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DEPARTMENT OF ENVIRONMENTAL SCIENCE AND SUSTAINABILITY

Prescribed Browsing by Goats Controls Multiflora Rose in a Black Cherry-Red Maple Deciduous Forest at the Erie National Wildlife Refuge in Northwestern PA

A report submitted to the Erie National Wildlife Refuge, Guys Mills, PA

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ABSTRACT

Multiflora rose (*Rosa multiflora* (MFR)) is an invasive species, originally from northern Asia, that was introduced to the United States for aesthetic and utilitarian purposes. The plant has since invaded many temperate forests across the eastern United States, often excluding native plants by out-competing them for sunlight and other resources. In a black cherry-red maple deciduous forest in the Erie National Wildlife Refuge (ENWR) in Pennsylvania, the United States

Fish and Wildlife Service introduced prescribed goat-browsing as an exploratory management operation to control MFR. In four treatments: browsed, browsed/herbicided, cut/herbicided, and a reference, we evaluated preliminary effects of these treatments, after the first year, on MFR stem density, stem height, leaf and stem mass, native plants, and light at ground level. The goat-browsed treatment had 56% lower leaf/stem mass ratios and 35% shorter stem lengths, than the reference. Stems in the cut and herbicided treatment were 40% lower than the reference treatment. We did not detect a difference in biomass, likely due to lower biomass in the reference plot at the time the management was initiated. Stem density was not reduced because goats did not kill the MFR plants in this first year of treatment. Plots treated with herbicides had fewer non-MFR plants. Light levels at ground level did not differ among the treatments. Preliminary results suggest that prescribed browsing by goats has potential as an effective alternative control method for MFR, however long-term success will be best evaluated after consecutive treatment seasons.

Keywords: Multiflora rose, goat browsing, invasive species, herbicides, black cherry-red maple deciduous forest, Erie National Wildlife Refuge

INTRODUCTION

Invasive plant species can have a multitude of negative impacts on ecosystems, including soil toxicity (Bailey et al. 2001, Charles and Dukes 2008), outcompeting native plants for water (Lemke 2011), and altering nutrient (Rodgers et al. 2008) and light regimes (Funk 2013). Exotic plant species pose a major threat to ecosystem biodiversity (Stinson et al. 2007) and often dramatically reduce populations of native plant species (Wilcove et al. 1998). Invasive plants tend to have a number of properties that contribute to their ability to dominate ecosystem processes, including rapid growth and prolific seed production (Rejmanek and Richardson 1996, Huebner 2003) that allows them to colonize rapidly and outcompete native plants (Mesléard et al. 1993). They can also have a resource use-efficiency that enables them to compete successfully in low resource conditions (Funk 2013). Among invasive plant species in the United States, multiflora rose (*Rosa multiflora* (MFR)) is particularly abundant because it can thrive in a wide variety of conditions, ranging from forest understories (Huebner et al. 2014) to open fields (Myster and Pickett 1990). MFR often grows into dense thickets and its stems are covered in thorns. Each rose bush can produce one million seeds per year, which can remain viable for up to 20 years (Kurtz and Hansen 2013). Furthermore, fruit consumption by frugivores facilitates the spread of the species (Lafluer et al. 2007). Collectively, these attributes enable multiflora rose to dominate areas where it invades.

Traditional methods of controlling MFR populations commonly include cutting stems, applying herbicides, or a combination of the two. Glyphosate is a commonly used herbicide (Eckardt 1987, Wahlers et al. 1997). Although these methods are typically effective, especially when herbicides are employed, use of herbicides brings a number of concerns, including water contamination (Scribner et al. 2007), health impacts on crucial pollinators such as honeybees

(Motta et al. 2018), effects on soil biota (Nguyen et al. 2016), and health impacts on non-target plants and animals. (Gill et al. 2018). These concerns have stimulated research into solutions that avoid herbicide use.

