Invasive Plant Management at Huguenot Flatwater

Antonia Kempe

Abstract

Invasive plants have become a wicked problem of the 21st century. Brought to areas outside of their native range by humans, they cause ecological and economic harm by disrupting ecosystem dynamics that in turn affect humans. Management methods include mechanical, chemical, and biological treatments, but each of these have their own advantages and limitations, which further adds to the complexities of invasive plant management. Units of the James River Park System in Richmond, Virginia are plagued by invasive plants, which are managed by the Invasive Plant Task Force. One of these units, Huguenot Flatwater, is overrun by invasive plants but does not have a recent written management plan. Data about the treatment methods at six other units were collected from site leaders of the Invasive Plant Task Force. Using literature research, these data were analyzed in order to create a potential management plan for six invasive plants at Huguenot Flatwater- English ivy, Chinese privet, Amur honeysuckle, Japanese honeysuckle, wintercreeper, and tree of heaven. The groundwork for a removal event at Huguenot Flatwater with volunteers from the University of Richmond was established so that a future student could implement it. Invasive plant management is a complex field full of trial and error, but the recommendations in this paper are a start.

Introduction

As humans began to globalize and spread across the world, so did plants. Intentionally or not, humans have allowed plants to establish in environments to which they are not native- an estimated 6,500 nonnative plant species have been introduced and established in U.S. ecosystems (Kerns & Guo, 2012). When these nonnative plants start to cause harm in the ecosystem and eventually negatively impact the ecosystem services provided to humans, they are classified as invasive (also referred to as alien or non-indigenous). Invasive plants can outcompete native plants for resources, affect water availability and damage the quality of soil nutrients, decrease habitat provided by native plants needed by native wildlife, and alter the frequency of wildfires (Garcia & Clusella-Trullas, 2017). Climate change also threatens to amplify the harm caused by invasive plants through the impact of rising temperature and precipitation level changes on population dynamics and species distribution, increased disturbance to ecosystems such as wildfires and hurricanes, enhanced competitiveness of some invasive plants as a result of higher CO2 levels in the atmosphere, and overall increased stress to native species and ecosystems (Breshears et al., 2005). The presence and management of invasive plants has become a truly wicked problem.

Invasive plants threaten the biodiversity of ecosystems, and biodiversity is the marker of a healthy ecosystem (Garcia & Clusella-Trullas, 2017). They can also threaten the very existence of certain native species. For example, at Lake St. Lucia in the eastern part of South Africa, Nile crocodiles lay their eggs in open sunny areas, but that area has been invaded by the alien plant *Chromolaena odorata*, or blue mistflower, which is native to the Americas. Like other reptiles, Nile crocodile eggs have a temperature-dependent sex determination. When they lay their eggs in spots shaded by blue mistflower, the soil temperature in those shaded spots is about 5-6℃ cooler than the uninvaded sunny spots. These cooler temperatures resulted in a higher female-biased sex ratio, and sometimes would prevent any embryonic development (Leslie & Spotila, 2001). This implied that without management, the blue mistflower could mean the eventual extinction of the Nile crocodile.

A well-known example of an invasive plant wreaking havoc in the United States is kudzu (*Pueraria montana*). Originally introduced in 1876 as a method of reducing soil erosion, it spread rapidly throughout southeastern U.S.; in 1953, it was taken off the list of approved plants for erosion control, and in 1997, it was officially classified as invasive on the Federal Obnoxious Weed List (Forseth & Innis, 2004). Since its introduction, it has invaded over three million hectares across the U.S. and is estimated to spread at a rate of 50,000 hectares per year. It shades out native plant species in forest understories, alters soil chemistry by fixing nitrogen in invaded soils, and decreases overall native biodiversity. Kudzu has also negatively impacted humans: forestry companies pay about $500 per hectare per year for five years to control kudzu infestations, and power companies pay up to 1.5 million dollars per year to manage kudzu and make up for power loss. The overall annual cost of managing kuzu on the U.S. economy is as much as 100 million dollars (Harron et al., 2020). When added to the damage caused by other invasive plants that have spread to that scale, the ecological and economic cost is devastating.

The management of invasive plants falls under three categories: mechanical, chemical, and biological. Mechanical treatments include hand pulling and using weed wrenches, shovels,

chainsaws, etc. to physically remove a plant in some way. Chemical treatments most often consist of two types of herbicide: glyphosate and triclopyr. Glyphosate is non-selective, meaning it kills everything it contacts, while triclopyr is selective and does not injure monocots, which are grasses and grass-like flowering plants (Sheley & Smith, 2012). Biological treatments consist of finding, testing, and releasing herbivores and pathogens to control invasive plants. Although there has been some success with biological control methods, there has also been disaster, notably the introduction of cane toads in Australia in 1935 to control cane beetles that resulted in the toads eating everything in sight and becoming highly invasive (Seastedt, 2015). Due to the controversy of biological control, management methods most often utilize mechanical and chemical treatments, which both have their advantages and disadvantages. Herbicide is very effective, but can only be applied in certain seasons when the target plant is green and growing, and runs the risk of killing native plants as well as altering soil composition. While mechanical treatments can be applied year round and do not introduce chemicals into the environment, methods such as hand pulling and using tools to dig out plants can contribute to erosion and destroy soil structure (Weidlich et al., 2020). Invasive plant management is a field littered with complexities for these reasons; the goal of removing invasive plants must be balanced with the goal of restoring native ecosystems, but matters become more complicated when those removal methods might damage native ecosystems.

