Protecting Carolinian Canada: Controlling the Spread of Tree-of-Heaven (*Ailanthus altissima*) within Rondeau Provincial Park

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Abstract

*Tree-of-Heaven (*Ailanthus altissima*) is a proliferate, non-indigenous invasive species that is threatening the integrity of the largest remaining protected Carolinian habitat in Ontario, located in Rondeau Provincial Park. Given the invasive characteristics of* A. altissima, *including sexual and asexual reproduction, prolific growth habits and allelopathic properties, this species has the capability to become a threat to restoration efforts throughout the Carolinian Zone of Canada. This project investigated management methodologies for* A. altissima *within Rondeau Provincial Park, developing efficient and effective methods of controlling the spread of this invasive species in the Carolinian Zone. Using both qualitative and quantitative approaches based on a stratified random sample, this research examined the effects of prescribed burning, as well as chemical and mechanical methods of controlling* A. altissima *within Rondeau Provincial Park. Through the examination of these methods, the further expansion of* A. altissima *within Rondeau Provincial Park has been minimized, thereby assisting with the restoration of this unique ecosystem.*

Introduction

The loss of biodiversity is heralded as one of the most critical issues facing the world today. This problem is especially evident in the rapid decline of native vegetative species in the Carolinian Zone of Southwestern Ontario. Despite the scarcity and small size of the remaining Carolinian fragments in Southern Ontario, 351 of Ontario's 542 rare plants are located in this ecological zone (Oldham, 1990). Furthermore, this region contains more nationally endangered plant species than any other life zone in Canada (Allen, 1990). However, the fantastic biodiversity of this ecozone is being jeopardised by the invasion of non-indigenous species. Tree-of-Heaven (*Ailanthus altissima*) is a proliferate, non-indigenous invasive species that is threatening the integrity of one of the largest remaining protected Carolinian habitats in Ontario, located in Rondeau Provincial Park. The implementation of

invasive species management techniques is necessary to combat the spread of such species and prevent the degradation of this rare ecozone.

Tree-of-Heaven (*Ailanthus altissima*)

Phenology of Ailanthus altissima

While a component of the success that *A. altissima* has had colonizing Rondeau Provincial Park is related to the presence of existing human-induced disturbance within the park, the phenology of *A. altissima* has greatly contributed to its invasive success. This plant is highly prolific, with an individual tree producing as many as 325 000 seeds per year (Bory and Clair-Maczulaijtys, 1980), which can produce 6000 - 7000 viable plants (Little, 1974). *A. altissima* also produces both sexually and asexually, thereby increasing its reproductive potential. *Ailanthus* grows quickly, with mature trees reaching heights of 15-20 m (Adamik, 1955), and is considered by some to be the fastest growing tree species in the northeastern United States (Petrides, 1978). It has also been identified as one of the 40 most invasive woody angiosperms from 40 different genera (Rejmanek and Richardson, 1996). The rapid growth of *A. altissima* is facilitated by the allelopathic properties possessed by *A. altissima* (see Heisey, 1990, 1991, for further information). Therefore, the phenological characteristics of *A. altissima* partially explain its invasiveness and resilience.

Ailanthus altissima at Rondeau Provincial Park

A. altissima is currently only established within the northern Development Zone within the park, but it is beginning to encroach upon the southern Nature Reserve zone. Although *A. altissima* is recognized as an important non-indigenous invasive species by The Nature Conservancy (Hoshovsky, 1999), it is not usually identified as a threat to forests (Cronk and Fuller, 1995) as it is thought to be unable to compete within a forest community (Bordeau and Laverick, 1958; Newton, 1986). However, Knapp and Canham (2000) have shown that *A. altissima* can out-compete native tree species and reach the top of the canopy. *A. altissima* is "gap-obligate" as it is able to achieve dominance in forest communities in this manner through a single rapid release period facilitated by gaps in the canopy (Knapp and Canham, 2000). Kowarik (1995) also reports that *A. altissima* root shoots demonstrate "gap-facilitative" properties, and they are able to survive for many years under an intact canopy. *A. altissima* is able to utilize these characteristics within Rondeau due to severe windstorm that occurred on July 24, 1998, which created numerous large canopy gaps within previously closed canopy areas (Larson and Waldron, 2000), creating ideal openings for non-indigenous plant invasions. Therefore, given *A. altissima*'s ability to not only invade and establish itself within disturbed habitats, but also to persevere in established woodlands, it poses a major threat to the integrity of the Carolinian community at Rondeau.

