

CHANGES IN FOREST COMPOSITION OVER 22 YEARS IN SOUTHEASTERN NEW YORK

DANIEL KATZ

Bard College, Annandale-on-Hudson, NY 12504 USA

MENTOR SCIENTIST: DR. GARY M. LOVETT

Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Abstract. Forest structure and composition change over time due to a variety of internal dynamics such as succession and external drivers including disturbance and anthropogenic stresses. By observing changes in the abundance of various tree species one can gain insight into the processes at work. In 2006 I re-sampled vegetation plots in the forest of the Cary Arboretum (located in southeastern New York State) that were first measured in 1984, and analyzed the changes in the forest over that 22 year period. Substantial shifts in tree species composition were observed including a decline in basal area of flowering dogwood (*Cornus florida*) and chestnut oak (*Quercus prinus*) as well as a decline in the relative basal area of red maple (*Acer rubrum*). Northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), and eastern hemlock (*Tsuga canadensis*) increased in basal area over the same period. The decline of *Cornus florida* is attributable to an introduced disease, but causes of other observed changes are more difficult to infer. This study elucidates contemporary trends in the composition of upland forests of southeastern New York.

INTRODUCTION

In the last century, forests of the northeastern U.S. have been subject to enormous changes from anthropogenic influences such as logging, climate change, fire prevention, fragmentation, and introduced species. Internal drivers such as succession also play a prominent role in determining forest composition (Foster 2004). These changes are often inferred by interpreting historical records and clues left in the forests (e.g. cut stumps, stone walls). Less common and more informative are long-term remeasurements of permanent vegetation plots. The purpose of this study was to investigate changes over the past 22 years in a forest in Millbrook, NY, by comparing a vegetation survey conducted in 1984 (Glitzenstein 1990) with contemporary data. Although this study encompasses shifts in trees, understory vegetation, and soil chemistry, this paper focuses exclusively on the abundances of tree species.

Prior to the study I hypothesized that several changes in tree composition had occurred. First, I predicted a decline in eastern hemlock (*Tsuga canadensis*). It is known that hemlocks in the study area are affected by two exotic pests: the hemlock wooly adelgid (*Adelges tsugae*), which has caused extensive hemlock mortality in the Northeast since the mid 1980s (Orwig and Foster 1998), and the elongate hemlock scale (*Fiorinia externa* Ferris), a less lethal but more widespread pest. I also expected an increase in red maple (*Acer rubrum*), as red maple populations in the Northeast are generally expanding due to the absence of fire and clear cutting (Abrams 1998). In addition I hypothesized that there would be a decline in oak (*Quercus sp.*) populations, as oaks are earlier successional species and are declining across the eastern United States due a relative lack of forest harvesting and fires in recent decades (Abrams 2003). I also predicted that sugar maple (*Acer saccharum*) would experience increased stress due to acid rain, to which they are especially vulnerable (Driscoll 2001). This would have been reflected in lower growth rates and higher mortality rates. I expected that flowering dogwood (*Cornus florida*) populations would be reduced by a fungal pathogen Dogwood anthracnose (*Discula destructiva*), which decimated flowering dogwood populations during the 1980s (Heirs 1997).

METHODS

Site Description

The research site was at the Institute of Ecosystem Studies (IES) which is located in Dutchess County, New York (41°50'N, 73°45'W), in the Hudson River Valley. This site was formerly known as the Cary Arboretum. About 325 ha of IES property is forested, with the majority of wooded area located around the Canoo Hills and Teahouse Hill. The annual average temperature is 9.6°C and precipitation averages 111cm/yr, with a pH ranging from 4.0 to 4.4 between 1984 and 2004 (Kelly et al 2006). The bedrock is mostly shale and slate and soils are predominantly thin and well drained silt loams of the Nassau and Woodlawn series (Glitzenstein 1990).

