Bull Run Mountains American Chestnut Survival Study: Summary

Principle Investigators

William McShea and Norm Bourg
Smithsonian Conservation Biology Institute
1500 Remount Rd., Front Royal, VA 22630
mcsheaw@si.edu 540-636-6563

Introduction

The ecology of forests in the Bull Run Mountains, located in Fauquier and Prince William Counties, mirrors that of many forests in Virginia. The ridges were extensively settled and cleared in the 1700's, but as the farmland was abandoned after the Civil War a mixed deciduous forest regenerated. This secondary forest contained a strong component of American chestnut (*Castanea dentata*) which was subsequently lost due to the chestnut blight epidemic in the 1920's and 30's. Today, the secondary forest of the Bull Run Mountains is predominantly oak (*Quercus* sp.; VDCR 2002; Figure 1). In addition to the loss of American chestnut, a second major biotic change in the region has been the growth of white-tailed deer (*Odocoileus virginianus*) populations, which were effectively extirpated from Virginia in the 1800's, but now number over 2 million individuals statewide. Their browsing activity on seedlings and saplings can change succession patterns in deciduous forests and alter the success of any forest restoration project (McShea 2012).

The American Chestnut Foundation (TACF) and other organizations have worked for decades to produce a viable American chestnut hybrid that can resist the blight and repopulate the forests of eastern North America. However, the restoration of this tree species as a significant component in eastern forests requires a better understanding of seedling survival, in terms of both forest canopy cover and deer browsing pressure. The purpose of this project was to quantify the germination success and short-term survival rate of 1,200 chestnuts planted in the forest habitat of the Bull Run Mountains where American chestnuts once thrived. We compared germination and survival rates in open and closed canopy, as well as for seedlings exposed to, or sheltered from, deer browsing. It is expected that further research will develop based on the results of this project, but our goal was to help TACF refine its restoration strategy in light of the current stressor of chronic deer overabundance in eastern U.S. forests.

Methods

The Principal Investigators worked with staff at the Bull Run Mountains Conservancy (BRMC) to prepare a detailed study protocol and locate sites for experimental chestnut plantings in the Bull Run Mountains. The 150 selected sites included two microhabitats: recent canopy gaps in mature oak forest, and mature closed-canopy oak forest without additional treatment. Within each habitat type, we selected 75 sites; at each site half of the plantings were protected from deer with either wire fencing or *in situ* downed woody debris (i.e., slash) and half were unprotected controls. All geospatial data were entered into a GIS containing topographic and habitat layers for future reference.

Planting sites were prepared and planted in March 2012 using seed provided by either Meadowview Research Farms or harvested by the Virginia Chapter of TACF (VATACF). Each site had 8 seeds planted along the cardinal directions around a central post, with 2 m spacing between seeds (Figure 2). Each seed was marked with a small numbered, wooden dowel, and its location and treatment were recorded. All numbered plantings were entered into a MS Excel database and inspected on subsequent visits. BRMC and VATACF recruited and trained volunteers to help SCBI monitor the sites and maintain germination and survival records.

During the remainder of the growing season in 2012 and again through the 2013 growing season, each site was visited regularly (2-4 weeks) by SCBI staff or a BRMC volunteer. The number of seeds to germinate was recorded. We replenished planting sites that had suffered seed predation first with additional seeds in May 2012 and later with first-year seedlings in November 2012. At each visit the staff or volunteer recorded the presence/absence of each seedling, its height, and any evidence of browse or insect damage.

Results

As mentioned above, seed survival was low. After the first planting of 1208 seeds we immediately noticed extensive digging at planting sites, which we attributed to rodent excavation and consumption of seeds. Within 1 month of the first planting we replaced all seeds that had been obviously removed. The vast majority of these seeds were also removed. As of June 2012 only 77 planted seeds (6%) had germinated and survived. Once germinated, the survival rate matched the planted seedlings, and 30 of the original seeds (39% of those alive in June 2012) were still present in October 2013.