Methodology

Site Location

Rondeau Provincial Park is located in the Western basin of Lake Erie, 40 km southeast of the city of Chatham, in Kent County (Figure 1), in the Carolinian Zone of Southwestern Ontario. Rondeau was officially established as a provincial park in 1894 (OMNR, 1991) and is the second oldest provincial park in Ontario. Classified as a Natural Environment park in recognition of the provincially significant landforms, flora and fauna located in the park, Rondeau has 3254 ha of marsh, dune, savannah and woodland habitats (OMNR, 1991). Due to this classification, the preservation of these features, and consequently, the control of invasive non-indigenous species, is paramount to Rondeau Provincial Park.

Figure 1. Location of Rondeau Provincial Park within southwestern Ontario.

Experimental Design

Three treatment methods, plus a control, were replicated factorially four times in two disjunct areas based on a stratified random block, split plot design. The plot configuration was based on a 2x2 m block size. Treatments were randomly assigned to the stratified blocks and monitoring occurred over the 2001 and 2002 field seasons.

The first treatment method that was tested was a mechanical treatment method, which entailed the manual pulling of seedlings under 30 cm, followed by an application of mulch. Two chemical treatment methods, including a Cut Stump/Herbicide application, and the EZJect Capsule Injection System were also tested. The Cut Stump/Herbicide treatment involved the complete removal of all saplings and ma-

ture *A. altissima* trees within the identified plots through the use of a motorized or hand saw, with the application of the biodegradable spot specific herbicide, Roundup Transorb®, to the exposed stumps. The EZJect Capsule Injection system treatment, which consists of a 4.5 kg, 1.5 m long aluminum lance that inserts a .22 caliber casing filled with 0.15 g of dry glycophosphate herbicide gel into the trunk of the tree (Strobl, 1999a). The lance is gravity fed and spring-loaded, such that the pressure exerted by the operator forces the capsule into the tree. This method inserts the water-soluble herbicide directly into the sap, aiding in the translocation of the herbicide and subsequently killing the tree. The effects of a prescribed burn on *A. altissima* were also investigated. The area of the prescribed burn was spatially separated from the other three treatments and a separate stratified random block design, based on 8x8 m plots was established in an area of the burn zone. Four treatment blocks were located and identified in the areas that possessed stands of *A. altissima.*

Results

Cut Stump/Herbicide and Manual Removal Treatment Results

The examination of the means of each treatment across the dates on which observations were taken revealed that the number of seedlings of Tree-of-Heaven in the treatment plots decreased steadily across the observation dates, while the number of control plots remained relatively stable (see Table 1).

The results of the analyses of variance (ANOVAR) revealed that while the Cut Stump/Herbicide and Manual Removal treatments were significantly different than the Control treatment on each of the observation dates ($f=0.000$, $p=0.05$), there was no significant difference between the Cut Stump/Herbicide and Manual Removal treatments on any of the dates, at a 0.05 level of significance.

An analysis of variance of repeated measure was performed to determine if there were variations between subject effects, indicating differences between the two plot areas. The ANOVAR results indicate that there is no significant differences between the results of the two plot areas on either date. Consequently, the results were not unduly influenced by uncontrollable environmental factors. Hence, while the results indicate that both the Manual Removal and Cut Stump Herbicide treatments were significantly different than the Control group, they were not significantly different than each other. Therefore, it is necessary to not only take into consideration the means of each treatment, but it is also necessary to examine the efficiency of the treatment methods.

