US as early as the late nineteenth century with plantings of Asian chestnut trees.[38] Six years later, the *Trenton Evening Times* reported that American chestnut trees in New Jersey and other mid-Atlantic states were threatened by the blight.[39] By 1924, a search in New Jersey found less than two dozen American chestnut trees remaining in the state and even those were infected.[40] Mr. Nicholas Loveless, who was born in a house on the eastern edge of the Big Woods in 1925, recalls digging up chestnut sprouts and replanting them in an effort to save some from the blight, but those attempts were unsuccessful.[41] In hindsight, the demise of the American chestnut may have been hastened by advice to cut living chestnuts in advance of the blight to salvage their wood, reducing the probability that some trees may have had the genetic diversity to survive.[42]

The loss of chestnuts from the Big Woods is recorded in the growth of remaining oak and American beech trees today. Neighboring trees typically experience a release from suppressed growth conditions when a canopy tree dies because of the increase in available light.[43] These events are recorded as a subsequent, abrupt increase in tree-ring widths and can be objectively identified as statistical outliers in tree-ring width time series using intervention detection.[44] Using the latest version of this approach, both tree species record pronounced growth releases after the 1912

[38] Susan Freinkel, *American Chestnut: The Life, Death, and Rebirth of a Perfect Tree* (CA: University of California Press, 2007), 27-35, 68.
[39] "This and Other States Fear Chestnut Blight," *Trenton Evening Times*, April 13, 1912.
[40] Freinkel, 77.
[41] Nicholas Loveless, email message to author, June 9, 2014.
[42] Freinkel, 80.
[43] C.D. Canham, "Suppression and release during canopy recruitment in *Fagus grandifolia*," *Bulletin of the Torrey Botanical Club* 117 no. 1 (1990): 1-7.
[44] C. G. Lorimer and L. E. Frelich, "A methodology for estimating canopy disturbance frequency and intensity in dense temperate forests," *Canadian Journal of Forest Research* 19, no. 5 (1989): 651-663; D. L. Druckenbrod, "Dendroecological reconstructions of forest disturbance history using time-series analysis with intervention detection," *Canadian Journal of Forest Research* 35 no. 4 (2005): 868-876.

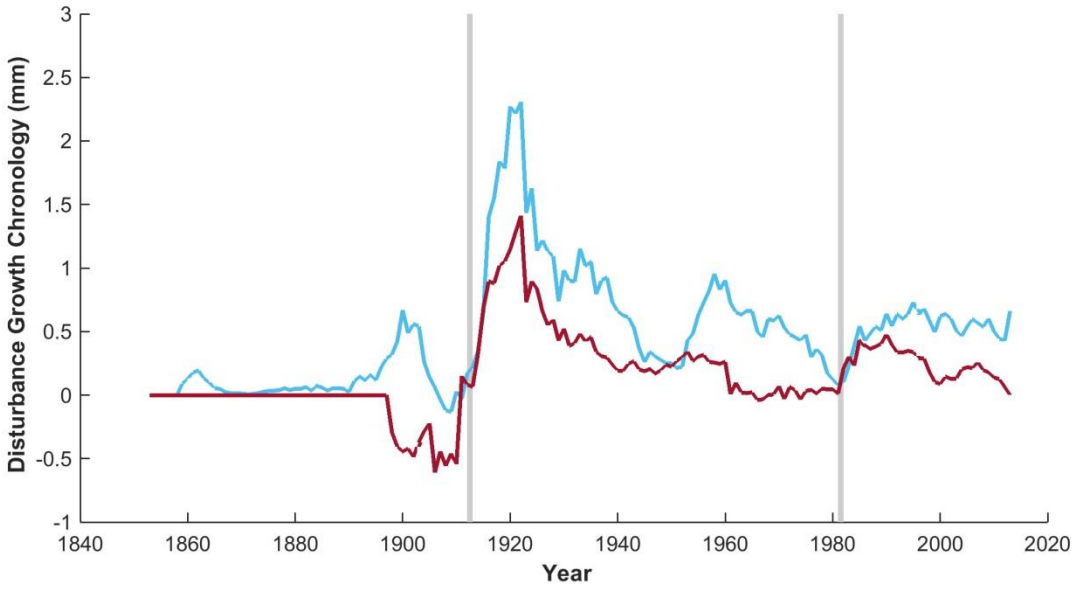


Figure 3. Tree-ring measurements showing a release event in oak (blue line) and American beech (red line) trees in the 1910s and a smaller one in the 1980s within Aldo Leopold's Big Woods that is coincident with the arrival of the chestnut blight in central New Jersey circa 1912 and gypsy moth peak outbreak in 1981, respectively (marked with vertical gray lines).