One alternative method of control is using browsing mammals such as sheep, cattle, or goats to reduce or clear invasive plant species (Abaye et al. 2009). Using goats is often considered a safe control method because goats can be contained in defined areas and do not introduce toxins into the environment. Goats defoliate plants and kill seeds in their digestive tract, preventing the plants from spreading rapidly, and they are considered to be cost-effective (Luginbuhl et al. 1998). The typically low costs of prescribed goat browsing may provide an advantage compared to labor-intensive cutting practices or herbicide application (Magadlela et al. 1995). One downside of using goats is that repeated browsing is usually necessary to reduce the presence of established invasive plants, whereas herbicides usually eliminate the plant after one application (Jenner 2013). Additionally, few studies have investigated the effectiveness of using goats. Goat browsing can also be used in tandem with other control methods if so desired. Utilizing goats to physically clear space in a MFR infestation can increase access for manual cutting and clearing, and damage caused to the rose allows herbicides to more readily enter the plant (Rathfon et al. 2014).

On protected and managed lands, including wildlife refuges, managers aim to protect biodiversity, but they have constraints on how they can maintain that protection. The Erie National Wildlife Refuge (ENWR), in northwestern Pennsylvania has areas with high MFR density that threatens native biodiversity, thus there is a desire to reduce MFR abundance. However, the refuge must also protect surrounding ecosystems (U.S. Fish and Wildlife Service 2014). Due to numerous aquatic habitats on the refuge, goats had been suggested previously as a means to reduce areas with a high MFR population (Brown et al 2020), thus eliminating risks of water contamination due to herbicide application.

Prescribed browsing may be a promising method of managing non-native invasive species in some locations, but its effectiveness needs to be quantified to determine if it is an appropriate replacement for traditional management practices. The purpose of our study was to evaluate the effectiveness of goat herbivory as a control method for MFR. The objectives of our study were to determine: 1) whether MFR density, height, and biomass differs among four treatments (goat-browsed, goat-browsed and herbicided, cut and herbicided, unmanaged reference); 2) whether non-MFR plant populations are affected by the treatments; and 3) to assess changes in the availability of light on the forest floor caused by browsing or herbicide treatment. Our hypothesis was that goat-browsing would reduce MFR height, leaf/stem ratio, and increase the amount of light reaching the forest floor.

METHODS

The staff at the ENWR selected an approximately two ha area that was identified previously as having a high density of MFR (Brown et al. 2020). This identified area maintained a management goal of protecting native plants and increasing biodiversity, and was in close proximity to toe slope drainage and a nearby stream. This area was in the Sugar Lake division of

the ENWR, a temperate deciduous forest in northwestern Pennsylvania (Fig. 1). Northwestern PA has an average temperature of 13.3 °C and an average rainfall of 105 centimeters (NOAA 2021). The site of our study lay on a gentle slope (7°) with a northeasterly aspect, and was formerly used as farmland, evident from its overall level soil surface, piles of field stones, abandoned farm machinery, and a line of trees that appear to have grown along the edge of a former open field. The distinct lack of pit and mound structures suggested that the site was a relatively young forest and had been plowed. The overstory was dominated by black cherry (*Prunus serotina*) and red maple (*Acer rubrum*), with a canopy of approximately 20m, and which represented 42% and 29% of total stems, respectively (Hemmelgarn et al. 2020). Basal area of the site was $22.7 \pm 4.3 \text{ m}^2 \text{ ha}^{-1}$. Mean black cherry DBH was $27.3 \pm 1.3 \text{ cm}$, and red maple was $20.8 \pm 1.5 \text{ cm}$. The subcanopy consisted of apple (*Malus domestica*), hophornbeam (*Ostrya virginiana*), and ironwood (*Carpinus caroliniana*). The forest understory was sparsely covered by herbaceous plants and limited native growth or tree regeneration.

Prior to planning and initiation of our study, the ENWR began a management operation in 2019 that included three treatments – browsed, browsed and herbicided, and cut and herbicided. The browsed area was approximately 0.8 ha, the browsed/herbicided area was approximately 0.2 ha, and cut/herbicided area was approximately 0.1 ha. We established an approximate 0.2 ha reference section, immediately adjacent to the browsed section, and that had MFR density, plant height, and tree overstory characteristics that visually resembled the treatment plots. Browsed and browsed/herbicided plots had portable, electrified fences to contain eight goats and one donkey that were leased from Allegheny Goatscape™ (<https://www.alleghenygoatscape.org/>) of Pittsburgh, PA. The role of the donkey was to protect the goats by scaring away potential predators. The browsed area was divided into eight adjoining subsections and the goats were rotated among the subsections approximately each week. Due to time constraints, we conducted our measurements within the five central subsections. The browsed/herbicided area was divided into two adjoining sections, and goats spent about a week in each section. The fences were removed from the browsed areas at the end of the summer following the departure of the goats. The MFR in the cut and herbicided plots was cut by hand in July, and was then treated on September 6, 2019 with the herbicide Rodeo™ as a 1.5% foliar spray. The active ingredient in Rodeo is 53.8% isopropylamine salt of glyphosate. The browsed/herbicided plots were browsed by goats, and then herbicided in on September 9-10, 2021, immediately after goats had departed the site, and approximately one month before we began field measurements, allowing sufficient time for the herbicide to kill the plants. For analyses, we used the entire browsed/herbicided and cut/herbicided sections, and five of the central, connected sections of the browsed area.

