Report to The American Chestnut Foundation
March 2013

Project Title

Chestnut restoration in Northeastern forest gaps: experimental plantings to advance forest structure and restoration ecology practice

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Narative Summary

1. Objectives

   Forest gaps created through invasive species removal provide a new and ecologically important opportunity for restoration of American chestnut. In 2010, we established experimental plots at Duke Farms, NJ, a 2,700 acre center for land stewardship where invasive species removal has created many forest openings. We planted B3-F3 and B3-F2 hybrid families, American, and Chinese chestnut in 9 forest gaps ranging in size from 1,699 – 10,629 ft ^{2} and one edge reference site. On-going monitoring will test the relative performance of genotypes in these gaps and the potential to use chestnuts as part of regional forest restoration efforts.

   <u>Short-term goals</u>
   1. Monitor hybrid families and American and Chinese check trees to test for survival and other performance variables in forest gaps of varying sizes
   2. Monitor hybrid families and American and Chinese check trees to test for blight resistance in this forest restoration scenario to inform restoration and hybrid breeding studies

   <u>Long-term goals</u>
   1. Determine whether gaps created through invasive species removal can successfully be used to restore chestnut to Northeastern forests
   2. Determine whether there are size limits (lower thresholds) to which gaps can successfully be used
   3. Identify hybrid families with the best performance in forest gaps
   4. Educate the general public to the devastating effects of invasive pests and the hope of chestnut restoration
   5. Educate land managers (of regional parks, municipalities, corporate lands, and private preserves) on the potential of making chestnut restoration a component of their management and ecological restoration plans

2. Methods of Monitoring, Evaluation

   <u>Experimental Design</u>

   The experimental protocol was designed from the testing guidelines "Testing Blight Resistant American Chestnuts" adopted by the TACF Board in October 2002, modified for seedling survival in the greenhouse and seed availability at Meadowview Research Farms. We planted four (4) B3-F3 hybrid families (D5 25 147, D5 17 89 x OP, D5 29 3, W3 32 49 x OP), one (1) B3-F2 (GB 41 x OP) family, American chestnut of local provenance (HAUN OP) and Chinese chestnut (CD x OP) (see Table 1 for corresponding names in this report). Three (3) replicates of each family and six (6) replicates of American and Chinese chestnut were planted in each of nine (9) forest gaps and one edge plot for a total of 27 trees per gap and 270 trees in all. The forest gaps range in size from 1,699 – 10,629 ft^2 (see Table 2). The

American chestnut seeds were supplied by Sara Fitzsimmons of TACF at Penn State University; the hybrid families and Chinese chestnut were supplied by Fred Hebard of Meadowview Research Farms. Some seedlings grown at the Duke greenhouse died and the experimental stock had to be supplemented from seedlings grown at Meadowview Research Farms to complete the full experimental design.

Chestnut seeds were planted in April 2010 in the Duke Farms greenhouses, cages were built to protect the plants from herbivory (greenhouse windows were open for cooling and thus possible rodent entry), and plants maintained all summer. Forest gaps on the Duke property were measured and mapped using GPS technology, then a representative selection was chosen to maximize the range of available gap sizes (see Figures 1 & 2 and Table 2). All gaps used are on the same soil series. Seedlings were outplanted in these forest gaps and measured for stem height and diameter in November 2010 .
Weed cloth was place around each seedling to minimize early competition from herbaceous plants. The tall deer fence that surrounds the central portion of the Duke Farms property (blue dashed line in Figure 1) eliminated most winter deer browsing.

Table 1. Chestnut varieties planted in forest gaps and abbreviations used in this report.