Trenton Evening Times article warning of the arrival of the blight (Figure 3 above).[45] American beech trees increased their average growth rate by more than 1 mm while oaks by more than 2 mm after the arrival of the blight. These trees also survived the arrival of the gypsy moth (*Lymantria dispar*) in New Jersey which had its most severe year in 1981 across New Jersey.[46] Oaks are preferred foliage for gypsy moths, but they may also impact other species including American beech.[47] While these trees were older at that time and may have already entered the forest canopy, their smaller growth release to the gypsy moth suggests that the chestnut blight had a larger impact

[45] Daniel L. Druckenbrod, Neil Pederson, James Rentch, and Edward R. Cook, "A comparison of times series approaches for dendroecological reconstructions of past canopy disturbance events," *Forest Ecology and Management* 302 (2013): 23-33.

[46]Associated Press and Thomas Barlas, "Gypsy moths: they came, they ate - and now they're gone." *The Press of Atlantic City*, accessed July 27, 2016, available from http://www.nj.com/news/index.ssf/2014/08/gypsy_moths_they_came_they_destroyed_thousands_of_acres_and_now_theyre_gone.html.

[47] Andrew M Liebold, Kurt W Gottschalk, Rose-Marie Muzika, Michael E Montgomery, Regis Young, Kathleen O'Day, and Brooks Kelley, *Suitability of North American tree species to the gypsy moth: a summary of field and laboratory tests* (Washington, D.C.: USDA Forest Service), 1995.

on this forest. Even with a relatively smaller impact, the gypsy moth may have also decreased the relative abundance of oak trees in the Big Woods and could also contribute to the prevalence of American beech trees within it currently.

The chestnut blight and the gypsy moth are not the only agents that have affected the composition of the Big Woods. Deer browse has also severely limited the recruitment of seedlings into this forest. White-tailed deer (*Odocoileus virginianus*) populations in New Jersey have increased because of the extirpation of mountain lion, fewer people engaging in hunting, and an increase in fragmented habitat preferred by deer.[48] Deer are common in the Big Woods and their impact on the amount of green vegetation can be observed using vertical cover boards, which when placed 15m away from the observer, are used to estimate the percent of an upright, wooden panel obscured by vegetation at increasing heights.[49] While the high proportion of American beech in this forest may also limit regeneration because of its dense foliage, it is remarkable how the percent cover increases as it becomes more difficult for deer to reach (Figure 4 below) as a typical white-tailed deer is approximately 1 m tall at its shoulder.[50] The Big Woods no longer has the abundant saplings that Leopold described, instead there is a pronounced browse line allowing increased visibility and little forest regeneration throughout the understory.

Leopold's story of the green fire is so insightful because he recognizes, counterintuitively to the prevailing wisdom of his time, that without predators such as wolves, deer populations can

[48] Benjamin Baiser, Julie L. Lockwood, David La Puma, and Myla F. J. Aronson, "A perfect storm: two ecosystem engineers interact to degrade deciduous forests of New Jersey," *Biological Invasions* 10, no. 6 (2008): 785-795.
[49] Thomas D. Nudds, "Quantifying the vegetative structure of wildlife cover," *Wildlife Society Bulletin* 5, no. 3 (1977): 113-117.
[50] D. A. Saunders, *Adirondack Mammals* (State University of New York: College of Environmental Science and Forestry, 1988), accessed July 24 2016, available from http://www.esf.edu/aec/adks/mammals/wtd.htm.

grow dramatically becoming irruptions that impact forest regeneration.[51] Years after Lawrenceville, Leopold would observe and describe patterns of deer browse like that now present

