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Case Studies

English Ivy (*Hedera* spp., Araliaceae) Response to Goat Browsing

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English ivy is an exotic liana that invades forests by forming dense monocultures on forest floors and by climbing trees. In this study, we evaluated the effectiveness of high-intensity–short-duration goat browsing to control English ivy in the Willamette Valley of Oregon. Species composition and percent cover were determined in August 2006 before the first browsing treatment and before and after treatments in 2006 and 2007. A final assessment was made in July 2008. Browsing effects were evaluated by comparison of multiple means statistical methods. English ivy cover declined significantly in samples browsed once or twice compared with untreated samples. The difference between levels of browsing was also significant, indicating that repetition of browsing for a second year is effective. Species composition change was minimal, with the appearance of sword fern and removal of Himalayan blackberry from 2006 to 2008.

Nomenclature: English ivy, *Hedera* spp., goats, Himalayan blackberry, *Rubus armeniacus* Focke, RUBDI.

Key words: English ivy, high-intensity–short-duration browsing, old field plant community, mixed conifer–broadleaf tree canopy, invasive plant control.

English ivy (*Hedera* spp.), a temperate liana native to Eurasia, was introduced to North America in the colonial era. It is now naturalized in the eastern and western United States (Reichard 2007). Invasion of forest fragments and disturbed forests by English ivy is problematic in the Mid-Atlantic and Pacific Northwest of the United States (Randall 1996), as well as in Europe (Butaye et al. 2001; Laskurain et al. 2004). Recent sampling of invasive populations in British Columbia, Washington, and Oregon revealed that 83% of 58 populations were actually *Hedera hibernica* (Kirchner) Bean rather than *Hedera helix* (Clarke et al. 2006). In Oregon, English ivy is a B-list noxious weed (ODA Plant Division 2008) due to its ecological and economic impact west of the Cascade Mountains. The specific epithet of the species at this study site was not confirmed and is thus referred to as English ivy herein.

New source populations of English ivy arise from bird endozoochory (Butaye et al. 2001). In southern Spain, 98% of emergent seedlings survived to 6 mo, and 96% of those survived to 1 yr (Laskurain et al. 2004). High seed survival and seedling establishment were attributed to the heavier weight of English ivy seeds compared with native species, as well as drought and shade tolerance (Laskurain et al. 2004). Zotz et al. (2006) assert that ivy suppresses regeneration of native herbs and tree seedlings. Forest patches with a history of logging and plantation where English ivy is present had significant ($0.001 \leq P \leq 0.01$) reductions in species richness (Butaye et al. 2001).

Control methods for English ivy include herbicide application, mechanical removal, and livestock browsing. In trials of dicamba, glyphosate, glycine, triclopyr amine, acetic acid, and 2,4-D amine, only glyphosate reduced new shoot growth (Derr 1993). English ivy was tolerant of pre-emergent herbicides (Derr 1992). Spring application of glyphosate at a rate of 3.1 kg ha^{-1} (2.7 lb ac^{-1}) controlled the juvenile growth form (Reichard 2007). However, spring rainfall is usually high in the Pacific Northwest, and desirable herbaceous plants are also vulnerable. The waxy leaves of English ivy challenge the use of herbicides, but Soll (2005) found that addition of surfactant aided penetration. A much higher rate of glyphosate, at 4.5 kg ha^{-1} (4 lb ac^{-1}), and two applications were needed to control vines (Soll 2005).

Although chemical control methods are used, their use is not practical at some locations due to the susceptibility of desirable species and public sensitivity to the use of herbicides. In these locations, hand-pulling is commonly employed. In 1999, more than 55,000 h of labor were

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Interpretive Summary

The development of methods for the control of English ivy (*Hedera helix*) is a critical need for managers of parks and open spaces in the Pacific Northwest and elsewhere. Monocultures of English ivy have reduced the value of land, and the loss of biodiversity in these areas is of scientific and aesthetic concern. The use of targeted grazing, specifically high-intensity–short-duration goat browsing, offers a new option for the toolbox of managers who seriously consider integrated pest management techniques. This research revealed that a goat herd in good nutritional status can be effective at consuming large amounts of English ivy ground cover despite the presence of the secondary plant compound hederin. One high-intensity–short-duration treatment for 1 day significantly reduced the percentage of English ivy. Repetition of this treatment in 2 consecutive yr offered even greater benefit, with a further reduction of English ivy cover to $< 5\%$ of total foliar cover. However, goat browsing alone is not sufficient to completely control the plant; seed dispersal by birds and regrowth from stolons is likely.

Additionally, this research should be repeated at other sites invaded by English ivy to determine whether plant response differs. One's scope of inference could be broadened only if site replication of the study design were undertaken.

expended to remove this plant from parks and open spaces in Portland, OR (Anonymous 2000).