Field Methods

A vegetation survey was carried out, sampling the same plots established in 1984, in order to determine what changes have occurred in the vegetation over the past 22 years. Importantly, the stake marking the exact centerpoint of each original plot was relocated, allowing for a highly accurate geographic reconstitution of each plot. This allowed for a valid comparison of vegetation over time (Loeb 1989). A total of 43 of the original plots were sampled, out of a total of 46 plots in the Canoo Hills area. The remaining plots were not sampled because the center stakes could not be located. Additional data on 20 of the 44 plots were available from a survey of canopy condition conducted in 1993, 1997, and 2002. One aspect of these canopy surveys was to tag each individual tree in those 20 plots, allowing the life history of individual trees to be traced.

A variety of measurements were taken at each plot, using the same methods as the original study (Glitzenstein et al. 1984). I had access to the original data sheets from the Glitzenstein et al study and was able to compare results on a plot-by-plot basis. The diameter at breast height (DBH) of each standing tree (stem >10cm DBH) within the plot was measured, the species recorded, and a canopy class (understory, subcanopy, canopy, or dead) assigned. Additionally, the total number of saplings (>1m in height and <10cm DBH) within two random quarters of the plot were counted, approximate DBH measured for each, and species recorded. In each plot a transect was placed from east to west, along which eight quadrats (1m by 0.5m) were placed. In each quadrat the percent cover of each type of surface was recorded, including litter layer, exposed rock, dead wood, and a percent cover estimated for each species of herbaceous plant found within a quadrat. Additionally, in each quadrat the number of seedlings of each tree species were tallied. Shrub cover was also recorded, based on cover along the main east-west transect. A species list of all vascular plants occurring within each plot was also compiled, although for practicality certain plants belonging to the genera *Rubus*, *Solidago*, and *Asteraceae* were recorded by genus, not species. Likewise, due to difficulty in species identification, most graminoids were identified to genus. Nomenclature largely follows Gleason and Cronquist (1963).

Basal area was calculated from dbh assuming a circular bole cross-section. Relative basal area was calculated as the basal area of a given species divided by the basal area of all species for that plot. Relative density was calculated similarly. Data was analyzed using SAS and Microsoft Excel, and the significance of shifts in forest composition were determined using a paired t test.

RESULTS

In the resampled plots a total of 1174 trees >10 cm dbh were recorded, including 24 tree species. Comparison between this dataset and the original dataset show many significant changes in species basal area and density (Table 1). Some of the most notable changes were a decline in chestnut oak (*Quercus prinus*) (Figure 1) and an increase in red oak. The decrease in chestnut oak density between 1984 and 1993 (Figure 2) is a result of mortality, but also reflects low recruitment of saplings (Figure 2). Other notable trends include the decline in

flowering dogwood, an increase in sugar maple, decline in red maple (in terms of relative basal area, density, and relative density), and an increase in eastern hemlock (Table 1).

DISCUSSION

I hypothesized that there would be a decline in eastern hemlock because of the effects of two introduced pests, the hemlock woolly adelgid and the elongate hemlock scale. However, an overall increase in eastern hemlock density, relative density, basal area and relative basal area was recorded. Eastern hemlock is a later successional species, due to its high shade tolerance. This could explain both the strong recruitment of new trees and high growth rates of already established hemlocks at IES, and therefore why hemlocks would be increasing relative to other tree species. Indeed, the only two sites exhibiting declines in hemlock were both affected by an ice storm in 1997. (Gary Lovett, personal communication) Although findings indicate that the two pests are not yet severely reducing the overall growth rate of the hemlock population, it is possible that they will cause a general decline in hemlock in the future.

This study also found a significant increase in sugar maple basal area and density from 1984-2006. This was unexpected, as I predicted that sugar maple would show a significant decrease in basal area and density due to the effects of acid rain. Acid rain can result in the depletion of certain soil cations that are important for plant growth, such as calcium, magnesium and potassium with concurrent increases in aluminum mobility, and sugar maple is particularly sensitive to these cation imbalances (Driscoll et al. 2001). I predicted that the combined effects of acid rain would lead to increased stress on sugar maples, which could potentially decrease growth, increase mortality rates, or cut down on sugar maple recruitment. However, sugar maple showed significant gains in basal area and density instead of losses. One possible explanation is that soil pH has actually increased significantly in the Canoo Hills since 1984 (Katz, unpublished data).

