To Burn Or Not To Burn Oriental Bittersweet:

A Fire Manager's Conundrum

Final Report

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Abstract: Oriental bittersweet (*Celastrus orbiculatus*) is an introduced liana (woody vine) that has invaded much of the Eastern United States and is expanding west into the Great Plains. In forests, it can girdle and damage canopy trees. At Indiana Dunes, we have discovered that it is invading non-forested dune habitats as well. Anecdotal evidence suggests that fire might facilitate its spread, but the relationship between fire and this aggressive invader is poorly understood. We investigated four areas important to fire management of oriental bittersweet, each of which we will briefly summarize here.

1) What fire temperatures cause seed mortality? For seeds, temperatures above 140°C for three minute or more kills the embryo. For fruits, temperatures above 140°C kill the seeds inside after five minutes. While oriental bittersweet fruits ripen in October and November, the seeds are not dispersed until later in the early to mid December. Thus fall fires will not have any impact on the seeds unless perhaps if they are near the ground. Late winter and early spring fires are likely to kill seeds in the top litter at least. Thus spring fire can reduce the pool of seeds available to germinate.

2) Does fire modify habitat susceptibility to invasion? We found that post fire environment had no effect on the emergence and survival of oriental bittersweet, except that the tallest plants, after two years since sowing, were in the control plots. Highest establishment occurred in mesic silt loam prairie and oak forest. Survival was greatest in mesic prairie and greatest biomass occurred in the oak forest.

3) Both fire and cutting can cause oriental bittersweet to resprout and root sucker. Does the resprouting response differ between these two treatments and can a combination of cutting and pre- or post-fire treatment facilitate its removal? Cutting sometimes increased stem density between one and two times, but burning increased density by two or more times depending on the maximum fire temperature and duration. Cutting in early July reduced total nonstructural carbohydrates by 50% from normal July levels and 75% below dormant season levels. Thus burning established populations will only serve to increase their local density.

4) How does oriental bittersweet abundance vary with fire regime and can we predict the abundance of this species in a fire mosaic landscape based on fire return interval and time since last fire? At the landscape scale, we can predict the presence and abundance of oriental bittersweet, but have less success predicting its cover and distribution. The presence of oriental bittersweet was significantly negatively influenced by canopy closure, burn frequency, and distance to roads and railroads. In plots where *C. orbiculatus* was present, abundance was significantly greater in plots with low to moderate burn frequency, and marginally ($p = 0.056$) lower in plots with greater canopy cover. Both cover and distribution of C. orbiculatus was not significantly affected by the measured variables. These results suggest the frequent fire may be effective in preventing the establishment of oriental bittersweet.

Background and purpose: Oriental bittersweet (*Celastrus orbiculatus)* is an exotic liana (woody vine) introduced from Asia as a horticultural plant into the northeastern United States in the 1860s. It is present in many habitats, including open dry foredunes, forest understories, oak savannas, "edge" habitats, and eastern deciduous forests (Pavlovic and Young, pers. obs.). This species continues to spread westward from the east coast of the US, and now can be found from Maine to Georgia and west to Minnesota, Iowa, Arkansas, and Missouri. Oriental bittersweet is of great concern to land managers because of its ability to completely blanket the vegetation that it uses as support for climbing, to overtop neighboring vegetation, to girdle trees, weigh down tree limbs resulting in wind and ice damage, and to alter successional trajectories (Fike and Niering 1999). Vine diameters can reach as much as 18 cm after reaching canopy tree crowns (Leicht-Young et al. 2007). This species is particularly threatening because of its ability to invade high quality habitats and mature forests with low light levels at the ground layer (Leicht-Young et al. 2007, Leicht-Young and Pavlovic, pers. obs). Land managers at places such as Indiana Dunes National Lakeshore (INDU) are trying to curtail oriental bittersweet before it becomes completely dominant as it has in much of the northeastern and mid-Atlantic regions of the United States, and to slow its westward expansion (McNab and Loftis 2002). The unknown effect of fire on oriental bittersweet adds another layer of complexity to an already challenging species to manage.

There have been few published studies examining the effects of fire on invasive non-native plant species in the Eastern US (Richburg et al. 2004, Dibble et al. 2007, Glasgow and Matlack 2007). Most studies on fire in this region focus on the response of native species to fire (Elliott et al. 1999). Glasgow and Matlack (2007) made the observation that since many native species experience increased recruitment and growth in response to fire, there is no reason to believe that non-native invasive species would not respond in the same way.