Table 1. Mean data scores from manual removal, cut stump/herbicide, and control treatment data.

Date	Number of *A. altissima* plants within the plots.		
	Manual Removal	Cut Stump	Control
May 25/01	2.97		11.0
June 27/01	5.36		10.84
July 24/01		2.81	10.63
August 02/01	3.81	2.25	10.47
August 13/01	2.91	1.56	10.47
August 28/01	1.74	0.75	10.31

EZJect Capsule Injection System Treatment Results

The results of the EZJect treatment were ranked upon a scale developed by the researcher that rates the decay of the injected trees, with 0 indicating no decay and 10 indicating complete death. The results of these analyses indicated that the impact of the EZJect treatment steadily increased over time, as seen in Table 2.

Table 2. Mean data results from the EZJect Capsule Injection System treatment.

Date	Decay Rating of *A. altissima* trees	
	EXJect	Control
July 24/01	3.52	0
August 02/01	5.85	0
August 13/01	7.5	0.5
August 28/01	8.43	1
September 27/01	9.09	1.5

The results of the Friedman Test (Chi-square=74.608, Asymp. Sig.=0.000, df=4) reveal that the ranks across the dates are statistically different than each other. The mean ranks from this test increase over time, from 1.20 on July 24/01, to 2.04 on August 2/01, to 3.17 on August 13/01, to 4.07 on August 28/01, to 4.52 on September 27/01. Consequently, it can be determined that the impact of the EZJect treatment on *A. altissima* increased in significance over time.

Burn Treatment Results

The mean percent coverage of *A. altissima* underwent a steady increase across the observation period, from 6.25 – 46.25%, with the exception of May 25, during which the percent coverage decreased to 1.25%. However, despite the steady increase in grass coverage, there were no significant differences in the percent coverage over the observation dates, except for the initial date immediately following the completion of the burn (May 1, f-statistic=81.00, Sig.=0.000, df=1, 7).

In order to evaluate the efficiency of the treatment methods, it is necessary to examine the financial, personnel and temporal requirements of each treatment methods (Table 3). Due to financial constraints imposed on many parks and protected areas, the fiscal implications of management techniques must be taken into consideration in planning an active management program for invasive species. Consequently, the choice of management techniques for *A. altissima* is dependent on the various costs associated with each methodology.

Discussion

A variety of factors must be taken into consideration when determining and developing a treatment program for the control of invasive, non-indigenous species. Not only must the life history and growth characteristics of the species be considered, but also the immediate and long-term needs and resources of the protected area. Consequently, the most effective treatment method is not always equivalent to the treatment that is best suited to the situation under consideration.

Treatment Determination

The unique setting of Rondeau Provincial Park complicates the development of a management program for *A. altissima*. With its large contingent of cottage residents and recreational uses, management programs at Rondeau must appeal to all visitor profiles, including nature enthusiasts and recreational day users. However, the underlying purpose of the management plan must remain rooted in the principles of ecological restoration and ecological integrity. Financial prudence is another key component, as government funding of Ontario Parks has decreased substantially in recent years. Consequently, the development of a policy to control the spread of Tree-of-Heaven within Rondeau Provincial Park is a complicated and intricate task.

Given the number of variables that must be taken into consideration, a decision matrix has been developed to assist in ascertaining the most effective and efficient method of controlling the spread of *A. altissima* within Rondeau Provincial Park (Table 4).