VARIETY	ABBREVIATION
American HAUN OP	American (AMER)
Chinese CD x OP	Chinese (CHIN)
Intermediate GP 41 x OP	Intermediate (INT)
Hybrid D5 25 147	Hybrid 1 (H1)
Hybrid D5 17 89 x OP	Hybrid 2 (H2)
Hybrid D5 29 3	Hybrid 3 (H3)
Hybrid W3 32 49 x OP	Hybrid 4 (H4)

Table 2. Forest gap sizes and corresponding #s. Gaps were numbered according to their geographic location relative to each other (see Figure 2).

GAP SIZE (FT ^{2})	GAP #
1,699	9
2,091	2
2,439	5
3,585	8
3,877	4
3,964	6
4,008	3
8,364	7
1,0629	1
Edge (appx.120,00)	10

Figure 1. Duke Farms, Hillsborough, NJ. The red star indicates the woodlot with the gaps where chestnut were planted.

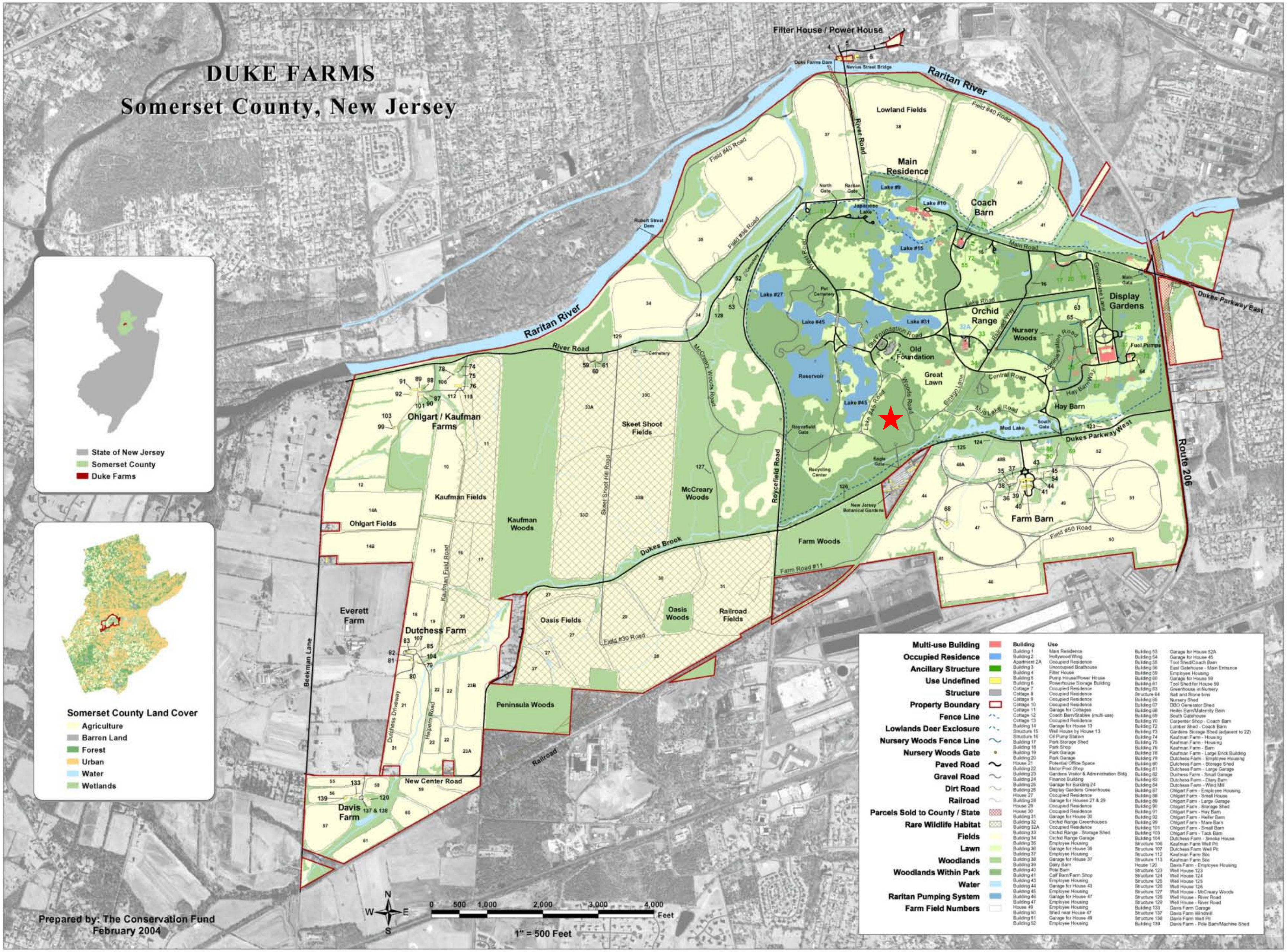
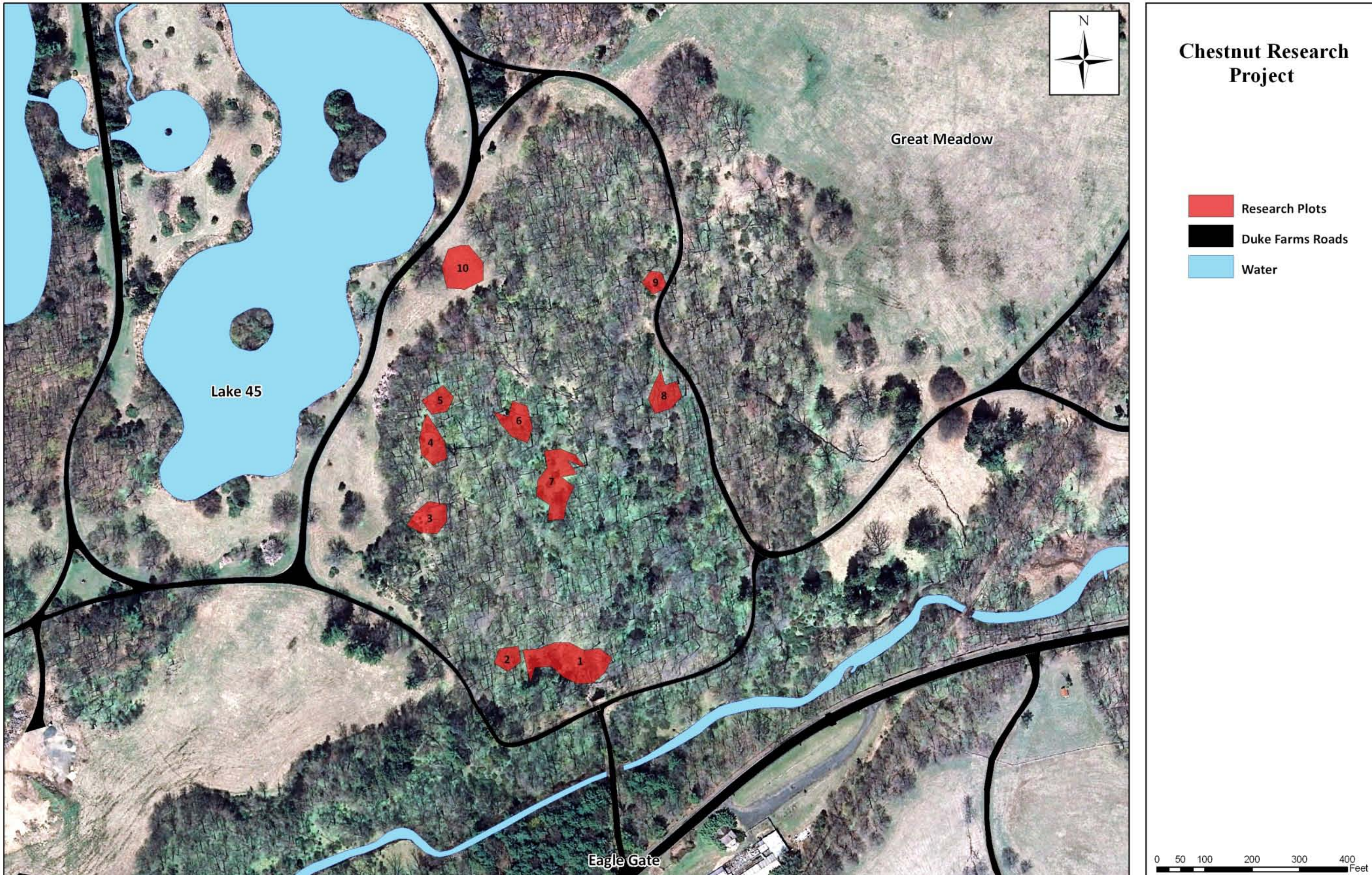