In each area, we randomly selected 1 m^2 plots for measurements, with eight plots each located in the cut/herbicided and browsed/herbicided treatments, 24 in the reference, and 40 in the browsed treatment. The number of plots was selected to provide an approximately equal number of plots per treatment area ($0.01 - 0.03 \text{ ha plot}^{-1}$). Beginning approximately three weeks after the goats were removed from the site, MFR characteristics were measured within each plot from Sept 19 to Oct. 24. First, the stem was cut directly above the root ball, and each stem was stretched and

measured from the root ball to the furthest leaf of the plant. Given that the stems bend over as they mature, we defined this measurement as stem length rather than height. After removing all the rose plants from the plot, we counted the number of non-MFR vascular plants in the quadrat. MFR stems were returned to the laboratory, and separated into stems, mature leaves, new growth sprouts and stems. Rose hips were not common; any we found were removed from the plants, but not included in analyses. New growth was defined as the new leaves (leaflets and petioles; there were no stems) emanating laterally from the mature stems. They could be distinguished easily by their light green color and soft texture, although we do not know when new growth was initiated. Samples were dried at 105°C for 48 hours, and weighed.

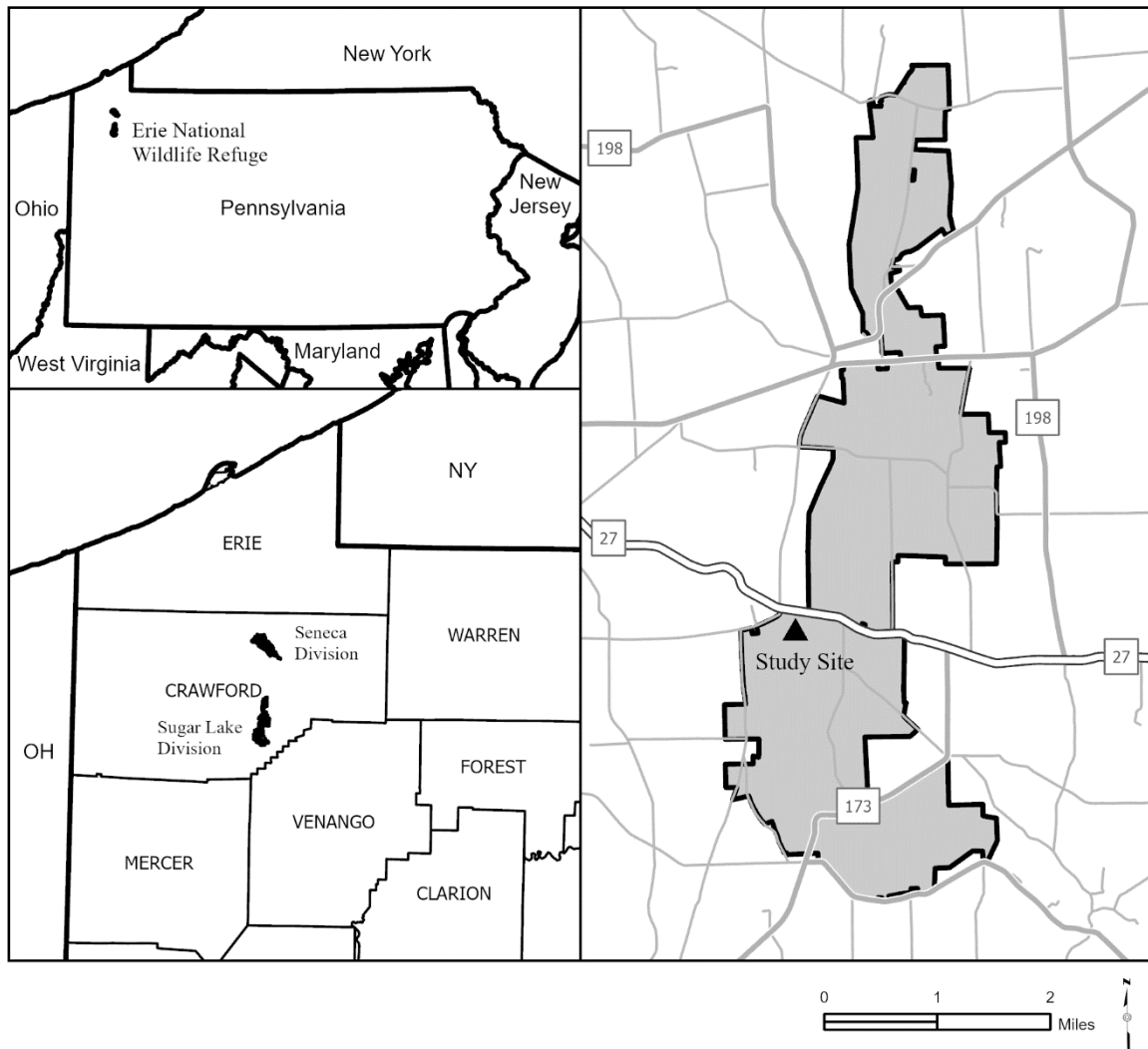


Figure 1. Location of goat-browsed study site in the Erie National Wildlife Refuge, Crawford County, Pennsylvania.

To determine the influence of MFR on ground-level light, we used Plexon LX1010B Lux Meters to measure the light level above each one m² quadrat, above the uppermost layer of rose plants, at ground level in the middle of each plot, and in an open area with direct daylight.

None of our data were normally distributed, thus treatment comparisons were analyzed using Kruskal-Wallis non-parametric ANOVA and Dunn's tests (SigmaPlot ver. 12.5, 2016 Navendu Vasavada (<https://astatsa.com/KruskalWallisTest/>; accessed December 10, 2020).

RESULTS

Stem Density and Height

