THE USE OF PRESCRIBED FIRE TO CONTROL THE SPREAD OF FOUR DOMINANT INVASIVE PLANT SPECIES IN THE GREAT LAKES REGION

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Abstract

Invasive plants are an ever increasing problem globally as they often out-compete native plants and become the dominant species in the region, disrupting the natural communities and ecological processes. In the Great Lake States region, four invasive plant species, *Centaurea maculosa*, *Alliaria petiolata*, *Rhamnus cathartica*, and *Cirsium arvense*, have established themselves as dominant members of plant communities. Prescribed fire has often been used to control invasive species while supporting the growth of native species, its effectiveness dependent on both the species' physiology and life history, and specific burn methods, such as the season of burn, and burn frequency (how often burn is repeated) and intensity (rate of heat produced by fire). The effects of prescribed fire on these four invaders is studied herein. Published scientific articles were gathered from online databases via keyword searches. The articles varied in how they measured fire's effects on the species, so any change in species abundance, population size, population density, reproductive rates, or relative percent cover (henceforth referred to simply as a change in species' population) was considered a response, and the responses of each species to fire treatments were encoded as either a decrease, or an increase or no change, depending on how they were effected. A chi -square test was performed on the data; the results from the analysis showed that the proportion of studies reporting a decrease in invasive species' populations was greater than the proportion of studies that reported no change or an increase ($P<0.05$). This suggests that prescribed fire can be used to control the spread of these species in the Great Lakes region; however, future research is needed to determine specific burn methods that are most effective for each species.

Introduction

Historically, wildfire has played a huge role in ecosystems, as fire influences, and is also influenced by, the structure of the plant community (Mandle *et al.*, 2011). While often viewed negatively (as evidenced by decades of fire suppression), fires can be quite beneficial for the health of forests.

Fire's Effects On Ecosystems:

- Renew or remove nutrients in the soil
- Remove dead brush from the forest floor
- Allow succession of new species
- Create community gaps
- alter biodiversity
- change niches and resource use
- suppress or kill some species, and benefit or sustain others (Chen, 2006).

Fire's Effects on a Species is Dependent on:

- Vegetation
- Available fuel
- Geography
- Soil type
- Climate
- Fire intensity and frequency
- Season of burn
- Phenology and
- physiology of the species

Invasive plants are a problem globally as they can out-compete native plants and become the dominant species in the region, disrupting the natural communities and ecological processes. One management option for controlling the spread of invasive species is the use of prescribed burns. However, prescribed fires are not universally successful for the control of all species, and may even cause proliferation of the undesirable invaders. **The purpose of this study was to determine whether fire is an effective tool for control of four plant species regarded by the USDA as invasive in the Great Lakes region.**

Methods

- Key word searches using the terms "fire", "burn", "prescribed", and the four focal species' scientific and common names, were conducted on a database of articles dealing with fire provided by the Lake States Fire Science Consortium. Results found only a few articles pertaining to these topics, so additional key word searches utilized Google Scholar and UW Madison online library databases.
- Articles containing primary research studies with data documenting the plant species' response to a fire treatment were utilized for data analysis.
- Because of the wide variety of methods used among the articles, the plant species' responses to fire treatments were encoded as an "increase/no change", or a "decrease" in abundance.
- A chi-square test at a significance level of $P<0.05$ was conducted on the data for all species at once, as there was not enough data to do an individual test for each species. The test addresses whether there is a significant difference, not due to random chance, in 'increase/no change" and "decrease" responses for all four species.

