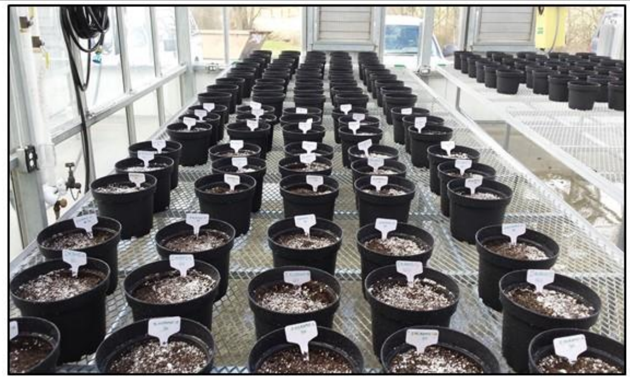
Removal, Propagation, and Transplantation of Michaux's Sumac (*Rhus michauxii*) Colonies from the Infantry Platoon Battle Course, Fort Pickett – Maneuver Training Center, Virginia



Virginia Tech
College of Natural Resources and Environment

Verl Emrick, Matthew Fields, and Jessica Fitzpatrick

The Conservation Management Institute
College of Natural Resources and Environment
Virginia Polytechnic Institute and State University
1900 Kraft Dr. Suite 105
Blacksburg, VA 24061

Cite as: Emrick, Verl R, Matthew Fields, and Jessica Fitzpatrick. 2018. Removal, Propagation, and Transplantation of Michaux's Sumac (*Rhus michauxii*) Colonies from the Infantry Platoon Battle Course, Fort Pickett –Maneuver Training Center, Virginia Conservation Management Institute, College of Natural Resources and Environment, Virginia Polytechnic Institute and State University, Blacksburg. VTCMI-Technical Report 05-2018. 33pp.

Abstract: Michaux's sumac (*Rhus michauxii* Sarg.) is a rare and federally endangered, densely pubescent, rhizomatous shrub found in periodically disturbed habitats in the inner Coastal plain and piedmont of the southeastern United States. At Fort Pickett, conflicts between military training and Michaux's sumac are uncommon. Current management of the Fort Pickett population restricts all military activity, with the exception of foot traffic, within colonies of Michaux's sumac. However, the dynamic and constantly evolving military mission has resulted in range expansion and alteration thus isolating small colonies of Michaux's sumac. At Fort Pickett, six colonies of Michaux's sumac occurred within two active firing ranges. The goal of the research project was the careful excavation of Michaux's sumac rhizomes from up to six small, isolated colonies on two active direct fire ranges at Fort Pickett, propagation of these individuals in a controlled greenhouse setting, and the subsequent transplantation of the propagated individuals to suitable habitat on Fort Pickett. In March 2017, while the plants were dormant, all rhizomes in colonies were excavated by digging with a hand trowel. We planted 168 bare rhizomes in 1-gallon plastic greenhouse pots with equal parts of peat, clay, and perlite, along with 25 grams of soil from the original colony location to ensure inoculation by native mycorrhizae. Approximately ½ of the individuals showed signs of stress and wilting by May of 2017. The source was a soil-borne pathogen, *Rhizoctonia solani*. All plants, including the healthy individuals, were treated with fungicides registered for control of rhizoctonia. On April 26-27, 2018, 39 of the greenhouse grown Michaux's sumac were successfully planted in DF6. The remaining 20 grown outside under shade cloth will be planted in the fall of 2018. In July 2018, all 39-transplanted individuals were alive and vigorous with, 17 (44%) individuals producing female flowers and one (2.5%) male flowers. While these procedures were specifically researched and developed for the removal and transplantation of Michaux's sumac stems from Range 12 and the IPBC, they can serve as the basis for any future propagation of Michaux's sumac rhizomes for conservation and recovery.

Keywords: Michaux's sumac, Fort Pickett, Propagation, Rhizoctonia

Introduction

Michaux's sumac (*Rhus michauxii* Sarg.) is a rare and federally endangered, densely pubescent, rhizomatous shrub found in periodically disturbed habitats in the inner Coastal Plain and Piedmont of the southeastern United States (Emrick and Jones 2008). It was listed as endangered by the U.S. Fish and Wildlife Service in 1989 (USFWS 1989) and was discovered on Army National Guard Maneuver Training Center-Fort Pickett (Fort Pickett) in 1993 (Fleming and Van Alstine 1994). Michaux's sumac is endemic to the inner Coastal Plain and Piedmont of the southeastern United States, where it occupies sandy or rocky savannas and open woods (USFWS 1993). These sites typically have low cation exchange capacities and depend on some form of disturbance to maintain the open character of the habitat (Savage et al. 1991, Emrick and Jones 2008). Primary disturbances are fire (accidental or prescribed), right-of-way maintenance, and agricultural brush clearing (USFWS 1993). Many authors concluded that Michaux's sumac requires a combination of soil disturbance and occasional fire to maintain a healthy population (Hardin and Phillips 1985, USFWS 1993, Wilkinson 1996, Emrick and Hill 1998, Emrick and Jones 2008, Teets et al. 2012). Soil disturbance appears to stimulate rhizomatous growth while periodic fire keeps other scrub/brush species from out-competing Michaux's sumac for sunlight and soil nutrients.

At Fort Pickett, conflicts between military training and Michaux's sumac are uncommon. Current management of the Fort Pickett population restricts all military activity, with the exception of foot traffic, within colonies of Michaux's sumac. However, the dynamic and constantly evolving military mission has resulted in firing range expansion and alteration thus isolating small colonies of Michaux's sumac.

Overall, Fort Pickett supports the largest protected population of Michaux's sumac known to occur on public lands and is second only to the nearby Deepwater property in terms of overall numbers (Teets and Emrick 2012). The large and self-sustaining population of Michaux's sumac at

Fort Pickett is primarily due to disturbance associated with military live-fire training (Emrick and Jones 2008, Bolin et al 2011, Emrick 2014). Before the discovery of the Fort Pickett population, most Michaux's sumac populations clung to disturbed edges along open brushy fields, power lines, railroads, agricultural clearings, and pine plantations. On Fort Pickett, almost all Michaux's sumac colonies occur within a 4400 hectare controlled access area (CAA) that serves as a buffer zone for a variety military live-fire ranges. Military live-fire training has occurred consistently for over 60 years, resulting in frequent low intensity wildfires throughout the CAA (Emrick 2013). Fire frequencies have historically ranged from 1-3 years, which have resulted in the development fire-adapted plant communities throughout the years of active military training (Emrick and Jones 2008, Emrick 2013). Full, or nearly full, sunlight is widely thought to be essential to the shade-intolerant Michaux's sumac. Thrush (2002) speculates that ideal light conditions for Michaux's sumac are full sunlight in the morning when photosynthesis is at its peak and partial shade in the afternoon for water conservation. Emrick and Hill (1998) reported that low vegetative cover above 3 meters resulted in an increase in cover of Michaux's sumac. In addition, Emrick and Jones (2008) found that woody competition is negatively correlated with density of all types of Michaux's sumac, but the effects were not equal among non-flowering, staminate, and pistillate stems. Competition in the 2 - 5 m strata negatively correlated with pistillate density while showing little or no correlation with staminate density and non-flowering density.