Figure 2. Forest gaps where the chestnut were planted. Gap sizes range from 1,699-10,629 ft².



Chestnut trees were monitored in Spring 2011 and 2012 for date of budburst and Fall 2011 and Fall 2012/Winter 2013 for survival, height, and diameter at 5 cm from the ground. Overhanging vegetation such as *Rubus phoenicolasius* (Japanese wineberry), *Vitus spp.* (wild grape), *Rubus allegheniensis* (wild blackberry), *Toxicodendron radicans* (poison ivy), and *Urtica spp.* (stinging nettle) was manually trimmed 1-2 times in the Summer 2011 and 2012. Landscape cloth was replaced as needed. Light measurements were taken in the gaps with a light meter in Summer 2011. Although the Duke Farms property experienced much mature tree loss due to Hurricane Sandy (October 2012), few chestnut seedlings were affected. Any fallen branches lying on seedlings were removed. Tree branches and trunks that fell in locations where they will block continued chestnut growth will be removed in Spring 2013.

Experimental Analysis

Seedling survival was analyzed with GLM (binomial distribution with logit link function, R version 2.15.3) with tree survival (0 or 1) as the dependent variable and genotype and gap size as independent variables. Seedling growth was analyzed with GLM (normal distribution) with height (cm), growth in height (cm), basal area (mm^2), and growth in basal area (mm^2) as dependent variables, genotype and gap size as independent variables, and the previous year's height and previous year's basal area as covariates in the growth analyses.

Phenology data have not yet been analyzed.

Plots 6 and 7 lost all but 5 and 8 trees respectively during winter flooding of 2010/2011. These plots were excluded from the analyses.

3. Actual results and any differences from objectives

<u>Results</u>

Survival

Chinese chestnut survival exceeded that of American chestnut and all hybrids ($p<0.001$) in 2011, but in 2012 there were no survival differences among genotypes (Figure 3). There was no relationship between survival and gap size in 2011, but in 2012 survival was lower in the larger gaps (Figure 4).

Figure 3. Survival rate (0 to 1) of each genotype for the 2012 growing season. Red dots indicate the mean for each genotype. Box plots are represented in black.

