ALLEGHENY COLLEGE
DEPARTMENT OF ENVIRONMENTAL SCIENCE AND SUSTAINABILITY

Damage to Trees Caused by Goats used to Control Multiflora Rose in a Northwestern Pennsylvania Hardwood Forest

A Report Submitted to the Erie National Wildlife Refuge

Grace L. Hemmelgarn, Editor
Alexandria N. Martin, Editor
Rachael M. Ankney
Victoria Bajek
Mitchell G. Carrigan
Ross A. Carter
Alton Caylor
Tianna A. Clay
Gretchen E. Dancewicz-Helmers
Jakob L. Drozd
Francis J. Faiello
Sarah A. Foster
Sara G. Galley
Taylor D. Gates
Lynsey M. Gutzmer
Samantha L. Hall
Delaney H. Harrison-Peters
Luke Kellett
Bailey J. Kozalla
Megan G. Kresse
Isabelle Krzys
Margaret R. Malley
Isabella R. Pettita
Max Savino
Benjamin B. Slack-Foust
Steve Spotts
Richard D. Bowden

21 October 2020

Allegheny College Department of Environmental Science Publication 2020-4

Citation: Hemmelgarn, G.L, A.N. Martin, R.M. Ankney, V. Bajek, M.G. Carrigan, R.A. Carter, A. Caylor, T.A. Clay, G.E. Dancewicz-Helmers, J.L. Drozd, F.J. Faiello, S.A. Foster, S.G. Galley, T.D. Gates, L.M. Gutzmer, S.L. Hall, D.H. Harrison-Peters, L. Kellett, B.K. Kozalla, M.G. Kresse, I. Krzys, M.R. Malley, I.R. Pettita, M. Savino, B.B. Slack-Foust, S. Spotts, and R.D. Bowden. 202_. Damage to trees caused by goats used to control multiflora rose in a northwestern Pennsylvania hardwood forest. Allegheny College Department of Environmental Science and Sustainability Publication 2020-4.

Abstract

Multiflora rose (MFR) is a non-native invasive species that drastically alters forests in the eastern United States. Herbicides can be used to control MFR; however, they can also reduce non-target plant species and threaten organisms in nearby aquatic ecosystems. The Erie National Wildlife Refuge assessed the viability of using domestic goats to reduce MFR in an area of high MFR density and avoid detrimental effects of herbicides applied in close proximity to streams. After nearly three months on site, goats were effective in reducing MFR, but they also browsed on the bark of mature overstory trees within the treatment area. To assess damage to trees, we measured the extent of browsing on trees within the treatment area. Overall, 33.4% of trees were browsed, with 8.7% of trees being completely girdled, which will likely result in their mortality. Browsing rates differed among tree species; most browsing occurred in red maple and ironwood, with 64.7% and 60.0% of these species browsed, respectively. Although goats can reduce MFR, their presence may increase tree mortality and shift tree species composition. Goat browsing may reduce tree biomass and productivity in stands dominated by trees with high browsing rates; however, effects on diverse stands may be less pronounced.

Keywords: Multiflora rose, goats, tree browsing, invasive species, hardwood forest, Erie National Wildlife Refuge

Introduction

Invasive species may cause ecosystem-level damage (Bartz et al. 2010), including reduced biodiversity, lowered ecosystem productivity, altered nutrient cycling, and compromised ecosystem services (Dukes and Mooney 2004, Pejchar and Mooney 2009). Forty-two percent of all threatened or endangered species are considered to be at risk because of invasive species (Pimentel et al. 2005). More than 25,000 non-indigenous plant species in the United States incur control expenses and cause losses for crops, pastures, and forests (Pimentel et al. 2005), leading to economic damages estimated (for 2005) at nearly $120 billion annually (Pimental et al. 2005). Multiflora rose (*Rosa multiflora* Thunb., (Fig. 1)) is an invasive species, found originally in eastern China, that was introduced to the United States in the late 1880s and which presently infests approximately forty-five million acres in the United States (Epstein and Hill 1999). After its introduction, it was commonly believed to have conservation and ornamental value (Epstein et al. 1997). MFR was considered to be valuable for soil stabilization and erosion prevention (Steavenson 1946), and from the 1930s until the 1950s (Doll n.d.), it was promoted for use in producing living hedges. It was also planted to provide wildlife with food and shelter (Kurtz and Hansen 2013).

Figure 1. Multiflora rose (Left, USDA-NRCS PLANTS Database and Herman 1996) flowers and leaves (Right, Trnkoczy 2018).

Multflora rose is a member of the rose family (*Rosaceae)*, a diverse family containing more than 100 genera of herbs, shrubs, and trees (Hummer and Janick 2009). Both native and introduced species of the rose family are present in the 48 contiguous United States, Alaska, and most of Canada (USDA NRCS n.d.). The *Rosaceae Rosa* genus contains over 100 species that grow in cold and temperate areas of the northern hemisphere, many of which are economically and culturally valuable as cut flowers, landscape plants, and perfume oil sources (Hummer and Janick 2009). Despite being part of the *Rosa* genus, MFR is generally considered a harmful weed (Hummer and Janick 2009) that can inhabit diverse ecosystems, including forests, pastures, abandoned agricultural fields, and roadsides. It can exist in fully sunlit and shaded environments, although it cannot grow in extremely wet or dry areas (Kurtz and Hansen 2013). The current extent of its range, as of 2013, is 39 states and 5 Canadian provinces (Kurtz and Hansen 2013). MFR has extensive seed production and wide seed dispersal, facilitating its spread and survival (Banasiak and Meiners 2008).