Fire can promote recruitment of seedlings by removal of litter (Glasgow and Matlack 2007), enhancement of nutrients, and a decrease in canopy cover (Elliott et al. 1999). Previous research has shown that fire can increase germination of Japanese stiltgrass (*Microstegium vimineum)* and multiflora rose (*Rosa multiflora)* in Eastern forests (Glasgow and Matlack 2007). Oriental bittersweet seeds require cold stratification for germination, but little is known about fire temperature effects on these seeds. While Leicht-Young et al. (2007) demonstrated that oriental bittersweet seedlings can survive and grow under a broad range of light levels, establishment from seeds across gradients in light and soil chemistry have not been examined. Whether fire creates groundlayer light and soil conditions that increase the susceptibility of habitats to bittersweet establishment is unknown as well. Therefore we propose to examine burning and post fire effects on the germination, establishment and growth of oriental bittersweet.

Fire may also enhance the spread of oriental bittersweet by causing plants to sprout from root crowns, root fragments, and runners (Howard 2005). While prescribed fire is limited to sandy regions of

the Northeast and mid-Atlantic region, it is a prevalent management tool for habitat restoration in the Midwest, Great Lakes region, and Southeast. This presents a potential conflict between using fire as a community restoration tool and promoting the spread of oriental bittersweet. Howard (2005) states "there is no literature suggesting that fire can be used as a management tool to control oriental bittersweet…However, wildfire that removes much of oriental bittersweet's aboveground biomass may provide opportunities for other control measures." While sprouting in shrubs has been studied (Richburg et al. 2004, Gurvich et al. 2005), sprouting of lianas such as oriental bittersweet has been little documented except in tropical forests. Understanding how to manage lianas in a more general sense is of increasing importance as researchers report that lianas are increasing worldwide (Wright et al. 2004). Gerwing (2001) found that lianas in the Amazon have significant effects on tree growth and that cutting was more effective in reducing liana impact than burning. Bebawi and Campbell (2002) determined that the season of fire had differing effects on mortality of the invasive rubber vine (*Cryptostegia grandiflora*) in Australia. Both studies showed that lianas of different size classes experienced different levels of mortality when burned. Quantifying oriental bittersweet resprouting ability at both the population and individual levels and determining which combinations of cutting and season of fire are most effective for its control are critical for resource managers if they are to curtail the spread of this species.

Interest in sprouting, as an ecologically and evolutionarily important trait, has increased with the recognition that this trait may be an additional characteristic for understanding vegetation structure, function, and dynamics (Bond and Midgley 2001). After top killing, resprouting in plants occurs from the root crown, root caudex or roots. Research has shown that total nonstructural carbohydrates (TNC) in roots influences seasonal resprout growth rate and that burning when TNC reserves are low can increase mortality (Richburg et al. 2004, Gurvich et al. 2005). Thus, we will investigate the influence of fire on resprouting ability and on TNC by examining how these two factors may influence post-fire regeneration of oriental bittersweet. We hypothesize that growing season burns (June) will have a greater negative effect on Oriental bittersweet than dormant season burns. Since soil productivity influences resprouting in woody plants (Iwasa and Kubo 1997), we will investigate how soil productivity influences oriental bittersweet resprouting.

The spread of oriental bittersweet even further west than its current distribution is likely because of its wide light and moisture tolerances, including an ability to grow in very dry conditions (Leicht-Young et al. 2007) and because of long-distance seed dispersal by birds. Finally, when one examines the native range of oriental bittersweet in China, it has not yet reached the same latitudinal extent in the United States (Zheng et al. 2004). Landscape scale models have predicted oriental bittersweet occurrence based on land use history and strength of association between correlated environmental and habitat variables. In the Appalachian Mountains, mesic forests tended to be invaded (McNab and Loftis 2002),

whereas upland flats were more invaded in southern Illinois (Pande et al. 2007). Neither of these studies, however, examined how past and current fire regimes may influence oriental bittersweet distribution on the landscape. Studies on other non-native invasive species have used fire regime as an explanatory variable. Floyd (2006) showed that depending on the habitat and soil characteristics, a location could be more prone to invasion after burning than if had not burned. We propose to model the relationship among fire regime, habitat and soil, and oriental bittersweet distribution. As a result of the lack of systematically collected data on oriental bittersweet, our research will make a major contribution to the problem of invasive non-native plant species in the Eastern US.