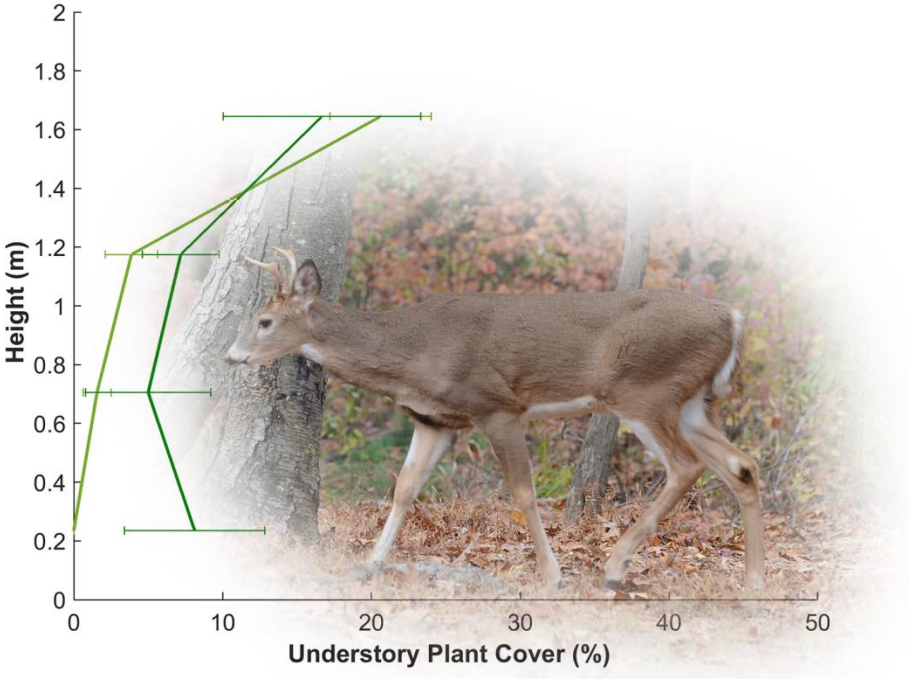


Figure 4. Vertical cover estimates (mean and standard error) showing the extent of deer browse within Leopold's Big Woods for 2013 (light green) and 2014 (dark green). Rider University students measured vertical cover by averaging observations from four cardinal directions in each of four plots (selected as a group for their interior location within the Big Woods out of the larger set of 25 plots). Deer photograph by Pete Borg.

in the Big Woods in many different forest settings.[52] He also wrote a 1947 scientific paper outlining areas in the US impacted by deer irruptions.[53] Notably, New Jersey was not included as a problem area at that time. More recently, scientists have returned to Leopold's ideas in studying the re-introduction of wolves into Yellowstone National Park and have documented the increased deer

[51] Susan L. Flaser, *Thinking like a Mountain: Aldo Leopold and the Evolution of an Ecological Attitude toward Deer, Wolves, and Forests* (Columbia: University of Missouri Press, 1974).
[52] William J. Ripple and Robert L Beschta, "Linking wolves and plants: Aldo Leopold on trophic cascades," *BioScience* 55, no. 7 (2005): 613-621.
[53] Aldo Leopold, Lyle K Sowls, and David L Spencer, "A survey of over-populated deer ranges in the United States," *The Journal of Wildlife Management* 11, no. 2 (1947): 162-177.

populations in the East Coast concurrent with the extirpation of large predators, a concept now known as a trophic cascade.[54] Smaller predators, such as coyotes or foxes, have also become

Figure 5. Rider University students walking a boundary between the older extent of Big Woods with trees extending back to Leopold's time in Lawrenceville (visible on the left) and younger, successional forests on former farmland (smaller trees visible on the right). Japanese stiltgrass is also present in the understory of the younger forest. Photograph by author.

more abundant after the extirpation of wolves, but they do not have the same influence on deer populations.[55]

While portions the Big Woods have undergone development since 1930, new forests have also established on the northeast side as secondary succession from abandoned agricultural lands.

[54] Ripple and Beschta, 613-621.
[55] Leopold, Sowls, and Spencer, 162-177; Ripple and Beschta, 613-621.

The differences in older and younger forests are evident along an old-field boundary that is present within the forest canopy today (Figure 5 above). In a testament to their growth towards greater sunlight, trees from the older forest still lean towards what would have been farmland decades ago, but is now young forest. Today this boundary is still marked by metal fence wire embedded in trees within the older forest and the greater prevalence of Japanese stiltgrass (*Microstegium vimineum*) in the younger forest. Greater deer populations have the additional incidental effect of promoting the spread of non-native understory plants, such as Japanese stiltgrass through forest understories.[56] This plant is common in the younger forest (since it was more recently disturbed) but not yet in the older forest.