Eradicating MFR is important because of ecological changes it brings to native ecosystems (Massé and Vulinec 2010). MFR often grows in dense thickets that limit available light and nutrients for surrounding native vegetation (Kurtz and Hansen 2013), and invasions of MFR in fields have been shown to cause a reduction in plant species richness (Yurkonis et al. 2005). The diversity of breeding bird species is also reduced in areas of high MFR abundance (Massé and Vulinec 2010), and MFR can be a prime habitat for deer ticks, facilitating the spread of Lyme disease (Adalsteinsson et al. 2018).

Removing MFR is challenging because any removal method must be sustained for multiple years for eradication to be successful; seeds remain viable in the soil for many years and new plants can sprout easily from existing roots (Loux et al. 2005). Successful removal methods include two steps: destroying existing plants and developing a yearly program to control new seedlings (Loux et al. 2005). Traditional MFR removal methods include brush mowing and a variety of herbicides (e.g. glyphosate)(Johnson et al. 2007). Mowing is only moderately effective due to resprouting from roots; manual removal of roots is a labor-intensive process that can increase soil vulnerability to erosion (Loux et al. 2005).

As an alternative to herbicides such as glyphosate, which can be toxic to non-target plants, mammals, birds, fish, and aquatic invertebrates (Solomon and Thompson 2003, Relyea 2005),

domestic goats have been used as a more environmentally-conscious and less expensive method of MFR reduction (Luginbuhl et al. 1998). Goats are considered to be valuable browsers due to their wide-ranging and varied diet (Huston 1978), and their propensity for consuming tree leaves and twigs when available (Cory 1927). When used to reduce MFR over four grazing seasons in cattle pastures in the Appalachian region of North Carolina, goats nearly eliminated MFR, which led to an increase in favorable native forage species (Luginbuhl et al. 1998). Combining cattle and goats within plots was the most effective method of controlling MFR (Luginbuhl et al. 2000).

Despite numerous advantages of using goats to eliminate MFR, there are several concerns. Due to their wide-ranging diet, extensive browsing by goats has caused habitat disruption and biodiversity loss in a variety of ecosystems (García et al. 2012). To decrease the ecological damage caused by goats, wire fences may be required to contain them (Brann 2006) into desired areas. Goats also carry a reputation for being ecologically destructive, which may cause hesitation when considering their use as browsers in a management plan (Hart 2001).

The Erie National Wildlife Refuge (ENWR) in northwestern Pennsylvania has large areas that are overrun by MFR and has experimentally implemented goats as a control method for one summer season in an area adjacent to streams that could be negatively impacted by herbicides. A previous study by Allegheny College(Brown et al. 2020) identified the area as a location with a high abundance of MFR and suggested the use of goats as a sustainable option to control the invasive plant. The goats were provided by Allegheny Goatscape, which is a 501(c)3 nonprofit organization located in Pittsburgh, Pennsylvania. Within the first season, the goats reduced MFR height and leaf/shoot ratios, and these results were considered to be promising (Caylor et al., in prep). An unintended consequence of this approach was that goats browsed on the bark of subcanopy or canopy trees. Such browsing can reduce the viability of trees, increase the likelihood of disease or insect damage, and if completely girdled, cause immediate tree mortality (Neely 1988). Tree damage or mortality can reduce forest productivity and lead to changes in forest composition. The purpose of this study was to quantify damage to trees caused by the use of goats to control MFR in this temperate hardwood stand in the ENWR. We examined the extent of browsing on individual trees, the rate of browsing across the site, and differences in browsing by tree species and size.

Methods

The study site is a temperate deciduous forest located in the Sugar Lake division of the ENWR in northwestern Pennsylvania (Fig. 2). The forest is largely populated by black cherry (*Prunus serotina*) and red maple (*Acer rubrum*) in the overstory, with hawthorn (*Crataegus sp.*), ironwood (*Carpinus caroliniana*), and apple (*Malus sp.*) interspersed in the understory. The terrain lays on a slope of approximately 6° with a northeasterly aspect. Parts of the site have fairly moist ground, and a creek runs along the northeastern edge of the site. Soils are silt loams of the Chenango, Holly, and Scio soil series (USDA NRCS 2020).

The area has a history of agricultural use, including plowing and pasturing, as evidenced by a line of field stones, a row of black cherry trees that appear to have grown along the edge of an open field, and abandoned old farming machinery. Examination of historical aerial photos indicates that agriculture was extensive in the area; in 1939, 36% of the refuge area was in sparse or dense forest, whereas 55% was in either active agriculture or reverting from agriculture to forest ecosystems (Reno et al. 2017). Additionally, the overall flat soil surface, lack of pit and mound

structure throughout most of the site, and uniformity of overstory tree size also imply an agricultural history at the site.

We used four plots that were each browsed by goats for approximately two weeks during the summer of 2019; one of the plots was browsed and subsequently treated with the herbicide Rodeo as a 1.5% foliar spray after the goats were removed. The active ingredient in Rodeo is 53.8% isopropylamine salt of glyphosate. The plots ranged in size from approximately 700 to 2,500 m^2, and they were fenced to contain eight goats and one donkey. The role of the donkey was to protect the goats by scaring away potential predators. The fences were removed at the end of the summer following the departure of the goats.