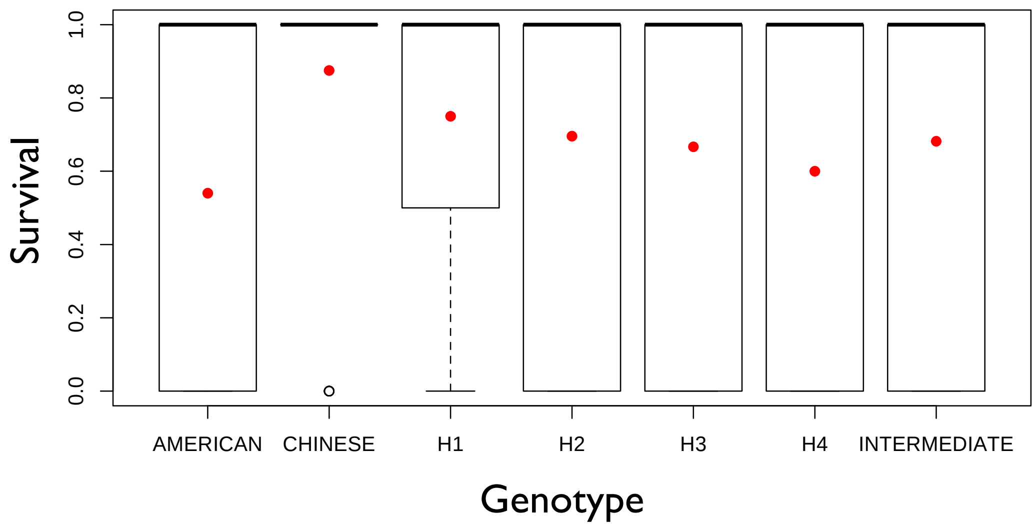
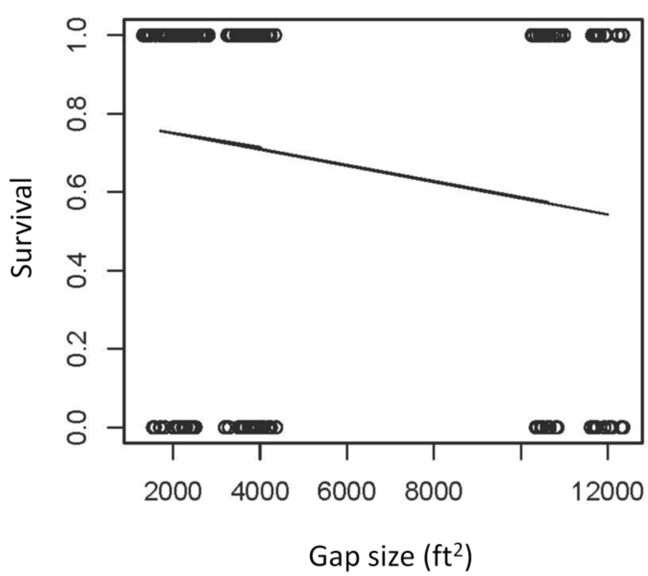


Figure 4: Survival rate (0 to 1) of chestnut seedlings in forest gaps of different sizes for the 2012 growing season.

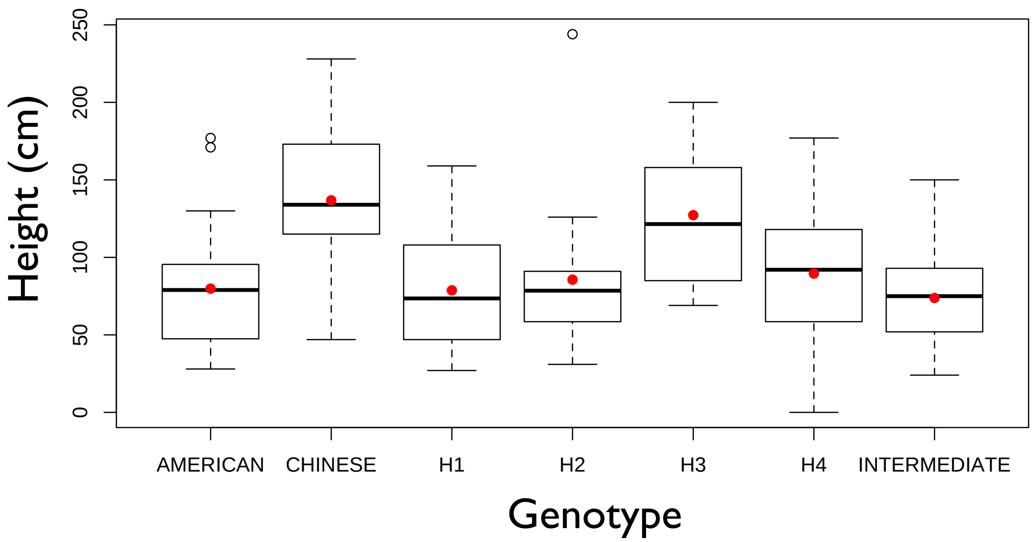


Height

Chinese chestnuts and hybrids H3 and H4 were significantly taller than the other genotypes in 2011; in 2012 Chinese chestnut and hybrid H3 were still taller, but H4 was not (Figure 5). Height was not related to gap size in either year.

