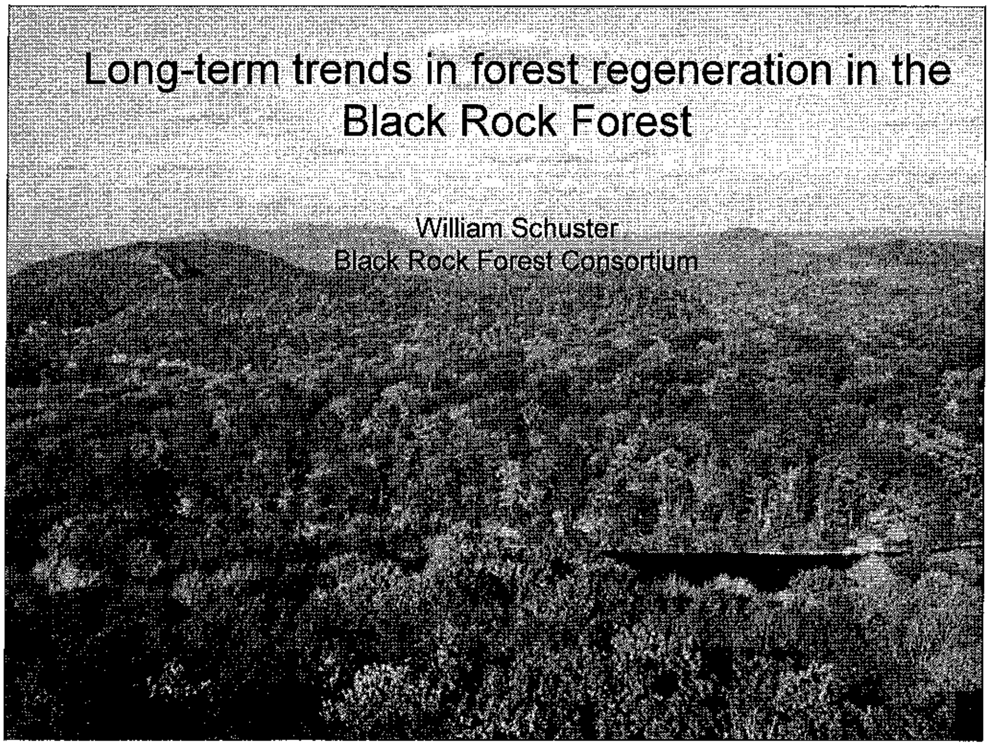
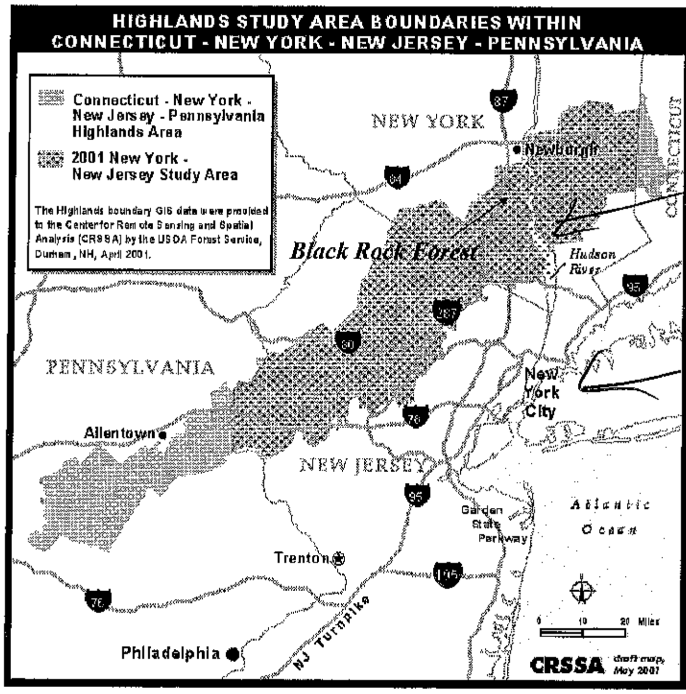


In this ecological case study, I will present an analysis of health and sustainability in forests of the New York Bioscape region by examining patterns of forest regeneration in the Black Rock Forest.