The density of MFR stems (Table 1) among the treatments differed significantly ($p < 0.005$), ranging from 3.5 ± 1.5 stems m⁻² in the cut and herbicided treatment, to nearly four-fold greater in the browsed treatments. Multiflora rose stem heights (Table 1) were shorter in all the treatment plots than the reference plots ($p < 0.001$), with a 35% reduction in the browsed treatment and a 40% reduction in the browsed/herbicided treatment. Browsed and browsed/herbicided treatments did not differ in height.

Biomass

Total MFR mass ($p = 0.067$), as well as stem ($p = 0.074$) and mature leaf mass ($p = 0.769$) (Table 1) did not differ among treatments. New growth mass was higher in the browsed treatment than in the cut/herbicided treatment, but did not differ among the other treatments ($p < 0.002$). The mature leaf/stem mass was reduced by 56% in the browsed treatment ($p = 0.016$, Fig. 2). The new growth/stem mass did not differ among treatments ($p = 0.062$). The cut/herbicided treatment was excluded from tissue/stem analyses because cutting and herbicide applications results in too few leaves or new growth for statistical analysis.

Light

Full daylight during the study period averaged $76,100 \pm 8,900$ lux, fluctuating among sampling dates, as well as within the same days of fieldwork. Light above MFR ranged from 4.9 to 10.8% of full sunlight (Table 2), and differed among treatments ($p = 0.045$; differences among treatments could not be detected). At ground-level, light was higher in the browsed/herbicided plots than reference plots ($p = 0.012$). Because light was not uniform above MFR among treatments across the site, we calculated ground-level light as a percentage of light levels above the MFR plants (Figure 3), and found that there was no detectable difference among treatments ($p = 0.131$); the relative amount of light reaching ground level was not statistically different among treatments.

Table 1. Density and length of multiflora rose stems within the four goat-browsing treatments at the Erie National Wildlife Refuge, PA. Treatments with the same letter within each column are not statistically different. SE=Standard Error.