While sugar maple is experiencing declines in some parts of the Northeast (Driscoll, 2001), red maple is generally thought to be increasing. Some researchers have concluded that widespread fire suppression allows red maples to proliferate in areas outside of their pre-colonization range (Abrams 2003). However, red maple declined in relative basal area, density, and relative density at this site during the study period. The cause of this decline is unknown, but may be related to competition from more shade tolerant species such as hemlock and sugar maple.

A significant decline in flowering dogwood (*Cornus florida*) was observed, supporting my hypothesis. I infer that this was largely due to the fungal pathogen *Discula destructiva* (Heirs and Evans 1997). First entering the area in the early 1980s this pathogen did a large amount of damage to flowering dogwoods, resulting in heavy mortality. Glitzenstein's survey showed this decline in progress; in 1984 they recorded five live flowering dogwoods, of which four exhibited dieback, as well as 12 dead flowering dogwoods. By 2006, only one live and one standing dead flowering dogwood tree (>10cm DBH) were left. Thus, the circumstantial evidence strongly points to a decline in flowering dogwood due to *Discula destructiva*.

Interestingly, the largest changes in forest composition involved two oak species, northern red oak and chestnut oak. Many experts believe that oak populations are decreasing in northeastern forests due to both a lack of disturbance caused by patterns such as widespread fire suppression (Abrams, 2003). Since oaks are earlier successional species, they are not as adept at recruiting under their own canopies, which results in the infiltration of more shade tolerant trees into the understory, which eventually replace the canopy. This led me to predict a slight decrease in all oak populations. While chestnut oak did decline, red oak increased significantly, perhaps as a competitive response to chestnut oak mortality.

Chestnut oak exhibited widespread decline in both basal area and density (Figure 1) whereas red oak increased in these categories (Figure 2). There are several possible causes for elevated chestnut oak mortality: (1) competition from other plant species, (2) a climactic event that would have affected chestnut oaks more than red oaks, or (3) response to defoliation by gypsy moth (*Lymantria dispar*), an introduced defoliating insect.

Because the decline in chestnut oak density and basal area occurred over a short period of time (1984-1993, as seen in Figure 2), it seems unlikely that it could have been caused by plant competition or gradual successional forces. Additionally, there were no severe droughts in that period and it is unlikely that some other climatic phenomenon was responsible, as it would have damaged red oaks as well. However, records of gypsy moth populations at IES show very high population levels and defoliation in 1980-1981, and moderate populations and defoliation in 1989-1990 (Goodwin et al. 1995). Although the extreme gypsy moth outbreak during the summers of 1980 and 1981 occurred before the period of recorded mortality of the chestnut oaks, it is plausible that the gypsy moths could be the root cause of the mortality, and that many chestnut oaks succumbed after 1984 to stresses induced during 1980-81. The literature provides a variety of possibilities as to why gypsy moths could disproportionately damage either red or chestnut oaks. An experiment has shown that while both chestnut oak and red oak increase foliar astringency and proanthocyanidins after exposure to gypsy moth defoliation, fertilization prevents chestnut oak from developing anti-herbivory compounds (Hunter 1995). It is therefore conceivable that increased atmospheric deposition of nitrogen could have assisted in making chestnut oaks better targets for gypsy moths. However, other studies have seen higher mortality in red oaks than in chestnut oaks (Stalter 1983). It therefore seems possible that the chestnut oak were either more vulnerable or less resilient to gypsy moths for other, unknown reasons. It is likely that the increased growth and recruitment of red oaks was a competitive response to the decline in chestnut oaks. It is also possible that the lack of recruitment in chestnut oaks is tied to the winter browse habits of deer, and their preference for the upland sites which are dominated by chestnut oaks (Raymond Winchcombe, personal communication).