The second experiment started with the planting of seedlings in May and November 2012. By the end of these plantings 456 seedlings were present at 56 sites. Overall survival of these and the germinated seedlings was 62%, with 284 seedlings currently distributed across 72 sites at BRMC (Table 5). We examined the survival of all seedlings (i.e., planted seeds that survived to germinate, as well planted seedlings) with respect to location (which ridge they were planted on), canopy condition (was the canopy open or closed), and protection from deer (no protection, slash piled around seedling, or wire cage).

Several generalized linear mixed models were set up to analyze the seedlings' survival rates under different scenarios. An overarching model was created with survival as the response variable, the canopy treatments (open or closed) and deer protection treatments (no protection, slash pile, or fenced) as fixed effects, and the planting location (the ridges Central, East, North, or West) as a random effect. Following that, two secondary models were created: one examined only canopy treatment while the other tested only the type of deer protection.

For the 4 ridges with seedlings planted, there were higher survival rates at Central and West (Table 1 and 3), but the differences observed are not significant ($z = 1.76$, $p = 0.077$). We detected no significant effect of canopy opening on seedling survival (partial $z = -0.74$, $p > 0.1$). Seedlings in canopy openings did not exhibit significantly different survival than seedlings planted in closed canopy sites (Table 2). We did detect a significant effect of deer protection on seedling survival (partial $z = 7.69$, $p < 0.001$). Seedlings protected from deer were twice as likely to survive as unprotected seedlings (59.1% vs 29.9%, respectively). When we analyzed deer protection methods the survival rate of fenced seedlings (83%) was slightly higher than seedlings protected with a slash pile (72%) and these differences were significant ($z = -2.73$, $p < 0.001$).
For the timing of mortality we divided the year into 3 periods: winter (November through March), spring (April through June), and summer (July through October) and examined the last month each seedling was observed. More seedlings were lost during the winter period (138 total; average 28 per month) than the spring (69 total; average 23 per month) or summer (116 total; average 29 per month) but the rate of loss was about even through the year. We do not know if this mortality was due to deer herbivory or environment.

When we examined the final height of the seedlings we found that deer control did make a significant difference ($F = 14.46$; d.f. 2,238; $p < 0.001$). The mean height of control plants (21.85 cm) was similar to seedlings in slash piles (25.85 cm), but significantly shorter than fenced plants (36.15 cm). The slash pile seedlings were also significantly shorter than the fenced seedlings ($p = 0.003$). In other words, protection from deer by fencing increased the height of surviving seedlings by 65%. When we controlled for deer control there was only a small difference in the mean height between seedlings planted in a canopy opening (32.3 cm) and those planted in a closed canopy (27.7 cm) and the difference was not significant ($F = 3.29$; d.f. 1, 239; $p = 0.071$). A graph of final heights observed for seedlings in both groups shows that deer-protected seedlings have the potential for significant growth (Figure 3).

BRMC volunteers and staff surveyed the ridge areas at BRMC for mammals using a system of trip-cameras that were moved at regular intervals (Table 4). The list of mammals photographed in the study area included multiple species (fox, raccoon, bear, coyote, opossum, and gray squirrel), but only deer were photographed at all stations. Deer were widespread and were the only herbivore present in the study area (no rabbits or ground hogs were detected). The relative abundance of deer appeared to be highest on E Ridge and in the winter (Table 4), but the study area is so small relative to deer home ranges that we do not place a heavy weight on these differences. It is possible that the ridges are used more during the winter months, as deer do leave agricultural areas for wooded areas during winter months. As noted above, there was no evidence of increased seedling mortality over the winter months.

Discussion

With the developing plans for restoration of American Chestnut into Appalachian forests, it is important to have a realistic estimate of survival for seeds or seedlings planted in the secondary oak forests prevalent in the region. We would not recommend planting seeds as the primary means of establishment. Seeds suffered a high mortality rate due to seed-eating rodents, which are abundant in oak forests. It could be that our planting activity left detectable signs that allowed rodents to focus on seed sites and elevated the overall predation rate. However, regardless of the ultimate cause, planting seeds did not result in high recruitment rates into the sapling age class. In the long term, successful American Chestnut restoration will rely on seeds maturing into saplings, but this will result from mature trees each producing many thousands of seeds and not volunteer corps planting hundreds of seeds.