Forests comprise the natural vegetation around most of this region. They are
2 primary reservoirs of native biological diversity and provide critical services such as provision of drinking water and forest products.

They remain abundant in this region despite centuries of extraction,
3 development, and urbanization and alterations to ecosystem attributes such as trophic structure and disturbance regimes.

4 But answering the question of whether these forests are healthy and sustainable requires a close examination of the forests' critical regeneration system.

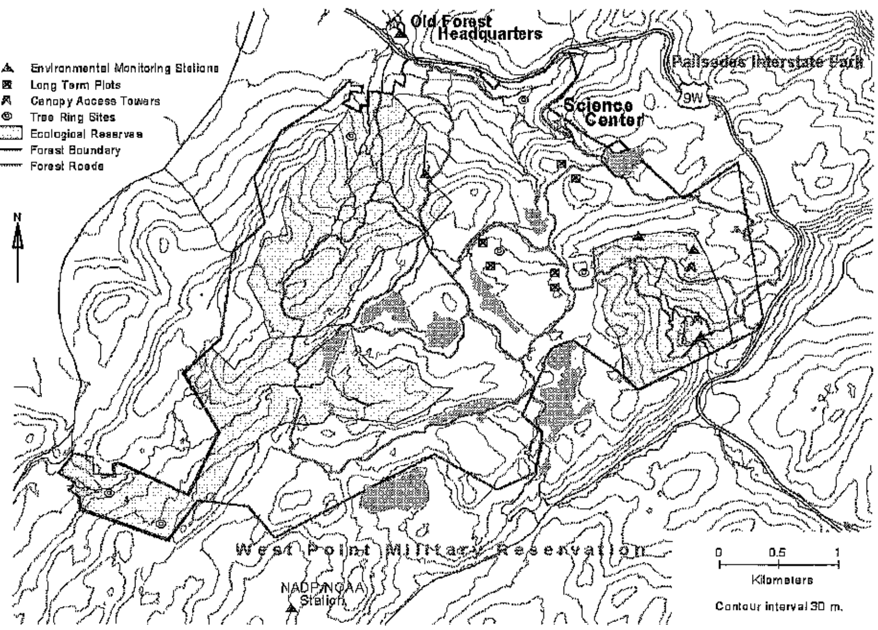


Black Rock represents a typical forest within the physiographic region known as the **New York-New Jersey Highlands,** about which you will hear more later in this symposium. The Highlands region represents a nearly 2 million acre section of the Eastern Deciduous Forest running from Pennsylvania to western Connecticut.

This is a map from the recent USGS study of the area done by CRSSA.

It represents a very important greenbelt around the New York Metropolitan area and provides high quality drinking water for over 10 million people.

Map of the Black Rock Forest Field Station



The Black Rock Forest research station was part of the Harvard Forest system for 40 years and for the past 15 years has been operated by a Consortium of institutions, including Columbia University and the American Museum of Natural History.

It is 4000 acres in size and has forest growth records from long-term plots dating as far back as 1929.

The successful transition from seedling to forest canopy tree is a critical process that operates on a long-term time scale

In any forest, the population dynamics of the dominant canopy tree species, mainly oaks in this area, will substantially determine the ecosystems' dynamics.

To be healthy and sustainable, a forest must be capable of replacing itself with trees of the same or appropriate other native tree species. And this can be a tenuous process, making successful transitions between the critical phases of seed dispersal, germination, establishment, and growth into a tree that may eventually comprise part of the forest canopy.