The use of goat browsing to control this plant in public parks prompted the objectives of this research. Objectives included determining the efficacy of high-intensity–short-duration goat browsing for the control of juvenile, ground cover, English ivy and determining whether percent cover between plots treated once or twice was different.

Materials and Methods

Study Site and Design. The research was conducted in Memorial Park, Wilsonville, OR, where the plant community is an old field with a dense mixed conifer–broadleaf tree canopy of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), Western red cedar (*Thuja plicata* Donn ex D. Don), and bigleaf maple (*Acer macrophyllum* Pursh). Historically, this vegetation was logged and cleared for agricultural use. In 2006, English ivy was the dominant plant species at ground level. Herbaceous species in the research area included waterleaf (*Hydrophyllum tenuipes* A. Heller), western trillium (*Trillium ovatum* Pursh), stinging nettle (*Urtica dioica* L.), and sword fern (*Polystichum munitum* (Kaulf.) C. Presl). All shrubs present are members of Family *Rosaceae*, including the nonnative Himalayan blackberry (*Rubus armeniacus* Focke), and two native brambles, thimbleberry (*Rubus parviflorus* Nutt.) and trailing blackberry (*Rubus ursinus* Cham. & Schltdl.).

Rainfall averages 991 mm yr^{-1} (39 in yr^{-1}), with July being the driest month. July is also the warmest month, with average high and low temperatures of 27 C (80 F) and 12 C (53 F), respectively. December is the coldest month when average high temperatures reach 8 C (46 F) and average lows are 1 C (33 F) (National Weather Service 2008). The soils are Chehalis silt loam (USDA Soil Survey Staff 2008).

This study was initiated in the summer of 2006 as a completely randomized design (CRD) with 32, 1-m^2 samples located under forest canopy. English ivy had been removed from the trunks of some trees but no control of ground cover had been undertaken in the research area.

Browsing Treatment and Levels. Treatment consisted of browsing by experienced doe-kid pairs for 1 day during the last week of August 2006 and 2007. Does had prior experience eating English ivy. This was important because Hederin, a saponin secondary plant compound, in the English ivy can suppress intake by livestock (Cheeke 1998), whereas experience ingesting secondary compounds early in life can increase intake later in life (Distel and Provenza 1991).

Goats (400) were herded into the 500m^2 research area in the morning and kept there by temporary electric fencing until most of the English ivy plants were defoliated and the goats ceased to consume the vegetation. Behavioral indicators of satiety included animals lying down to ruminate and walking within the enclosure without browsing. Goats were not returned to this area until the following year.

Samples treated twice were browsed in 2006 and 2007. Those treated once were browsed only in 2007. Unbrowsed samples were excluded from browsing by 1.2-m (4-ft)-high wire mesh fencing for the duration of the study and served as controls, or treatment level 0. Treatments were randomly assigned to each of the 32 samples. Eleven samples were treated in 2 consecutive yr (2006 and 2007), 11 samples were treated in 1 yr (2007), and 10 samples were not browsed.

Each 1-m^2 sample was separated from other samples and walking paths by at least 75 cm to reduce the possibility of interaction between samples. Wooden stakes marked the four corners of each sample.

Percent Foliar Cover. Percent foliar cover of all plant species was estimated using a 1-m^2 quadrat frame placed at 5 to 20 cm above ground level. Pretreatment data were recorded 2 wk before treatment in August 2006 and 4 wk before treatment in 2007. Posttreatment data were recorded 2 wk after treatment in September 2006 and 2007 and again in July 2008. The last data set, from July 2008, represents re-growth over an 11-mo period from the time of the last browsing treatment.

Statistical Model and Analysis. A general linear model (GLM) was fit to the data with the primary predictor being treatment at three levels: 0, 1, and 2 yr (Figure 1). A term for baseline English ivy, $\beta\chi_{ij}$, was included because mean

$$Y_{ij} = \mu + \alpha_i + \beta\chi_{ij} + \varepsilon_{ij}$$

Y_{ij} = % change in English ivy cover from 2006 to 2008 for the *ith* treatment, *jth sample*

μ = grand mean of English ivy percent cover in 2008

α_i = effect of treatment group *i*

β = relationship between baseline % cover of English ivy and treatment

χ_{ij} = over-all mean of *H. helix* cover in 2006 prior to start of study

ε_{ij} = error term ~ normal $(0, \sigma^2)$

Figure 1. General linear model to predict English ivy response to goat browsing.

percent cover English ivy differed significantly by treatment level ($F = 9.15$, $P = 0.0002$) before the start of the study. The Tukey–Kramer adjustment for multiple comparisons was used to compare percent change among treatment levels. Analyses were performed with SAS 9.1.3 Statistical Package (SAS 2003).

