SUSTAINABLE LANDSCAPES: EVALUATING STRATEGIES FOR CONTROLLING AUTUMN OLIVE (*ELAEAGNUS UMBELLATA*) ON RECLAIMED SURFACE MINELAND AT *THE WILDS* CONSERVATION CENTER IN SOUTHEASTERN OHIO[1]

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Abstract: Autumn olive (*Elaeagnus umbellata)* was planted during the reclamation process to reduce erosion and improve nitrogen content of the soil. However, since its establishment, *E. umbellata* has spread prolifically and control measures are difficult. The primary objective of this case study was to evaluate the effectiveness of various control methods on eradication of *E. umbellata* in varying degrees of infestation. A two-phase case study was conducted at The Wilds conservation center in Cumberland, OH. Phase 1 began in 2007-2008 to evaluate three treatments in areas with moderate cover (15-30%) of *E. umbellata:* mechanical removal, foliar herbicide and dormant stem herbicide. Nine 200m^2 study plots were established with three replications of each treatment. Effectiveness of each treatment was evaluated in 2009 through tracking 225 individual shrubs. The foliar herbicide controlled 98% of *E. umbellata*; dormant stem herbicide achieved 71% and the mechanical treatment controlled only 15%. Statistical comparisons indicated the foliar and dormant stem herbicides were more effective (P = 0.0008) than mechanical removal. This suggests that foliar applications can be a reliable tool for control of *E. umbellata* in areas with a 15-30% density level. Based on these findings, phase 2 of this study was initiated in 2010 to evaluate removal techniques in dense shrub infestations (95-100%). Treatments included a combination of mechanical clearing then a chemical treatment of stumps to reduce re-sprouts. The fracture treatment was most effective during the second phase (63%) when compared to the cut-stump (46%) mechanical treatment (P = 0.004). Results demonstrate that a combined mechanical-chemical approach is efficient in dense infestations. Mechanical land clearing through fracture and re-sprout treatment appeared to be most effective in *E. umbellata* control and the most cost effective in dense cover; however replicated studies are needed to provide conclusive information about the fracture re-sprout treatment.

Additional Key Words: invasive species, landscape management, grassland bird habitat, native plant restoration

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Introduction

Autumn olive (*Elaeagnus umbellata*) is one of the most aggressive species within the landscape of reclaimed mine land in southeastern Ohio. Native to Eastern Asia, *E. umbellata* is a deciduous shrub up to 6 m in height with alternate silvery leaves and red fruits speckled with pale scales (Gleason and Cronquist 1991). Due to its ability to fix-nitrogen and establish on marginal soils, *E. umbellata* was among several non-native woody species utilized in re-vegetation efforts during surface mine reclamation in the early 1980's (ODNR, 1983). Since its establishment, this shrub continues to invade open pastures, thereby reducing the quality of these grasslands for obligate birds and other wildlife species. This conversion alters the function of these habitats by interrupting the open space with woody vegetation that may increase chances for nest predation (Swanson 1996). This is a specific threat to certain obligate grassland nesting species, such as Henslow's sparrow *(Ammodramus henslowii)*, which depend on open grasslands for nesting and brood rearing (Bajema et al., 2001, Ingold et al., 2009). Eradication of these invaders is difficult due to multiple reproduction strategies, profuse seed production, high germination rates, clonal behavior with vegetative root suckers and re-sprouting following mechanical treatments (Kohri et al., 2002).

Efforts to determine treatment options are under way at an innovative conservation research center in southeastern Ohio. Located on 3,700 hectares of reclaimed strip mine land, *The Wilds* is a unique preserve dedicated to advancing conservation through science, education and personal experience. The center seeks to educate the public on conservation issues while demonstrating land management techniques that increases biodiversity on a landscape scale. A central focus of the Restoration Ecology Program is to improve the health of wildlife habitats by removing invasive species and that may promote natural succession into native plant communities. This case study evaluated the effectiveness of five different treatments in multiple infestation levels within a two-phased approach. Phase 1 was conducted from 2007-2009 and included the following measures: mechanical removal alone, foliar herbicide and dormant stem herbicide in moderate infestation (15-30%). Sites with moderate infestations were chosen to represent high priority grassland bird habitat restoration areas. Phase 2 was implemented in 2010-2011 and involved: mechanical land clearing followed by stump treatment versus land clearing through fracture re-sprout treatment in dense infestation (95-100%). Sites with dense infestation were selected to represent areas for conversion to more productive landscapes. Both conditions of infestation represent sites within *The Wilds* property and may provide a similar point of reference to other reclaimed mine sites. The objective of the project was to determine the most appropriate ecological solution and cost benefit ratio to help inform land management decisions.