Methods of invasive plant removal depend on which plants are being removed as well as the conditions of the surrounding environment. There are currently 90 invasive plant species that threaten or potentially threaten natural areas in Virginia, each with a variety of potential removal methods (VADCR Division of Natural Heritage, 2015). I aim to analyze the treatment methods used at six units of the James River Park System (JRPS) in Richmond, Virginia using literature research in order to create a potential management plan for Huguenot Flatwater, a unit of the JRPS closest to the University of Richmond. I will also lay the groundwork for an invasive plant removal event at Huguenot Flatwater with volunteers from the university so that in the future, students might be inspired to volunteer and help with the management of this unit.

Terminology

Many invasive plant removal methods go by multiple names, and some of the sources I will cite refer to these methods differently. I will use the method names listed in Table 2 and method names used in sources interchangeably, so for clarification: cut-treat is also known as cut and paint and cut-stump; goat herd management is also referred to as goat browsing, and hand removal is also called hand pulling.

Methods

Huguenot Flatwater, spanning approximately 36.4 acres, is the westernmost unit of the James River Park System (“Huguenot Woods Flatwater Study Area", 2019). It is located about 2.5 miles south of the University of Richmond and lies directly underneath the Huguenot Bridge. This unit includes a series of footpaths as well as a river access point, which visitors can use for canoeing, kayaking, and fishing. It is co-managed by the JRPS and the University of Richmond. This unit, along with the other units of the JRPS, is plagued by invasive plant species. The Invasive Plant Task Force (IPTF), an organization within the JRPS founded by the Riverine

chapter of the Virginia Master Naturalists and the Richmond Tree Stewards in 2015, heads the invasive plant management efforts in the park through partnership with other nonprofits and agencies, public awareness and education, and citizen involvement (Invasive Plant Task Force, 2019). In 2015, the Riverine chapter of the Virginia Master Naturalists led a baseline study of this site as a part of the JRPS Habitat Restoration Project. They identified which invasive plants were present across eight management units, ranked them as low, medium, or high invasiveness, and assessed the percentage of invasive plant cover for each management unit using a modified Braun-Blanquet Cover Scale (Virginia Master Naturalists, 2015).

As shown in Figure 1, there was only one management unit at Huguenot Flatwater where the invasive plant cover was as low as 5-20%; the other seven were classified as having 75-100% cover. The most prevalent species across all management units was the vine wintercreeper (*Euonymus fortunei*), which contributed to the overall high cover class values (JRPS Habitat Restoration Project, 2015). Two other dominant invasive plants were the shrubs Chinese privet (*Ligustrum sinense*) and Amur honeysuckle (*Lonicera maackii*) (Virginia Master Naturalists, 2015). In this baseline study, 19 other invasive plants were identified and treatment methods were listed, but the suggested treatment for each plant was not determined (Table 1 & 2).

Removal efforts primarily stem from volunteer groups led by the IPTF and students sent from geography, environmental studies, and biology classes from the University of Richmond once or twice a semester; however, as of November 2018, only partial sections of three management units had been treated by students and volunteers, as shown in Figure 2. Since the existing management data about Huguenot Flatwater is from seven years ago and treatment methods for individual plants were never determined, there is no written invasive plant management plan for Huguenot Flatwater. In order to create a potential plan, I used the existing data as a foundation, and I interviewed IPTF leaders from four other JRPS units (Belle Isle, Chapel Island, Texas Beach, and Buttermilk Trail) and asked the following set of questions:

- What is the most dominant plant(s) at your site?
- What treatments have you used so far? Which ones were the most effective? Did any result in unexpected problems? (e.g. hand removal sometimes resulting in trampling native vegetation)
- Have any contractors been enlisted to remove invasive plants from your site before? (e.g. RVA Goats and Honey) Were any particularly effective?
- How do you organize volunteers for removal days?
- Is there a method of gathering volunteers that works better than others?

I was given access to the IPTF Basecamp, which allowed me to collect data related to these questions for the adjacent sites Pony Pasture and the Wetlands. I also conducted literature research regarding invasive plant management strategies and removal methods. Additionally, I had planned to organize an invasive plant removal event at Huguenot Flatwater with a large group of volunteers from the University of Richmond (UR) in order to 1) remove invasive plants and 2) educate and promote awareness about the needs of Huguenot Flatwater to UR students so that they keep volunteering and keep up the consistency that is required for successful invasive

plant management (Blossey, 1999). I was limited by time, so I will instead lay the groundwork for this event so it can be picked up by another student in the future.

Results

Chapel Island (Site Leader: Joseph Walton)

The most dominant plant has been Chinese privet. Chinese privet, autumn olive (*Elaeagnus umbellata*), Japanese honeysuckle (*Lonicera japonica*), and Amur honeysuckle have been treated by using the cut and paint method with herbicide, while English ivy (*Hedera helix*), small shoots of honeysuckle, garlic mustard (*Alliaria petiolata*), small shoots of Chinese privet, Japanese hops (*Humulus japonicus*), and ground ivy (*Glechoma hederacea*) have been hand pulled. Mulching has also been used to treat Chinese privet by enlisting a contractor from Charlottesville. Herbicide has been the most effective treatment. The only unexpected problem arose after a large removal of Chinese privet that opened up the forest floor to sunlight not previously available, which caused other invasive plants to emerge in areas they had not been seen in before. Volunteers have been gathered through word of mouth and the IPTF social media, with word of mouth being the most effective recruiting method.