Mt. Misery, Black Rock Forest 1934 CTG.118

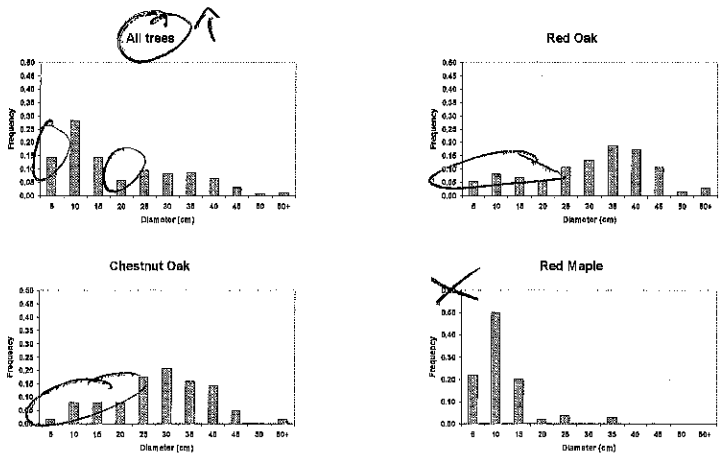
Fortunately the Black Rock Forest has a forest database of some 75 years thanks to investigators like Hal Tryon and Hugh Raup in the 1930s, to Ben Stout and other Harvard investigators in the middle 20th century…

Mt. Misery, Black Rock Forest 1998

…to the work of botanists Steve Clemants and Kerry Barringer at the Brooklyn Botanic Garden and other ecologists at the forest in more recent years.

Analyses of inventories, long-term plot records, and experimental treatments over the years enable a detailed evaluation of the actual long-term patterns of regeneration in this forest.

Black Rock Forest
Tree Size Distribution 2004



For a first indication of forest health and sustainability we must look at the size distribution of trees in the forest, overall and by key species. Size distribution analysis enables understanding of past replacement trends and future population growth.

projected

For the forest as a whole we do not see the reverse-J pattern typical of a forest with continuous replacement, ~~enhancing~~ sustainability. Instead we see an absence of trees in the smallest size class, less than 5 cm in diameter, indicating a serious lack of recruitment in recent years.

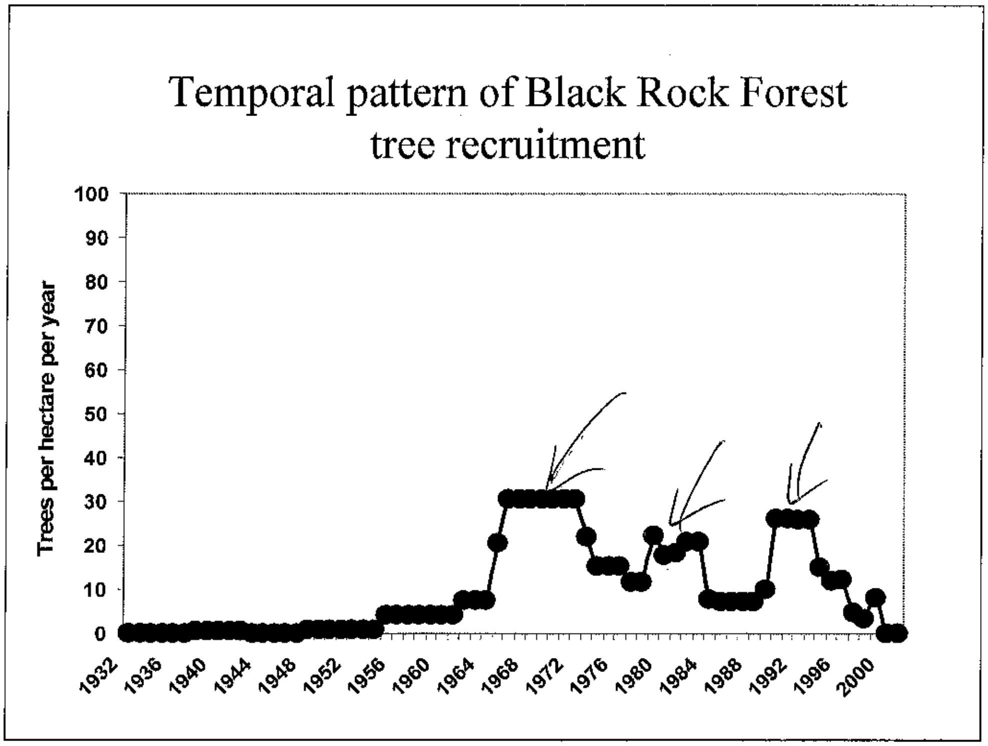
We also see a gap in the 10 – 15 cm size class. However, we do see a pulse in the 5 to 10 cm size class suggesting some successful recruitment of trees at some point in the past.