Genetic and taxonomic studies have indicated a close phylogenetic relationship between Michaux's sumac and smooth sumac (*Rhus glabra*) (Hardin and Phillips 1985, Burke and Hamrick 1995). Sherman Broyles et al. (1992) suggested that smooth sumac might in fact be the progenitor of Michaux's sumac. An interspecific hybrid has been observed *in situ*, in cultivated plants, and studied in greenhouse experiments (Hardin and Phillips 1985). Fleming and Van Alstine (1994) and Teets and Emrick (2011) identified morphologically intermediate plants at Fort Pickett, believed to be interspecific hybrids. A genetic study of the Fort Pickett population by Burke and Hamrick (1995) reported that while hybridization is occurring at Fort Pickett, it appears to be local in nature. In addition, they noted that the Fort Pickett Michaux's sumac population was genetically more diverse than the North Carolina Sandhill populations.

There have been three projects reported where removal and transplanting Michaux's sumac was implemented as the selected management/mitigation option. In 2003 at Fort Pickett, Virginia, a small colony was excavated and transplanted to avoid conflicts with the development of a live fire range (Emrick 2003). In 2006 (Braham et al. 2006) and 2009 (Stanton 2009) projects were initiated to move Michaux's sumac from imperiled sites that were under threat from road expansion in North Carolina.

At the time of the 2003 project at Fort Pickett, the standard method for removal and transplantation was to carefully excavate the rhizome during the dormant season, cut the rhizome into 4-6 inch sections, and plant in prepared soil (Emrick 2003). While the previous transplantation project implemented at Fort Picket was considered successful, individual rhizome survivorship was not measured quantitatively. Nevertheless, anecdotal observations indicated that approximately 25% of the rhizomes planted resulted in aboveground stems during the following growing season (pers. Observation V. Emrick). Braham et al. (2006) compared a series of excavation and propagation techniques, including greenhouse studies, with different combinations of potting mediums to identify the most successful excavation, propagation and transplantation techniques. The study concluded that root cuttings were sufficient and that by propagating each cutting for up to one year in the greenhouse following excavation survivorship was significantly increased after transplanting (Braham et al. 2006).

The colonies transplanted as part of this study were located within **Range 12** and the **Infantry Platoon Battle Course** (IPBC). While these colonies were properly delineated and marked, the potential for accidental damage during military training activities has increased. In addition, range management (i.e. wildfire control) requires that the grass be mowed around each colony thus eliminating any possibility for colony expansion through rhizomatous growth, the primary means by which Michaux's sumac reproduces (Emrick and Jones 2008). Internal Fort Pickett stakeholder meetings concluded that the preferred management option for these isolated colonies would be to remove, propagate, and transplant the individuals to a location on Fort Pickett where the potential for military training conflicts is effectively non-existent and the potential for expansion is high (ARNG-MTC Fort Pickett 2014).

The goal of the research project was the careful excavation of Michaux's sumac rhizomes from up to six small, isolated colonies on two active direct fire ranges at Fort Pickett, propagation of these individuals in a controlled greenhouse setting, and the subsequent transplantation of the propagated individuals to suitable habitat on Fort Pickett.

Thus, we had three research objectives:

1. Remove the Michaux's sumac (aboveground ramets and belowground rhizomes) from each range through careful excavation.

2. Propagate the removed rhizomes based upon established methods (Braham et al. 2006)

3. Plant propagated individuals in suitable habitat on Fort Pickett where there are no conflicts with military training and sufficient area to expand and reproduce both sexually and asexually.

Field Site Description

Fort Pickett is located in the predominantly rural piedmont of southeastern Virginia, approximately 5 km east of the town of Blackstone and approximately 25 km west of the fall line demarcating the coastal plain (fig. 1). Fort Pickett encompasses 16,592 ha of land in three counties: Nottoway (8647 ha), Brunswick (2645 ha), and Dinwiddie (5300 ha). The military mission of Fort Pickett is to provide a maneuver-training center capable of handling live-fire and maneuver-training requirements for brigade sized combat, combat support, and combat service support elements of the active and reserve components of all services. Training doctrine requires military installations to maintain large acreages of natural and semi-natural landscapes to simulate a variety of potential combat scenarios. Though some portions of the training areas receive high levels of disturbance, the vast majority of the lands used for training are maintained in a relatively natural state (Emrick and Jones 2008).

The Virginia piedmont is a humid sub-tropical climate with hot, humid summers and mild winters with frequent short cold spells. The mean annual temperature is 14.4°C, with a mean maximum temperature of 20.0°C, and a mean minimum temperature of 8.8°C. Precipitation is evenly distributed throughout the year with a mean annual precipitation of 115 cm. Fort Pickett soils generally consist of a quartz sandy loam surface layer, ranging in depth from 15-46 cm, over a micaceous clay loam, and have a frost depth of 61 cm. The majority of the upland soils found on Fort Pickett are non-hydric, infrequently flooded, and have slow to moderate infiltration rates. Loams and sandy loams are the most common soil types with an organic matter fraction ranging from 2-10%. The majority of these soils support woody vegetation under natural conditions (Emrick 2013). Regionally, the vegetation type is characteristic of the oak-hickory-pine region described by Braun (1950). However, because of the unique disturbances associated with the long history of military training at Fort Pickett the uplands are a unique mosaic of open forests, woodlands, shrublands, and grassland plant communities (Emrick and Jones 2008). There are 1,128-ha of grasslands dominated by native grasses such as, little bluestem (*Schizachyrium scoparius* Michaux), Indian grass (*Sorghastrum nutans* Linnaeus) and *Panicum spp.* (Barden 1997) interspersed with 669-ha of shrublands comprised of native woody and herbaceous species (Emrick 2013). Frequent fires from military training have resulted in over 400-ha of mixed deciduous and coniferous woodlands with an open understory dominated by native grasses and forbs. Many of these plant communities are uncommon or absent altogether in the surrounding Piedmont and several are considered state and/or globally rare (Emrick 2013).