Texas Beach (Site Leader: Mary Wickham)

The most dominant plants were English ivy, oriental bittersweet (*Celastrus orbiculata*), Amur honeysuckle, Chinese privet, and autumn olive. All species have been treated using the cut and paint, and that has been the most effective; however, the site leader reported autumn olive to be particularly resistant to treatment. Volunteer contractors have been previously enlisted to remove Chinese privet using chainsaws and the herbicide glyphosate; consulting the Virginia Forestry and Wildlife Group was also reported to be helpful in these endeavors. There is no current volunteer work crew for this site, but using the website HandsOn was most effective in the past.

Buttermilk Trail (Site Leader: Anne Wright)

The most dominant plants have been English ivy, in addition to kudzu (*Pueraria montana*) that originates from private land across from the site. English ivy has been treated with hand pulling, which has been effective when the treated area is done thoroughly- little maintenance is required for 2-3 years. Kudzu has also been treated with hand pulling, but in the spring of 2021, cutting and painting with the herbicide triclopyr was used. The results have yet to be seen. A consequence of hand pulling to consider is the erosion of dirt if ivy is removed on a steep enough slope. Contractors have been used to saw down and chemically treat tree-of-heaven (*Ailanthus altissima*), but that was done too recently to determine if it was effective. Using HandsOn has been the most effective way of gathering volunteers.

Belle Isle (Site Leader: Catherine Farmer)

The most dominant plants have been Chinese privet, tree of heaven, Japanese honeysuckle, and English ivy. Weed wrenches were used in the past to remove Chinese privet,

but that method was abandoned because it left large holes that contributed to erosion and destroyed the soil structure. Cut and paint has been used for larger removals and smaller vines and shoots have been hand pulled. The contractors True Timber Arborists and Sawtooth Tree & Garden LLC have been used to remove large trees and shrubs with trunks too large to cut by hand. Volunteers have been most effectively gathered through HandsOn and Signup Genius for Richmond Tree Stewards.

Pony Pasture/The Wetlands

The most dominant plants have been wintercreeper, English ivy, Amur honeysuckle, Chinese privet, and garlic mustard. The "free a tree" method has been used for English ivy and wintercreeper, which involves cutting the vines girdling trees and pulling back ground cover vines at the base of the tree. Cut and paint has been used for thicker vines and Chinese privet, and hand pulling has been used for garlic mustard. Volunteers have been gathered using HandsOn.

Discussion

Of the invasive plants mentioned by site leaders, six were also listed in the existing baseline study of Huguenot Flatwater: English ivy, wintercreeper, Chinese privet, Amur honeysuckle, Japanese honeysuckle, and tree of heaven. Although there were other plants listed in the study, I will only be discussing these six because I have both data from the IPTF and literature research to support my reasoning; I would not feel confident suggesting treatments for other invasive plants based only on literature research, as factors such as soil composition, precipitation, and temperature that are specific to Richmond could influence the effectiveness of treatment methods. The following paragraphs will consist of a full analysis of treatment methods for each plant- for an abbreviated version, see Table 3 in the "Figures and Tables" section. The best way to gather volunteers across sites was listing removal events on the website HandsOn RVA, which should also be done for future events at Huguenot Flatwater.

English Ivy

JRPS sites that have dealt with English ivy have hand pulled vines from the ground and used the cut-treat and free a tree methods for ivy on trees. These methods have been successful across sites, especially when done thoroughly and consistently, so these should continue to be applied at Huguenot Flatwater. If resources allow it, seeding the soil with native seeds after hand removal is worth consideration; a study in the Piedmont region of Georgia found that the addition of native seeds in the soil after hand removal of English ivy greatly increased seedling density and diversity and promoted regeneration of native vegetation over a five month period (Biggerstaff & Beck, 2007). The study also used herbicide as a treatment, and although it was effective at removing the ivy, it significantly lowered seedling density and diversity and impeded native seed addition efforts (Biggerstaff & Beck, 2007). If this is applied, it should only be done in areas treated with hand pulling. Goat herd management has been used at Huguenot Flatwater

in the past for invasive vines and shrubs with notable success (Greenleaf, 2019). For English ivy, goat herd management has been shown to decrease cover significantly, especially when browsing is repeated in the second year, and there is minimal change in the composition of native species (Ingham & Borman, 2010). If feasible, it would be advantageous to bring the goats back, especially in the management units that have 75-100% cover, as they would make a dent in the existing cover and allow for an easier follow up with hand pulling and cut-treat.