The significance assigned to the factors in this matrix were adapted from the Rondeau Provincial Park Management Plan, taking into account the park's objectives, operating principles, zoning and designated uses. This matrix reveals that a combination of EZJect Capsule Injection System and Cut Stump/Herbicide treatment methods would present the best management program against *A. altissima*. A dual approach would allow managers to effectively target both mature, seed-producing trees (EZJect treatment), as well as younger, fast-growing saplings (Cut Stump/ Herbicide treatment). However, due to the high initial fees associated with the EZJect Capsule Injection System, this strategy is only efficient in situations where the EZJect will be used for multiple species, or is purchased in cooperation with other organizations. However, as Rondeau has already purchased this equipment, it is cost-effective to utilize it. In situations where the purchase of an EZJect Lance System has not been factored into the protected areas budget, the Cut/Stump Herbicide treatment would still be an effective stand-alone management program against *A. altissima*, and other invasive species with similar growth habits.

The Cut/Stump Herbicide and EZJect treatments method are favoured as a more effective and efficient treatment strategy in the control of *A. altissima* over the Manual Removal and Prescribed Burn technique based on a number of factors. While the statistical analysis revealed that there were not significant differences between the cut stump/herbicide and manual removal treatment methods, an examination of the mean number of seedlings/saplings present after the treatment across the dates indicates that the average means of the Cut Stump/Herbicide treatment (mean average = 1.84) was slightly more effective than that of the Manual Removal (mean average = 3.36). However, the decreases in seedling/sapling survival may have been a result of natural reductions in growth rate at the end of growing season. The degree to which this factor affected the results cannot be measured, but must be recognized in the analysis. Furthermore, given that the main threat posed to Rondeau is associated with the further spread of this species, it is critical that the reproductive potential is controlled.

Table 3. Efficiency Evaluation Matrix for each treatment method.

Treatment	Number of Persons Involved	Rate of Pay	Time Necessary to Complete (hours)	Equipment Necessary	Cost of Equipment	Total Cost
Manual Removal	1	1 student @ $8.50/hr	4 days x 6 hours/day = 24 hours	spade; mulch	spade = $10.00; mulch = readily available on site	$215.00
Cut Stump/Herbicide	4	3 students @ $8.50/hr 1 maintenance person @ $16.50/hr	4 hours	wick wand; herbicide; herbicide applicator's license	$20.00 for 500 ml of herbicide; $5.00 for wickwand herbicide applicator's license (including course and exam) = $280.00	$473.00
EZJect Capsule Injection System Treatment	2 (could be done by 1)	1 student @ $8.50/hr	6 hours	EZJect Capsule Injection Lance; EZJect Capsules	$800.00 for EZJect lance $700.00 for 4800 capsules	$1,550.00
Prescribed Burn Treatment	park personnel used during planning OMNR Burn Team	$16.50/hr Incidental costs only	preparation = 8 person weeks (total of planning and maintenance work) actual event = 2 days	Only direct costs not normally incurred by the Burn Team are paid by provincial parks (i.e., hotels, meals, overtime) and any consumable equipment costs	Costs paid by park for Burn team expenses / consumable equipment is approximately 25% of total cost of the burn	For a subsidized burn of up to 100 ha, the cost is approximately $10,000.00 (the cost would be higher for a non-provincial park)

Table 4. Treatment Evaluation decision matrix.

Treatment	Effectiveness (score x 7) Score: Low (1) Moderate (2) High (3)	Fulfills Rondeau Objectives (Score x 6) Objective 1 (4) Objective 2 (3) Objective 3 (2) Objective 4 (1)	Cost (score x 5) Score: Low (3) Moderate (2) High (1)	Negative impact on Cultural / Social Community? (Score x 4) Score: Low (3) Moderate (2) High (1)	Negative impact on Ecological Community? (Score x 3) Score: Low (3) Moderate (2) High (1)	Facilitates the restoration of the indigenous ecosystem? (Score x 2) Score: Low (1) Moderate (2) High (3)	Aesthetically Pleasing? (Score x 1) Score: Low (1) Moderate (2) High (3)	TOTAL
Manual Removal	1 x 7 = 7	2 x 6 = 12	3 x 5 = 15	3 x 4 =12	2 x 3 = 6	1 x 2 = 2	3 x 1 = 3	57
Cut Stump/Herbicide	3 x 7 = 21	4 x 6 = 24	2 x 5 =10	1 x 4 = 4	1 x 3 = 3	2 x 2 =4	1 x 1 =1	67
EZJect Capsule Injection System	3 x 7 = 21	4 x 6 = 24	1 x 5 =5	3 x 4 = 12	3 x 3 = 9	1 x 2 = 2	3 x 1 = 3	76
Prescribed Burn	1 x 7 = 7	4 x 6 = 24	1 x 5 =5	1 x 4 =4	3 x 3 = 9	2 x 2 =4	1 x 1 = 1	54