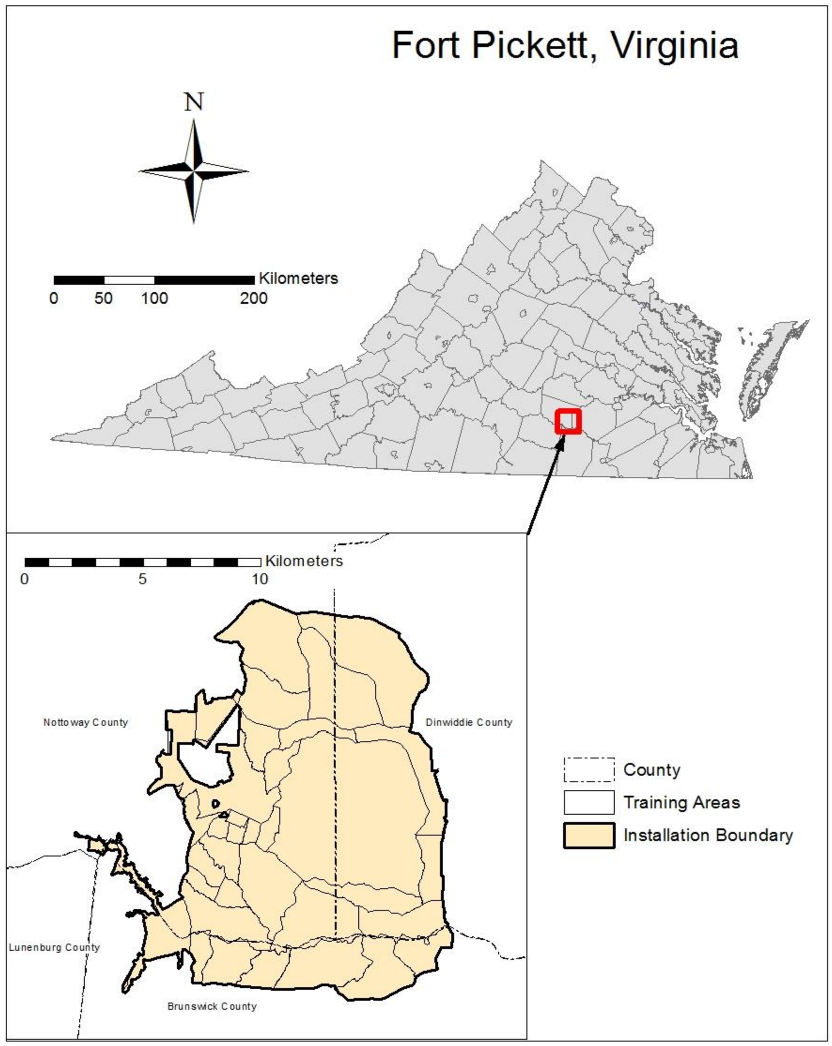


Figure1. Location of the study site. The 16,592 ha Army National Guard Maneuver Training Center-Fort Pickett (Fort Pickett).

Methods

The following are the systematic methods involved in the removal, propagation and transplanting of Michaux's sumac. We developed these procedures based upon previous work at Fort Pickett (Emrick 2013), and the recommendations of Braham et al. (2006) and Stanton (2009).

Identification of colonies for removal and transplant locations

As discussed previously, internal Fort Pickett stakeholder meetings-during the last INRMP update- identified six colonies that were isolated on active ranges, susceptible to accidental damage, and did not have an opportunity to expand. For these isolated colonies, the preferred option identified was to remove, propagate, and transplant the individuals to a location on Fort Pickett where the potential for military training conflicts is effectively non-existent and the potential for expansion is high (ARNG-MTC Fort Pickett 2014). For each of the six colonies, we surveyed and mapped existing stems, labeling each with brightly colored flagging and/or aluminum tags in order to identify all potential plants and rhizomes.

We subsequently identified a suitable location for transplantation based upon the following requirements. The location (s) identified must have substantially reduced potential for conflict and encroachment from military training, be managed by Fort Pickett, have no restrictions on access, and have suitable habitat for expansion. Transplant sites must be greater than 100 m from Michaux's sumac Smooth sumac (*Rhus glabra*) to reduce the potential for hybridization.

Removal of stems and rhizomes

In March 2017, while the plants were dormant, all rhizomes in colonies (85A, 85B, and 85C) were gently excavated by digging with a hand trowel 3-8 cm below the base of an aboveground stem, locating the rhizome, and then creating a shallow trench to follow its entire length[1]. After each rhizome was exposed in a shallow trench, it was cut into 15cm sections (with or without shoots), and placed in plastic tubs/buckets with shredded, wet paper[2]. The rhizomes were immediately transported to the *Virginia Tech Biological Sciences-VBI Plant Growth Facility*[3] keeping the rhizomes moist but not saturated.

Propagation of rhizomes

We planted bare rhizomes in 1-gallon plastic greenhouse pots with equal parts of peat, clay, and perlite, along with 25 grams of soil from the original colony location to ensure inoculation by native mycorrhizae. Each rhizome was treated with growth hormone to promote rooting and sprouting. Approximately 6-months into the propagation phase the individual Michaux's sumac were showing evidence of being root bound. We therefore repotted all live individuals in to three-gallon pots using the same mixture as above and added 5 grams of 5-1-1 organic fertilizer. All potted

[1] Three of the colonies originally identified as under threat were not located (see results section for more details).

[2] If during the removal of the above ground ramets seed heads were present, the seeds would have been collected and tested for viable embryos using a standard flotation test. Seeds that sink to the bottom of the container would be considered to have viable embryos (Pairon et al. 2006). Viable seeds (if any) would have been scarified using sulfuric acid and propagated following the methods in Wilkinson et al. (1996).

[3] http://www.biol.vt.edu/greenhouses/

Michaux's sumac stems were grown for approximately 13 months (i.e. March 2017-April 2018) in the Virginia Tech Biological Sciences greenhouse facility.

Planting of propagated rhizomes

In advance of planting, the transplant area was prepared by removing competing vegetation (mechanical, herbicide, and prescribed fire), in a series of one m^2 circular plots on a 1.5 x 1.5 m grid. Any smooth sumac individuals within 100 m of the planting area were removed using herbicide. In April 2018, we excavated a hole (using a gas powered augur) within each of $1m^2$ circles that was slightly wider and equivalent in depth to each potted Michaux's sumac. We placed a single Michaux's sumac plant in each hole maintaining the depth and mixing with excavated soil and watered thoroughly. We side dressed each planted individual with approximately 5g of organic 5-1-1 fertilizer. Growth and survivorship for all individuals was monitored during the first growing season and watered periodically during drought conditions.

Results

Identification of colonies for removal and transplant locations

In 2014 the distribution of Michaux's sumac colonies at Fort Pickett were systematically mapped and their ecological status assessed (Emrick et al. 2015). In addition, a geospatial model of potential suitable habitat was created utilizing the intersection of soils, vegetation, and slope within each mapped colony. A total of 74 colonies covering 27.9 total acres were identified and their boundaries delineated and mapped using high accuracy GPS (fig. 2).

The colonies identified for removal and propagation occur on two live fire ranges, the IPBC and Range 12. The Michaux's sumac colonies on the IPBC consisted of three small sub colonies (i.e. 89A, 89B, 89C) separated by mowed pathways and surrounded by extensive mowed areas (fig. 3). Michaux's sumac colonies located on Range 12 (27, 50, and 51) were very small (2-4 ramets) when last located and surrounded by frequently mowed grass thus effectively isolating them from suitable habitat (fig. 4). Furthermore, during the pre-removal field assessment no Michaux's sumac ramets were located in any of the colonies located on Range 12. Since the pre-removal assessment represented the third survey attempt resulting in no evidence of Michaux's sumac, these colonies are now considered extirpated. Thus, no removals occurred on Range 12.