Methods

Study site

The study site is on a 3,700 hectare property of reclaimed coal mine land known today as *The Wilds* conservation center, located within in Muskingum County, near Cumberland, Ohio, USA (40° 11' 32" N, 81° 98' 35" W). The Ohio Department of Natural Resources permitting records show that American Electric Power began mining in the 1940's and 1950's followed by a resting period. Mining resumed in 1968 and continued throughout the property until 2001. Following mining and more than 25 years post-reclamation recovery, predominate vegetation within the grasslands is comprised of non-native species utilized in the original reclamation plantings. These species include: Kentucky Bluegrass (*P. pratensis*), Tall Fescue (*F. arundinacea*), Chinese Lespedeza (*L. cuneata*), Sweet Clover (*M. officinalis*), Birdsfoot Trefoil (*Lotus corniculatus)* and Autumn Olive (*E. umbellata*). On average, this area receives 40 cm of precipitation annually. During the 2007 and 2008 summer seasons, conditions were relatively dry to moderate drought with annual temperatures averaging 22° C during the growing season (17°, 28°, and 11° C, spring, summer and fall, respectively; National Climatic Data Center, 2009).

Phase 1: Moderate Cover Treatments (2007-2009)

Phase 1 of this study evaluated three control methods within moderate stands (15-30%) of *E. umbellata*. Nine 200m^2 study plots were established, with three replications per treatment in areas with invasive cover ranging from 15-35%. Global Positioning System (GPS) data was recorded and metal marker tags were assigned to 25 random shrubs (*E. umbellata)* per 4 hectare plot. Dormant (winter) and foliar (summer) herbicide applications were applied with a 300 gal sprayer unit using a handgun nozzle.

1) Summer foliar herbicide applications were conducted in August, 2007 using the following product concentration according to label specifications: 27.6% imazapyrisopropylamine salt (Arsenal Powerline™) at 0.12%, 60% metasulfuron methyl

(Escort XP™) at 0.01% flowable product, surfactant (Surf Plus 584 MSO™) at 0.12% and drift retardant (Mist Trol 336™) at 0.03%.

2) Fall mechanical removals were conducted in November 2007 using a John Deer 3110D backhoe to extract the aboveground plant material and the main root ball, this treatment averaged 6 hours per 4-hectare plot.

3) Winter dormant stem treatments were completed in February, 2008 using the following product concentration according to label specifications: 61.6% triclopyr: 3,5,6-trichloro-2-pyridinyloxyacetic acid,butoxyethyl ester (Garlon 4™) at 1.5 % , 27.6% isopropylamine salt of imazapyr (Stalker™) at 0.12%, 90% alkylarypolyoxethylene glycols free fatty acids (Invade 90™) at 1%, Axit Oil™ (surfactant) at 0.03% and Mist Trol 336™ (drift retardant) at 0.03%, as recommended for control of *E. umbellata*.

Phase 2: Dense Cover Treatments (2010-2011)

Phase 2 of this study compared the combined technique of mechanical land clearing using a hydraulic rotating mulch attachment followed by chemical treatment of stumps and re-sprouts at separate time intervals. Following removals, single plots were established within each treatment and 25 individual stumps (per treatment) were assigned GPS data points for evaluation of re-sprouts the following season. Plots were located within areas of dense cover with *E. umbellata*, representing 95-100% of the vegetation. Two treatments were compared:

1) The first method employed was the “cut-stump” herbicide treatment by means of removal with a GyroTracGT-25™ cutter head, which grinds the brush into mulch and leaves the stumps flush with the ground. This operation was followed with a chemical application of a 3% concentrated solution of Stalker™ and basal oil applied to the stumps in February 2010.