We do see potential for American Chestnut restoration using seedlings. Overall, our 2-year seedling survival rate was 44.8%. These trees had not yet reached sapling height (approximately 2 m) where they would escape the mortality due to deer browsing, but their mortality rates were low enough that we estimate some will escape deer herbivory. It is a very rough approximation, but if mortality rates hold constant for 6 more years (so the saplings reach 8 years of age) 23 saplings would be alive from the current 272 seedlings.

We saw no significant differences in mortality rates between open and closed canopy sites. Concerns about ambient light levels available to developing seedlings were not reflected in differences in mortality rates. Growth rates of seedlings in open and closed sites do not appear to be different but there is wide variability that was not explained. It is true that the seedlings within slash piles grew significantly less than fenced seedlings. Either the slash piles did not provide total protection from deer or the reduced light levels did slow the growth of these plants. We think the second hypothesis is more plausible as the slash piles created an obvious shadow over the seedlings and this may reduce light levels more than the diffuse differences across the small canopy openings.

We were not as able to track seedling survival or height as well as we anticipated because of the frequent browsing on exposed plants. The browsing did not always kill the seedlings but the seedling would resprout at a later period. Unfortunately, the volunteers often stopped checking seedlings once they were severely browsed and the trees were haphazardly detected at later dates after resprouting. We are doubtful these reduced stature seedlings will persist, but they complicated our analysis of seedling survival or growth.

This overall survival rate can be explained by some of the factors we measured. Protection from deer herbivory did make a significant difference in seedling survival. The survival of seedlings doubled over the study period when they were protected. It is encouraging that using available materials (slash and wood debris) worked almost as well as the constructed fences. These haphazard structures were a deterrent to deer herbivory. We would point out that for this advantage to be maintained for the 10 year browse period the structure would have to be replaced. After 2 years most slash piles were decayed to the point of being dysfunctional. The need for fence maintenance to keep this survival advantage would be similar however, and would also include the added cost and labor required to purchase, build and transport fence material into forest planting sites. Therefore, we recommend that protection from deer herbivory by employing naturally occurring woody debris and slash be incorporated into American chestnut restoration planting strategies, despite the slower growth rate of these seedlings during the protection period.

It would be valuable to know the longer-term survival rate of the remaining seedlings and length of time needed for saplings to escape browse height. This would entail an annual or biannual check for survival and height. If most mortality occurs during the first three years then the construction of slash piles around seedlings would be sufficient to get seedlings past the critical seedling-sapling transition period. If mortality is constant over the 8-10 years needed to escape deer, then a three-year assistance strategy would still be worthwhile (as it would boost the number of third year seedlings), but increased planting rates would be needed for a sufficient number of saplings to be produced.

Literature

McShea, W. J. 2012. Ecology and management of white-tailed deer in a changing world. Annals of the New York Academy of Sciences. 1249:45-56.

Virginia Department of Conservation and Recreation. 2002. Ecological Communities of the Bull Run Mountains, Virginia. Baseline Vegetation and Floristic Data for Conservation Planning and Natural Area Stewardship. Natural Heritage Technical Report 02-12

Figures:

Figure 1. Habitat composition of the study area. Most deciduous forest was composed of multiple oak species. The lower figure included most planting sites and the box encompasses the planting sites (Shooter Hill and North) in that region.