Study description and location: We hypothesize that fire is an important facilitator of the spread and growth of oriental bittersweet on the landscape. We will test this general hypothesis on oriental bittersweet life history stages at scales up to the landscape level. More specifically, in our study we propose to:

1. Examine fire effects on the different life stages of oriental bittersweet, and determine how fire modifies the susceptibility of habitats to invasion by oriental bittersweet.
2. Quantify the rate of oriental bittersweet resprouting caused by fire compared to cutting to determine whether fire response is equivalent and whether both in combination can reduce reserves.
3. Determine if growing season cutting or burning are more effective at controlling bittersweet when root reserves may be low compared to cutting or burning during the dormant season.
4. Model for the first time the presence and abundance of oriental bittersweet in a fire mosaic landscape.

From this project we will be able to identify the positive and negative interactions of fire with bittersweet life history and how that may translate into its distribution on the landscape.
The information derived from our proposed research will determine:

1. If fire affects recruitment of oriental bittersweet from seed
2. If fire affects the growth rate of oriental bittersweet
3. If pre-fire cutting or fire seasonality can reduce the positive response of oriental bittersweet to fire
4. If past and current fire history influences the current distribution of oriental bittersweet on the landscape

The Indiana Dunes National Lakeshore (INDU) is a 6,000 hectare natural area at the southern tip of Lake Michigan, known for its high native biological diversity. INDU is a mosaic of upland and wetland vegetation across a dune to wetland to glacial moraine landscape with soils ranging from sands of low productivity to rich morainal clay soils. The dominant oak savanna-woodland complex is largely fire

dependent, but large portions have tracts that have experienced decades of fire suppression. Research burns commenced in 1986 and prescribed management burns have increased in frequency and coverage since 1992. Fire history of the park is known for the 20th century from tree core analysis fire histories with complete fire maps for 25 years commencing in 1982 (Henderson and Long 1984). While present in the landscape for at least 40 years (Pavlovic, pers. obs.), the highly invasive oriental bittersweet is currently beyond the lag phase of invasion and is invading all units of the park. Therefore, the period of invasion matches the period for which detailed fire records are available allowing us to model possible effects of fire history on oriental bittersweet distribution.

Key findings:

Fire effects on seeds and fruit

We subjected fruit and seed of oriental bittersweet to dry and wet heat to simulate the impacts of fire on this lifestage. When dry heat was applied, seeds became a 100% invariable at 140 C after three minutes. Seed in fruit became inviable after five minutes at 140 C. The greater the volume of boiling water the higher was the exposure temperature of the seeds and fruit and the longer they were exposed to high temperatures. After exposure to 100 ml of hot water greater than 85°C, seeds whether in fruits or separate were completely killed.

The influence of fire on subsequent germination, survival, and growth of oriental bittersweet

Fire effects on invasive species are an important aspect to land management in areas subjected to prescribed fires as well as wildfires. Fire is often used as a management tool to eliminate excess fuels and promote biodiversity of native species. The effect of fire on invasive species can be manifested in a variety of life stages. This study examined if prescribed fire makes these habitats more susceptible to invasion of oriental bittersweet by seed. Four treatments (control, litter removed, high and low intensity fire) were applied in six distinct habitat types (sand savanna/woodland, sand prairie, moraine prairie, sand oak forest, beech-maple forest, and oak-hickory forest) and germinating seedlings were tracked over two growing seasons. Treatment did not affect the germination, survival, or biomass of oriental bittersweet. Control plots with intact litter had the tallest seedlings at germination compared to the other treatments. However, habitat type did influence these responses mostly in the first growing season. The moraine prairie, beech-maple forest, and oak-hickory forests had the greatest maximum percentage of germinants, while the sand prairie and sand savanna/woodland had the lowest. The moraine prairie had significantly greater survival than the oak forest and savanna habitats. The tallest initial germination heights were in

the moraine prairie, likely because of its thick but light litter layer. Biomass was greatest in the sand oak forest. Thus, fire and litter removal did not increase the susceptibility of these habitats to germination of oriental bittersweet. These results do indicate that most eastern U.S. habitats are vulnerable to invasion of this species via seed regardless of the level of disturbance of the litter layer by fire or other sources.