2) Ground fracture was the other method employed. This involved mechanical removal with use of a skid-steer driven Fecon Bullhog™ model BH74 SS armed with 30 single carbide tools on the drum head. The brush was fractured at ground level and the splintered material was left to biodegrade in September 2010. Herbicide treatment was a spot treatment of re-sprouts in the following season.

Data Collection and Analysis

Treatments within phase 1 of this study were evaluated for effectiveness in 2009 through tracking 225 individual shrubs. Within these three treatments, analysis was based on average total mortality among the 25 individuals tracked per treatment. At the end of the 2011 growing season, the second phase of the two mechanical land clearing treatments were evaluated based on re-sprout incidence among the 25 individuals tracked per treatment.

To determine differences in % mortality among treatments used under phase 1 (foliar herbicide, dormant stem herbicide, and mechanical control with backhoe), an AVOVA followed by Tukey's HSD post hoc was used. Differences were considered significant when $p \leq 0.05$ according to the F test. An independent sample t-test was used to determine differences during phase 2 between the fracture treatment and the "cut-stump" mechanical treatment. Log(n + 1) transformations used to control for unequal variance. All statistical analyses were performed using JMP software (8.0, SAS Institute, Cary NC, USA).

Results and Discussion

The foliar herbicide application resulted in 98% mortality of *E. umbellata*; dormant stem herbicide application caused 71% mortality and mechanical control with backhoe alone yielded 15% mortality. Statistical comparisons indicated the foliar herbicide and dormant stem herbicide was more effective than mechanical removal alone (df = 2, F = 28.86, P = 0.0008; Table 1). Results of phase 2 show that both land clearing methods were moderately effective at removing the aboveground cover of *E. umbellata* shrubs in dense cover. The fracture treatment was most effective during the second phase (63%) when compared to the "cut-stump" (46%) mechanical treatment (t (1) = 3.06, P = 0.004).

E. umbellata is extremely difficult to eradicate on a landscape scale, though some control is possible. The level of re-sprout incidence varied among all five treatments and follow-up control is likely needed to achieve total mortality. Mortality is defined as achieving complete removal of shrub with no re-sprouting.

In areas of moderate infestations, phase 1 results demonstrate the summer foliar herbicide application as the most effective method for achieving total mortality. However, this method is resource intensive when applied on a landscape scale or in dense cover, requiring large quantities of mixed product to coat the leaf surface and causing damage to herbaceous understory, as reported with other foliar herbicides by Ohlenbusch and Ritty (1979). Winter dormant stem application was less effective than the foliar treatment, but only moderate damage to herbaceous understory was observed. A similar study by Kuhns (1986) showed that similar dormant stem applications provided satisfactory control. The foliar and dormant stem herbicide applications in phase 1 cost $741 per hectare and averaged 2 hours per hectare. As the treatment costs were equivalent, the dormant method may be most desirable in areas of sensitive habitats where off target damage is of higher concern. The mechanical backhoe treatments were completed at the cost of $167 per hectare averaging 1.5 hours per hectare. Although this treatment was the most affordable, it resulted in major soil disturbance, high re-sprout occurrence, and therefore was not an effective treatment.

Table1.Comparison of *E. umbellata* control strategies: Phase 1 (moderate cover treatments) which included mechanical, foliar and dormant stem herbicide applications. Of these, foliar and dormant stem herbicide treatments resulted in a significantly higher plant mortality (P = 0.0008). Means sharing the same letter do not differ significantly according to $\alpha = 0.05$ to Tukey's HSD. Phase 2 (dense cover) treatments resulted in significantly higher mortality from the fracture treatment (P = 0.004; indicated in bold).