Chinese Privet

A variety of methods have been used to remove Chinese privet at other JRPS sites- cut-treat, weed wrenches, mulching, hand pulling smaller shoots, and goat herd management. Of these treatments, I recommend cut-treat, mulching, hand pulling smaller shoots, and goat herd management. I do not recommend weed wrenches, as when they were used at Belle Isle, they left large holes that contributed to erosion and destroyed the soil structure. The cut-treat method has proven successful at other sites and also within scientific literature; a study conducted in Alabama compared the efficacy of applying the herbicides glyphosate or triclopyr after cutting, as well as comparing the efficacy of treatment when applied in the spring (April) or fall (November) (Enloe et al., 2018). Enloe et al. (2018) found that both herbicides were found to be effective at preventing regrowth in both seasons, but that privet treated in November did have a lower percentage of regrowth than the privet treated in April. This seasonal timing could be worth consideration when using the cut-treat method at Huguenot Flatwater. Chapel Island has mulched privet in the past with success, and this is reflected in scientific literature. One study compared removing privet with the cut-treat method and mulching, and found that after two years both treatments had greatly reduced privet cover without reducing non-privet shrub cover and diversity; in fact, mulching resulted in over 60% non-privet plant cover after the two years (Hanula et al., 2009). If mulching is applied at Huguenot Flatwater, it would have to be repeated for a period of time longer than two years, because repetition and consistency is what will lead to a return of native plant communities (Blossey, 1999). Goat herd management has been previously used for privet at Huguenot Flatwater, so I would once again recommend it for the future, especially for management units with 75-100% invasive plant cover.

Amur and Japanese Honeysuckle

I am including both species of *Lonicera* in this paragraph because the removal methods and the results of removal across JRPS sites and scientific literature aren't dissimilar enough to warrant separate paragraphs for each. At other sites, the cut-treat method has been used for Amur honeysuckle and Japanese honeysuckle on trees. Small shoots of Amur honeysuckle and Japanese honeysuckle on the ground are hand pulled. The success of these methods is reflected in scientific literature; one study found the cut-treat method was more effective at preventing regrowth of Amur honeysuckle than mulching after two growing seasons, and there was a notably quick return of native plants (Frank et al., 2018). Another study found that cut-treat using glyphosate effectively killed mature Japanese honeysuckle vines and eliminated most regrowth 28 months after treatment (Regehr & Frey, 2004). I recommend these methods (with seasonal repetition as needed) for Huguenot Flatwater.

Wintercreeper

Other sites of the JRPS, notably Pony Pasture/the Wetlands, have found promising results in the removal of wintercreeper through the free a tree method. Those two sites are the closest geographically to Huguenot Flatwater, which explains the overlap in their most dominant invasive plants. The free a tree method is an adaptation of the cut-treat method, which has been found to be effective in other areas of land invaded by wintercreeper (Mattingly, 2016) (Conover et al., 2017). I would recommend that this method continue to be applied, as well as hand removal of any wintercreeper on the ground. As previously mentioned, goat herd management has been used at Huguenot Flatwater to remove wintercreeper along with English ivy and Chinese privet, and again I strongly recommend the goats return to clear the dense cover of most of the management units. This will make removal efforts by the IPTF less difficult. Since the IPTF mostly relies on volunteers for removals, it is important to keep in mind that a mature wintercreeper vine looks very similar to a native mature Virginia creeper vine. Volunteers should first be educated on how to distinguish between the two so accidental damage to native vines is minimal.

Tree of Heaven

Tree of heaven is one of the dominant invasive plants at Belle Isle through sheer volume, but applying the cut-treat method has been effective for its control. Meloche & Murphy (2006) compared the effects of hand pulling & mulching, cut-treat with glyphosate, cut-treat alone, and the EZJect Capsule Injection System using glyphosate on tree of heaven and found cut-treat with glyphosate to be the most effective at the control of juvenile shoots along with minimal disturbance to soil or native plants. The EZJect system was effective at controlling mature shoots, but it is an expensive system, which limits its financial feasibility (Meloche & Murphy, 2006). The contractors True Timber Arborists and Sawtooth Tree & Garden LLC have helped to cut down and chemically treat trees too large to cut by hand at Belle Isle, which could be an option for trees of that size at Huguenot Flatwater. For trees of heaven that can be cut by hand, I recommend the cut-treat method.

Groundwork for a Removal Day

Collaboration

This could be a great joint effort with the JRPS/IPTF. Ideally a member of the IPTF like Gera Williams and/or Laura Greenleaf would be present in order to show volunteers how to perform the removal methods, as well as educate them on what the invasive plants they are removing look like and which native plants to avoid. Based on the ability and knowledge level of volunteers about invasive plant removal (which could be zero), it might be easiest to do a free a tree event focusing on English ivy and wintercreeper.

Timing

Since free a tree involves the application of herbicide, late spring or fall would be a realistic time to plan this event, which means the student heading this event should reach out to

the IPTF and/or Todd Lookingbill at the beginning of the fall or spring semester. Based on previous experience with student availability, most students would be able to attend a removal on a late Friday or Saturday morning- if the event takes two hours, any two hours within 10 am- 2 pm would likely work best.

Organizations to Include

Student clubs and organizations to include could be GreenUr, UR Sustainability Advocates, the community service fraternity APO, and Outdoors Club. The student could reach out to environmental studies, biology, and geography professors to see if they could incentivize or require their classes to take part, or at least advertise the event..

Advertising

Digitally, the student could advertise this event with a link to a Google form to sign up in SpiderBytes, the environmental studies, geography, and biology list-servs. They could also table in THC, as well as use the methods listed above. Student organizations could also help with advertising by posting on social media

Transportation

Vans can be acquired from the Center of Student Involvement and the Biology Department, but volunteers can have the option to drive themselves and others. Volunteers also have the option to walk since Huguenot Flatwater is so close.

Equipment

As this would hopefully be a joint event with the JRPS/IPTF, the student could ask for gloves, handsaws, garden shears, etc. to be provided based on volunteer numbers. The student should also encourage volunteers to wear sturdy shoes, long pants and long sleeves to prevent contact with poison ivy or ticks.