For the dominant species in the forest, red oak, we see a pattern characteristic of an aging population. Red oaks are most frequent in the larger size classes and there is a serious lack of trees to replace them in all the smaller size classes.

Chestnut oak, another dominant forest species shows a similar pattern.

Red maple, in contrast, shows an abundance of trees in smaller size classes, indicating the potential for population expansion. ~~Even for red maple, however, there is still a low percentage of trees in the smallest size class.~~

The Black Rock Forest long-term plots records, dating to 1930, provide some of the historical detail about how these patterns developed.



There has been only limited recruitment of trees into the sapling stage, that is reaching a diameter at breast height of at least 5 cm, over the history of these long-term plots. There was no recruitment at all over the first 30 years.

Then there have been three periods during which some young trees have become established, first in the late sixties through early seventies, then in the early 80s, and again in the early 90s.

But these recruitment rates are pretty modest, as mortality has generally been several times greater in any given year.

And the success of these small, new recruits of entering the forest canopy has thus far been almost nil.

Average tree recruitment rates over 75 years, by species

Species	Recruitment	Mortality
	(trees per hectare per year)	
Red maple	4.6	4.9
Black birch	0.9	1.2
Red oak	0.8	4.0
Chestnut oak	0.6	5.0
Sugar maple	0.6	2.8
American chestnut	0.6	0.6
Yellow birch	0.4	1.5
Striped maple	0.2	0.1
Total	**8.7**	**25.3**

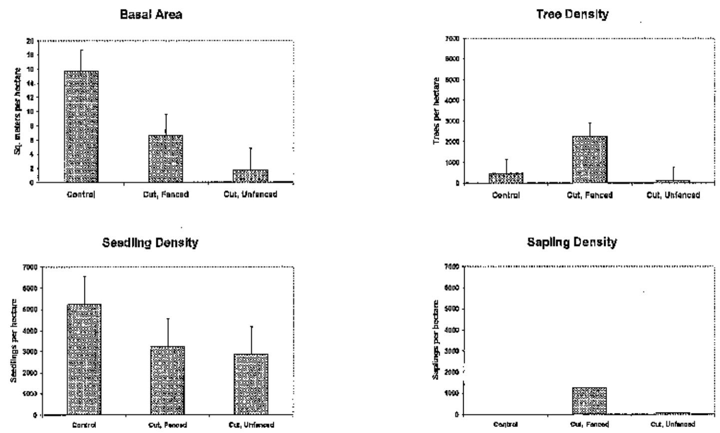
The recruitment and mortality data, by species, demonstrate how much higher mortality rates have been as these stands have matured and thinned, and also which species are benefiting and losing the most.

Red maple, by far, and then black birch, show the highest recruitment over this period. Their mortality rates are similar and thus they are maintaining about the same absolute density in these stands.

In contrast, red oak and chestnut oak are not regenerating much, and have mortality rates five to eight times as high as their recruitment, thus their absolute density is decreasing dramatically.

The data that I have seen indicate that these results are generally consistent in intact, relatively undisturbed forests around the region.