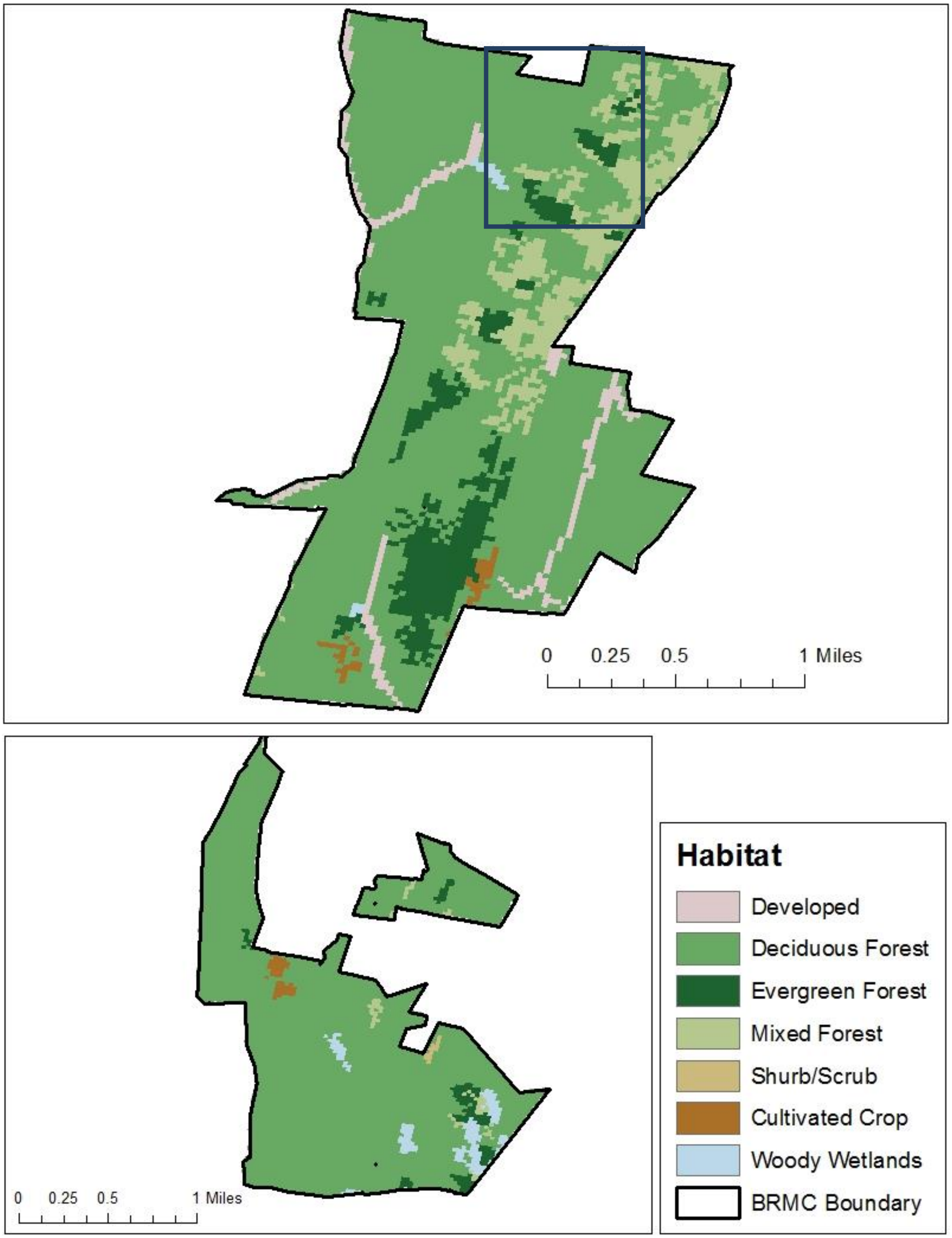


Figure 2. Planting site layout. The first location on each cardinal direction was 1 m from the center stake, with all subsequent locations at 2 m spacing. Eight seeds or seedlings were placed at each site. Each site had 4 seeds protected from deer herbivory by either fence or slash pile.