Conclusion

Invasive plant management is a complex field with a noble goal. Restoring ecosystems that have been affected by invasive plants is a long and arduous process, but it is imperative that native plants return to fulfill their ecological roles, as they provide services for both the environment and humans. After talking with the site leaders of the IPTF, it is clear that invasive plant management in the JRPS has been a process of trial and error, but consistency in removal shows promising results. Along with being an important part of the James River ecosystem, Huguenot Flatwater serves a recreational role for the city of Richmond and a potential educational role for the University of Richmond. By creating this potential management plan for some of the invasive plants at this site, I hope to spur future removal efforts and get University of Richmond students involved with a place that is worthy of restoration.

Literature Cited

About the James River Park System. (2017, June 25). Retrieved March 24, 2022, from Friends of the James River Park.

Andersen, M. C., Adams, H., Hope, B., & Powell, M. (2004). Risk Assessment for Invasive Species. *Risk Analysis*, *24*(4), 787–793.

Biggerstaff, M. S., & Beck, C. W. (2007). Effects of Method of English Ivy Removal and Seed Addition on Regeneration of Vegetation in a Southeastern Piedmont Forest. *The American Midland Naturalist*, *158*(1), 206–220.

Blossey, B. (1999). Before, During and After: The Need for Long-term Monitoring in Invasive Plant Species Management. *Biological Invasions*, *1*(2), 301–311.

Breshears, D. D., Cobb, N. S., Rich, P. M., Price, K. P., Allen, C. D., Balice, R. G., … Meyer, C. W. (2005). Regional vegetation die-off in response to global-change-type drought. *Proceedings of the National Academy of Sciences*, *102*(42), 15144–15148.

Cipollini, K., Ames, E., & Cipollini, D. (2009). Amur Honeysuckle (*Lonicera maackii*) Management Method Impacts Restoration of Understory Plants in the Presence of White-Tailed Deer (*Odocoileus virginiana*). *Invasive Plant Science and Management*, *2*(1), 45–54.

Conover, D., Geiger, D., & Sisson, T. (2017). Slowing the Spread of Wintercreeper in Wooded Natural Areas in Ohio. *The Ohio Journal of Science*, *117*(1), A8.

Ding, J., Wu, Y., Zheng, H., Fu, W., Reardon, R., & Liu, M. (2006). Assessing potential biological control of the invasive plant, tree-of-heaven, *Ailanthus altissima*. *Biocontrol Science and Technology*, *16*(6), 547–566.

Enloe, S. F., O'Sullivan, S. E., Loewenstein, N. J., Brantley, E., & Lauer, D. K. (2018). The Influence of Treatment Timing and Shrub Size on Chinese Privet (*Ligustrum sinense*) Control with Cut Stump Herbicide Treatments in the Southeastern United States. *Invasive Plant Science and Management*, *11*(1), 49–55.

Forseth, I. N., & Innis, A. F. (2004). Kudzu (*Pueraria montana*): History, Physiology, and Ecology Combine to Make a Major Ecosystem Threat. *Critical Reviews in Plant Sciences*, *23*(5), 401–413.

Frank, G. S., Saunders, M. R., & Jenkins, M. A. (2018). Short-Term Vegetation Responses to Invasive Shrub Control Techniques for Amur Honeysuckle (*Lonicera maackii* [Rupr.] Herder). *Forests*, *9*(10), 607.

Garcia, R. A., & Clusella-Trullas, S. (2017). Invasive plants have a much bigger impact than we imagine. Retrieved April 25, 2022, from The Conversation.

Greenleaf, L. (2019, October 13). Sometimes Invasive Plant Warriors Are Four-Legged. Retrieved April 25, 2022, from Invasive Plant Task Force.

Hanula, J. L., Horn, S., & Taylor, J. W. (2009). Chinese Privet (*Ligustrum sinense*) Removal and its Effect on Native Plant Communities of Riparian Forests. *Invasive Plant Science and Management*, *2*(4), 292–300.

Harron, P., Joshi, O., Edgar, C. B., Paudel, S., & Adhikari, A. (2020). Predicting Kudzu (*Pueraria montana*) spread and its economic impacts in timber industry: A case study from Oklahoma. *PLOS ONE*, *15*(3), e0229835.

Huguenot Woods Flatwater Study Area. (2019). Retrieved February 17, 2022, from James River Park System Invasive Plant Task Force.

Ingham, C. S., & Borman, M. M. (2010). English Ivy (*Hedera* spp., *Araliaceae*) Response to Goat Browsing. *Invasive Plant Science and Management*, *3*(2), 178–181.

James, J. J., Smith, B. S., Vasquez, E. A., & Sheley, R. L. (2010). Principles for Ecologically Based Invasive Plant Management. *Invasive Plant Science and Management*, *3*(3), 229–239.

Kerns, B., & Guo, Q. (2012). *Climate Change and Invasive Plants in Forests and Rangelands*. US Department of Agriculture Forest Service.

Leslie, A. J., & Spotila, J. R. (2001). Alien plant threatens Nile crocodile (*Crocodylus niloticus*) breeding in Lake St. Lucia, South Africa. *Biological Conservation*, *98*(3), 347–355.