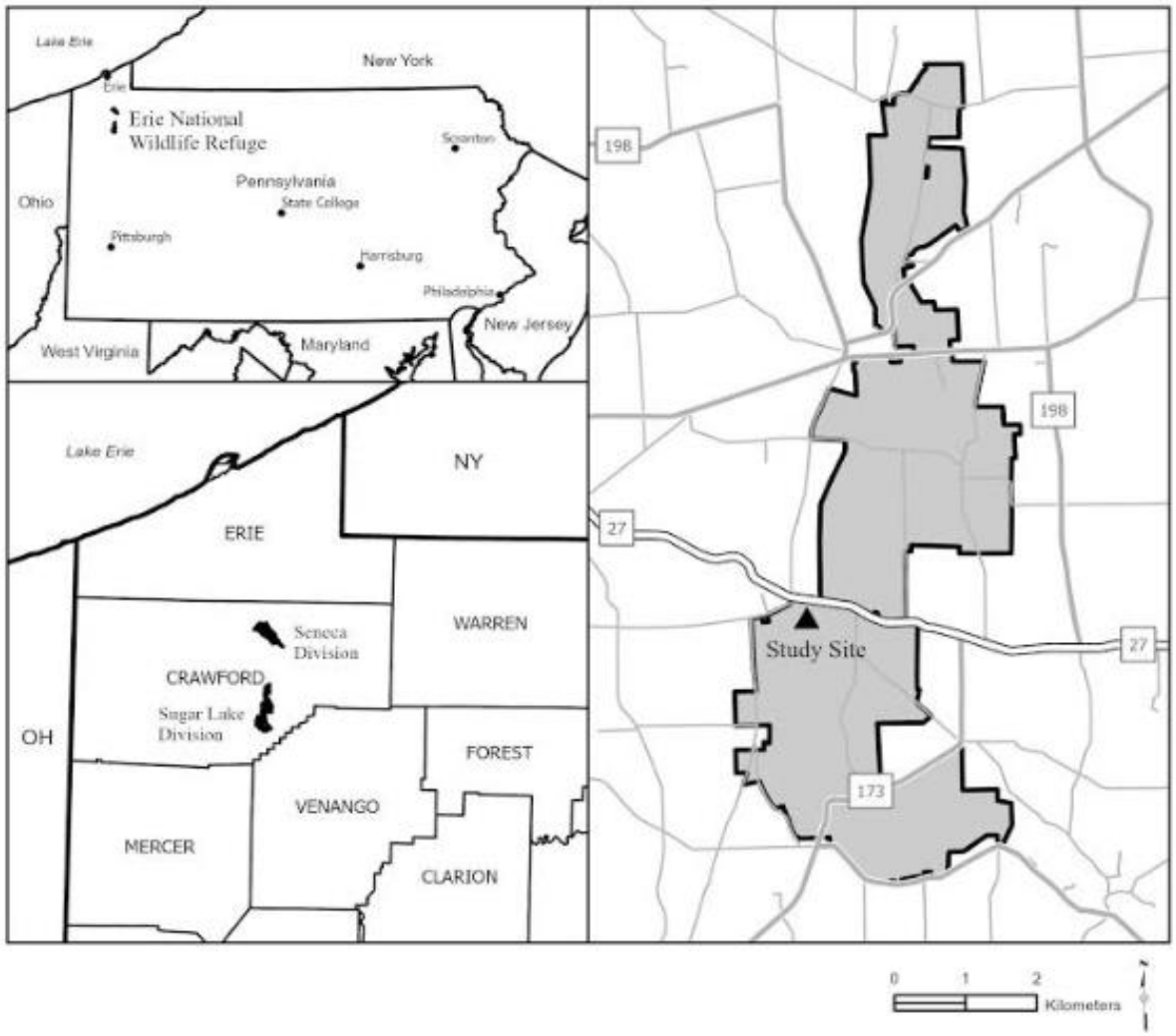

Figure 2. Location of goat-browsed forest stand in the Erie National Wildlife Refuge, Crawford County, Pennsylvania. Maps created with ArcGIS Pro.

Data on tree damage were collected from January to March of 2020. The goats had been observed actively browsing tree bark in the plots, and there are no other local species that are known to browse tree bark in the same manner. To evaluate damage to the trees by goats, we randomly selected 67-74 trees per plot that were at least two cm diameter at breast height (DBH) and recorded their species and DBH. If the tree was browsed through the bark and the cambium, we measured the circumference of the tree and the browsed arc of the circumference at the point of greatest browsing. A tree was considered to be girdled if 100% of the circumference was browsed through the cambium and browsed if girdling was not complete. A tree was designated as nibbled if there were teeth marks on the bark, but the browsing did not extend through the cambium (Fig. 3).

Figure 3. Trees that have been browsed (Left) and girdled (Right) by goats in the Erie National Wildlife Refuge in northwestern Pennsylvania where goats were used to control multiflora rose. Photos by Grace Hemmelgarn.

Results

Tree Composition and Size

The sites were dominated by black cherry and red maple, which represented 42.1% and 28.9% of total stems, respectively (Fig. 4). Hawthorn, ironwood, and apple represented most of the other species present. Species in the category entitled "other" were not abundant, and included shagbark hickory (*Carya ovata*), sugar maple (*Acer saccharum*), quaking aspen (*Populus tremuloides*), white ash (*Fraxinus americana*), and white oak (*Quercus alba*). The largest tree species was black cherry (DBH: 27.3 ± 1.3 cm, Fig. 5), followed by red maple (DBH: 20.8 ± 1.5 cm). The smallest tree species were hawthorn and ironwood, with diameters of 7.3 ± 0.5 cm and 10.4 ± 1.3 cm, respectively.