Fire effects on established plants:

Cover of oriental bittersweet was reduced more on the sand dunes than on the moraine. Cover was reduced most in the summer cut and herbicide treatments compared to the control, cut, and cut and burn treatments and was also reduced more in the burn treatment compared to the control. Seedling density was reduced across the board on the moraine in the spring series. On the sand dunes, seedling density increased in the cut and burn treatments, while little change occurred at the remaining treatments. Fall treatments had no appreciable effect on seedling density. Density of the smallest size class (< 2.5 mm) increased in the burn and cut and burn treatments and summercut on sand only, compared to the rest of the control, cut and moraine summer cut. Fall treatments had a lesser effect on this size class compared to the spring series. Herbicide had a greater reduction on sand than on the moraine. Burning and cutting and burning, and cutting on the moraine significantly increased the density of these smallest stems. Overall burning and cut and burning increased the density of stems more that 100% especially on the sand sites. Increases were less on the moraine. which in part may be due to the lower maximum temperatures in the spring burns

Influence of fire history on current distribution of oriental bittersweet:

The presence of oriental bittersweet was significantly negatively influenced by canopy closure, burn frequency, and distance to roads and railroads. Thus the presence of oriental bittersweet is reduced with increasing canopy closer, increasing fire frequency, and increasing distance from human disturbance adjacent to railroads and roads. These results imply that if we restore an oak savanna from an oak woodland, by reducing canopy cover, it is likely that oriental bittersweet will arrive and survive and thus be noted as present. Presence in fire dependent habitats, if burned frequently, would be inhibited by fire's killing arriving seeds and seedlings and juvenile plants. But this is only half the story.

In plots, where oriental bittersweet was present, abundance was significantly greater i with low to moderate burn frequency, and marginally ($p = 0.056$) lower with greater canopy cover. Once bittersweet was established in a burn dominated site, infrequent fire would allow greater regrowth and thus greater cover .

The fact that cover was not predicted by fire frequency is because cover can be high when fire frequency is high due to root suckering, but it can also be high in sites without fire due to other factors such as wind throw or other disturbances. Furnessville, Learning Center, and Mineral Springs exaemplify sites where cover is high but there has not been any fire.

The local distribution of oriental bittersweet was not significantly affected by the measured variables, suggesting that local distribution would be determined by local conditions and processes rather than by landscape scale processes.

In conclusion, if fire were frequent on the order of 2 to 5? years, the invasion of oriental bittersweet might be prevented. While we do not know when juvenile plants grow lateral roots and become able to root sucker, determining the age when plants attain this ability would be important in specifically identying an optimal burn frequency to prevent invasion and lateral spread. Since most habitats that are dependent on frequent fire, these are the likely sites where oriental bittersweet would spread rampantly once established, as we have seen at the West Beach and Marquette Trail units of the Indiana Dunes.

Management implications:

Clearly managers have no option but to burn to maintain fire dependent communities; however, the presence of oriental bittersweet does present a conundrum in these contexts. Fire managers can be confident that prescribed or wildfire will kill the seeds and seedlings of oriental bittersweet when fires occur in the late winter and early spring depending upon the intensity of the fires. Since the seeds only live for one season, and there is very little to no seed bank, late summer and fall fires are less likely to impact the seed pool, because few of the current seed crop will have been dispersed. But fall fires will increase the mortality of seedlings. Thus fires can have negative impacts on the seed and seedling stages of oriental bittersweet.

The bad news is that where bittersweet is established, fire can increase the density of oriental bittersweet by top killing stems and inducing prolific resprouting and root suckering. The density of stems can be more than doubled! It is for this reason that we recommend that managers cut and stump treat with herbicide before the fire application. If the cutting is conducted in late June and early July, this will have a considerable impact on bittersweet reserves. We would expect that repeated cutting and or burning would prevent the reaccumulation of root reserves and make bittersweet more vulnerable to

additional control measures. In some isntances managers might foliar herbicide the plants, but we found that there was some secondary kill from overspray.