Mattingly, K. Z. (2016). Recovery of forest floor diversity after removal of the nonnative, invasive plant *Euonymus fortunei*. *The Journal of the Torrey Botanical Society*, *143*(2), 103–116.

Matzek, V., Covino, J., Funk, J. L., & Saunders, M. (2014). Closing the Knowing–Doing Gap in Invasive Plant Management: Accessibility and Interdisciplinarity of Scientific Research. *Conservation Letters*, *7*(3), 208–215.

McDonald, C. J., & McPherson, G. R. (2011). Fire behavior characteristics of buffelgrass-fueled fires and native plant community composition in invaded patches. *Journal of Arid Environments*, *75*(11), 1147–1154.

Meloche, C., & Murphy, S. D. (2006). Managing Tree-of-Heaven (*Ailanthus altissima*) in Parks and Protected Areas: A Case Study of Rondeau Provincial Park (Ontario, Canada). *Environmental Management*, *37*(6), 764–772.

Mervosh, T. L., & Gumbart, D. (2015). Cutting and Herbicide Treatments for Control of Oriental Bittersweet, Pale Swallow-Wort and Morrow's Honeysuckle. *Natural Areas Journal*, *35*(2), 256–265.

Mission and Vision. (2019). Retrieved April 24, 2022, from Invasive Plant Task Force.

Ramula, S., Knight, T. M., Burns, J. H., & Buckley, Y. M. (2008). General guidelines for invasive plant management based on comparative demography of invasive and native plant populations. *Journal of Applied Ecology*, *45*(4), 1124–1133.

Regehr, D. L., & Frey, D. R. (2004). Selective Control of Japanese Honeysuckle (*Lonicera japonica*). *Weed Technology*, *2*(2), 139–143.

Seastedt, T. R. (2015). Biological control of invasive plant species: A reassessment for the Anthropocene. *New Phytologist*, *205*(2), 490–502.

Sheley, R., James, J., Smith, B., & Vasquez, E. (2010). Applying Ecologically Based Invasive-Plant Management. *Rangeland Ecology & Management*, *63*(6), 605–613.

Sheley, R. L., & Smith, B. S. (2012). Prioritizing Invasive Plant Management Strategies. *Rangelands*, *34*(6), 11–14.

VADCR Division of Natural Heritage. (2015). Invasive Plant Species of Virginia. Retrieved April 25, 2022, from Virginia Department of Conservation and Recreation.

Weidlich, E. W. A., Flórido, F. G., Sorrini, T. B., & Brancalion, P. H. S. (2020). Controlling invasive plant species in ecological restoration: A global review. *Journal of Applied Ecology*, *57*(9), 1806–1817.

Figures and Tables

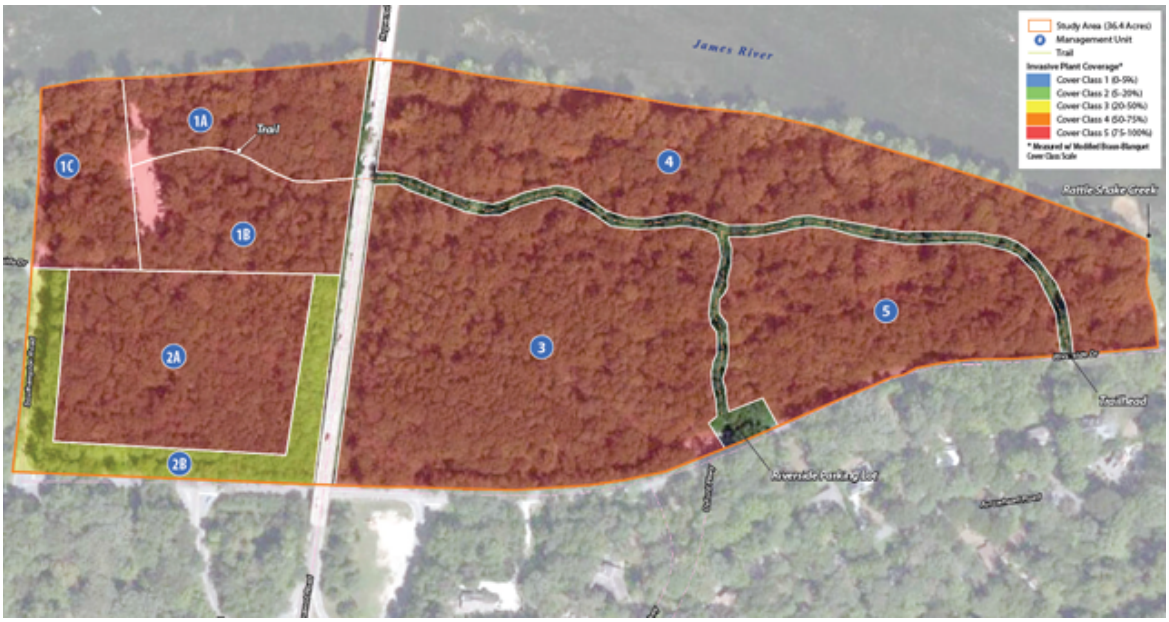

Figure 1. Management units and cover classes of Huguenot Flatwater. (Invasive Plant Task Force, 2015)