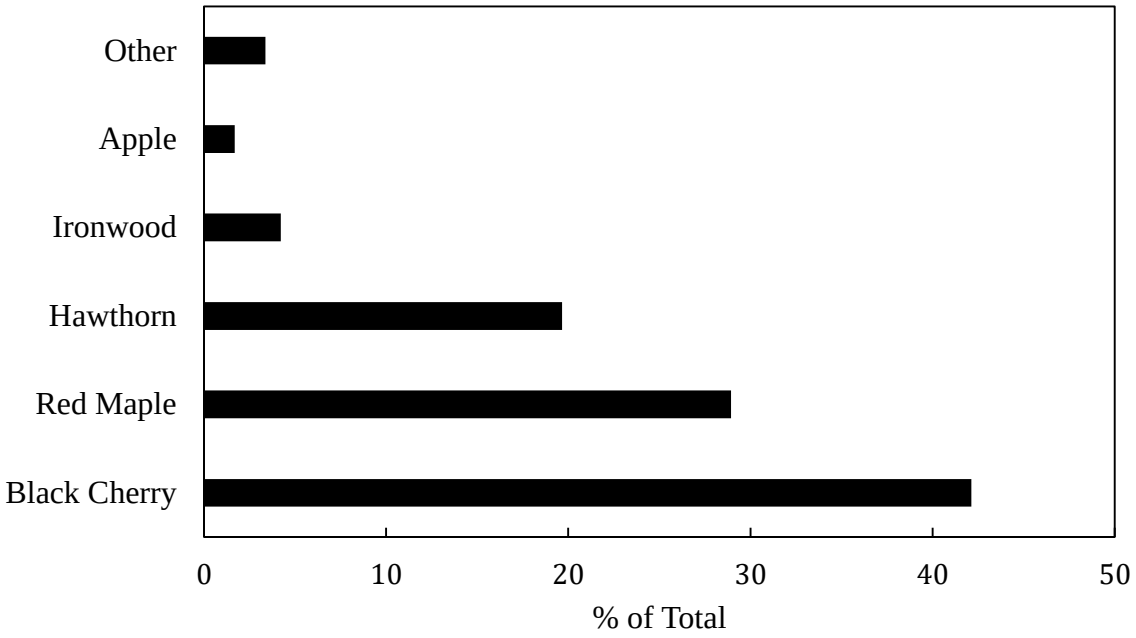

Figure 4**.** Tree species composition in a goat-browsed temperate forest stand in northwestern Pennsylvania.

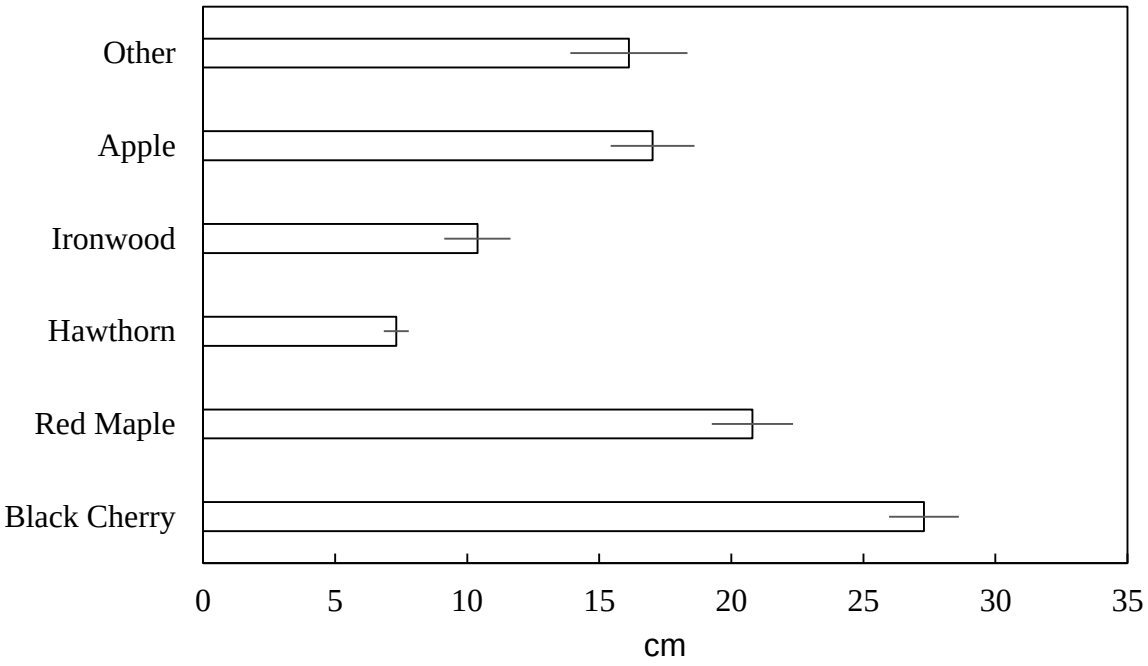

Figure 5. Tree diameters (Mean ± SE) in a goat-browsed hardwood forest stand in northwestern Pennsylvania.

Table 1. Percent of total trees (n=356) girdled, browsed, nibbled, and not browsed by goats during multiflora rose treatment in a goat-browsed forest stand in northwestern Pennsylvania.

Goat Browsing	% of Total Trees
Girdled	8.7
Browsed	18.3
Nibbled	6.5
Not browsed	66.6

Browsing by Species

Of the 356 trees sampled, 8.7% were girdled, 18.3% were browsed, and 6.5% were nibbled (Table 1). Red maple and ironwood were browsed and girdled most frequently by goats, with 41.2% and 46.7% of trees browsed and 23.5% and 13.3% of trees girdled, respectively (Fig. 6). Apple and hawthorn were browsed less frequently; black cherry was least browsed, with 88.0% of trees untouched by goats. No trees in the "other" category were browsed. Nibbling remained fairly consistent among species, ranging from 5.9% of red maples to 7.7% of "other" trees. Apple trees were not nibbled. Of the trees with goat damage extending through the cambium, the average proportion of the circumference that was browsed ranged from 38.9% to 63.0% among species, with no significant differences among species (Fig. 7). The percentage of circumference browsed was highly variable within most of the species.

Browsing by Tree Size

For nearly all tree species we examined, there was no significant difference between the size of trees that were browsed or girdled, nibbled, and not browsed (Fig. 8). Only hawthorn showed a significant difference ($p=0.009$) in tree diameter between browsed and unbrowsed trees, with browsed trees approximately 50% larger than unbrowsed trees.