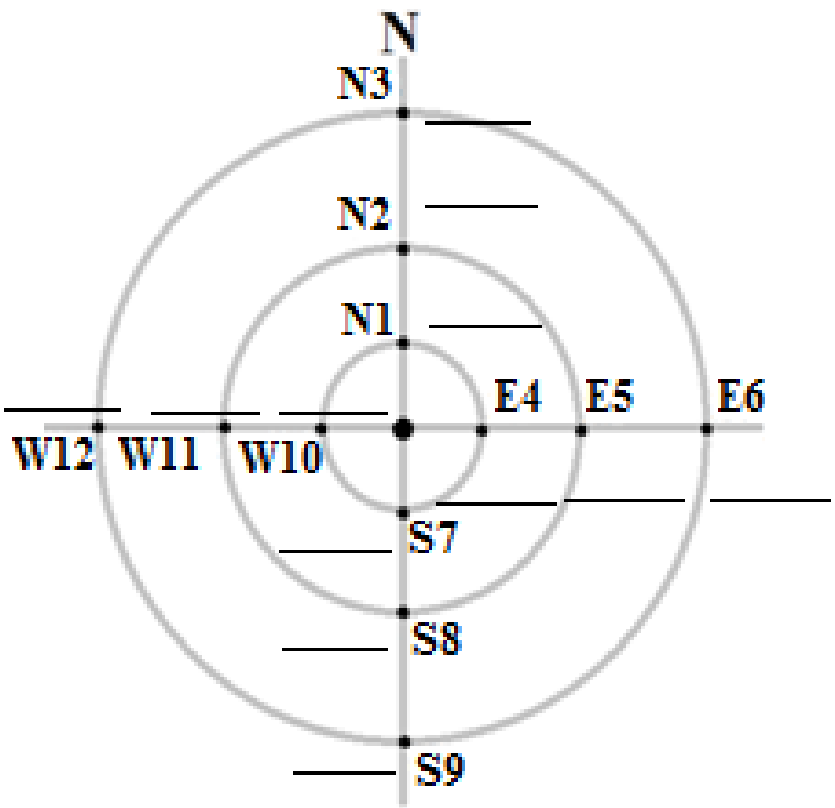
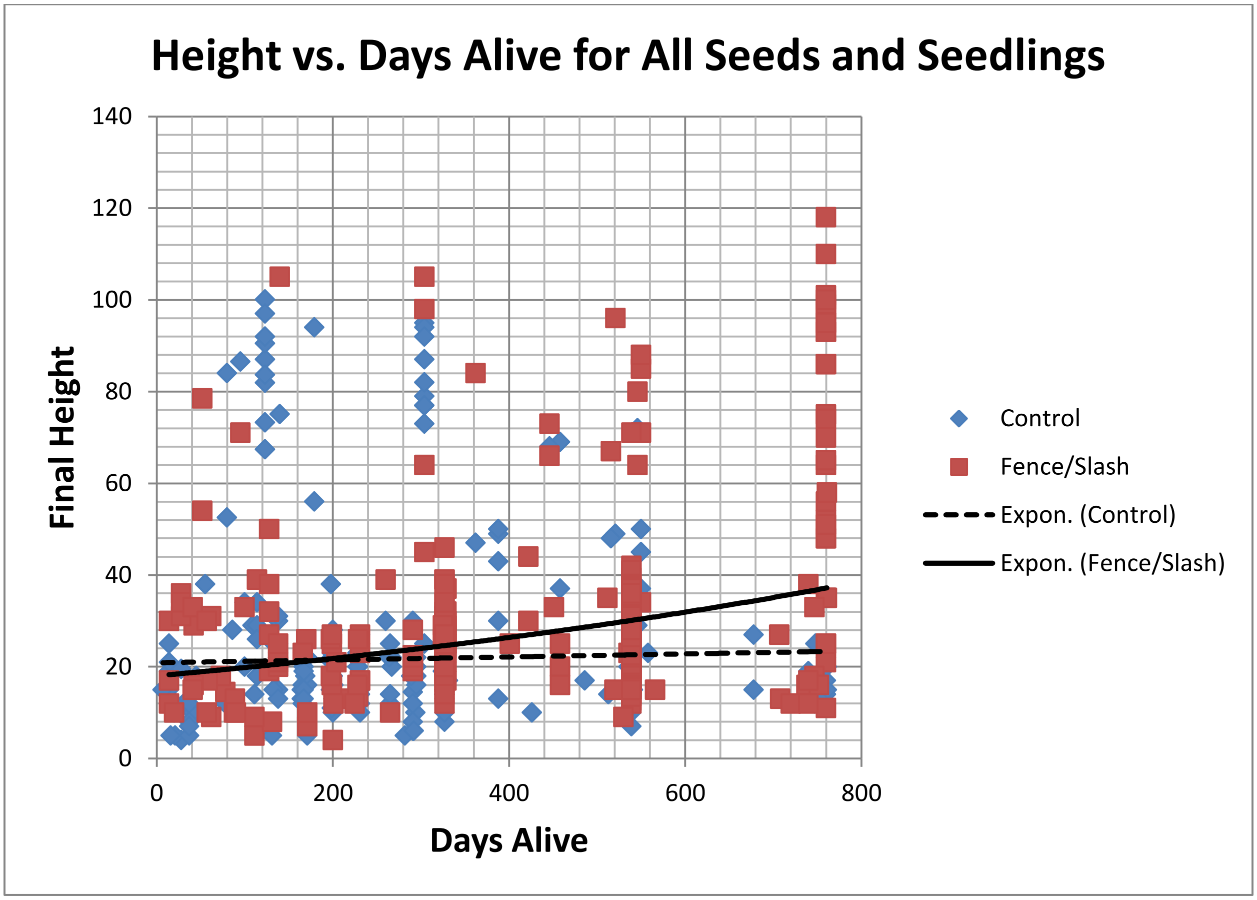