Treatment		Mass (g m ⁻²)					
		Stem Density (# m ⁻²)	Stem Height (cm)	Stems	Leaves	New Growth	Total
Reference	Ave	4.9 a	79.0 a	31.1 a	1.0 a	0.8 ab	32.9 a
	SE	1.6	4.5	12.9	0.4	0.6	13.7
Browsed	Ave	12.1 b	51.3 b	34.7 a	0.7 a	0.7 a	36.0 a
	SE	1.7	1.8	7.6	0.2	0.2	7.7
Browsed/Herbicided	Ave	11.1 ab	47.3 bd	23.8 a	0.5 a	0.2 ab	24.5 a
	SE	4.5	2.7	15.8	0.3	0.1	16.2
Cut/Herbicided	Ave	3.5 ab	35.6 c	17.9 a	0.3 a	0.004 b	18.2 a
	SE	1.5	11.1	14.8	0.2	0.004	15.0

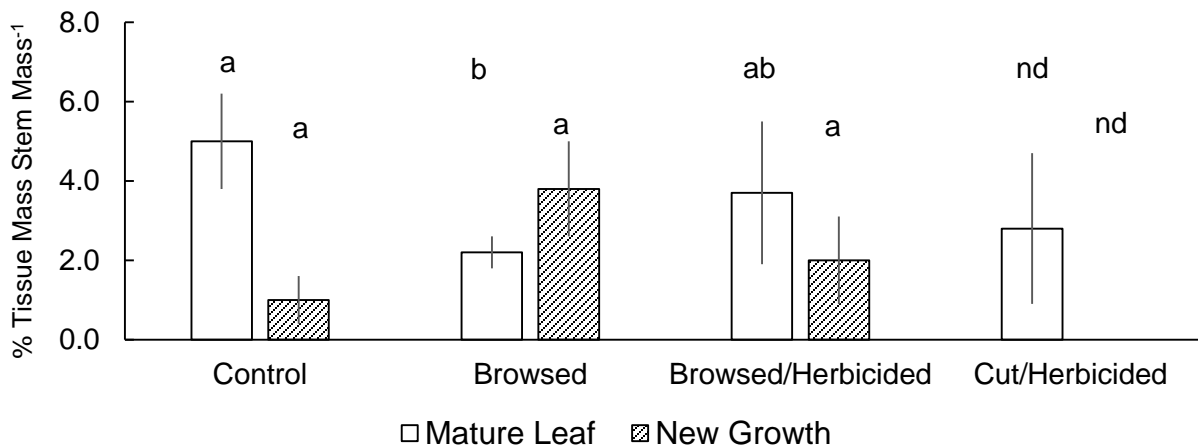


Figure 2. Percentage of mature leaf and new growth mass on MFR stems within the four treatments at the Erie National Wildlife Refuge, PA. Treatments with the same letter within each tissue type are not statistically different. nd: not determined. Lines are Standard Errors.

Table 2. Light above and below multiflora rose among the four treatments at the Erie National Wildlife Refuge, PA. Treatments with the same letter within each row are not statistically different. Light at ground-level differed significantly, however differences among treatments could not be detected. SE = Standard Error.

		Light (lux)			
		Control	Browsed	Browsed/ Herbicided	Cut/ Herbicided
Above MFR Mean	Mean	6.6a	9.2a	10.8a	4.9a
	SE	0.9	1.7	0.8	0.6
Ground-Level	Mean	4.3a	6.2ab	8.3b	3.3ab
	SE	0.7	1.1	0.6	0.3

Non-Multiflora Rose Plants

The number of plants other than MFR (Fig. 4) ranged from 25.1 ± 6.8 (SE) to 73.7 ± 14.7 (SE) plants m^{-2} , differing significantly among treatments ($p = 0.015$). Browsed/herbicided plots did not differ from reference or browsed treatments, however cut/herbicided plots had fewer plants than the reference or browsed treatments.