The EZJect Capsule Injection System is also necessary to effectively combat *A. altissima*. The EZJect system successfully controls the growth of saplings and mature trees (mean score after 2 months = 9.09), and also affects not only the treated individuals, but also clonal duplicates. However, due to the differences in measurement units, it is not possible to compare the results of the Cut Stump/Herbicide treatment to those of the EZJect treatment. Given the different life-stages that the two treatments affect, it is not necessary for the two to be mutually exclusive. It was observed that the Cut Stump/Herbicide treatment was most effective on samplings, while the EZJect treatment was most effective and efficient on mature trees. Given the cost associated with the EZJect treatment, it is necessary to use the capsules judiciously. This can be done by targeting only mature trees in areas known to reproduce clonally (i.e., large monotypic stands).

The EZJect treatment results in the rapid defoliation of *A. altissima*, thereby preventing photosynthesis and resulting in the death of the tree. However, the leaves of *Ailanthus* possess the same allelopathic properties as the bark and roots. Consequently, if immediate restoration of the area is the primary goal of the invasive species removal program, it is possible that the leaf litter could negatively impact the success of the restoration program.

Given the growth habits of this species, simply removing the young seedlings is not sufficient to control the spread of this species. While the young seedlings do produce allelopathic chemicals that can prohibit the growth of other species, this consequence is not very applicable at Rondeau Park, given that the majority of the stands of *A. altissima* are monotypic. Hence, until this species is brought under some semblance of control, the allelopathic properties of this species are nullified. Hence, the manual removal treatment is not sufficient to assist with the achievement of Rondeau's management program. Consequently, in order to prevent the further spread of this species into the Nature Reserve Zone of Rondeau, it is necessary to target mature, seed producing trees, thereby preventing the establishment of new seedlings.

Prescribed Burn Treatment Results

The results of the burn treatment allude to the importance of timing in the use of prescribed burns to combat invasive, non-indigenous species. If the primary goal of the treatment program is to encourage the growth of native species, it is preferable to perform the burn in spring, when the stored nutrients released by the burn will most benefit the newly emerging seedlings. Alternately, if the control of invasive, non-indigenous species is the underlying objective of the active management program, the prescribed burn should be implemented during the fall when the species in the targeted area are unable to regenerate enough energy to survive the winter. As the primary purpose of the prescribed burn carried out at Rondeau Provincial Park was restoration-oriented, it was implemented in early spring when

enough moisture was still present in the ground to prevent damage to the existing native species. Consequently, control of non-indigenous, invasive species was a secondary goal of the burn, and included in this research only because it was a pre-existing management decision.

Despite the effectiveness of the burn, as evidenced by the high percentage of grass regrowth in the treatment plots, the percent coverage of *A. altissima* did not decrease significantly across the observation period. While an initial decrease in percent coverage of *A. altissima* was observed immediately following the treatment, this preliminary effectiveness can be attributed to the immediate stress placed upon individuals by the fire. The success of the treatment did not, however, progress beyond the first two observation dates. By implementing the treatment in the spring, the nutrients stored in the visible plant matter were released, providing an influx of available nutrients. *A. altissima* is an opportunistic species that is able to quickly utilize available resources and rapidly optimize ideal conditions through its prolific growth habits. Hence, the prescribed burn probably served to improve the conditions of the area for *A. altissima*, accounting for the elevated growth of seedlings and saplings immediately following the burn. The gradual decrease in numbers near the end of he observation period can probably be attributed to the end of the growing season rather than the increasing effectiveness of the treatment.