It is possible that the shift from chestnut oak dominance will have caused reverberations to other species. For example, the acorns of red oaks last over winter, whereas chestnut oaks do not. These differences in acorn properties influence the population cycles of white-footed mice and other rodents (McShea, 2000), which could potentially affect Lyme disease incidence (Ostfeld, 2006).

CONCLUSIONS

This study has documented many shifts in forest composition in the forests of IES during the period 1984-2006. Some of the changes, such as the increases in hemlock and sugar maple, appear to reflect maturation of the forest and increase in more shade-tolerant species. Others, such as the decline in flowering dogwood, appear related to new introduced pests or pathogens. Some, like the decline in red maple density, remain a mystery. The timing of the major decline in chestnut oak density suggests that it was caused by severe gypsy moth defoliations in the 1980s, and that the increase in red oak was a competitive response to the chestnut oak decline. Thus, a combination of internal successional properties and externally applied stresses, such as introduced pests, has influenced the trajectory of this forest over the past 22 years. Significant changes in species composition such as those reported here can have substantial effects on forest ecosystem processes and the on the forest food web. Further research into changes in understory vegetation and soil chemistry during the same time period is also likely to bring further insight.

ACKNOWLEDGEMENTS

My primary mentor for this project was Gary Lovett, a senior scientist at the Institute of Ecosystem Studies. Professor Catherine O'Reilly of Bard College offered additional mentoring. Julie Hart and Charlie Canham were also essential to this project. Additional thanks goes to Judy Sullivan, Linda Grapel, Ed Schmidt, Mark Lindeman, and Bill Maple. The Research Experience for Undergraduates program at the Institute of Ecosystem Studies is made possible by a grant from the National Science Foundation (Grant number 0244101). Further support was provided by the Environmental Studies Department at Bard College.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

LITERATURE CITED

- Abrams, M.D. 1998. The red maple paradox. *BioScience* 48.5: 355-364
- Abrams, M.D. 2003. Where has all the white oak gone? *BioScience* 53:10. 927-939
- Driscoll, C. T., Larence, G.B., Bulgur, A.J., Butler, T.J., Cronan, C.S., Eagar, C., Lambert, K., Likens, G.E., Stoddard, J.L., and Weathers, K.C. 2001. Acidic deposition in the northeastern United States: Sources and inputs, ecosystem effects, and management strategies. *Bioscience* 51:3.
- Foster, D.R. and Aber, J.D. 2004. Forests in Time. Yale University Press, New Haven.
- Glitzenstein, J.S., Canham, C.D., McDonnell, M.J., and Streng, D.R. 1990. Effects of environment and land-use history on upland forests of the Cary Arboretum, Hudson Valley, New York. *Bulletin of the Torrey Botanical Club*. 117.2:106-122.
- Heirs, J.K., and Evans, J.P. 1997. Effects of Anthracnose on Dogwood mortality and forest composition of the Cumberland Plateau, U.S.A. *Conservation Biology*. 11.6:1430-1435.
- Hunter, M.D. and Schultz, J.C. 1995. Fertilization mitigates chemical induction and herbivore responses within damaged oak trees. *Ecology* 76.4:1226-1232
- Kelly, V., Groffman, P., Lovett, G.M., Strayer, D.L., and Weathers, K.C. 2006. IES Environmental Monitoring Program: Trends in Sulfur and Nitrogen in Precipitation (1984-2004) & Air (1988-2004).
- Kleiner, K.W. and Montgomery, M.E. 1994. Forest stand susceptibility to the gypsy moth (*Lepidoptera lymantriidae*) –species and site effects on foliage quality to larvae. *Environmental Entomology* 23.3:699-711.
- Loeb, R.E. 1989. Measurement of vegetation changes through time by resampling. *Bulletin of the Torrey Botanical Club* 117:173-175.
- McShea, W.J. 2000. The influence of acorn crops on annual variation in rodent and bird populations. *Ecology*. 81.1:228-238.
- Orwig, D.A., and Foster, D.R. 1998. Forest response to the hemlock woolly adelgid in southern New England, U.S.A. *Journal of the Torrey Botanical Society*. 125.1:60-73.
- Ostfeld, R.S., Canham, C.D., Oggenfuss, K., Winchcombe, R.J., Keesing, F. 2006. Climate, deer, rodents, and acorns as determinants of variation in Lyme-disease risk. *PLoS Biol* 4.6. DOI: 10.1371/journal.pbio.0040145
- Stalter, R., and Serrao, J. 1983. The impact of defoliation by gypsy moths on the oak forest at Greenbrook Sanctuary, New Jersey. *Bulletin of the Torrey Botanical Club*. 110.4:526-529