Results and Discussion

High-intensity–short-duration goat browsing applied in the summer for 1 or 2 yr reduced English ivy percent cover. Samples treated for 1 yr were reduced to 23% cover and those treated for two years were reduced to 4% cover (Figure 2).

The difference between the means of samples treated once and those untreated was a reduction of 89% (CI = −1.16, −0.63; df = 2, 10; $P < 0.0001$; Table 1). Samples treated once had mean English ivy cover 22% greater than those treated twice (CI = 0.02, 0.42; df =2, 10; P = 0.029; Table 1). Samples treated twice had mean percent cover 112% less than untreated samples (CI = −1.38, −0.85; df = 2, 9; $P < 0.0001$; Table 1). The comparison

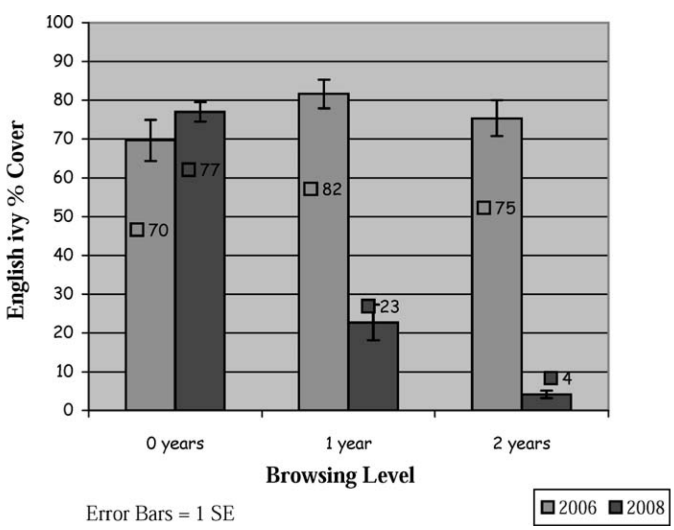

Figure 2. Mean English ivy percent cover before and after browsing treatments.

Table 1. Browsing level comparisons and confidence levels.

Browsing levels compared	Difference between means	Simultaneous confidence limits		Confidence level
1 and 0	−0.89	−1.16	−0.63	0.01
1 and 2	0.22	0.02	0.42	0.05
2 and 0	−1.12	−1.38	−0.85	0.01

of twice treated versus untreated samples has a value > 1 because of use of the correction term, $\beta\chi_{ij}$.

The success of goat browsing to control English ivy was due to several factors including plant physiology and growth rate, environmental conditions and livestock feeding preferences. English ivy grows vegetatively by producing stolons and this meristematic tissue is clearly vulnerable to the disturbance of goat browsing. English ivy does not have particularly high relative growth rates with 0.199 ± 0.019 for ground cover and 0.162 ± 0.013 for tree-climbing vines (Frey and Frick 1987). Thus, repeated removal of aboveground biomass should be an effective control strategy. Despite the relatively low rainfall before the browsing treatment in late August, the ivy would be actively growing because it tolerates low soil matric pressure under low light conditions (Sack 2004). The goats had experience with the target species and readily consumed it, despite the secondary compound hederin. Additionally, use of the goats at a time when plants are growing quickly, yet soil is relatively dry, means that plants are less subject to the indirect effects of soil compaction (Heitschmidt 1990).

The objectives were to examine the efficacy of goat browsing for control of English ivy and to examine the differences among treatment levels. Moving the plant community toward a set of more desirable, native species was also of interest. Before treatment in 2006, only three herbaceous species (waterleaf, trillium, and stinging nettle) were present in the study area. In 2008, these same species were present and only sword fern emerged as a new species. Himalayan blackberry was the only species present in 2006 that did not persist into 2008. This was likely due to goats' preference for this shrub.

English ivy is well-adapted to shade (Schnitzler and Heuzé 2006), and as long as seed and stolon propagules remain, these plants will persist and reinvade. The monoculture of English ivy at Memorial Park exists under a canopy where sunlight reaches the herbaceous layer intermittently. In summer sunlight reaches the forest floor for a few hours each day, and these conditions likely inhibit germination and emergence of other species (Radosevich et al. 2007) present in the seed bank. Removal of some trees would allow seed bank species to emerge and compete with the English ivy (Sack 2004). The absence of allelopathy from English ivy (Biggerstaff and Beck 2006) bodes well for restoration where other species can grow. Continued monitoring would reveal the extent to which active restoration, including the transplantation of desired plants, is needed to meet land manager goals.

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