At Fort Pickett a location identified as 'dove field 6' (DF6) met all of the planting criteria, reduced potential for conflict and encroachment from military training, be managed by Fort Pickett, have no restrictions on access, and have suitable habitat for expansion. One Michaux's sumac colony already existed at DF6 and it was the site of the previous successful transplantation (Emrick 2003) (fig. 5).

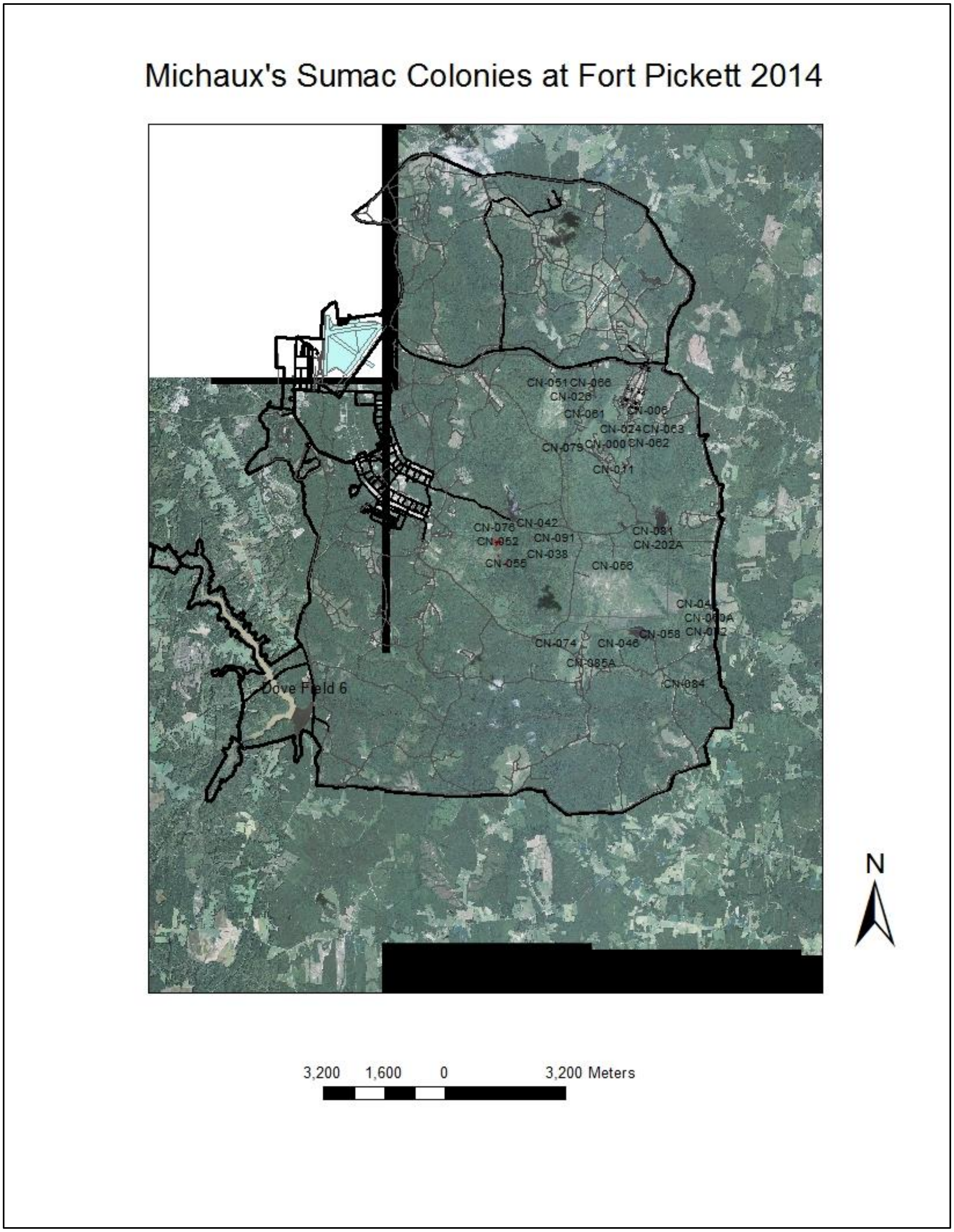


Figure 2: Distribution of Michaux's Sumac colonies across throughout Fort Pickett (Emrick et al 2015).