Tree Growth in an 18-year-old clearcut with and without deer exclosure fencing

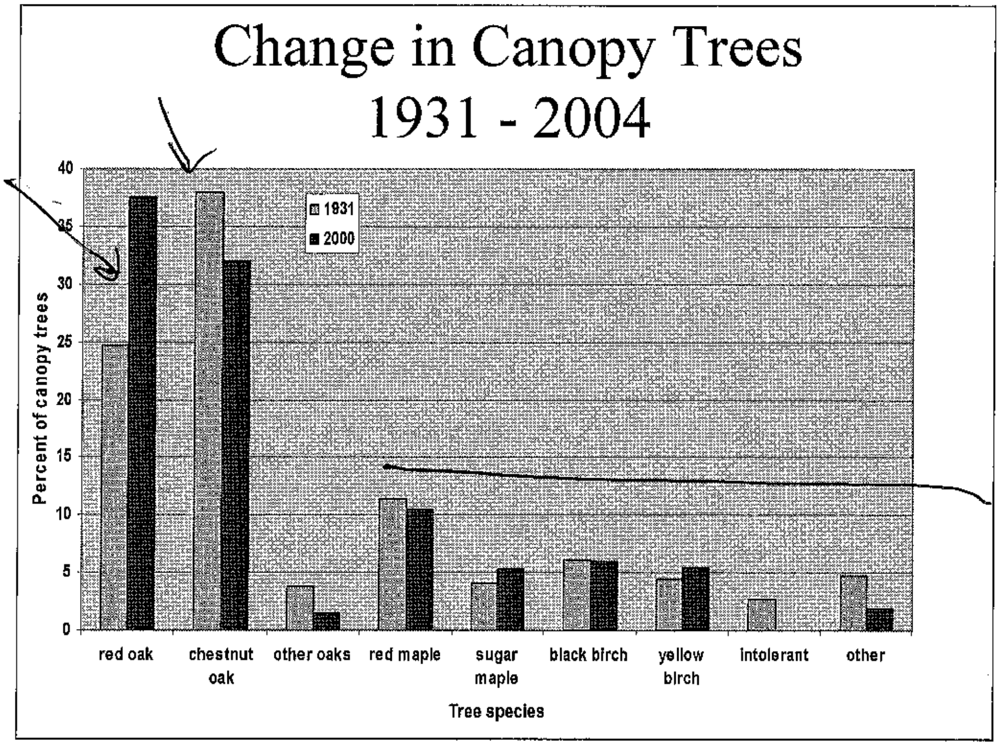


The reasons why regeneration has been so low and sporadic in intact forests include low light levels and the fact that the natural oak-regenerating disturbance regime that includes fire has been significantly changed after a century of fire suppression.

But evidence shows that if you do have disturbance, such as in this 18-year old clearcut, you still do not get tree regeneration unless you fence out deer. On the left in each of these graphs is data from a control stand of about 70 years of age with a basal area of around 16 square meters per hectare, a density of around 600 trees per hectare over 5 cm in diameter at breast height, and abundant small seedlings on the forest floor, but absolutely no trees getting though into the sapling stage: that is young trees taller than breast height but under 5 cm in diameter. After heavy defoliation of this part of the forest by gypsy moth caterpillars in the 1980s, an adjoining area was clearcut and half was protected by deer exclosure fencing with 10 cm fencing so that large animals like deer were excluded but not other small mammals. After 18 years there has been dense regrowth inside the fence with good biomass, abundant small trees, many seedlings, but also a good number of intermediate size saplings. On the right shows tree growth in the clearcut area without the deer fence: small biomass, almost no trees established, abundant small seedlings, but none making it through to the sapling stage.

Successful regeneration of trees is only happening where deer are excluded.