Phase 1: Moderate Cover Treatment	**Equipment**	**% Mortality**
Foliar Herbicide	*Arsenal Powerline™, Escort XP™*	98[a]
Dormant Stem	*Garlon 4™, Stalker™*	71[a]
Mechanical	*John Deer 3110 D backhoe*	15[b]
Phase 2: Dense Cover Treatment	**Equipment**	**% Mortality**
Fracture	*Fecon Bullhog BH74 SS™*	**63**
Cut-Stump	*GyroTrac GT-25™, Stalker™*	46

Within dense infestations, results of land clearing techniques in phase 2 showed that both equipment types used effectively removed the above ground woody biomass of the shrubs, improved site access for managers and reduced the quantity of herbicide applied. The cut-stump method of mechanical land clearing combined with direct herbicide application was completed at a rate of $1,166 per hectare within 6.5 hours per hectare. The initial cost of this method was the most expensive in comparison of the treatments within dense cover and may require additional costs for spot treatments. The fracture method of mechanical land clearing was completed at the cost of $300 per hectare within 1.25 hours per hectare. The cost of this treatment may be less than the cut-stump treatment, though overall costs are dependent on incidence of re-sprout treatment at approximately $50 per hour. Both mechanical land clearing techniques may yield variable re-sprout incidence based on site conditions and require follow up control (See Table 2).

Table 2. Cost, time and laborer comparison of various *Elaeagnus umbellata* treatment methods.

Treatment	**Foliar herbicide**	**Dormant stem**	**Mechanical**	**Cut-stump herbicide**	**Fracture***
Cost / hectare	$741	$741	$167	$1,166	$300*
Time / hectare	2 hrs	2 hrs	1.5 hrs	6.5 hrs	1.25 hrs
Laborer / hectare	2	2	1	2	1
% Cover Pre- treatment	15-30%	15-30%	15-30%	95-100%	95-100%

**Note: Fracture re-sprout treatment is variable and requires an additional cost of $50 per hour, as needed.*

Our hypothesis was that the cut-stump treatment would provide the most effective re-sprout control method; however, the cut-stump treatment was less effective than the fracture method as stated earlier. Possible factors increasing cut-stump re-sprout incidence may have been the resulting smooth surface, which effectively pruned the shrub at ground level and stimulated re-sprout growth. Conversely, the fracture method resulted in a damaged and coarse stump surface, which may have induced stress or inhibited vegetative recovery. In order to determine whether the fracture treatment is truly more effective at reducing re-sprouting than the cut-stump treatment, further replicated studies are needed.

Based on post-treatment observations, all techniques likely require continual management. Since each technique resulted in a degree of soil disturbance, this facilitated secondary invasions of other non-native species. In order to reduce this effect, plans for *E. umbellata* removal should include re-vegetation strategy for the disturbed area. By using hardy seed native to the US, vegetation is more likely to be well-adapted and provide appropriate wildlife habitat (Dasher 2003) (See Table 3).

Table 3. Recommendations for reseeding hardy US native species to improve wildlife habitat value and diversity following invasive species removal in reclaimed mine lands.

Grass	*Andropogon gerardii*	Big Bluestem
Forb	*Asclepias syriaca*	Common Milkweed
Forb	*Bidens cernua*	Bidens
Forb	*Helianthus maximiliani*	Maximilian Sunflower
Forb	*Monarda fistulosa*	Wild Bergamot
Grass	*Panicum virgatum*	Switchgrass
Forb	*Pycnanthemum virginianum*	Virginia Mountainmint
Forb	*Ratibida pinnata*	Yellow Coneflower
Forb	*Rudbeckia hirta*	Blackeyed Susan
Forb	*Rudbeckia laciniata*	Cutleaf Coneflower
Forb	*Rudbeckia subtomentosa*	Sweet Coneflower
Forb	*Rudbeckia triloba*	Browneyed Susan
Grass	*Sorghastrum nutans*	Indiangrass
Forb	*Symphyotrichum ericoides*	White Heath Aster
Forb	*Symphyotrichum laeve*	Smooth Blue Aster
Forb	*Symphyotrichum novae-angliae*	New England Aster

Recommendations for Restoration

This case study provided effective and cost-efficient treatment options for management of *E. umbellata* infestations while demonstrating the need for preemptive re-vegetation strategies on newly disturbed sites. In order to create sustainable landscapes and reduce secondary invasions by non-native species, restoration plans should include methods for planting native species that benefit local wildlife and increase biodiversity. Management priorities will likely be based on expense, treatment timeline and the resources available to meet the goals of the restoration plan. When managed for long term conversion to more productive cover, reclaimed mine lands provide tremendous potential to serve as healthy habitat corridors.

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