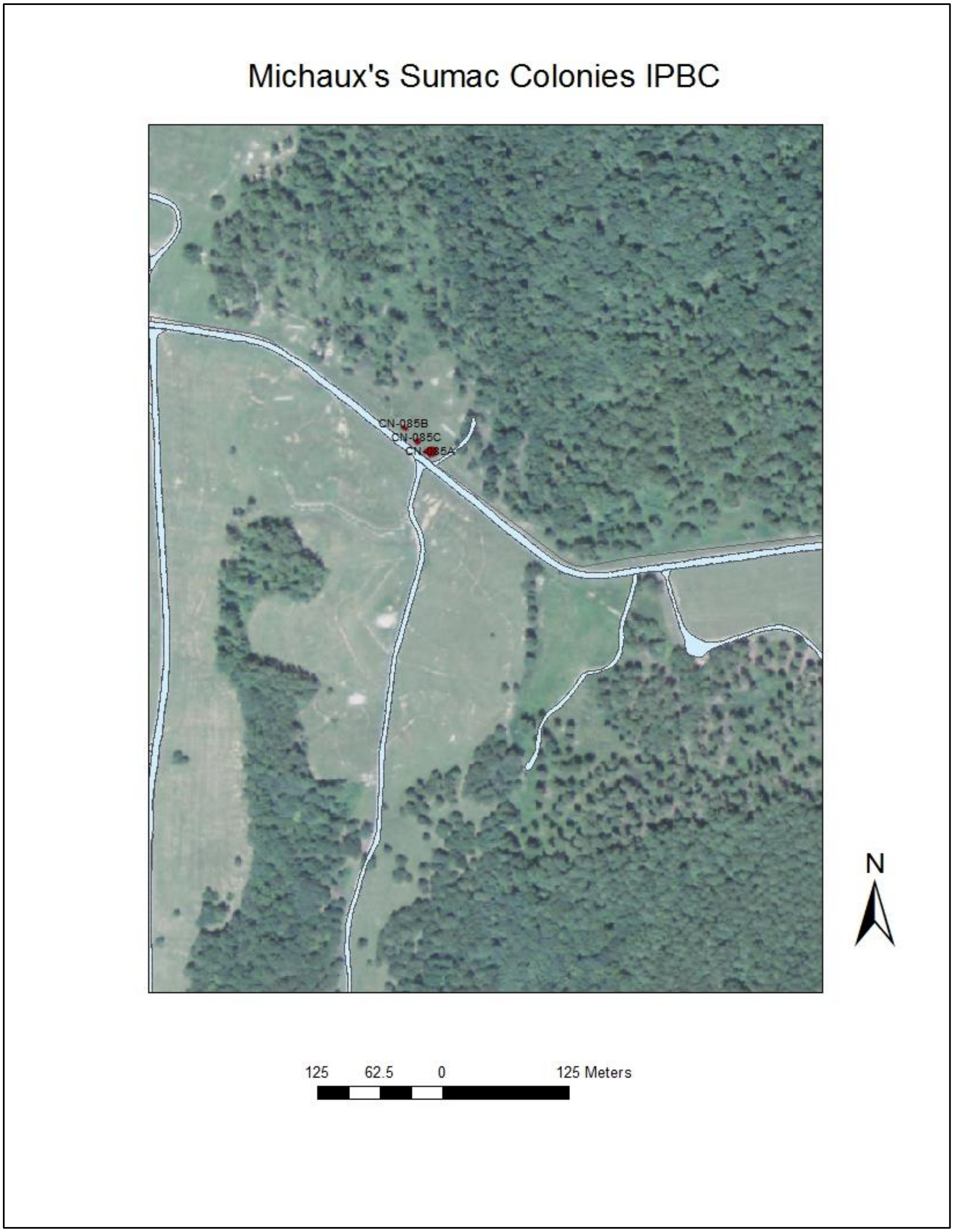


Figure 3. Michaux's sumac colonies (85A, 85B, and 85C) located on the active IPBC that were selected for removal and transplantation. Note the extensive mowed area between and surrounding the colonies.

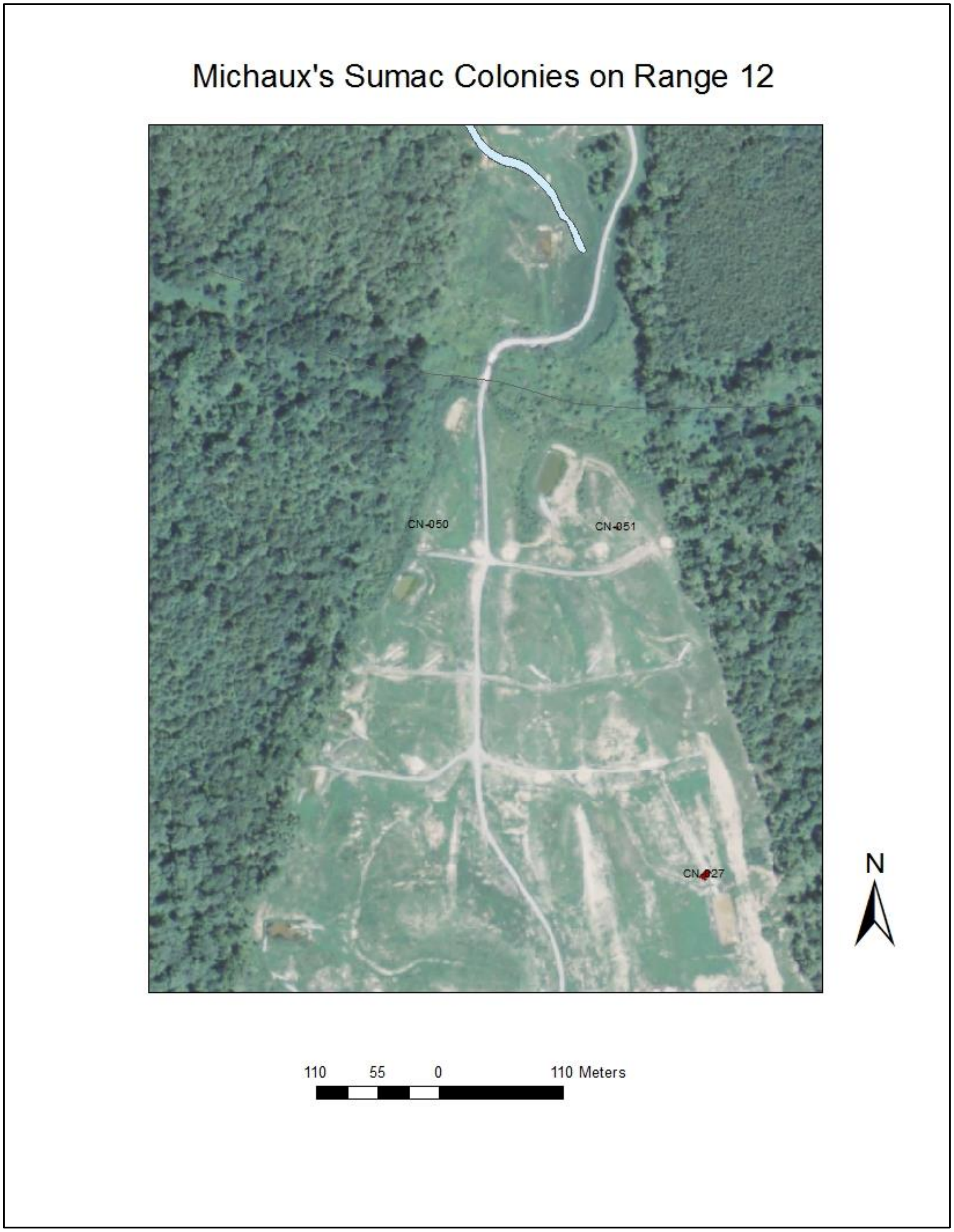


Figure 4. Michaux's sumac colonies (50, 51, and 27) located on Range 12 that were proposed for removal and transplantation.