Invasive Species

Centaurea maculosa (Spotted Knapweed)

- Tap-rooted, flowering perennial
- Grows well on recently disturbed rangeland or grassland, and in eroded or poor soil conditions, making it a forerunner in ecosystems subject to disturbance (Lacey *et al.*, 1995)
- Can live up to 9 years, flowering each year, so it is able to proliferate quickly and yearly (Sheley *et al.*, 1998)
- Outcompetes native plant species due to high seed production, its tap root which quickly sucks up water faster than neighboring species, and an allelopathic toxin released from the roots which stunts the growth of other plants (Maddox, 1982)

Jim Story, Montana State University, www.invasive.org

Alliaria petiolata (Garlic Mustard)

- Biennial flowering plant
- Common invasive in undisturbed forest floors, but can also be found in disturbed areas such as trails and gaps in the forest (Dhillion and Anderson, 1999)
- Can reproduce by self-pollination or by crosses facilitated by insects, producing hundreds of seeds per plant (Nuzzo, 1991)
- Its high reproductive rate, multiple pollination options, and rapid second year growth enable it to outcompete native plants
- Success may be attributed to its ability to restrict mycorrhizal associations in other plants (Roberts, 1997)

http://dnr.wi.gov/invasives/fact/garlic.htm

Rhamnus cathartica (Common Buckthorn)

- Deciduous shrub
- Commonly invades oak forests as an understory shrub, and is also found in savannahs, forest openings, grasslands, rangelands, and other open or disturbed areas (Delanoy and Archibold, 2007)
- Produces many fruits, which are apt to fall not far from the parent, producing numerous individuals in an area and further crowding native species (Delanoy and Archibold, 2007)
- Its size, early leafing, and ability to retain leaves late into autumn, allow it to shade out smaller plants and dominate forest understories
- Can restrict nearby plants' growth with allelotoxins (Boudreau and Willson, 1992)
- Recognized as a severe agricultural weed as it contributes heavily to direct crop loss through competition for light, nutrients, and moisture

Purdue University Weed Ecology Lab, http://www.ppdl.purdue.edu/ppdl/weeklypics/1-31-05.html

Cirsium arvense (Canada Thistle)

- Herbaceous perennial
- Prefers areas with sunlight, moderate temperatures, and moisture, and is found to invade cropland, gardens, riparian areas, and pastures
- Competitiveness is due to high seed production and its deep, creeping root system which is able to reproduce vegetatively, creating clonal stands (Jacobs, 2006)
- Recognized as a severe agricultural weed as it contributes heavily to direct crop loss through competition for light, nutrients, and moisture

Douglas County Government, http://www.douglas.co.us/weedmanagement/Canada_Thistle.html

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Results

- 20 primary research articles with data on the species' response to fire were located via the online key word searches
- These yielded 42 treatments and associated responses

Table 1. Primary Research Article Data

Spotted Knapweed

Article	Response to Fire†
Pre- and post-burning reduces establishment of spotted knapweed seedlings (Michigan) MacDonald *et al.*, 2001	Low fuel, pre-germination- DEC Low fuel, cotyledon- DEC Low fuel, primary leaves- DEC High fuel, pre-germination- DEC High fuel, cotyledon-DEC High fuel, primary leaves- DEC
Effects of timing of prescribed fire on the demography of an invasive plant, spotted knapweed Centaurea maculosa Emery and Gross, 2005	Summer: DEC Spring: DEC Autumn: NC
Mid-Spring Burning Reduces Spotted Knapweed and Increases Native Grasses during a Michigan Experimental Grassland Establishment MacDonald *et al.*, 2007	DEC
Fire alters emergence of invasive plant species from soil surface-deposited seeds Vermeire and Rinella, 2009	Fuel load (g/m^2): 100-DEC 200-DEC 300-DEC 400-DEC 500-DEC 700-DEC

Common Buckthorn

Article	Response to Fire
Long-Term Changes in an Oak Forest's Woody Understory and Herb Layer with Repeated Burning Bowles *et al.*, 2007	Shoots < 2.5cm: DEC Shoots >(or = to) 2.5-5cm: DEC Shoots >5-10cm: slight INC
Structure and Dynamics of Midwest Oak Savannas Apfelbaum and Haney, 1987	DEC
Buckthorn Research and Control at Pipestone National Monument Boudreau and Willson, 1992	DEC
Just a few oddball species: restoration and the rediscovery of the tallgrass savanna Packard, 1988	DEC

†, DEC = a decrease, INC = an increase, NC = No change. When provided in the article, variables surrounding the treatment are listed along with the responses.