The life cycle model (Figure 1) illustrates the life cycle of oriental bittersweet. Arrows show transitions from one stage to another. Circular returning arrows might represent yearly transitions, but the model is not explicitly on a yearly basis. The primary vegetative response of oriental bittersweet is indicated by the central box labeled as resprouting and root suckering. Colored bars that cut across the transition arrows represent total (solid) or partial disruption of the transitions. Red indicates fire effects, orange indicates cutting, and brown indicates herbicide treatment. Arrows leading to the central vegetative response all show fire as causative factor in the conversion from a single shoot to a multiply spreading vegetative plants. This transition can be caused by other disturbances as well.an impact demonstrating the fire leads to this condition that makes control difficult. Excavation of roots of bittersweet in sand dunes demonstrated that fine roots can proliferate for dozens of meters. Bolded lines indicate management actions that might be the highest priority either because they would eliminate seed production. Cutting and herbiciding reproductive plants would be the highest priority because it would eliminate seed production.

Recent findings:

Future work needed: The results of this study have contributed to our understanding of the role that fire plays in the local expansion of oriental bittersweet and have demonstrated that cutting in late June or early July induces regrowth that reduces total non-structural carbohydrates below typical levels. This latter point illustrates a potential weak point in the species life cycle. Future work would investigate the role of multiple treatments including cutting and burning on the control of oriental bittersweet. Studies of the impacts of fire on individual plants of known ages would give us a better idea when lateral root growth occurs in the species and the rate that lateral roots can increase the spread of this species.