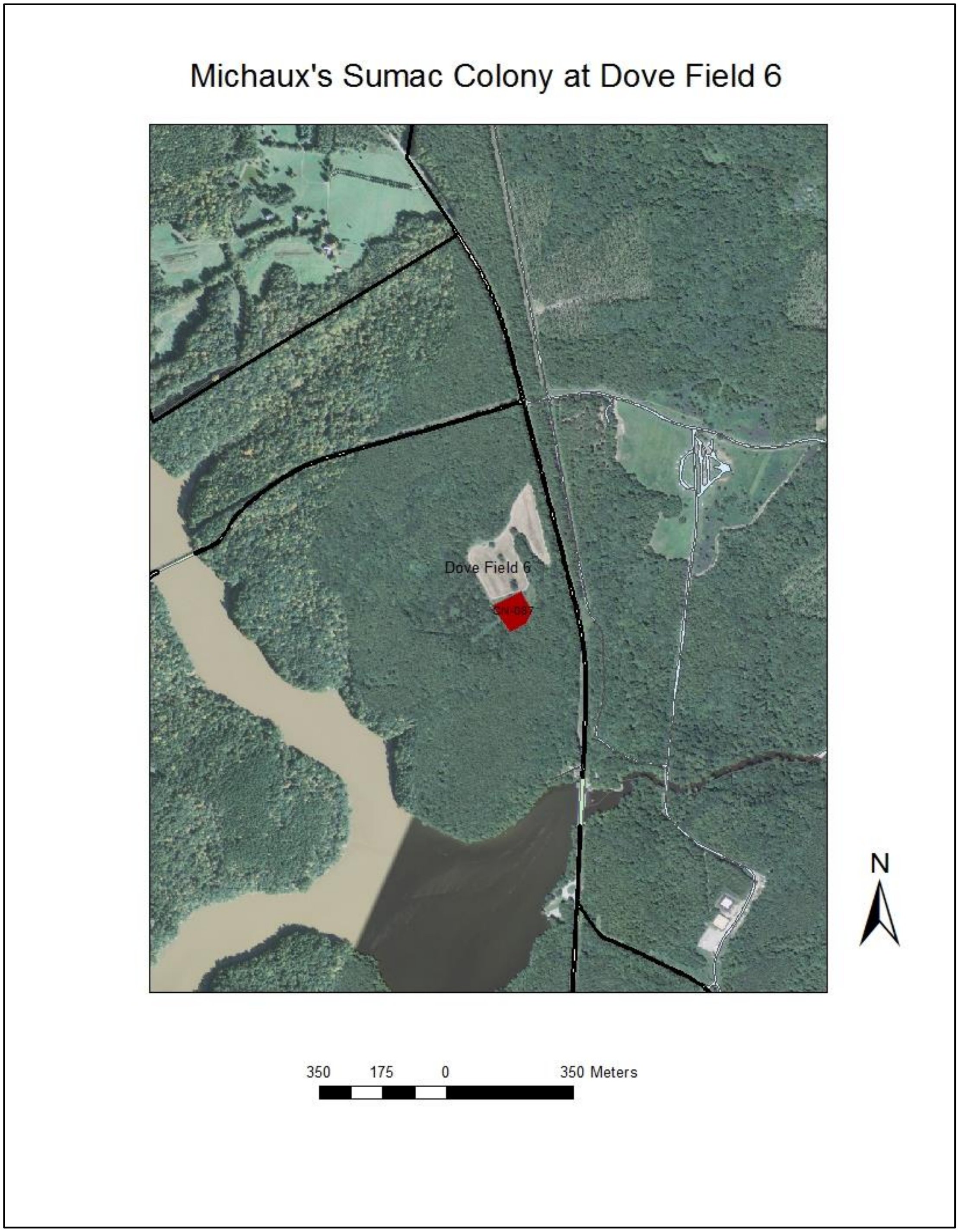


Figure 5. Dove Field 6 and Michaux's sumac colony 87, the proposed location for the planting of the propagated individuals removed from the active firing ranges.

Removal of stems and rhizomes

On March 29th and 30th, we excavated and removed ramets and rhizomes from three small sub-colonies (i.e. 89A, 89B, 89C) on the IPBC (fig. 3). Prior to beginning the excavation and removal, we counted 13 above ground ramets. No seed heads were present (see plates 1 and 2 below). Beginning at each ramet, we carefully removed the soil until we located the main rhizome (plate 3). Once the main rhizome was located, we followed it and gently removed the soil from above and below (plate 4). Once an entire rhizome was entirely excavated, we cut in into 15cm sections and placed each section into a bucket with moist newspaper. We meticulously excavated one of the rhizomes completely in order to examine its full extent (Plate 5).

Plate 1: Michaux's sumac ramets prior to excavation and removal. Note lack of surrounding vegetation due to fire within the sub-colony.

Plate 2: Close view of Michaux's sumac ramets prior to excavation and removal in March 2017. Note tags from previous identification.

Plate 3: Michaux's sumac ramets during excavation and removal in March 2017.

Plate 4: Michaux's sumac rhizome during excavation and removal.

Plate 5: Completely excavated Michaux's sumac rhizome with ramets in March 2017.

Propagation of rhizomes

After the excavation of the rhizomes, we cut 168, 15cm long sections that were a minimum of 2mm in diameter. Any root material < 2mm diameter were placed in shallow holes within appropriate habitat immediately outside of the range complex. The material was returned to Virginia Tech greenhouse facility on Friday March 31, 2017 and all were immediately planted lengthwise in one-gallon pots in a 1-2 cm "trench" and covered with the potting mixture previously described (plate 6). The first record of emergence occurred on April 7, 2017and by April 14, 2017, 127 of the 168 originally planted rhizomes had emerged (plates 7 and 8).

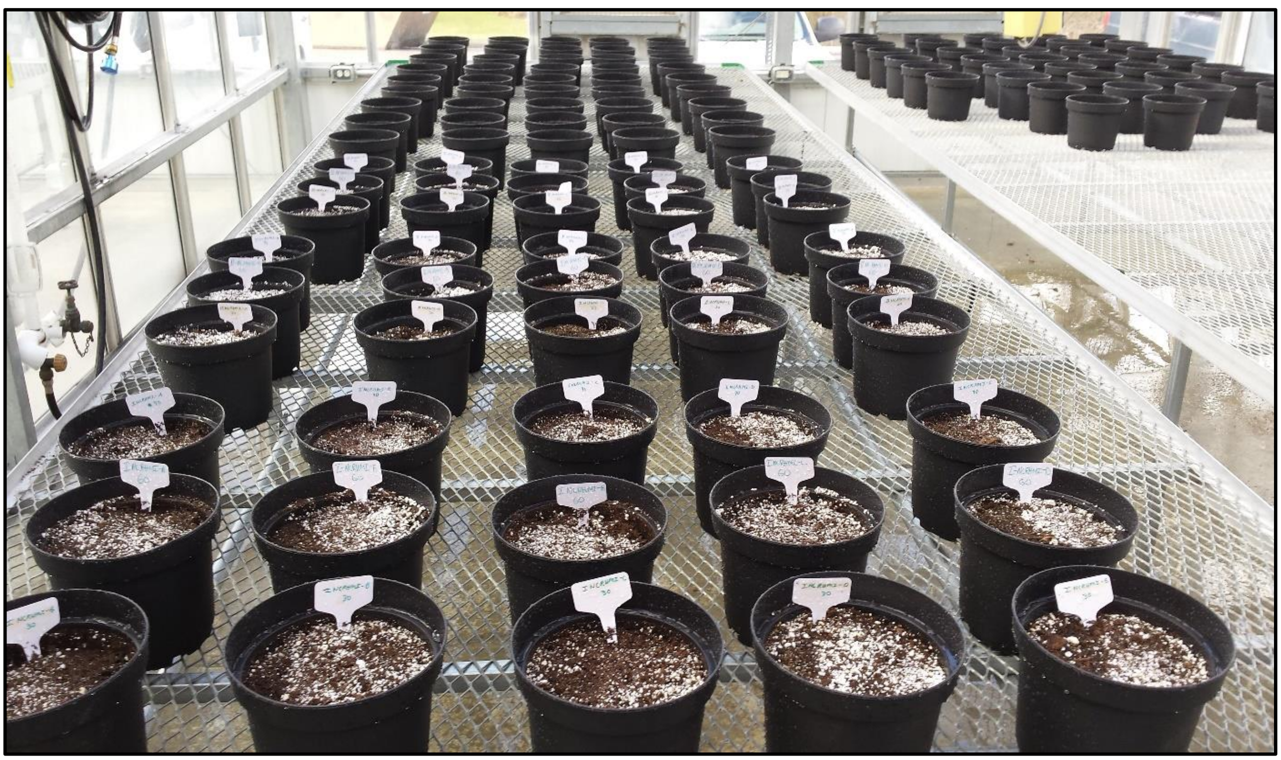


Plate 6: Recently planted Michaux's sumac rhizomes in greenhouse at Virginia Tech in March 2017.