APPENDIX

TABLE 1: Changes in basal area and density by species over 22 years. Basal area is in m²/ha and density is in stems/ha. Variables that have changed significantly (p<.05) since 1984 are bolded. Significance was calculated using a paired t-test.

species	area 1984	area 2006	basal area	basal area	density 1984	density 2006	density 1984	density 2006
Acer rubrum	2.367	2.339	9.76	8.69	85.5	59.5	15.88	12.51
Acer saccharum	1.629	2.217	6.72	8.24	54.5	70.9	10.14	14.90
Betula lenta	0.992	1.204	4.09	4.48	26	25	4.81	5.16
Carya glabra	1.629	1.653	6.71	6.14	42	34	7.77	7.07
Cornus florida	0.025	0.004	0.10	0.01	2	0.5	0.42	0.10
Fraxinus americana	0.473	0.649	1.95	2.41	17	14	3.13	2.96
Pinus strobus	2.460	3.015	10.14	11.20	49.1	42	9.12	8.79
Quercus alba	0.818	1.028	3.37	3.82	14	13	2.62	2.77
Quercus prinus	6.198	5.037	25.55	18.72	78.2	50.0	14.53	10.51
Quercus rubra	3.024	4.545	12.47	16.89	45	50.9	8.28	10.70
Quercus velutina	0.610	0.809	2.52	3.01	12	13	2.20	2.67
Tsuga canadensis	2.352	2.913	9.70	10.82	57.3	65.0	10.64	13.66
other	1.682	1.494	6.93	5.55	56	39	10.47	8.21