Figure 3. Final heights of seedlings (cm) planted or emerged at BRMC, with a comparison between deer-protected and control seedlings. Each represents the height of the plant on the last check when it was observed. Control seedlings are not showing increased height with age, while the deer control seedlings (slash and fence) show marked increase for some seedlings.



Tables:

Table 1. Number of seeds planted and survived, seedlings planted and survived, and percent survival for each organized by planting location. The Roland Farm location was dropped from the study after the first round of planting and as such did not have any seedlings planted.

Location	Seeds			Seedlings		
	# Locations Planted	# Seeds Survived	% Survival	# Planted	# Survived	% Survival
East	240	0	0	148	78	52.7

Central	344	9	2.6	132	95	72
West	112	7	6.25	32	26	81.2
Boulder	96	5	5.2	0	0	N/A
North	272	7	2.6	144	73	50.7
Shooter	80	2	2.5	0	0	N/A
Roland	64	0	0	0	0	N/A

Table 2. Summary of seedling survival for the different treatment groups.

Experimental State	Total planted	Alive as of 10/2013	% Survival
Protected by Fence	156	129	82.7
- Closed Canopy	79	65	82.3
- Open Canopy	77	64	83.1
Protected by Slash	72	52	72.2
- Closed Canopy	33	28	84.8
- Open Canopy	39	24	61.5
No Protection	228	91	39.9
- Closed Canopy	117	51	43.6
- Open Canopy	111	40	36.0
Closed Canopy	229	144	62.9
Open Canopy	227	128	56.4

Table 3. Summary of seedling survival rates for each treatment level at each of the planting areas.