Plate 7: Newly emerged Michaux's sumac in greenhouse at Virginia Tech in April 2017.

Plate 8: Michaux's sumac three days after emergence in greenhouse at Virginia Tech in March 2017.

For the first 50 days after emerging, the greenhouse grown Michaux's sumac plants continued to perform well, with only 16 of the original 127 that emerged failing to grow, (greenhouse and/or CMI staff monitored the individuals once/day-plate 8). However, by late May 2017 approximately ½ of the individuals showed signs of stress and wilting. The affected plants were immediately separated from the healthy ones. We sent samples to the **Plant Disease Clinic** Department of Plant Pathology, Physiology, and Weed Science at Virginia Tech and the disease was diagnosed as **Rhizoctonia Root Rot** (*Rhizoctonia solani*). All plants, including the healthy individuals, were treated with fungicides registered for control of rhizoctonia. In addition, 20 healthy individuals were removed from greenhouse conditions and propagated, outdoors under shade cloth, further isolating healthy individuals from infected ones. Of the 111 healthy Michaux's sumac individuals at the time of the rhizoctonia infection, 59 (including the individuals propagated outdoors) survived.

Plate 8: Michaux's sumac monitoring in greenhouse at Virginia Tech in July 2017.

Planting of propagated rhizomes

Prior to planting, DF6 was subjected to prescribed fire for consecutive years (spring 2016 and 2017) to assist in the control of non-native woody plant species, encourage native grasses, and extant Michaux's sumac. In addition, limited mechanical clearing and herbicides were used to control woody vegetation in the immediate vicinity of the selected planting zone.

On April 26-27, 2017, 39 of the greenhouse grown Michaux's sumac were successfully planted in DF6. The remaining 20, that were grown outside under shade cloth, will be planted in the fall of 2018 in the same location[4] for a total of 59 Michaux's sumac individuals planted by the end of 2018 (plates 9-12).

Plate 9: Digging initial holes for planting propagated Michaux's sumac in Dove Field 6 at Fort Pickett in April 2018.

[4] The individuals grown outdoors had broken dormancy thus they will be planted after they go dormant in the fall of 2018

Plate 10: Healthy propagated Michaux's sumac prepared for planting in Dove Field 6 at Fort Pickett in April 2018.

Plate 11: Example of strong root growth from healthy propagated Michaux's sumac prepared for planting in Dove Field 6 at Fort Pickett in April 2018.

Plate 12: Planting healthy propagated Michaux's sumac prepared for planting in Dove Field 6 at Fort Pickett in April 2018.

Monitoring

On July 6, 2017, we visited the planting location to assess survival and vigor of the 39 Michaux's sumac individuals planted in April 2018. All 39 individuals were alive and vigorous despite the dense growth of switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*) within the planted area (plate 13). In addition, of the 39 individuals, 17 had female flowers and one had male flowers, which represented 46% of the total (plate 14).

Plate 13: Successfully planted and cultivated Michaux's sumac growing in dense switchgrass in Dove Field 6 at Fort Pickett in July 2018.

Plate 14: Successfully planted and cultivated Michaux's sumac flowering and setting seed amongst dense Switchgrass in Dove Field 6 at Fort Pickett in July 2018.

Discussion

The project as a whole was explicitly- at least in part-a conservation effort. The colonies involved in the project and selected for removal were actually three sub-colonies (89A, 89B, 89C, fig. 2)[5] located on the IPBC. These sub-colonies had a total area of 168m^2 or only 0.06% of the total area of Michaux's sumac at Fort Pickett making them some of the smallest in terms of area (Emrick et al. 2015). Due to the small isolated nature of these sub-colonies, the mowed boundaries, and lack of structural diversity resulted in suboptimal to poor habitat on the IPBC compared to other habitat available on Fort Pickett. As a result, the removal, propagation, and transplantation of Michaux's sumac from active firing ranges to more suitable and protected habitat has already resulted in an increase of ramets from 13 that we removed to the 39 that were successfully transplanted. The number will increase to 59 when the remaining Michaux's sumac individuals (i.e. 20 grown outdoors) are planted in the fall of 2018. Furthermore, current management (i.e. prescribed fire and control of invasive species) implemented to prepare DF6 for planting has resulted in a substantial increase in the number of the extant Michaux's sumac already present.

The sandy soils and the relatively high soil moisture facilitated the excavation of the Michaux's sumac rhizomes. The rhizomes were relatively large, ranging from 2-5 mm in diameter for most of their length. There were relatively few fine roots emerging from the rhizomes but many nodes where finer roots could quickly proliferate when soil conditions were optimal and/or during the active growing season. The relatively large rhizomes cut easily and were removed from the soil with little damage to the root sheath, which helped facilitate propagation.

[5] The three colonies located on Range 12 (50, 51, 27, fig. 3) had not been located in recent formal or informal surveys and all are considered extirpated.

Propagation in the greenhouse was initially very successful with over 75% of the rhizomes sprouting new growth within 1 week of being placed in the greenhouse. In addition, 66% (111 individuals) of the rhizomes that sprouted new growth actively grew new shoots and multiple leaves. The rhizomes with aboveground, live ramets, all had new leaves and shoots emerge from the ramets. Often rhizomes, without aboveground ramets, had multiple stems emerge from belowground along the length of the planted rhizome.

The emergence of rhizoctonia-a soil-borne fungus that causes root rots, stem rots, damping off, and leaf wilting- led to the death of approximately ½ of the active growing Michaux's sumac individuals approximately 1 month after emergence. While rhizoctonia affects agricultural plants in both the field and greenhouse settings, its effect on native species-both greenhouse propagation and in situ-has not been examined or previously reported. Rhizoctonia is a pervasive, soil-borne plant pathogen that inflicts damage on a wide range of economically important crops (Ajayi-Oyetunde and Bradley 2017). For the purposes of this project, and for any future propagation efforts, identifying possible sources of rhizoctonia is paramount. In this instance, two sources were most probable-native soil inoculant and the potting mix. We followed the propagation methods developed by Braham et al. (2006) which suggested inoculating each greenhouse pot with 25g of native soils to encourage native mycorrhizae. The inoculant soil[6] may have also contained rhizoctonia and/or have already been on the rhizomes. In this case, the greenhouse environment may have caused accelerated growth of rhizoctonia. The other source would be the potting mix used to propagate Michaux's sumac, though all the constituents used to create the potting mix were from new, sterile sources.