Chinese chestnut showed greater relative growth in height than other genotypes and hybrids H3 and H4 showed less relative growth in 2011. In 2012 Chinese chestnut, hybrid H3 and H4 all showed less relative growth in height than other genotypes. Relative growth in height was not related to gap size in either year.

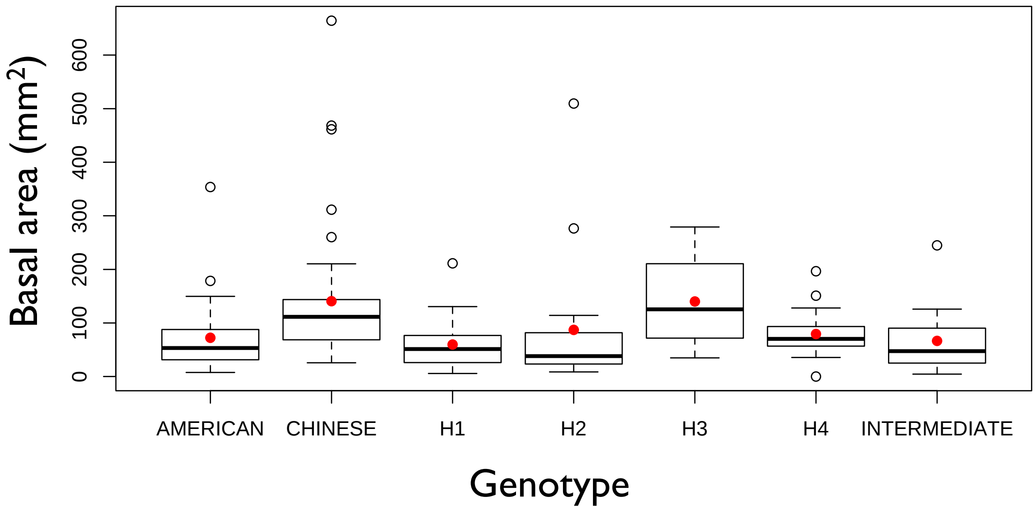
Figure 5. Mean tree height (cm) of each genotype (red dots) at the end of the 2012 growing season. Box plots are represented in black.



Basal area

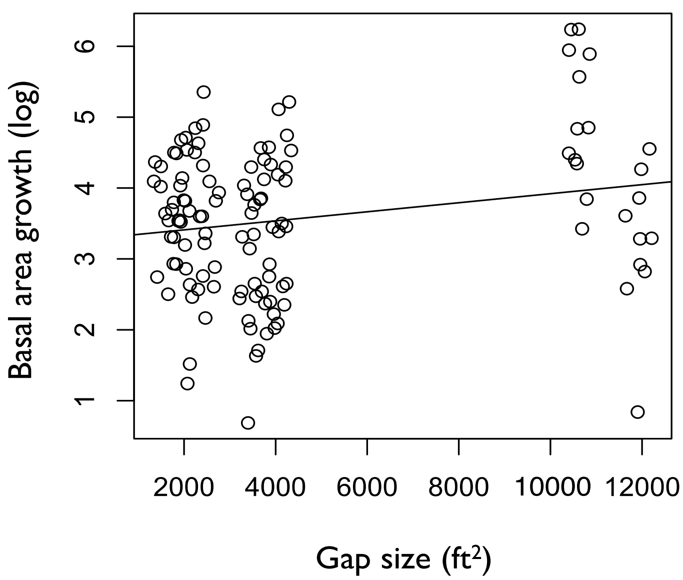
Chinese chestnut and hybrid H3 had greater basal area than other genotypes in both 2011 and 2012 (Figure 6).