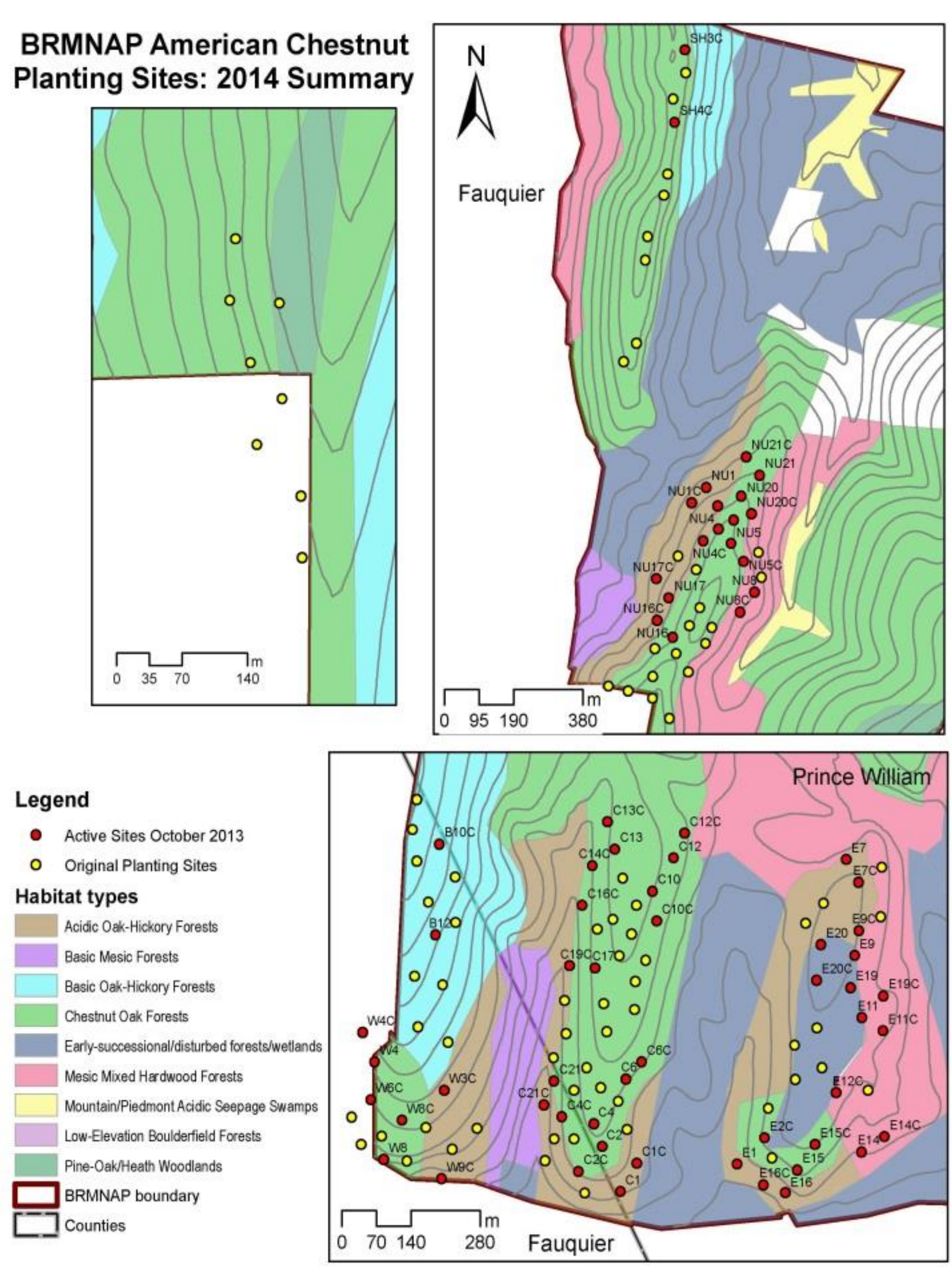
Survival Rate of Seedlings by Site by Treatment				
	Site			
Treatment	Central	East	North	West
Fenced	0.91	0.72	0.84	0.92
Slash	0.96	0.68	0.41	0.75
Control	0.49	0.36	0.28	0.75
Total Survival	0.72	0.53	0.51	0.81

Table 4. The number of deer detections recorded during the survey period on three ridges within the study area. The Camera months indicates the amount of survey effort on each ridge. In parentheses is the mean number of detections per survey month. Detections do not represent deer numbers but are an index of deer activity in that area. Deer activity was heaviest in the winter and along E Ridge

Location	Spring		Summer		Winter		All Seasons
	Camera Months	Deer Detections	Camera Months	Deer Detections	Camera Months	Deer Detections	Total Detections
B Ridge	5	41 (8.2)	4	16 (4.0)	3	63 (21)	120 (10.0)
C Ridge	3	22 (7.1)	--	--	--	--	3 (7.1)
E Ridge	1	3 (3.0)	4	94 (23.5)	3	278 (92.7)	375 (46.9)
Total	9	66	8	110	6	341 (56.8)	

Table 5. UTM (NAD83) locations of chestnut seedlings alive as of October 2013 and the number of seedlings at each site.