[6] The inoculant soil was obtained from the soil removed from around the rhizomes that were removed on the IPBC. The soil was placed in a 5 gallon bucket, any large plant material removed and homogenized before being transported to the greenhouse.

For future propagation efforts, we recommend that native soil inoculant not be used unless the soil can be tested to ensure that rhizoctonia levels are too low to damage plants. For the rhizomes, a prophylactic treatment with fungicides registered for control of rhizoctonia prior to planting may be considered after any potential negative effects of the fungicide are examined. In addition to using sterile constituents to produce the potting mix, the resultant mix can be sterilized prior to planting. Finally, during the early stages of emergence (45days) when the plants are most susceptible, closely monitor individuals and treat immediately when symptoms appear.

The transplantation in DF6 has, thus far been very successful. The percentage flowering-especially pistillate flowers-far exceeds levels found in healthy "natural" populations at Fort Pickett (Emrick et al. 2017). However, this effect may be an artifact of the robust health of the Michaux's sumac individuals and/or the fertilization of each individual to assist in establishment. Overall, the planting site (i.e. DF6) and management appears to be suitable for Michaux's sumac as evidence by the abundant individuals from an earlier planting (Emrick 2003) and we expect a substantial expansion of Michaux's sumac. Thus, even with the mortality caused by rhizoctonia in the greenhouse, the number of Michaux's sumac ramets increased form the 13 originally removed to an eventual 59.

While these procedures were specifically researched and developed for the removal and transplantation of Michaux's sumac stems from Range 12 and the IPBC, they can serve as the basis for any future propagation of Michaux's sumac rhizomes for conservation. If suitable precautions are taken to limit the effect of soil borne-pathogens, the approach describe above can be used to propagate and expand the population of Michaux's sumac.

Literature Cited

ARNG-MTC Fort Pickett. 2014. Integrated Natural Resources Management Plan and Environmental Assessment, FY 2014-2018. Blackstone, Virginia. Prepared for the Virginia Army National Guard by the Conservation Management Institute, Virginia Polytechnic Institute and State University.

Ajayi-Oyetunde, O. O. and C. A. Bradley. 2017. *Rhizoctonia solani*: Taxonomy, Population Biology and Management of Rhizoctonia Seedling Disease of Soybean. Plant Pathology 67 (1):3-17

Bolin, J.F., M.E. Jones, and L. Musselman. 2011. Germination of the federally endangered Michaux's sumac (*Rhus michauxii*). Native Plants Journal 12(2):119-122.

Braham, R., C. Murray, and M. Boyer. 2006. Mitigating Impacts to Michaux's Sumac (Rhus michauxii Sarg.): a Case Study of Transplanting an Endangered Shrub. Castanea 71(4): 265-271.

Burke, J.M., and J.L. Hamrick. 2002. Genetic variation and evidence of hybridization in the genus *Rhus* (Anacardiaceae). Journal of Heredity 93:37–41.

Emrick, Verl and Hill, Alison. 1998. Plant Community Composition of *Rhus michauxii* Colonies at Fort Pickett Military Reservation, Virginia. Champaign, IL: USACERL; TR 98/49.

Emrick, Verl. 2003. Transplantation of Michaux's Sumac Stems from Range 15 to Dover Field 6. Virginia Tech Conservation Management Institute-Military Lands Division. Report R-17. February 2003.

Emrick, Verl and J. Jones. 2008. Influence of competition on the density of the federal endangered Michaux's sumac (*Rhus michauxii*) at Fort Pickett, Virginia. Southeastern Naturalist 7(1):61-68.

Emrick, Verl R. 2013. Disturbance, Functional Diversity, and Ecosystem Processes: Does Species Identity Matter? Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Biological Sciences. 141pages.

Emrick, Verl , Kevin McGuckin, Jesse Parker and Ingrid Mans. 2015. Mapping the Distribution and Occurrence of Michaux's Sumac (*Rhus michauxii*): A Federally Endangered Species Occurring on Maneuver Training Center- Fort Pickett, Virginia. VTCMI-Technical Note-03-2015. Conservation Management Institute, Virginia Polytechnic Institute and State University, Blacksburg.

Emrick, Verl R, Ingrid Mans, and Kevin McGuckin. 2017. Michaux's sumac (*Rhus michauxii*) Monitoring 2016 at Maneuver Training Center Fort Pickett-Stem density of Michaux's sumac. Conservation Management Institute, College of Natural Resources and Environment, Virginia Polytechnic Institute and State University, Blacksburg. VTCMI-Technical Report 07-2016. 28pp.

Fleming, G.P. and N.E. Van Alstine. 1994. A natural heritage inventory of Fort Pickett, VA. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA., Unpublished report submitted to U.S. Army. June 1994. 165 pp. plus appendices.

Hardin, J.W. and Phillips, L.L. 1985. Atlas of foliar surface features in woody plants, VII. *Rhus* subg. *Rhus* (Anacardiaceae) of North America. Bulletin of the Torrey Botanical Club. Vol 112. pg 1-10.

Pairon, Marie, Olivier Chabrerie, Carolina Mainer Casado, Anne-Laure Jacquemart. 2006. Sexual regeneration traits linked to black cherry (*Prunus serotina* Ehrh.) invasiveness. Acta Oecologica, Volume 30. pp 238-247.

Russo, M.J. 1993. Element stewardship abstract: *Rhus michauxii*. Carrborro/Raleigh, NC: NC Nature Conservancy/NC Natural Heritage Program.

Savage, Sherry and Bucher, Margit. 1991 Aug 28.Preliminary results of a demographic and genetic analysis of *Rhus michauxii*: NC. Nature Conservancy.

Stanton, T. 2009. Management Plan for the Recovery of Michaux's sumac (*Rhus michauxii* Sarg.) At Big Shoe Hill Preserve Conservation Area Scotland County, North Carolina. Report submitted to the U.S. Fish and Wildlife Service, Raleigh Field Office, Raleigh, NC.

Teets, Aaron and Verl Emrick. 2012. Stem Density of an Extensive Undocumented Population of Michaux's Sumac (*Rhus michauxii* Sargent). Conservation Management Institute College of Natural Resources and Environment, Virginia Polytechnic Institute and State University. Report Prepared for Virginia Department of Military Affairs.

Wilkinson, C.A., H.A. DeMarco, and J.L. Jones. 1996. Viability, germination, and propagation of *Rhus michauxii* at Fort Pickett. Southern Piedmont Agricultural Research and Extension Center, Virginia Polytechnic Institute and State University, Blackstone, VA. 32 pp.

USFWS. Federal Register. 1989. Endangered and Threatened Wildlife and Plants: determination of endangered status for *Rhus michauxii* (Michaux's sumac) 54(187):39853-39857.

USFWS. 1993. Michaux's sumac recovery plan. Southeast Region U.S. Fish and Wildlife Service, Atlanta, GA.