Leopold also observed the forest understory and was particularly intrigued by skunk cabbage (*Symplocarpus foetidus*), another plant species that he had not seen in Iowa (Figure 6 below).[57] Leopold observed that the early blooming of the plant had a "carrion-smell" which attracted flies and those flies were eaten by migrating phoebes that timed their arrival for this food source.[58] Leopold's ability to discern this seasonal ecological community on his own document his growing insight as a self-taught naturalist.[59] Subsequent research supports Leopold's observations that the flowers on these plants attract insect pollinators, although their heat-producing adaptation is also thought to be advantageous for melting through snow and ice covering the soil in early spring (Figure 7 below).[60]

[56] Baiser, Lockwood, La Puma, and Aronson, 785-795.
[57] Aldo Leopold to Clara Leopold, March 13, 1904.
[58] Aldo Leopold to Clara Leopold, March 14, 1904.
[59] Low, 804-807.
[60] Roger M. Knutson, "Plants in heat," *Natural History* 88 no. 3 (1979):42-47.

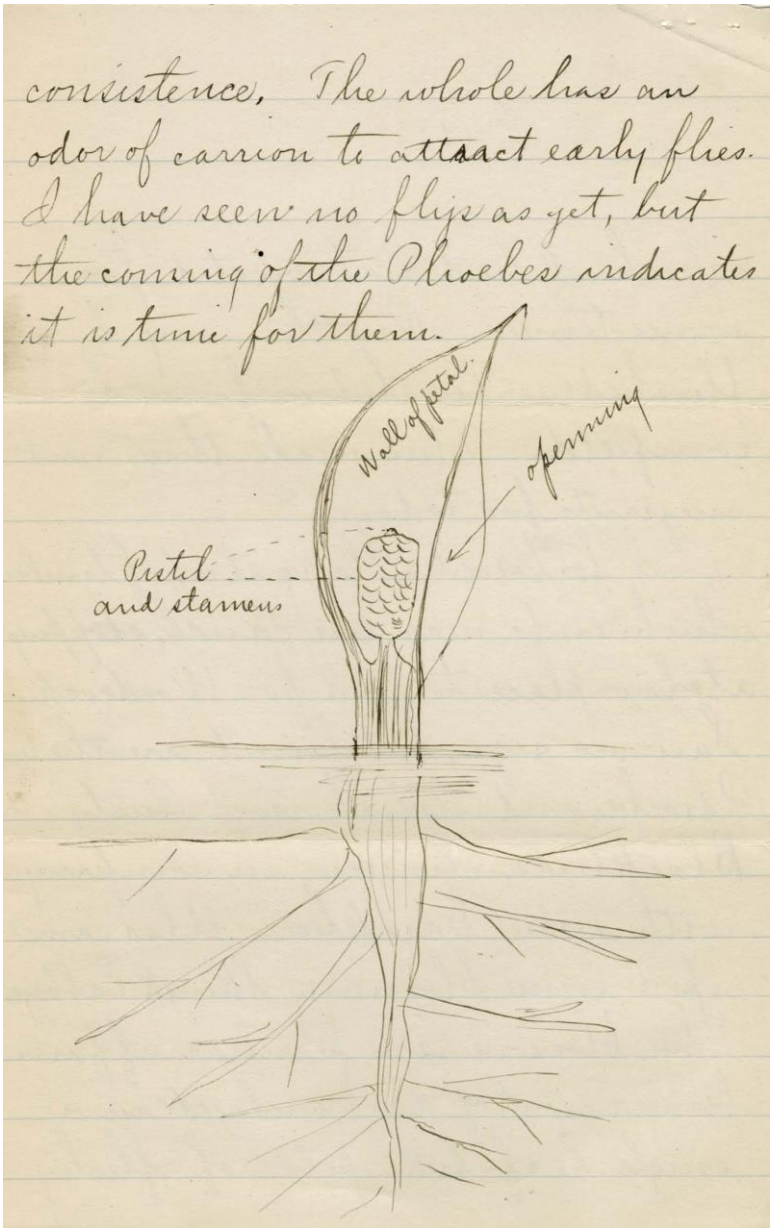


Figure 6. Excerpt of a letter with a drawing of a skunk cabbage by Aldo Leopold while in Lawrenceville, New Jersey, indicating the ecological relationship between these plants, insects attracted to their flowers, and migrating phoebes that feed on those insects in early spring. Image courtesy of the Aldo Leopold Foundation.