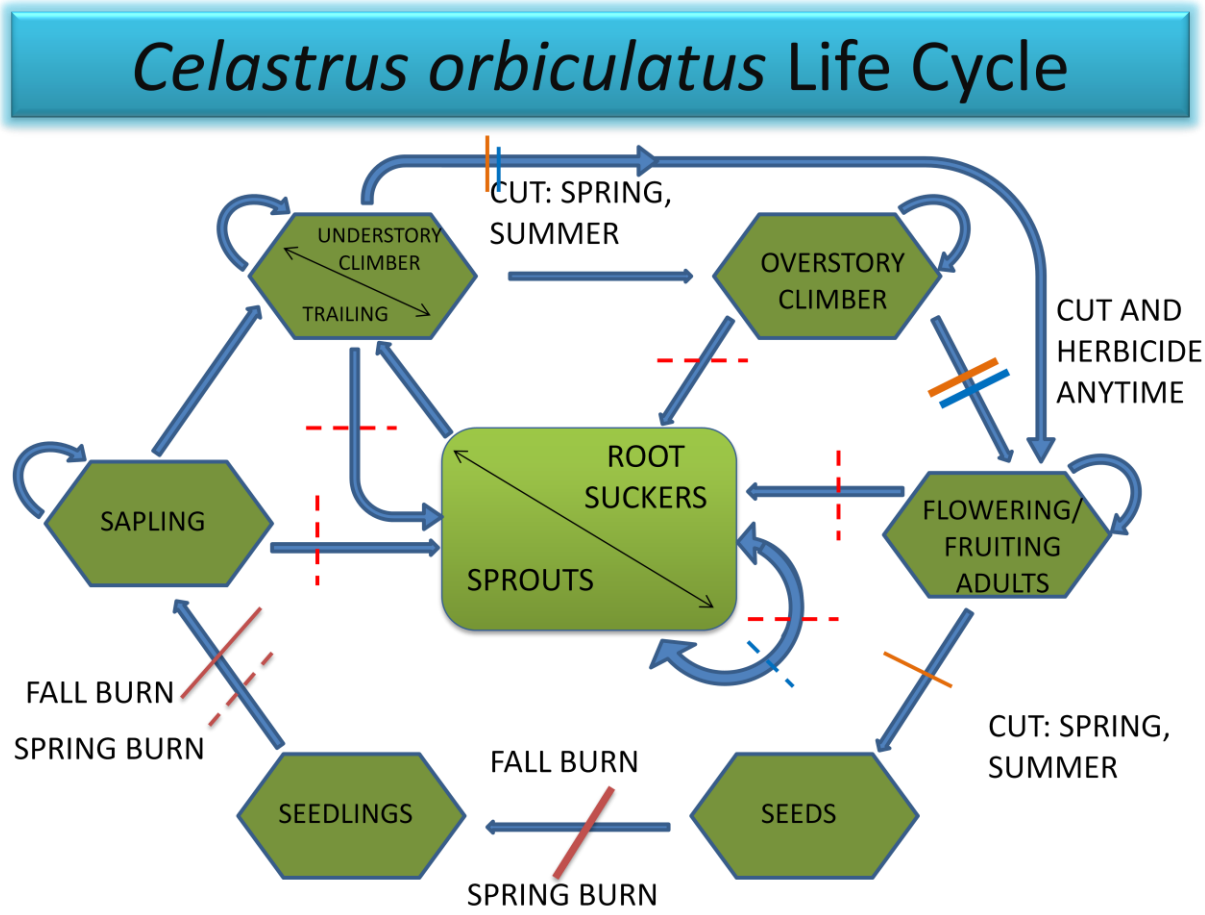

Figure 1. Diagram of the life cycle of oriental bittersweet. Colored bars across the transition arrows indicate factors that disrupt the life cycle. Disturbance including fire induces the transition to vegetative reproduction from a single stemmed vine.

Proposed	Delivered	Status
Refereed Publication	Leicht-Young, S., N. B. Pavlovic, and R. Grundel. Susceptibility of Eastern U.S. Habitats to Invasion of Oriental Bittersweet Following Fire	In review, posted on website
Refereed Publication	Pavlovic, N. B., S. Leicht-Young, and R. Grundel. Fire and cutting effects on the resprouting and growth of Oriental bittersweet	Draft in progress, posted on website
Refereed Publication	Leicht-Young, S., N. B. Pavlovic, and R. Grundel. Factors influencing the distribution and abundance of Oriental bittersweet in a fire-dominated and -suppressed landscape.	Draft in progress, posted on website
Field Demonstration/Tours	a) Education workshops for teachers b) Education workshop for high school students c) Public hike concerning fire and control	Completed
Workshop	Webinar for the Great Lake Fire Consortium	October 18, 2012
Conference Symposia	Symposium on Fire and Exotic Plant Management in the Eastern US at Ecological Society of America, It was silly to propose this before the research was complete. In addition, if I did organize the symposium, I would not be able to present our results in the symposium.	See professional presentation section (below). Will be presenting a talk "Fire effects on the highly invasive liana, oriental bittersweet (*Celastrus orbiculatus*) " at the 2012 Upper Midwest Invasive Species Conference, LaCross, WI on October 30, 2012.
JFSP Annual Conference	These were discontinued, so did not do such	Irrelevant
Non-refereed publication	USGS Fact Sheet Concerning Fire and Oriental Bittersweet: paper and web based.	Draft posted on the website
Non-refereed publication	Progress Summaries	Completed in 2009-2011
Non-refereed publication	Final Report	This document completed and posted on JFSP website
Non-refereed publication	Educational Video/DVD	60% completed, posted on website

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Professional presentations and invited talks

Pavlovic, N. B., S. Leicht-Young, and R. Grundel. 2012. Fire effects on the highly invasive liana, oriental bittersweet (*Celastrus orbiculatus*) " at the 2012 Upper Midwest Invasive Species Conference, LaCross, WI on October 30, 2012. [Invited}

Pavlovic, N. B., S. Leicht-Young, and R. Grundel. 2012. Fire effects on the resprouting and total nonstructural carbohydrates of the highly invasive oriental bittersweet. 97th Annual Meeting of the Ecological Society of America Conference, Portland, OR. August 10.

Zaya, D., S. A. Leicht-Young, N. B. Pavlovic, and M. Ashley. 2012. Asymmetric pollen flow between a native and introduced vine (Celastrus spp.). Botany 2012, Annual Meeting of the Botanical Society of America, Columbus, OH. July 2012.

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Zaya, David, Stacey A. Leicht-Young, Noel B. Pavlovic, and Mary V. Ashley. 2011. Using hand-crosses and field observations to investigate pollen flow between American bittersweet (*Celastrus scandens*) and Oriental bittersweet (*C. orbiculatus*). 96th Annual Meeting of the Ecological Society of America, Austin Texas. August 9.