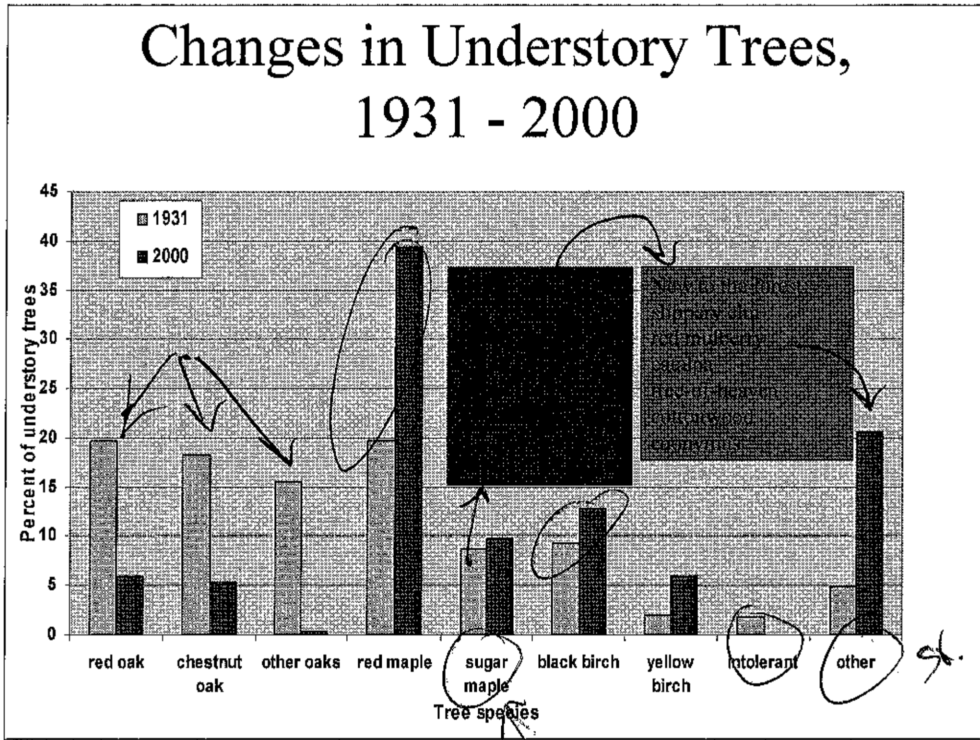
This is a picture within another deer-fenced exclosure that dramatically demonstrates the point. This is in a 15-year-old clearcut on the West Point military reservation. Outside of this fence, the only trees are seedlings less than 30 cm tall.



Across all plots in the Black Rock forest, over the last 73 years, the long-term pattern has ~~seen~~ little change in the forest overstory.

been any

Red oak has increased some in percentage of the canopy, 25 percent in 1931 versus 37 percent now, and chestnut oak has lost some dominance. But in general the relative dominance of the canopy oak, maple, birch species, and other trees have been mostly unchanged.



But the understory of the forest, comprised of saplings and small trees that should make up the future forest canopy, has changed significantly.

In the 1930s, red, chestnut, white and other oaks together made up more than 53% of the trees in the understory. Now they total only 10% of the understory.