Locations of Active Sites										
Area	Site	X	Y	# Alive October 2013		Area	Site	X	Y	# Alive October 2013
Boulder	B10C	264365	4301575	5		East	E19C	265262	4301281	8
Boulder	B12	264358	4301399	2		East	E20	265136	4301380	4
Boulder	B12C	26439	430142	1		East	E20C	265127	4301311	4
Boulder	B14	26432	430122	2		East	E2C	265022	4301006	4
Central	C1	264731	4300902	4		East	E7	265187	4301545	2
Central	C1C	264764	4300957	5		East	E7C	265212	4301501	7
Central	C10	264796	4301484	4		East	E9	265204	4301359	5
Central	C10C	264804	4301426	4		East	E9C	265213	4301407	7
Central	C12	264838	4301548	3		East	E11C	265261	4301213	1
Central	C12C	264860	4301596	5		North	NU1	267084	4309490	2
Central	C13	264720	4301565	5		North	NU1C	267043	4309449	3
Central	C13C	264705	4301618	5		North	NU16	266992	4309096	6
Central	C14C	264674	4301533	1		North	NU16C	266949	4309140	6
Central	C16C	264654	4301456	2		North	NU17	266981	4309199	2
Central	C17	264680	4301335	2		North	NU17C	266946	4309249	6
Central	C19C	264628	4301339	1		North	NU20	267180	4309467	3
Central	C2	264694	4300989	3		North	NU20C	267207	4309420	2
Central	C2C	264646	4300941	7		North	NU21	267230	4309522	3
Central	C21	264597	4301116	6		North	NU21C	267193	4309570	1
Central	C21C	264576	4301070	6		North	NU3	267159	4309404	2
Central	C4	264677	4301033	6		North	NU3C	267115	4309441	4
Central	C4C	264613	4301047	7		North	NU4	267117	4309380	5
Central	C6	264742	4301120	5		North	NU4C	267075	4309349	4
Central	C6C	264774	4301153	4		North	NU5	267152	4309342	3
Central	C19C	264628	4301339	1		North	NU5C	267186	4309295	3
East	E1	264967	4300955	2		North	NU8	267216	4309214	2
East	E11	265219	4301239	3		North	NU8C	267176	4309162	3
East	E11C	265261	4301213	5		Shooter	SH3C	267025	4310640	1
East	E12C	265166	4301093	1		Shooter	SH4C	266997	4310450	1
East	E14	265218	4300979	1		West	W3C	264375	4301098	2
East	E14C	265264	4301008	3		West	W4	264235	4301153	7
East	E15	265088	4300944	3		West	W4C	264210	4301210	7
East	E15C	265124	4300993	5		West	W6C	264227	4301080	3
East	E16	265064	4300900	4		West	W8	264253	4300964	7
East	E16C	265020	4300915	1		West	W8C	264290	4301040	4
East	E19	265196	4301297	5		West	W9C	264370	4300927	4



BRMNAP American Chestnut Planting Sites: 2014 Summary
N
Fauquier
Prince William
Fauquier
0 35 70 140 m
0 95 190 380 m
0 70 140 280 m
SH3C
SH4C
NU21C
NU21
NU1
NU1C
NU20
NU20C
NU4
NU5
NU4C
NU5C
NU17C
NU17
NU8
NU8C
NU16C
NU16
B10C
B12
C13C
C13
C12C
C12
C14C
C10
C16C
C10C
C19C
C17C
C6C
C21C
C6
C21C
C4C
C4
C2
C2C
C1C
C1
W4C
W4
W6C
W3C
W8C
W8
W9C
E7
E7C
E9C
E20
E9
E20C
E19
E19C
E11
E11C
E12C
E2C
E15C
E14C
E14
E1
E15
E16C
E16
Legend
Active Sites October 2013
Original Planting Sites
Habitat types
Acidic Oak-Hickory Forests
Basic Mesic Forests
Basic Oak-Hickory Forests
Chestnut Oak Forests
Early-successional/disturbed forests/wetlands
Mesic Mixed Hardwood Forests
Mountain/Piedmont Acidic Seepage Swamps
Low-Elevation Boulderfield Forests
Pine-Oak/Heath Woodlands
BRMNAP boundary
Counties