Figure 6. Mean basal area (mm^2) of each genotype (red dots) at the end of the 2012 growing season. Box plots are represented in black.



Hybrids H1 and H4 showed less relative growth in basal area than other genotypes in 2011. In 2012 hybrid H3 showed less relative growth in basal area than other genotypes. Relative growth in basal area increased with gap size in both 2011 and 2012 (Figure 7).

Figure 7. Relationship between basal area growth during the 2012 growing season and the size of the gap were the trees were planted (GLM t value=2.54, $p<0.05$).



Discussion

Genotype
Hybrid H3 was taller and had greater basal area than other genotypes in both years of the study, as did the Chinese chestnut seedlings (except H4 which was equally tall as H3 and Chinese chestnut in 2011). However hybrid H3 showed less relative growth in height than H1, H2, American and Chinese genotypes in 2011, less relative growth in height than genotypes H1, H2, and American genotypes in 2012 and less relative growth in basal area than all other genotypes in 2012.

H3 genotype was taller and had greater basal area in 2010 when the seedlings were outplanted, probably due to the fact that most of the trees belonging to this genotype (22 out of 30 trees) came from a different source (TACF's nursery at Meadowview; this genotype experienced high mortality in the Duke greenhouse.) This early growth advantage slowed in the 1^{st} or 2^{nd} year after planting in forest gaps, with other genotypes showing greater relative growth after field planting.

We will continue to monitor growth to determine if H3 maintains its lead over the other hybrid genotypes in height and basal diameter.

Gap size
Chestnut seedling survival is currently lower in the larger gaps, probably as a result of competition with surrounding vegetation. Although vegetation was manually trimmed once or twice a summer, plots in the larger gaps and the control area on the forest/field boundary still had substantial tall vegetation surrounding them: *Rubus phoenicolasius* (Japanese wineberry), *Vitus spp.* (wild grape) and *Urtica spp. (*stinging nettle) in the 10, 629 ft^2 plot, *Rubus* allegheniensis (wild blackberry) in the 4,008 ft^2 plot, and meadow grasses and wildflowers in the control plot.

We will continue to manage surrounding vegetation in the gaps. As the trees grow taller, and develop a broader canopy they will suppress competition from the surrounding briers and herbaceous vegetation.

Gap size did not influence seedling height, relative growth in height, or basal area. Relative growth in basal area, however, increased with gap size. It appears that greater growth of surrounding vegetation in the larger, sunnier gaps repressed most seedling growth responses to greater overall light availability. Alternatively, Anagnostakis (2007) found that chestnut seedlings grew better in partial shade, and the smaller, shadier gaps may have provided a good environment for early survival and growth.

Objectives
We monitored trees for survival and performance variables for two growing seasons (Short-term goal #1), and will continue to do so. We have not yet begun monitoring for blight resistance (Short term goal #2); we will do so as the trees develop signs of blight.

Initial survival and growth data indicate that chestnut can be reintroduced to Northeastern forests by planting seedlings in gaps created through invasive species management (Long-term goal #1). Survival ranged from 54-87% and all genotypes grew in both height and basal area. First year seedling survival may have been higher if the trees were larger at outplanting. Seedlings experienced heat stress during their early growth in the greenhouse (hot summer of 2010, no air-conditioning); most seedlings were small in height and basal area. Some seedlings died and the experimental stock had to be supplemented from seedlings grown at Meadowview Research Farms to complete the full experimental design.