The results of the treatment effectiveness are insignificant without an examination of the efficiency of the methodologies. The provincial park system is not the recipient of as much government financial support as it was previously. Consequently, less funding is available for programs such as invasive species management. Therefore, economic factors have become an integral factor in the determination of treatment options. The resources that the protected area have available for use need to be utilized and cost analysis performed on treatment options prior to management decisions being made. The efficiency analyses that were performed on each of the treatment options discussed in this research revealed that while the EZJect treatment displayed the highest start-up costs, it is a cost-effective methodology for Rondeau Provincial Park as this equipment is already a component of the park's resources. The Cut Stump/Herbicide treatment is also a fiscally responsible option, as the wickwand apparatus can be homemade and the chosen herbicide is readily available and affordable. Both of these treatments also have minimal personnel requirement, thereby reducing costs further. Conversely, both the Manual Removal and Burn treatments require large inputs of personnel for longer durations of time, thereby elevating the efficiency threshold past the effectiveness threshold, nullifying any benefits derived from effectiveness alone. Therefore, combining the EZJect treatment with the Cut Stump/Herbicide treatment will provide the most effective and efficient method of controlling the spread of *A. altissima* within Rondeau Provincial Park.

Conclusions

The resiliency of invasive, non-indigenous species requires intense active management techniques if eradication is the long-term goal of the program. While actively managing the ecosystem in a protected area is sometimes discouraged, the elimination of invasive species requires intense intervention by park managers. The public needs to be educated as to the need for invasive species management and recognize that undoing the results of human intervention often requires additional human intervention. It is sometimes necessary to use relatively severe means, such as the use of herbicides, to achieve the desired outcome. Within Rondeau Provincial Park, such measures are justified, even in the Nature Reserve Zone, given the severity of the *A. altissima* infiltration within the boundary. Furthermore, the scale of the application needs to be considered in determining a management strategy. Hence, determining a management program requires evaluating the trade-offs between the advantages and disadvantages presented by the proposal.

Controlling invasive species requires the development of a multi-tiered, multi-stakeholder, and cross-functional approach. The program should proceed in a sequential fashion, taking into consideration not only the targeted species, but also the other management goals and usage patterns of the area, as well as the climatic variability of the region. In order to assure full support for the program, all affected stakeholders should be consulted, including, but not limited to patrons, park managers, surrounding residents, and any associated non-governmental organizations. The cross functionality of the program will help to ensure that an interdisciplinary approach to invasive species control is employed, thereby drawing from the social, ecological, and scientific aspects of the issue. It is imperative that all facets of invasive species control be addressed in a management program in order to facilitate not only the immediate success of the program, but also to ensure the achievement of program goals in the future.

Limiting the scale and scope of the program also helps to ensure the accomplishment of the management goals. Implementing multiple smaller strategies over a period of time can be just as effective as a singular large-scale undertaking. In fact, staggering the onset of an invasive species restoration project can help combat the infestation, as the effectiveness of the strategy can be evaluated prior to the execution of the rest of the project, thereby saving valuable time and resources. Additionally, implementing the management program in stages may allow the program to impact any dormant growth habits of the species. Hence, it is possible to effectively and efficiently combat invasive species within the Carolinian Zone of Canada.

As Rondeau Provincial Park represents one of the last remaining examples of the vast Carolinian forests that once existed across Southern Ontario, it is crucial that the invasive non-indigenous species within the park be controlled in order to assist in the propagation of indigenous Carolinian flora. Research into the protection of the remaining remnants of Carolinian habitat through invasive non-indigenous

species control will help to ensure not only that vegetation indigenous to Southwestern Ontario is preserved, but also that the community of faunal species which rely on this habitat is also preserved. In this manner, the presence of indigenous Ontario environments will be secured for the enjoyment of future generations.

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