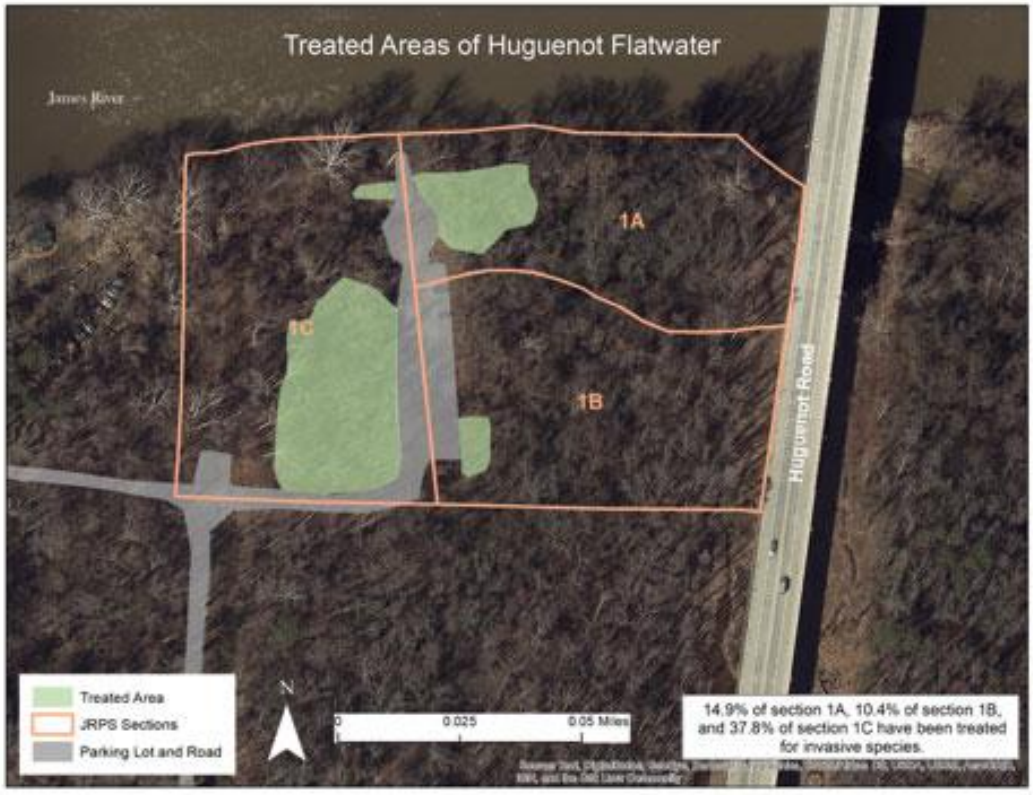

Figure 2. Treated areas of Huguenot Flatwater mapped in ArcGIS Collector (Invasive Plant Task Force, 2018).

Table 1. Identification and classification of invasive plants at Huguenot Flatwater (Virginia Master Naturalists, 2015).