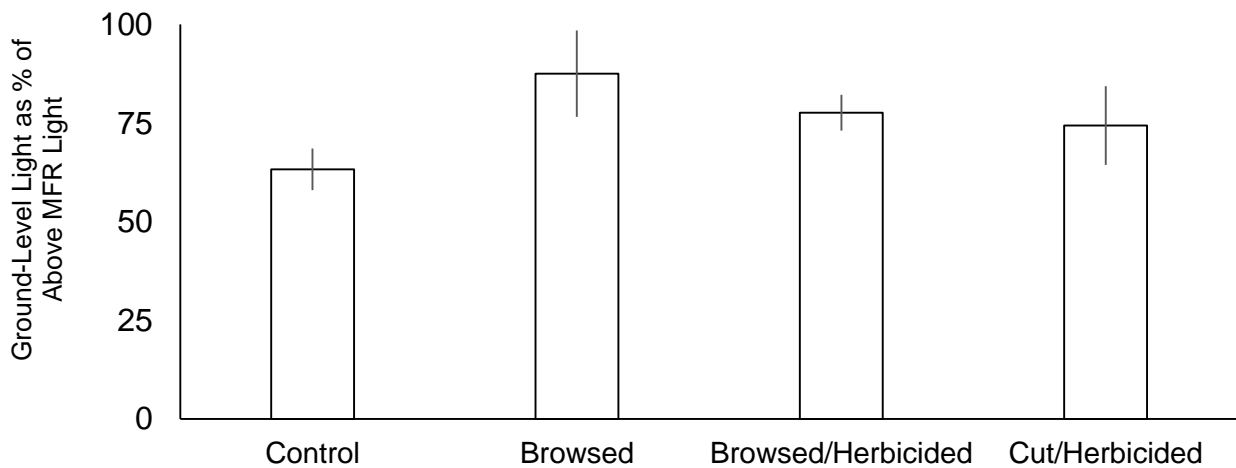


Figure 3. Light at ground level as a percentage of light over MFR within the four goat-browsing treatments at the Erie National Wildlife Refuge, PA. There were no significant differences among treatments. Bars represent means; lines are Standard Errors.

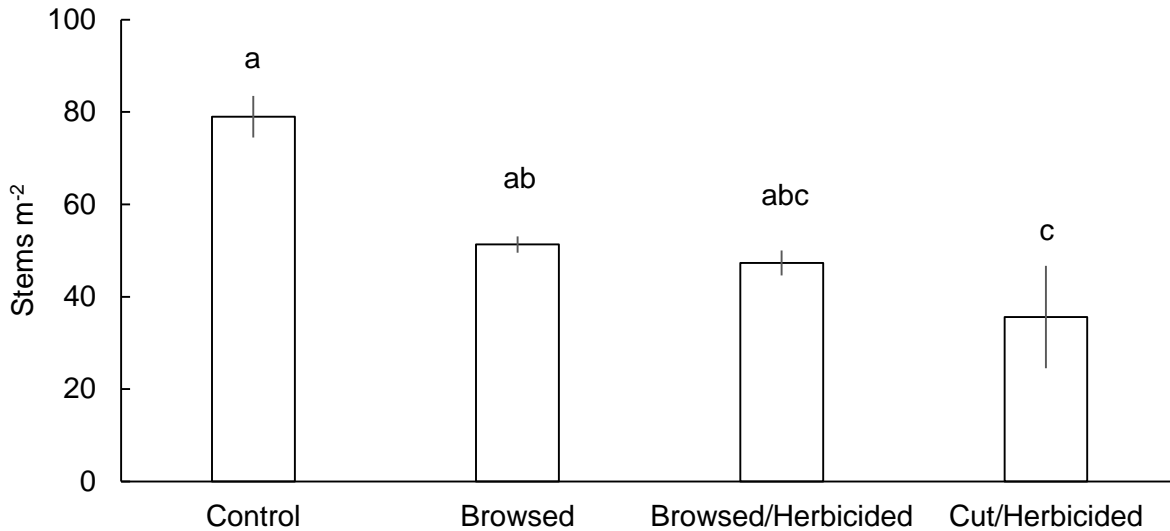


Figure 4. Non-multiflora rose plant abundance within the four treatments at the Erie National Wildlife Refuge, PA. Bars represent means; lines are Standard Errors. Treatments with the same letter are not statistically different.

DISCUSSION

Goats were brought to the refuge to control multiflora rose, thus it might appear counterintuitive that the browsed plots had a greater MFR stem density than control plots, and that total mass did not differ. Indeed, studies of feral goats have shown that vegetation mass is reduced by goat browsing (Gizicki et al. 2017). However, given that goats were placed into those areas at the ENWR site where MFR density appeared to be greatest when the management effort began, this is not surprising. Our study was conducted after the management operation was initiated. Despite selecting control plots that we thought visually resembled the treated plots, our reference plots had a lower stem density than the browsed treatment plots. We had not been expecting stem density to be reduced during the single summer of treatment, however, because goats do not remove the entire stem while browsing, but rather eat the conveniently accessible upper portions, leaving behind the remainder of the plant (Odo et al. 2001). Especially in the first year, complete mortality did not occur.