Discussion

Goats exhibited clear browsing preferences among tree species, which may be influenced by physical and chemical characteristics of the trees. For example, red maple and ironwood, the two most browsed species, both have thin, smooth bark, whereas black cherry, hawthorn, and apple trees have rough, scaly bark and were browsed much less than red maple or ironwood. The high sugar content and low acidity of red maple sap may also promote its selection by goats (Burns and Honkala 1990, Jones and Alli 1987). Black cherry bark contains cyanogenic glycoside that can harm domestic livestock (Burns and Honkala 1990) and may have discouraged goat browsing on black cherry. Interestingly, goats showed no preference for any particular tree diameter within any of the species, thus browsing or girdling is not likely to preferentially alter any particular tree size class within species. Although hawthorn was significantly smaller than the other species, trees of

this species do not grow very large, and the smallest trees may not be conducive to browsing. Hawthorn was not a species preferred by the goats.

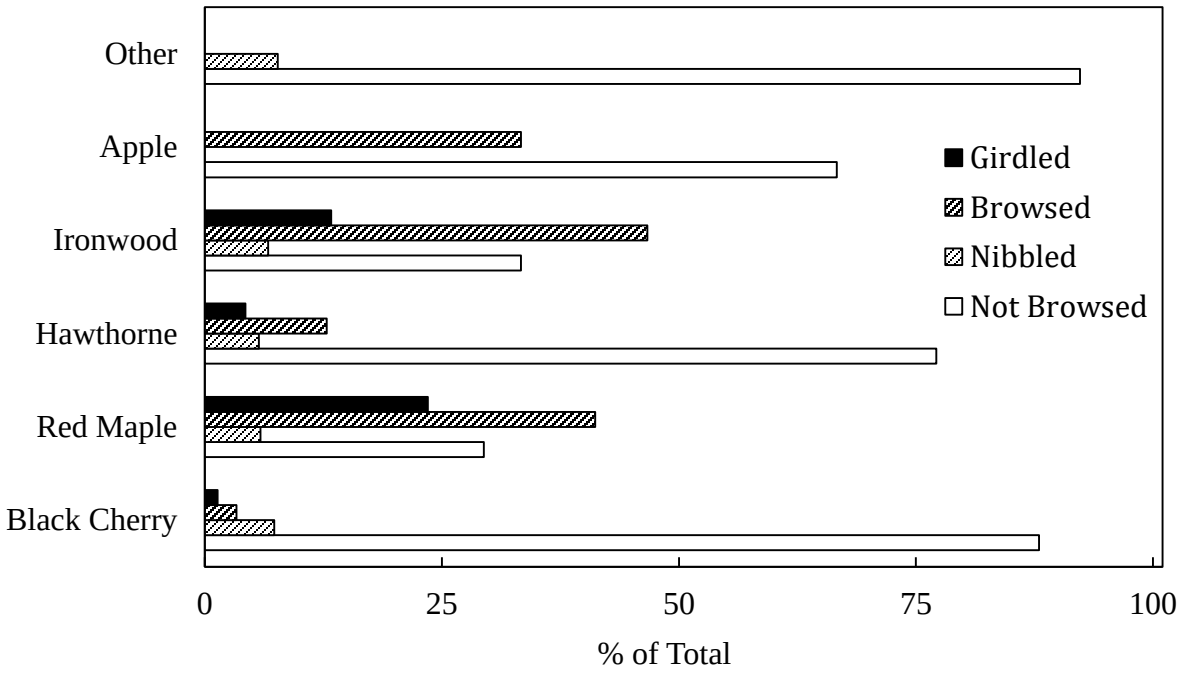

Figure 6. Percentage of each tree species girdled, browsed, nibbled, and not browsed by goats during multiflora rose treatment in a goat-browsed forest stand in northwestern Pennsylvania.

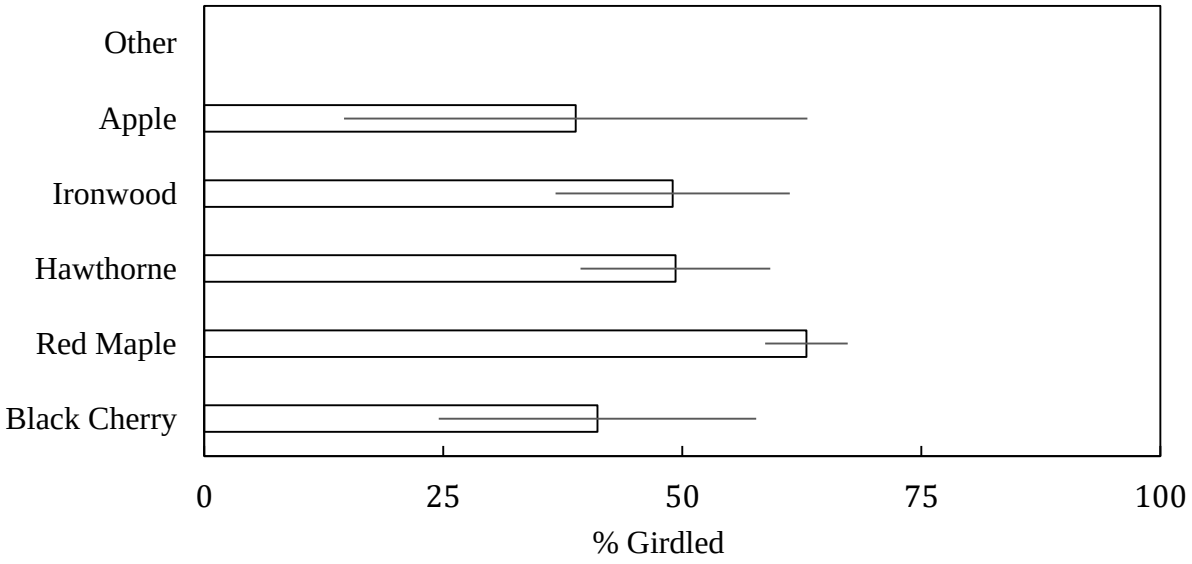

Figure 7. Percentage (Mean ± SE) of tree circumference browsed by goats in browsed trees during multiflora rose treatment in a goat-browsed forest stand in northwestern Pennsylvania.