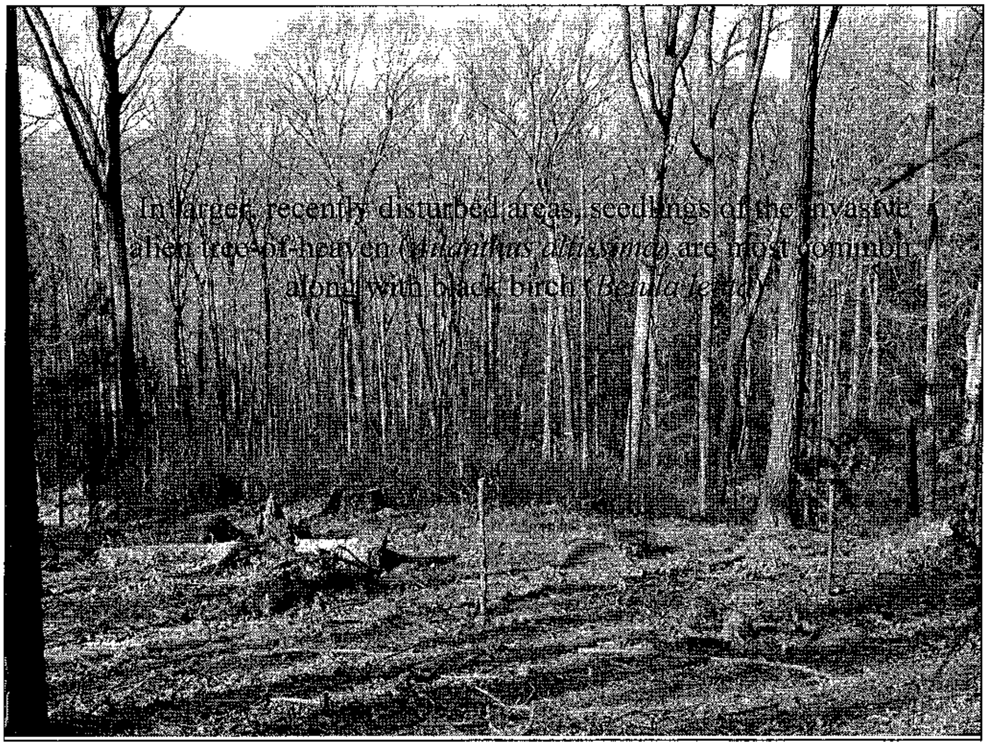
In the 1930s red maple and black birch made up 20% and 10% of the understory, respectively. Now they have been the major species successfully regenerating and together make up over 50% of the current understory.

Another change is that shade intolerant trees have been eliminated from the understory, but shade tolerant understory trees such as striped maple, and shadbush have increased. However these are species that generally do not become canopy trees.

Shade tolerant canopy species such as sugar maple, beech, and hemlock, more common in northern forests, have also not really increased.

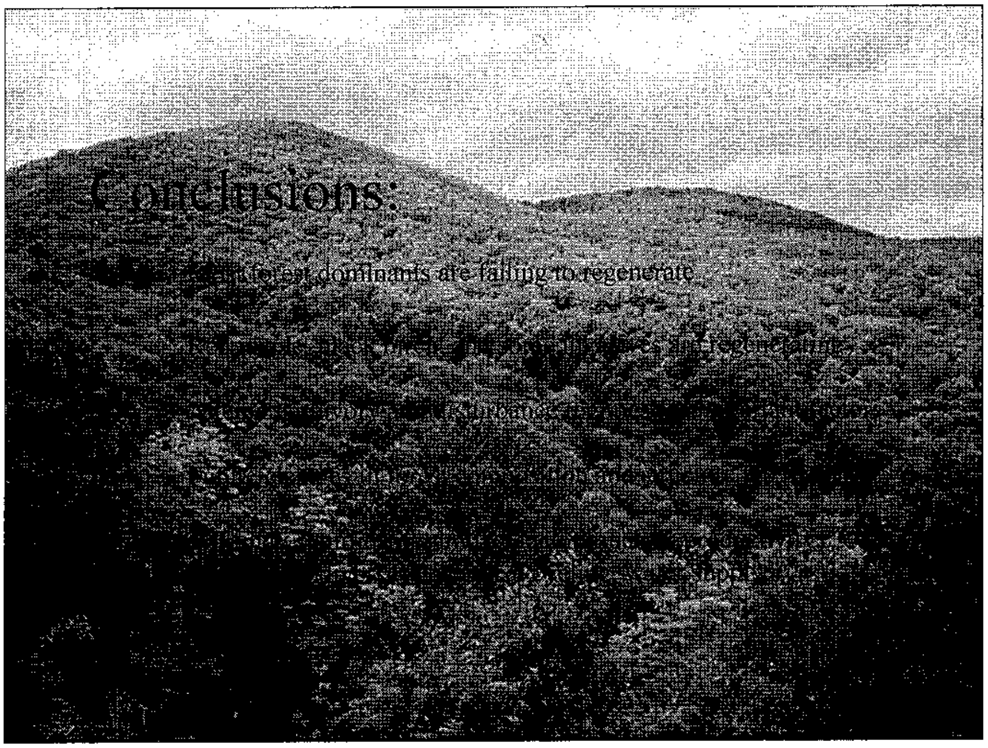
And other northern relict trees species such as black spruce and paper birch have died out completely, as well as species exterminated by introduced pathogens such as American elm and, before that, American chestnut.