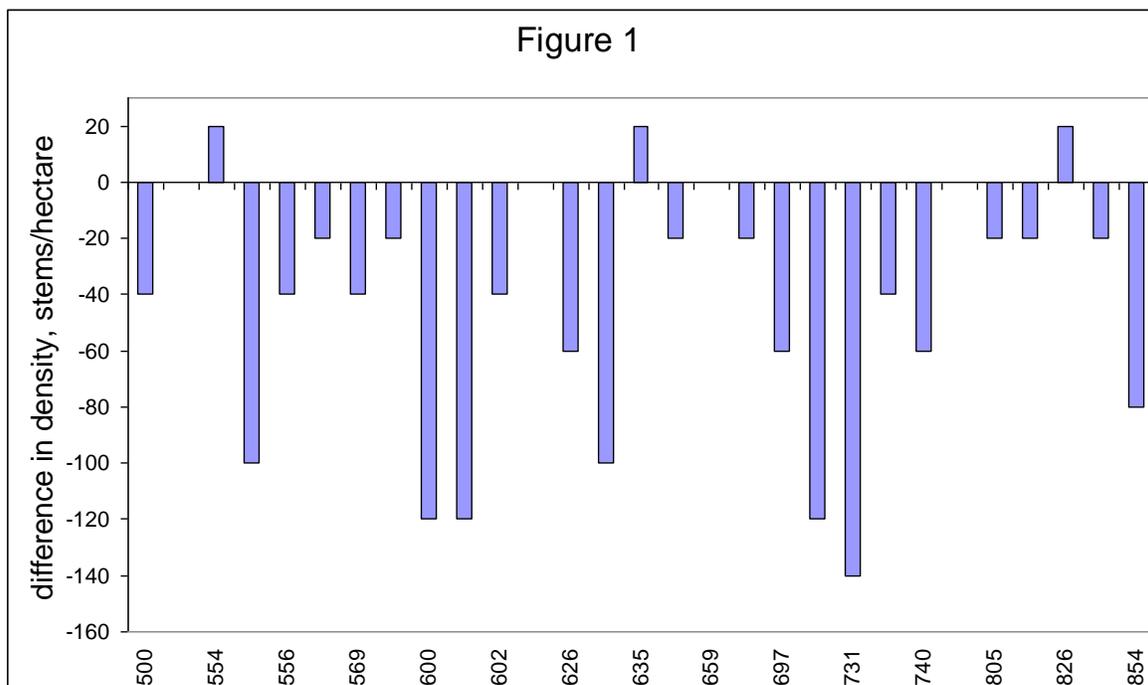


FIGURE 1: Decline in chestnut oak density by plot over 22 years. Each bar represents the change in number of chestnut oaks (DBH >10cm) per hectare. Only the 29 plots containing chestnut oak are shown.

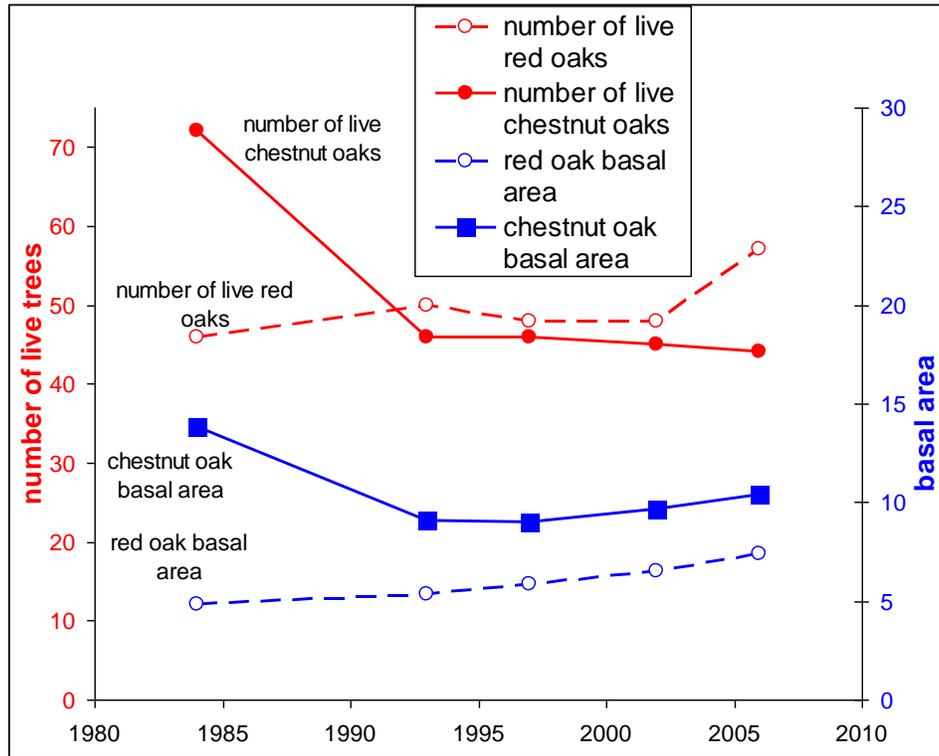


Figure 2: Chestnut and red oak basal area and density 1984-2006. Data points from the years 1993, 1997, and 2002 are derived from a canopy census of certain plots, and thus only a subset of plots are represented. These data were provided by Julie Hart (unpublished data).