Initial data do not indicate a size limit (lower threshold) to which gaps can successfully be used for chestnut reforestation (Long-term goal #2); we will watch to see if a size limit materializes as the trees grow. Hybrid H3 has been the tallest and largest in basal area of the blight resistant hybrid genotypes since the beginning of the experiment (Long-term goal #3) but it does not show the greatest growth rate. Genotype early performance comparisons are somewhat confounded by the need to supplement Duke-grown seedlings with those from Meadowview. We will continue to follow its growth performance of all genotypes.

Duke Farms opened to the public as a center for land stewardship in May 2012. The press coverage, especially for this experiment, has been extensive, educating the general public to the devastating effects of invasive pests and the hope of chestnut restoration (Long-term goal #4). Duke Farms received many phone calls requesting trees or asking how people could help; callers were directed to the TACF website. A "Research Day" is planned this summer, designed to educate the public on the value of scientific research. The chestnut study will be prominently featured.

Land managers are coming to Duke Farms for a variety of professional programs. The chestnut experiment is featured in tours lead by the Duke Farms Director of Stewardship (Long-term goal #5).

Future support
Funding from USDA Multistate Research Project NC-7 Conservation, Management, Enhancement and Utilization of Plant Genetic Resources will allow us to continue monitoring this study for the next five years.

Reference
Anagnostakis, S. L. 2007. Effect of shade on growth of seedling American chestnut trees. Northern Journal of Applied Forestry 24:317-318.

4. Published works and presentations

It is premature to publish these results in the peer-reviewed scientific literature. Preliminary results will be presented at Duke Farms "Research Day", designed to educate the public on the value of scientific research.

The experiment has been introduced in the following presentations:

Public outreach
Kaunzinger, C. M. K.* 2011. Duke Farms: from estate park to center for land stewardship and sustainability. Great Ecology (Ecological Consulting Firm), New York, New York.

Kaunzinger, C. M. K.* and S. N. Handel. 2010. The ecological garden: creating links to nature in your home and community. The Garden Club of America national annual meeting. New Brunswick, New Jersey.

Scientific audience
Kaunzinger, C. M. K.* 2011. Ecological QA/QC. Rutgers University, New Brunswick, New Jersey.

Kaunzinger, C. M. K.*, S. Handel and B. Hillman. 2009. Chestnut restoration in forest gaps, Duke Farms, Hillsborough, NJ. Biological Improvement of Chestnut through Technologies that Address Management of the Species, its Pathogens and Pests annual meeting, USDA. Ocean Grove, New Jersey.

5. Press coverage

NJTV's NJ Today, September 26, 2012, "Ecologists Try to Restore American Chestnut Tree in New Jersey
http://www.njtvonline.org/njtoday/video/ecologists-try-to-restore-american-chestnut-tree-in-new-jersey/

The Star Ledger, September 9, 2012, "N. J. Researchers Trying to Revive American Chestnut Trees"
http://www.nj.com/somerset/index.ssf/2012/09/nj_researchers_trying_to_reviv.html

NBC New York Cable Station (NBC NY nightly news?), August 30, 2012, "Restoring our Chestnut Trees"
http://www.nbcnewyork.com/video/#!/on-air/as-seen-on/Restoring-Our-Chestnut-Trees/168090536

YouTube video created by Whirlwind Creative, Inc. for Duke Farms, posted August 29, 2012, "American Chestnut Research Project – Duke Farms"
http://youtu.be/t1-pKb5bpj8
Wall Street Journal, August 19, 2012, "Hopes for a Chestnut Revival Growing"

http://online.wsj.com/article/SB10000872396390444233104577593571278706402.html

Rutgers Focus (online news letter) August 17, 2012, "Bringing the American Chestnut Tree Back to Life"
http://news.rutgers.edu/focus/issue.2012-07-27.2376140283/article.2012-08-17.2754275170

Rutgers, Department of Ecology, Evolution & Natural Resources website, January 31, 2012, "Restoring American Chestnut Trees to Northeastern Forests",
http://www-rci.rutgers.edu/~deenr/Chestnut_Research_Jan_2012.html