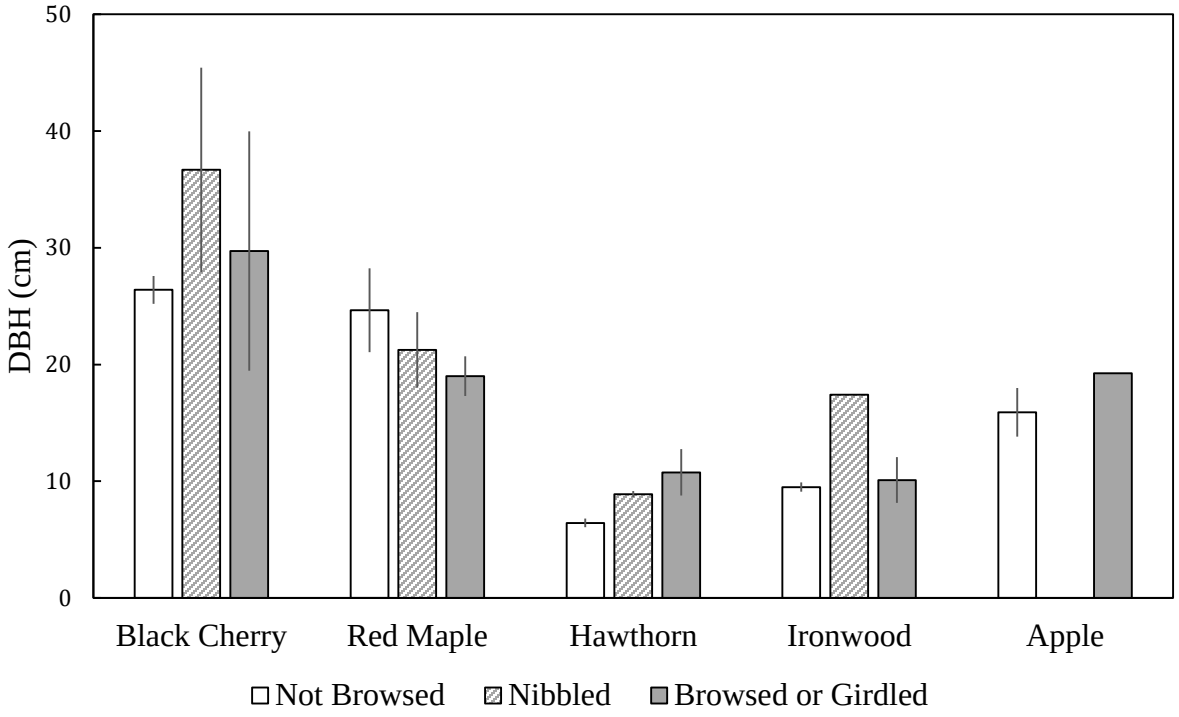

Figure 8. Tree diameters (Mean ± SE) of tree species not browsed, nibbled, and browsed or girdled by goats during multiflora rose treatment in a goat-browsed forest stand in northwestern Pennsylvania.

Feral goats can dramatically alter numerous patterns and processes in native ecosystems (Coblentz 1978) and considerable effort has been placed in managing and eradicating feral populations (Parkes 1990, Parkes et al. 1996). However, in this management study goats were on site only during the summer growing season when MFR was at its peak productivity. Further, goat diets were supplemented to ensure proper nutrition, and goats were rotationally grazed across the site when MFR showed noticeable browsing. Hence, browsing by goats is not likely to result in ecosystem-wide negative effects as seen in locations where feral goat populations are uncontrolled. Nonetheless, goats can alter forest composition. Although only 8.7% of all trees at the ENWR site were girdled completely, the difference in browsing rates by goats among tree species could change the forest composition. Red maple and hawthorn had the highest percentage of trees girdled both partially and completely. Complete girdling kills trees by disconnecting vascular tissues that transport water, nutrients, and food throughout the tree. Incomplete girdling may not initially kill a tree, but it can expose it to insect and microbial damage (Neely 1988). Red maple, the most browsed and second-most abundant species in the study area, may be most severely impacted by goat browsing. Only 29% of red maple trees were untouched by goats and nearly one-fourth were completely girdled and killed. An additional 41% of red maples were browsed with an average of nearly two-thirds of the circumference girdled. Partial girdling is especially harmful to red maples, as they seal wounds slowly and are highly susceptible to trunk rot (Hutnik and Yawney 1961; Shortle et al. 1995). Goat browsing could cause a decline in red maple in the study area, and black cherry could become increasingly dominant at the site. Both black cherry and red maple are

important food sources for wildlife and produce economically valuable lumber (Burns and Honkala 1990; Ray 2020).