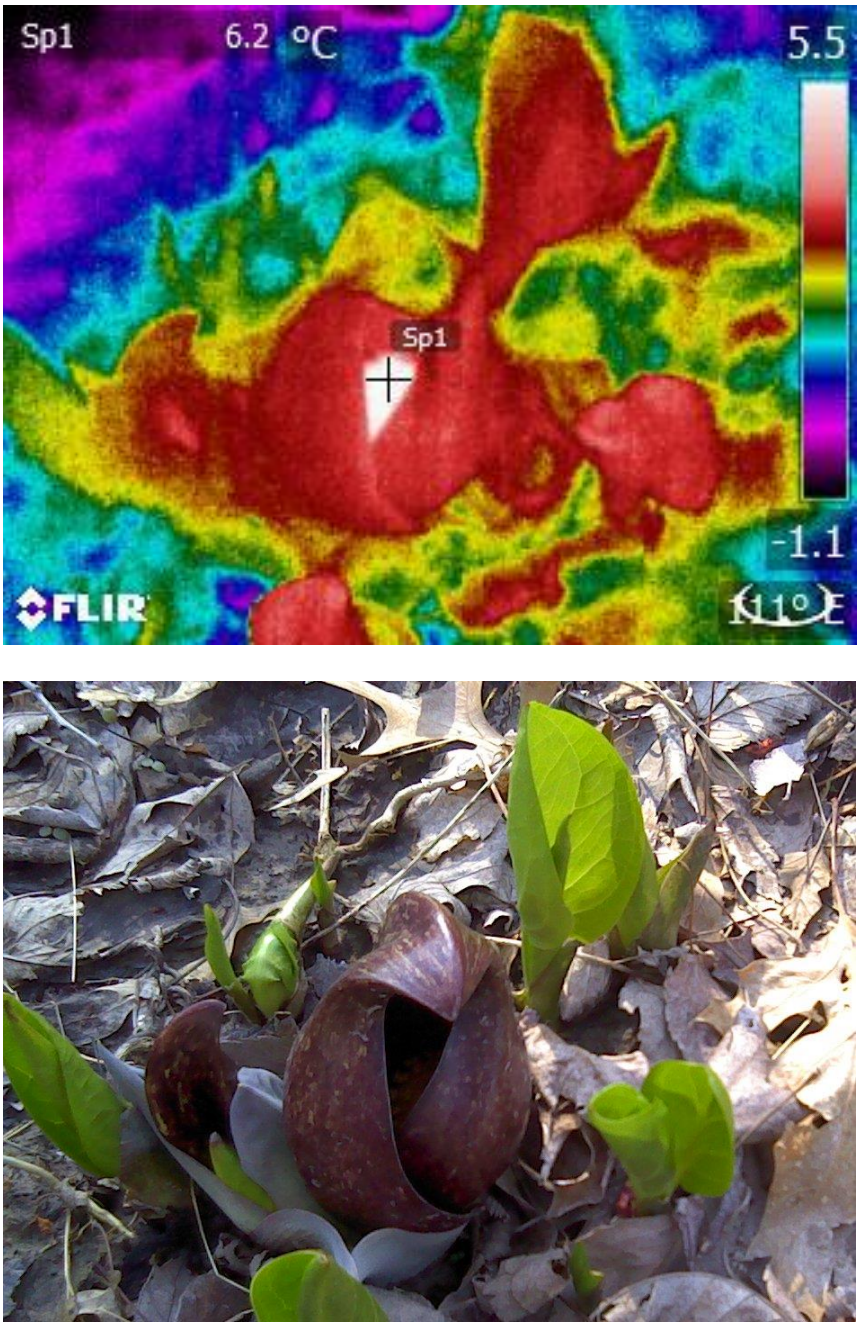


Figure 7. (A) Infrared and (B) visual images of a skunk cabbage flower near the Big Woods on March 27, 2016. Temperature of partially enclosed stem and flowers is 6.2°C, much warmer than the surrounding environment, which reaches freezing temperatures (see scale bar on right-hand side). Photograph by author.