Now the "other" category includes new tree species that arrived in the forest over this interval. These include mostly southern species that have been



In larger, recently disturbed areas, seedlings of the invasive alien tree-of-heaven (*Ailanthus altissima*) are most common, along with black birch (*Betula lenta*).

It is in the largest disturbed areas, and those areas nearest to highways and power lines, where we see the heaviest regeneration of invasives, such as tree-of-heaven. With their fast growth rate they now have an opportunity to race into the forest canopy on some sites.



In conclusion:

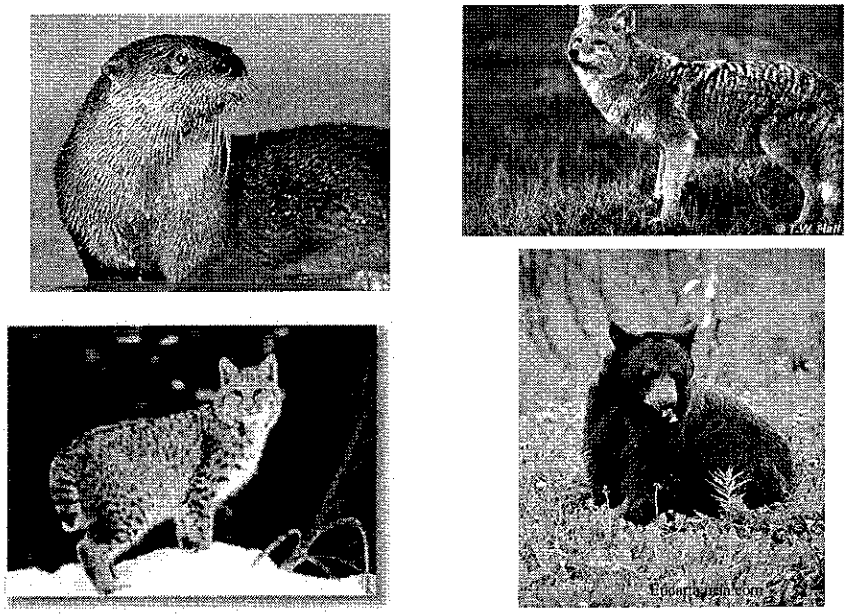
Most forest dominants are failing to regenerate

- Red maple, black birch, and some invasives are regenerating
- Altered herbivory and disturbance regimes are important factors
- Future changes in forest composition and structure are likely
- This may significantly impact factors such as productivity, biodiversity, chemical cycling, water supply

large
in canopy

if Sandy, sumac, sudden oak death and logging takes out the oak overstory we will change to a forest of red maple/black birch with tree-of-heaven

How will our native organisms respond to these altered forests?



These changes will cause a variety of impacts to forest flora and fauna, and to other processes. as well

Clearly forest health is challenged and these systems are not following anything like a sustainable trajectory.

But the system is dynamic, and this analysis is primarily a picture of where we are now and how we got here. Any predictions are only conjecture. Since we understand the pattern and many of the underlying causes, we may yet be able to devise management treatment actions and new land use strategies that can slow, alter, or mitigate against these future changes. and enhance sustainability, help restore a semblance of