The tree species composition of stands where goats are used as an MFR control method should be considered. In stands dominated by black cherry or other species with unpalatable rough bark, goats may cause minimal forest damage. However, in stands dominated by red maple, ironwood, or other species with smooth, thin, palatable bark, goats may cause significant tree damage, loss of productivity, and mortality. In this region, it is not likely that the reduction of red maple in selected stands would cause concern. Since 1980, red maple in the eastern US, including Pennsylvania, has increased its abundance in its natural range and has also extended beyond its documented historical range (Abrams 1998, Fei and Steiner 2007). In Pennsylvania from 1978 to 1989, there was an increase in red maple and a decrease in oak timber volume, indicating that red maple may be slowly replacing oak in the state's forests (Alerich 1993). Therefore, reductions in red maple abundance by goat browsing may be beneficial to maintain the historical abundance of oaks or other species in Pennsylvania. In areas with high proportions of red maple, girdling could also create snags (standing deadwood) that benefit forest ecosystems by contributing to wildlife habitat, nutrient cycling, and carbon storage (Fassnacht and Steele 2016) and hence goats may improve vegetation regeneration, biodiversity, and soil nutrients when managed properly (García et al. 2012).

Goats can be an effective alternative control mechanism for MFR that benefits both forest and aquatic ecosystems. Avoiding herbicides that are toxic to aquatic species can protect species diversity and maintain stream processes and functions (Solomon and Thompson 2003, Relyea 2005). In forests, using goats can reduce the unwanted loss of non-target plant species that may result from using herbicides. Although goats can also browse non-target species, other studies using goats to control MFR resulted in an increase in the abundance of desirable herbaceous species (Luginbuhl et al. 1998, 2000). We suggest that if rare, endangered, or especially desirable species are present, they should be protected from goats. Therefore, a detailed assessment of species composition and conservation status in each management plot may be required before goats are selected as an MFR control method.

Despite the morbidity and mortality to red maple, two-thirds of the trees on the site were not damaged, and the loss of one-third of trees is comparable to silvicultural timber stand improvement operations. Overall, considering local conditions and long-term goals, goats may be an acceptable MFR control method. Future studies may consider the potential role of goat feces in transporting and fertilizing multiflora rose seeds if they browse when mature fruits are produced, the long-term success of goats as a treatment for MFR, and the long-term impacts of goats on forest structure and composition.

Literature Cited

Abrams, M. D. 1998. The red maple paradox. BioScience 48(5): 355-364.

Adalsteinsson, S. A., W.G. Shriver, A. Hojgaard, J.L. Bowman, D. Brisson, V. D'Amico and J.J. Buler. 2018. Multiflora rose invasion amplifies prevalence of Lyme disease pathogen, but not necessarily Lyme disease risk. Parasites and Vectors 11(1). Article 54 (2018).

Alerich, C.L. 1993. Forest statistics for Pennsylvania-1978 and 1989. US Forest Service Resource Bulletin NE-126. Radnor, PA. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. doi: 10.2737/NE-RB-126.

Banasiak, S.E., and S.J. Meiners. 2008. Long term dynamics of *Rosa multiflora* in a successional system. Biological Invasions 11(2): 215–224.

Bartz, R., U. Heink and I. Kowarik. 2010. Proposed definition of environmental damage illustrated by the cases of genetically modified crops and invasive Species. Conservation Biology 24: 675-681. doi:10.1111/j.1523-1739.2009.01385.x.

Brann, G. 2006. Grazing program for goats. https://uknowledge.uky.edu/ky_grazing/2006-Jan/Session/5/. Retrieved 30 July 2020.

Brown, J., M. McCampbell, A. Adesiji, C. Aldana, D. Antinozzi, A. Arden, H. Baker, L. Benko, R. Bower, B. Capron, I. Chick, A. Fernandez, N. Ferreira, L. Kellett, J. Lovullo, E. Melanfant, E. McNamara, J. Raphael, E. Shanabrook, A. Spiro, A. Terasavage, A. Tolmachoff, E. Vallejo, Z. Wilson, R.D. Bowden. 2020. Invasive plant species abundance along forest edges in northwestern Pennsylvania. Allegheny College Department of Environmental Science and Sustainability Publication 2020-2.

Burns, R.M. and B.H. Honkala, Tech. Coords. 1990. Silvics of North America: Vo1. 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. Vol.2. 877 p.

Caylor, A., M.G. Kresse, C.F. Castle, R.S. Forsha, J.M. Holder, M.W. Johnston, B.L. Mickley, I.M. Petronka, R.M. Petula, J.T. Pittman, M.J. Savino, M.G. Sherman, O. Spiker, J.P. Steele, D.N. Studer, J.I. Sullivan, J.P. Tokasz, S. Winter and R.D. Bowden. In prep. Effectiveness of prescribed browsing by goats in controlling multiflora rose at the Erie National Wildlife Refuge. To be submitted to Allegheny College Department of Environmental Science and Sustainability Publication.

Coblentz, B.E. 1978. The effects of feral goats (*Capra hircus*) on island ecosystems. Biological Conservation 13(4): 279-286.

Cory, V. L. 1927. Activity of livestock on the range. Tex. Agr. Exp. Sta. Bull. 367.

Doll, J. (n.d.). Biology of multiflora rose. University of Wisconsin. https://ipaw.org/wp-content/uploads/2018/07/multiflora_doll.pdf. Retrieved Jul 31, 2020.

Dukes, J. S. and H.A. Mooney. 2004. Disruption of ecosystem processes in western North America by invasive species. Revista Chilena de Historia Natural 77(3): 411-437.

Epstein, A. H. and J.H. Hill. 1999. Status of rose rosette disease as a biological control for multiflora rose. Plant Disease 83(2). February, 1999. doi: 10.1094/PDIS.1999.83.2.92.

Epstein, A., J.H. Hill and F.W. Nutter, Jr. 1997. Augmentation of rose rosette disease for biocontrol of multiflora rose (*Rosa multiflora*). Weed Science 45(1): 172-178. www.jstor.org/stable/4045730.

Fassnacht, K.S. and T.W. Steele. 2016. Snag dynamics in northern hardwood forests under different management scenarios. Forest Ecology and Management 363(1): 267-276.