The Relevance of Leopold's Land Ethic Today

Much of the landscape that Leopold would have explored during the time while he was at the Lawrenceville School has changed, for example a boulder field towards Princeton that held impressive views is now surrounded by forest. However, Leopold would certainly still recognize some of the species he first learned about while in Lawrenceville, in addition to the common tree species in its forests. Leopold included a sample of a fern in a letter home, the Christmas fern (*Polystichum acrostichoides*), which can still be found amongst the area with boulders.[61] Leopold also wrote home about a yellow-spotted turtle (*Clemmys guttata*).[62] These too can still be found in Lawrenceville, although their conservation status is now listed as Special Concern in New Jersey.[63]

Going a step further, one might also wonder how Leopold would view the landscape surrounding Lawrenceville today in light of his ecological insights and land ethic which expanded our ethical responsibilities recognizing that: "[a] thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community."[64] While Leopold did remain an active hunter later in life and a recent critique argues that Leopold would still weigh human interests more heavily in these ecological relationships, his land ethic challenges us to recognize the existence and inherent value of the land and species that comprise these ecological communities.[65] Considering his ethical views, Leopold would likely be heartened that these forest parcels and native species remain in Lawrenceville, even though the surrounding land has changed largely

[61] Aldo Leopold to Clara Leopold, February 27, 1904.
[62] Aldo Leopold to Clara Leopold, May 14, 1904.
[63] Jason Dallas, " New Jersey Division of Fish and Wildlife Sightings Report," *Conserve Wildlife Foundation of New Jersey* May 8, 2013, accessed July 26, 2016, available from http://www.conservewildlifenj.org/species/fieldguide/view/Clemmys%20guttata/.
[64] Leopold, *Sand County Almanac*, 224-225.
[65] Mark Bryant Budolfson, "Why the Standard Interpretation of Aldo Leopold's Land Ethic is Mistaken," *Environmental Ethics* 36, no. 4 (2014): 443-453.

from farm fields to suburbs and offices. He would probably also wrestle with land use issues like deer overpopulation, the impact of forest fragmentation on bird diversity, and invasive species.[66] As he states later in his land ethic "nothing so important as an ethic is ever 'written'… it evolved in the minds of a thinking community," implying that solutions to these issues follows from thoughtful considerations of specific environments by those who are connected to them.[67]

One can be certain that he would value the role of environmental education in developing these solutions and thus, without assuming too much hubris, that he might be enthusiastic over the use of these forest parcels as part of a formal educational experience for students at both the Lawrenceville School and Rider University. Leopold is clear in his later writings that one's education should extend outside the classroom to the surrounding environment,[68] an idea that has helped inform the recent concept of place-based learning.[69] Appropriately, the extent of the Big Woods now owned by Rider University was referred to as the Rider College Natural Area several decades ago.[70] The Big Woods has been used regularly in classes at Rider University since that time. Rider University also now hosts a demonstration planting along the edge of the Big Woods including pairs of American chestnuts, blight-resistant Chinese chestnuts (*Castanea mollissima*), and Restoration 1.0 hybrid chestnuts from the American Chestnut Foundation. Lawrence Township protected other portions of the Big Woods within a park and the Loveless Nature

[66] Richard T. T. Forman, Anne E. Galli, and Charles F. Leck, "Forest size and avian diversity in New Jersey woodlots with some land use implications." *Oecologia* 26, no. 1 (1976): 1-8.
[67] Leopold, *Sand County Almanac*, 225.
[68] Low, 816.
[69] Donald M. Waller and Susan Flader, "Leopold's Legacy: An Ecology of Place," in *The Ecology of Place: Contributions of Place-Based Research to Ecological Understanding*, edited by Ian Billick and Mary V. Price (Chicago: University of Chicago Press; 2010), 40-62; Clifford. E. Knapp, "The "I – Thou" Relationship, Place-Based Education, and Aldo Leopold," *Journal of Experiential Education* 27 no. 3 (2005): 277-285.
[70] Mary L. Allessio and Robert L. Simpson, *Rider College Nature Trail Guide, Revised Edition* (Trenton: Rider College, 1974).

Preserve and constructed the Lawrence Nature Center nearby, testaments to the community's commitment to open space.

When asked by his mother if he would wish to study abroad after completing his education at the Lawrenceville School, Leopold responded with a foresight greater than his years: "We have so much to learn right here that by a life-time's labor we may not even reach a knowledge of our ignorance."[71] While Leopold did eventually learn much from his travels abroad regarding different approaches to land management, the basic idea of this quote remains true today in the long-term insights that the forests of New Jersey can provide in educating its future generations of environmental scientists, authors, and philosophers. As the nation pauses to reflect on 100 years of stewardship by the National Park Service, Leopold would likely encourage us to consider not only our iconic parks like Yellowstone, but also those environments that are near to where we live.

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[71] Aldo Leopold to Clara Leopold, January 29, 1904.

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