Functional Guild	Scientific Name	Common Name	Family	DCR Rank*	Suggested Treatment***	Management Unit**							
						1a	1b	1c	2a	2b	3	4	5
Trees	Acer platanoides L.	Norway Maple	Aceraceae	M	na								
	Ailanthus altissima (P. Mill.) Swingle	Tree of Heaven	Simaroubaceae	H	TBD		1+	1		1		1	1
	Albizia julibrissin Durazz.	Silktree	Fabaceae	M	TBD		1			1	1		
	Melia azedarach L.	Chinaberrytree	Meliaceae	L	na								
	Morus alba L.	White Mulberry	Moraceae	L	TBD							1	
	Paulownia tomentosa (Thunb.) Sieb. & Zucc. ex Steud.	Princesstree	Scrophulariaceae	M	na								
	Pyrus calleryana Dcne.	Bradford Pear	Rosaceae	M	na								
Shrubs	Berberis thunbergii DC.	Japanese Barberry	Berberidaceae	M	na								
	Elaeagnus umbellata Thunb.	Autumn Olive	Elaeagnaceae	H	na								
	Euonymus alatus (Thunb.) Sieb.	Burningbush	Celastraceae	H	TBD		1						
	Ligustrum sinense Lour.	Chinese Privet	Oleaceae	H	TBD	2	3	2+	5-	2	2	1	
	Lonicera maackii (Rupr.) Maximowicz	Amur Honeysuckle	Brassicaceae	H	TBD	3+	4+	4	3-	1	2+	2	3
	Rosa multiflora Thunb. ex Murr.	Multiflora Rose	Rosaceae	H	TBD		1	1	2-	3		1	1
Herbs/Grasses	Alliaria petiolata (Bieb.) Cavara & Grande	Garlic Mustard	Brassicaceae	H	na								
	Centaurea stoebe L. ssp. micranthos (S.G. Gmelin ex Gugle	Spotted Knapweed	Asteraceae	H	na								
	Cirsium vulgare (Savi) Ten.	Bull Thistle	Asteraceae	M	na								
	Commelina communis L.	Asiatic dayflower	Commelinaceae	L	TBD	1	1	1		1			1
	Hydrilla verticillata (L. f.) Royle	Hydrilla	Hydrocharitaceae	H	na								
	Iris pseudacorus L.	Paleyellow Iris	Iridaceae	H	na								
	Lythrum salicaria L. var. gracilior Turcz.	Purple Loosestrife	Lythraceae	H	TBD							1	
	Lespedeza cuneata (Dum.-Cours.) G. Don	Chinese Lespedeza	Fabaceae	H	TBD	1	2	1		3	2		
	Lysimachia nummularia L.	Moneywort	Primulaceae	H	na								
	Murdannia keisak (Hassk.) Hand.-Maz.	Marsh Dewflower	Commelinaceae	H	na								
	Perilla frutescens (L.) Britt. var. crispa (Benth.) Deane	Beefstake Plant	Lamiaceae	L	TBD	1		1					
	Persicaria longiseta (de Bruyn) Moldenke	Lady's Thumb	Polygonaceae	H	na								
	Phyllostachys aurea Carr. ex A.& C. Rivière	Golden Bamboo	Poaceae	H	na								
	Reynoutria japonica Houtt.	Japansese Knotweed	Polygonaceae	M	TBD						1		
	Rumex acetosella L.	Common Sheep Sorrel	Polygonaceae	H	na								
	Rumex crispus L.	Curly Dock	Polygonaceae	M	na								
	Securigera varia (L.) Lassen	Crownvetch	Fabaceae	L	TBD						1		
	Stellaria media (L.) Vill.	Common Chickweed	Caryophyllaceae	H	na								
	Urtica dioica L.	Stinging Nettle	Urticaceae	M	TBD	2	2	2+					
	Arthraxon hispidus (Thunb.) Makino	Small Carpgrass	Poaceae	M	na								
	Microstegium vimineum (Trin.) A. Camus	Japanese Stiltgrass	Poaceae	H	TBD	1	2	1		2	2	1	2
	Sorghum halepense (L.) Pers.	Johnsongrass	Poaceae	H	na								
Vines	Ampelopsis brevipedunculata (Maxim.) Trautv.	Amur Peppervine	Vitaceae	H	na								
	Celastrus orbiculata Thunb. [orthographic variant]	Oriental Bittersweet	Celastraceae	H	na								
	Dioscorea polystachya Turczaninow	Cinnamon Vine	Poaceae	H	na								
	Euonymus fortunei (Turcz.) Hand.-Maz.	Winter Creeper	Celastraceae	M	TBD	5	5	5	5	2	5	5	5
	Glechoma hederacea L.	Ground Ivy	Lamiaceae	M	TBD		2	1+		2	2	2	2
	Hedera helix L.	English Ivy	Araliaceae	M	TBD	1	3+	2+	2	2	1	1	
	Humulus japonicus Sieb. & Zucc.	Japanese Hop	Cannabaceae	M	TBD					1			
	Lonicera japonica Thunb.	Japanese Honeysuckle	Caprifoliaceae	H	TBD		2+	2	3+	2			2
	Pueraria montana (Lour.) Merr.	Kudzu	Fabaceae	H	na								
	Vinca major L.	Bigleaf Periwinkle	Apocynaceae	L	na								
	Vinca minor L.	Common Periwingle	Apocynaceae	L	TBD						1		
	Wisteria sinensis (Sims) DC.	Chinese Wisteria	Fabaceae	M	na								

Table 2. Treatment methods listed in the baseline study of Huguenot Flatwater (Virginia Master Naturalists, 2015).

Treatment Category***	Treatment Description***
A	Hand Removal: Removal of plant material from the soil in environmentally sensitive areas.
B	Goat Herd Management: Rotating herds to remove dense cover and combo treatments.
C	Mow-Treat Method: Application of herbicide-water mixtures to cut/damaged stems or foliage.
D	Cut-Treat Method: Application of herbicide-water mixtures to freshly cut stumps.
E	Basal Spray: Applications of herbicide-oil-penetrant mixture daubed onto lower stems.
F	Stem Injection: Applications of appropriate herbicide directly into tree stems.
G	Prescribed Burning: Drip torching and other methods utilizing experienced professionals.
H	Directed Foliar Spray: Application to leaves with herbicide-water-surfactant mixture.

Table 3. Suggested treatment methods for six invasive plants at Huguenot Flatwater.

Common Name	Scientific Name	Treatments Used at Other Sites	Proposed Treatments for Huguenot Flatwater	Previous Resulting Problems to Consider
English ivy	*Hedera helix*	Hand pulling (ground)	Hand pulling (ground)	For hand pulling, erosion of dirt if ivy is on a steep enough slope.
		Survival rings (trees)	Survival rings (trees)	
		Cut-treat (trees)	Cut-treat (trees)	
		Goat herd management	Goat herd management	
Chinese privet	*Ligustrum sinense*	Cut-treat	Cut-treat	After large removals, the forest floor receives previously unavailable sunlight,which may cause other invasive plants to emerge.
		Weed wrenches	Mulching	
		Mulching	Goat herd management	
		Hand pulling (small shoots)		
		Goat herd management		
Amur honeysuckle	*Lonicera maackii*	Cut-treat	Cut-treat	None.
		Hand pulling small shoots	Hand pulling small shoots	
Japanese honeysuckle	*Lonicera japonica*	Cut-treat	Cut-treat	None.
		Hand pulling (ground)	Hand pulling (ground)	
Wintercreeper	*Euonymus fortunei*	Free a tree	Free a tree	Easy to mistake with native vines such as Virginia creeper so first-time volunteers need to be able to tell the difference.
		Cut-treat	Cut-treat	
		Goat herd management	Goat herd management	
			Hand pulling (ground)	
Tree of heaven	*Ailanthus altissima*	Cut-treat	Cut-treat	Hand pulling followed by mulching for seedlings is an option, but has the chance to disturb the soil if applied too often.