Fei, S. and K.C. Steiner. 2007. Evidence for increasing red maple abundance in the eastern United States. Forest Science 53: 473-477.

García, R.R., R. Celaya, U. García and K. Osoro. 2012. Goat grazing, its interactions with other herbivores and biodiversity conservation issues. Small Ruminant Research 107(2-3): 49–64.

Hart, S. 2001. Recent perspectives in using goats for vegetation management in the USA. Journal of Dairy Science 84: E170-E176.

Hummer, K.E. and J. Janick. 2009. Rosaceae: Taxonomy, economic importance, genomics. *In* Folta K. M. and S.E. Gardiner (Eds.). Genetics and Genomics of Rosaceae. p 1-17. Springer-Verlag, New York, NY. doi:10.1007/978-0-387-77491-6.

Huston, J.E. 1978. Forage Utilization and Nutrient Requirements of the Goat. Journal of Dairy Science 61 (7): 988-993.

Hutnik, R.J. and H.W. Yawney. 1961. Silvical characteristics of red maple (*Acer rubrum*). Station Paper NE-142. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 18p.

Johnson, J., A. Gover and J. Sellmer. 2007. Managing multiflora rose. Pennsylvania State University. Conservation Reserve Enhancement Program Technical Assistance Series Factsheet 2.. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_018028.pdf.

Jones, A.R.C. and I. Alli. 1987. Sap yields, sugar content, and soluble carbohydrates of saps and syrups of some Canadian birch and maple species. Canadian Journal of Forest Research 17(3): 263-266.

Kurtz, C. and M. Hansen 2013. An assessment of multiflora rose in northern U.S. forests. U.S. Department of Agriculture, Forest Service, Northern Research Station. doi: 10.2737/nrs-rn-182.

Loux, M.M., J.F. Underwood, W.B. Bryan and R. Chandran. 2005. Multiflora rose control. Ohio State University Extension Publication 857. https://cpb-us-w2.wpmucdn.com/u.osu.edu/dist/7/3461.

Luginbuhl, J.M., J.T. Green, M.H. Moore and A.P. Conrad. 2000. Use of goats to manage vegetation in cattle pastures in the Appalachian region of North Carolina. Sheep and Goat Research Journal 16(3): 124–135.

Luginbuhl, J.M., T.E. Harvey, J.T. Green, M.H. Poore and J.P. Mueller. 1998. Use of goats as biological agents for the renovation of pastures in the Appalachian region of the United States. Agroforestry Systems 44(2-3): 241–252.

Massé, R.J. and K. Vulinec. 2010. Possible impact of multiflora rose on breeding-bird diversity in riparian forest fragments of central Delaware. Northeastern Naturalist 17: 647-658. doi:10.1656/045.017.0410.

Neely, D. 1988. Tree wound closure. Journal of Arboriculture 14(6): 148-152.

Parkes, J.P. 1990. Eradication of feral goats on islands and habitat islands, Journal of the Royal Society of New Zealand 20(3) 297-304. doi: 10.1080/03036758.1990.10416824.

Parkes, J., R. Henzell and G. Pickles. 1996. Managing Vertebrate Pests: Feral Goats. Australian Government Publishing Service, Canberra.

Pejchar, L., and H.A. Mooney. 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution 24(9): 497-504.

Pimentel, D., R. Zuniga and D. Morrison 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52(3): 273-288.

Ray, C.D. 2020. Pennsylvania Timber Market Report - Fourth Quarter 2019. Penn State Extension. Retrieved from https://extension.psu.edu/pennsylvania-timber-market-report-fourth-quarter-2019.

Relyea, R.A. 2005. The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. Ecological Applications 15(2): 618-627.

Reno, D., D.M. Anderson, J.L. Berry, H. Burns, C.A. Byron, G.N. Checchio, K.G. Click, J.D. Dzurica, L. Fares, N.L. Hesch, M.G. Hill, I.W. Johnson, S.L. Latour, K.L. Nicholson, S.L. Piper, D.E. Sponseller, D.E. Swann, L.D. Thomas, S.E. Washko, B.M. Whiting, Y. Yuan, Ye;

C.L. Shaffer and R.D. Bowden. 2017. Land Use Change on the Erie National Wildlife Refuge. Allegheny College Department of Environmental Science Publication 2017-1.

Shortle, W.C., K.T. Smith, K.R. Dudzik and S. Parker. 1995. Response of maple sapwood to injury and infection. European Journal of Forest Pathology 25(5): 241-252.

Solomon, K. and D. Thompson. 2003. Ecological risk assessment for aquatic organisms from over-water uses of glyphosate. Journal of Toxicology and Environmental Health, Part B: Critical Reviews 6(3): 289-324.

Steavenson, H.A. 1946. Multiflora rose for farm hedges. The Journal of Wildlife Management, 10(3): 227-234. doi: 10.2307/3795837.

Trnkoczy, A. 2018. *Rosa multiflora*; Multiflora Rose [Image]. *CalPhotos.* https://calphotos.berkeley.edu/cgi/img_query?seq_num=810421&one=T. Retrieved August 8, 2020.

USDA NRCS. (n.d.). *Rosa* L. *In* USDA NRCS Plants Database. https://plants.usda.gov/core/profile?symbol=ROSA5. Retrieved July 1, 2020.

USDA NRCS. 2020. USDA NRCS Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx. Retrieved August 5, 2020.

USDA-NRCS PLANTS Database and Herman, D.E., et al. 1996. North Dakota tree handbook. USDA NRCS ND State Soil Conservation Committee; NDSU Extension and Western Area Power Administration, Bismarck.

Yurkonis, K.A., S.J. Meiners and B.E. Wachholder. 2005. Invasion impacts diversity through altered community dynamics. Journal of Ecology 93(6): 1053-1061.