Even though they did not remove the entire stem, goats still hindered the plant's productivity and ability to survive by reducing stem mass and removing leaves, thus depleting the plant's stored energy and reducing photosynthetic potential. Stem height was reduced by a third or more in the browsed and browsed/herbicided treatments, attesting to the impact of browsing by goats on plant height. Not only was plant height reduced, but there was a major reduction in the proportion of photosynthetic tissue on remaining stems. Goats selectively consume vegetation that is soft and within their reach (Hart 2001), thus leaves and the soft upper portions of stems were

the primary tissues that were browsed. Stems that remained in the browsed plots were generally less than 50 cm tall, and constituted the lower, thicker portions of the stems that had fewer leaves. Loss of leaves will result in reduced photosynthesis, and the plants will gradually weaken after a few seasons of leaf removal (Meyer 2002). Similar reductions in productivity due to browsing have been noted in studies of white-tail deer, where chronic browsing of terminal buds on young tree saplings reduces sapling survival and can stunt growth over a tree's lifetime (Holm et al. 2013). Importantly, we also found that browsing did not spur increased new growth, as new growth mass per stem mass did not differ among treatments. Hence, in at least the first year of treatment, MFR was unable to respond to browsing by increasing the addition of new growth.

In this first year of treatment, we did not find more light at ground-level than above MFR plants among the treatments, even though browsing reduced the leaf/stem ratio. Distributions of branches and leaves within tree crowns as well as daily sunfleck frequency and intensity will all affect light variability near or at the forest floor (Chazdon 1988, Canham et al. 1990, 1994, Baldocchi and Collineau 1994), hence it is possible that more extensive and intensive light measurements would have been able to detect differences among treatments. As goats continue to remove leaves in subsequent years of treatment, we expect that more light will reach ground level, thus influencing understory vegetation diversity and productivity (Su et al. 2019, Helbeck 2020).

One concern about use of goats is their effect on non-target plant species. In a separate study at this site, the bark on a third of the mature trees were browsed to the cambium, with 9% of trees being completely girdled, thus likely to result in mortality (Hemmelgarn et al. 2020). Long-term browsing by feral goats can alter the structure, productivity, and composition of plant communities, as has been demonstrated on numerous studies on island ecosystems (e.g. Coblenz 1978, Coblenz and Van Vuren 1987, Walker 1991). In this case, however, it is important to recall that goat-browsing is intended to be of short duration. Nonetheless, it will be important to consider effects of goats on mature trees at sites where this approach is employed.

In this first summer of treatment, browsing did not reduce the density of non-MFR herbaceous plants. Even if longer-term browsing does reduce the quantity and diversity of non-MFR plants, rapid recovery of plant populations has been observed following feral goat removal (Campbell and Donlan 2005). Of course, it will be important as well to see if and how rapidly MFR regrows on the site. The cut/herbicide plots, which had the most extensive management treatment and the shortest stems, did have lower non-MFR plant density than the reference or browsed plots, perhaps caused by herbicide application. With much shorter stems, the herbicide may have had an easier time reaching ground level where non-MFR plants were located. The browsed and browsed/herbicide treatments, however, did not differ in non-MFR density, possibly due to the presence of remaining stems that reduced movement of the herbicide to ground level and prevented contact of the herbicide with non-MFR plants.

Goats did not eliminate the MFR from the site, but based on the drastically reduced stem length and lower leaf/stem ratio, we conclude that the goats altered the plants in a manner that will ultimately weaken the MFR without use of an herbicide. Clearly, additional questions remain. We emphasize that our findings represent only preliminary results following one year of treatment,

and the intention of managers at the refuge is for this to be a multi-year effort. We need to know the long-term efficacy of this management tool if it is to be adopted. Cost effectiveness is also important. Generally speaking, herbicides and application labor can be expensive, especially over large areas, but so too can operation of goats on a management site. A further limitation of this study is that the management treatments were not established as a robust experimental design. As such, our results represent findings for this one site only, and are not replicated across different areas infested with MFR. This approach clearly limits our ability to extrapolate these findings more broadly (Binkley 2008). Nonetheless, given the paucity of studies examining this management approach, our findings indicate that in areas where herbicide application may create undesired effects, goats may prove to be a suitable alternative for control of multi-flora rose.

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