Garlic Mustard

Article	Response to Fire
Long-Term Changes in an Oak Forest's Woody Understory and Herb Layer with Repeated Burning Bowles *et al.*, 2007	INC
Experimental Control of Garlic Mustard in Northern Illinois Using Fire, Herbicide, and Cutting Nuzzo, 1991	DEC
Repeated prescribed burning at Dinsmore Woods State Nature Preserve (Kentucky, USA): responses of the understory community Luken and Shea, 2000	INC
Effects of prescribed fire on degraded forest vegetation Schwartz and Heim, 1996	Growing season- DEC Dormant season-INC

Canada Thistle

Article	Response to Fire Treatment
First-year response of a Phragmites marsh community to seasonal burning Thompson & Shay, 1988	Summer- INC Fall- INC Spring- NC
Fall-Prescribed Burn and Spring-Applied Herbicide Effects on Canada Thistle Control and Soil seedbank in a northern mixed-grass prairie Travnicek *et al.*, 2005	INC
Canada thistle response to prescribed burning (North Dakota) Smith, 1985	DEC
Fire Ecology and Management in Plant Communities of Malheur National Wildlife Refuge Southeastern Oregon Young, 1987	INC
Frequent Fire Slows Invasion of Ungrazed Tallgrass Prairie by Canada Thistle (Colorado) Morghan *et al.*, 2000	Frequent burns: 1998- DEC 1999- NC Single Burn: 1997-INC
Five Years of Annual Prairie Burns Becker, 1989	DEC
Prairie Fires and Wildlife Kirsch and Kruse, 1973	DEC
Fire and drought experiments in northern wetlands: a climate change analogue Hogenbirk and Wein, 1991	Calmadgrostis meadow: Light burn-INC, Deep burn-INC Salix savannah: Light burn- DEC, Deep burn-DEC

- Of these 42 treatments, 28 documented a decrease in species' populations, while 14 reported an increase or no change
- There was a significantly higher proportion of "decrease" responses than "increase/no change" responses ($P < 0.05$)

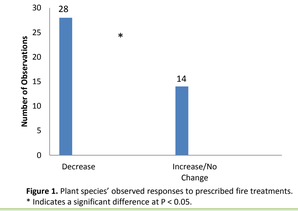

Figure 1. Plant species' observed responses to prescribed fire treatments.
* Indicates a significant difference at $P < 0.05$.

Discussion

- Results indicates that prescribed burns can be used to manage Spotted Knapweed, Garlic Mustard, Common Buckthorn, and Canada Thistle, four aggressive invasives in the Great Lakes region.
- Due to a scarcity of data, a chi-square test had to encompass all species at once, and couldn't be stratified into different treatment groups based on the specifics surrounding the prescribed burn methods.
- To determine what specific burn methods are most effective for each species, additional studies on prescribed fire's interactions with these species need to be conducted

Prescribed burn recommendations by species according to literature

Spotted Knapweed:

- Annual summer burns only treatment to reduce population growth rates (Emery and Gross 2005)
- Apply burn before early fall, while plants still retain seeds (Abella and MacDonald 2000)
- Annual spring burns have also been effective (MacDonald *et al*. 2001; MacDonald *et al*. 2007)

Garlic Mustard:

- Two studies advocate the use of repeated growing season (early spring to summer) burns (Nuzzo 1996; Schwartz and Heim 1996)
- Mid-intensity spring fires significantly reduced adult garlic mustard density as well as seedling frequency; however fall burns and low-intensity fires did little (Nuzzo 1996)

Common Buckthorn:

- Fire will top kill trees but roots persist
- Burn between late March and early May as low carbohydrate levels should reduce re-sprouting vigor (Dziuk 1998; Converse 1999)
- High intensity and frequent prescribed burns with substantial fuel to carry flames appear to be the best method for its control

Canada Thistle:

- Repeated late spring burns reduced abundance (Morghan *et al*. 2000)
- Late spring burns are also advocated by Hutchison (1992), and Smith (1985)
- Dormant season burns reduced flowerhead and seed production, and relative abundance (Young 1987; Carlson 1987).
- Early spring burns may increase cover by increasing sprouting and reproduction (Hutchison 1992; Thompson and Shay 1989)