Pavlovic, N. B., S. A. Leicht-Young, and D. Zaya. 2010. A tale of two bittersweets: Ecology, morphology, invasions, hybridization, control and conservation. 2010 Minnesota and Wisconsin

Invasive Species Conference, November 9, 2010, St. Paul, Minnesota. [Invited]

Leicht-Young, S. A., N. B. Pavlovic, K. J. Frohnapple, and R. Grundel. 2010. Liana habitat and host preferences in northern temperate forests. Ecological Society of America, 95th Annual Meeting, Pittsburg, PA. August 5, 2010.

Zaya D.N., Ashley M.V., Leicht-Young S.A. and Pavlovic N.B. (2010) Invasive oriental bittersweet vines (Celastrus orbiculatus) are marketed as native American bittersweet (C. scandens) by Midwestern vendors. . Illinois State Academy of Science Annual Meeting, Millikin University, Decatur, IL.

Zaya D.N., Leicht-Young S., Pavlovic N.B. and Ashley M.V. (2010) Invasion and hybridization as a potential mechanism for cryptic extinction: a bittersweet (Celastrus sp.) story. Midwest Ecology and Evolution Conference 2010, Iowa State University, Ames, IA.

Leicht-Young, S., A. M. Latimer, J. A. Silander, and N. B. Pavlovic. 2009. Density dependent responses of an invasive (Celastrus orbiculatus) and native (C. scandens) liana. Invasive Plants in the Northeast of Asia and America: Trading Problems, Trading Solutions, University of Connecticut, Storrs, CT, August 10-12.

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Pavlovic, N. B. 2008. The potential for hybridization between invasive and native bittersweets: *Celastrus orbiculatus* and *C. scandens*. Valparaiso University, Department of Biology, Biology Colloquium series, December 9, 2008. [Invited]

Posters:

Pavlovic, N., S. Leicht-Young, and R. Grundel. 2011. Fire effects on resprouting and total non-structural carbohydrates of the highly invasive oriental bittersweet. 4th Annual Fire in Eastern Oak Ecosystems Conference Springfield, MO.

Leicht-Young, S., N. Pavlovic, and R. Grundel. 2011. Post-fire susceptibility of habitats to invasion by seed of oriental bittersweet. 4th Annual Fire in Eastern Oak Ecosystems Conference Springfield, MO.

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Distinguishing Oriental (Celastrus orbiculatus) and American (C. scandens) bittersweet using morphology and genetics as tools. Invasive Plants in the Northeast of Asia and America: Trading Problems, Trading Solutions, University of Connecticut, Storrs, CT, August 10-12.

Education Workshops and Hikes

Pavlovic, N. B., S. A. Leicht-Young, D. Zaya, and S. W. Pavlovic. (2012) A Bittersweet Tale of Two Lianas, Public program at the Douglas Environmental Education Center, Indiana Dunes National Lakeshore, June 30, 2012.

Pavlovic, N. B. (2011) Nurturing Young Scientists Workshop, Bittersweet Field Trip and powerpoint presentation to high school students. July 20, 2011.

Pavlovic, N. B. and W. Smith (2010). Invasive species: A serious threat to our ecosystems. Invasive Species Educator Institute. Douglas Center, Indiana Dunes National Lakeshore. August 26, 2010.

Pavlovic, N. B. and W. Smith (2010). Invasive species: A serious threat to our ecosystems. Teachers Workshop. Douglas Center, Indiana Dunes National Lakeshore. Juluy 21. 2010.

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Undergraduate education

Fortelka, Mark. 2012. Effects of height of cutting Oriental bittersweet on the production of resprouts and root suckers. Student Independent Project, Kalamazoo College.

Kangas, Katie. 2010. Comparison between oriental bittersweet invaded and uninvaded habtats at the Indiana Dunes National Lakeshore.

Publications under review

Leicht-Young, S., N. B. Pavlovic, and R. Grundel. Susceptibility of Eastern U.S. Habitats to Invasion of Oriental Bittersweet Following Fire. Submited to Forest Ecology and Management.

Deliverables in preparation

Pavlovic, N. B., S. Leicht-Young, and R. Grundel. Fire effects on the resprouting and root suckering of oriental bittersweet.

Pavlovic, N. B., K Pitstick, C. Hoiland, and S. Leicht-Young. Educational Video: A bittersweet tale of two lianas. Final edits, and policy review.

Pavlovic, N. B., S. A. Leicht-Young, and R. Grundel. USGS Fact Sheet: Fire and Management of Oriental Bittersweet. In USGS policy review.

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